Roof hook mounting

General hints

Mounting on pitched tile roofs is still one of the most frequent kinds of mounting for photovoltaic plants. Usually, so-called "roof hooks" or "rafter anchors" are used. An anchor plate usually serves for the fixation to the roof rafter by means of 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 in case of big loads. As most tiles are grooved above each other, they inevitably have to be adapted in most cases, but the tiles must not be weakened in an unpermissible manner by these adaptions.

This documents compiles important hints on selection, 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 resulted in a certain awareness and professionalisation. This development is especially welcome 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 plant price 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 error sources

A flawless 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 modification of the tile is inevitable, but the tile definitely must not be weakened in an unpermissible manner (see a negative example on the picture at the left). The consequences of faulty mounting are roof untightnesses 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 big local snow loads, a seating-on of the hooks on the tiles may have to be tolerated, even if extra stable rof hook designs are used. In this case, substitute tiles made of sheet metal are recommendable in order to avoid consequential damage (please see also the section "structural dimensioning").

Dimensioning errors can often be observed if 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 patterns respectively the rail distances are made too big, so that far fewer fastening spots than required are installed. One-layer mounting systems often have more fastening spots at comparatively low costs. In case of distributed loads (wind load, snow load), a sufficiently high areal density of fastening spots is always the decisive factor.

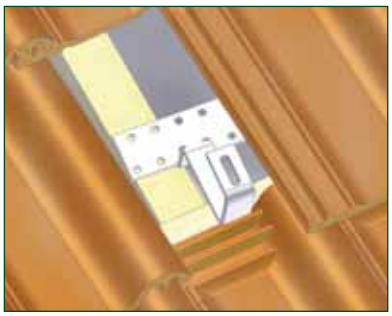
2 Roof forms and selection of suitable roof hooks

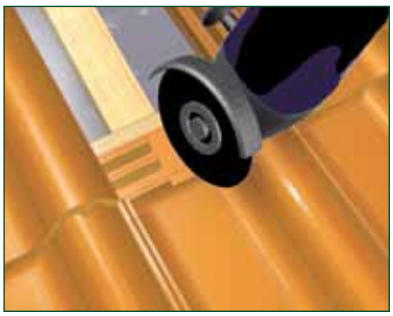
First of all, the roof hook used must be suitable for the roof covering. Besides special hooks for special roof forms (plain tile, Tegalit, Bitumen roof), roof hooks of the universal design "Frankfurter Pfanne" of different thicknesses are used for most pantile and grooved tile roofs. In case of doubt, 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 have an influence on the required hook form. In order to limit the variety of designs, usually all hooks are adapted to the lower tile forms. With higher tiles, underlayment plates under the mounting plates may be required. Plywood plates or also aluminum underlayments (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 broad mounting plate makes it possible to install the hook laterally shifted.

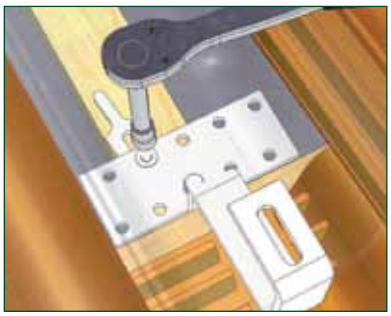
In order to cope with different structural loads, there are numerous roof hook forms with different thicknesses (for example the Schletter designs EcoG, EcoS, VAMax, VaMax2 are available for "Frankfurter Pfanne" pantiles). This allows for an adaption to the location. There are also adjustable versions 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.

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 on the following pictures. Generally, a modification of the tiles is unavoidable, but the tiles must not be weakended in an unpermissible manner by that. 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 at all sides, so that the hooks can elastically deform under load.







Mounting with aluminum underlayment shims

4 Fastening screws

The structural calculations always presuppose at least 2 screws per roof hook (one screw in the upper row of holes and one screw in the lower row of holes), 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. The screws can be chosen in galvanized quality if the installation site is reliably dry and vented and if there is no aggressive atmosphere, otherwise, quality steel is recommended. Different screw designs are applicable, 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 battens or not?), the pressure force can be transferred by distance tubes. An additional inclined screw transfers the downhill-slope forces into the construction.

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 between regions with normal loads (for example 0.55 to 0.75 kN/m²) and higher 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 big snow loads, roof hooks on every rafter are generally recommendable to safeguard a uniform loading of the roof. With big snow loads, substitute tiles made of sheet metal are generally recommendable, as the hook might load the tiles (depending on the 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-related 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. On 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 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 big distributed loads, it is not reasonable to save costs by mounting extra stable hooks to only every second rafter.

Special hint 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 more higher regions), shows that a professional planning and dimensioning of a fastening system always must be based on the specific loads on location. 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 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 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 hints on module mounting).

6 "Seating-on" of the roof hook

It is a widespread misunderstanding 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 loads. Considering the extreme snow loads that occur in individual regions, this is generally not even possible. 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 is not aware of that. Especially in case of 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 the load is not applied anymore.

Anlage 4.1: Tafel zur Ermittlung der erforderlichen Anzahl Dachhaken pro Flächeneinheit 1 m x 1 m - Modulneigung 30°

(ohne Aufsitzen)

Typenbezeichnung Dachaken		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
Rapid 2+ 45	430800	1,36	1,65	1,87	2,01	2,23	2,60	1,40	1,70	1,91	2,06	2,28	2,64	1,45	1,74	1,96	2,11	2,32	2,69	1,54	1,83	2,05	2,20	2,42	2,78
Rapid 2+ 45 longside	430801	1,68	2,04	2,30	2,47	2,74	3,18	1,75	2,10	2,37	2,54	2,81	3,25	1,82	2,17	2,44	2,61	2,87	3,31	1,96	2,31	2,57	2,75	3,01	3,45

Roof hook chart "with seating-on"

Anlage 4.2: Tafel zur Ermittlung der erforderlichen Anzahl Dachhaken pro Flächeneinheit 1 m x 1 m - Modulneigung 30°

(mit Aufsitzen)

Typenbezeichnung Dachaken		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
Rapid 2+ 45	430800	1,22	1,48	1,68	1,81	2,01	2,34	1,26	1,52	1,72	1,85	2,05	2,38	1,29	1,56	1,76	1,89	2,09	2,42	1,42	1,63	1,83	1,96	2,16	2,49
Rapid 2+ 45 longside	430801	0,76	0,93	1,06	1,14	1,27	1,48	0,85	0,94	1,07	1,16	1,29	1,50	1,09	1,09	1,09	1,17	1,30	1,51	1,56	1,56	1,56	1,56	1,56	1,56

Roof hook chart "without seating-on"

Menu item "seating-on" in the calculation program

System PP	400875	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	400590	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 hints 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 maintained.
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 long-term hardening behaviour.

EN 1304:2005 (D)

4.4.2 Bending load-bearing capcity

The bending load bearing criteria are not applicable for 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.

Carrying capacity of form tiles according to DIN EN 1034

Especially in areas with high 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. It has to be made sure that these substitute tiles are not unsupported, using suitable battens and planks it must be safeguarded that they rest solidly on the roof structure. Moreover, it is required in such high-load cases 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 of mounting using a sheet metal tile.






7 Roof hook material

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

Galvanized steel

Galvanized steel of suitable quality is quite suitable for an application as 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.

Aluminum

By means of suitable shaping, aluminum can be optimized rather well for the occuring loads. But due to the roof tile covering, the bar widths are always limited, which is a problem.

Quality steel 1.4301 or higher quality

Quality steel 1.4301 (also V2A) has very good production characteristics (good weldability, tough, elastic, bendable) and also good in-use characteristics, especially due to its good corrosion behaviour. A significant structural charcteristic 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 reserve until it reaches its breakage limit compared to other materials. This big reserves in the dimensioning can become decisive especially regarding the wind resistance if it comes to climatic changes in the future.
Only quality steel 1.4301 is generally approved by the building authorities (Z-30.3-6).

Quality steel 1.4016 or the like

This quality steel is often used for roof hooks due to its low price. „poorly weldable“, „poorly bendable“, „not suitable for exterior appliations“ (taken from: “material characteristics VA”) are only conditinally useable conditions for utilization.
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 in case of flat roofs. Thus, you must not forget that tile producers only guarantee a limited water-tightness of roofs with low inclinations. The following example data by a renowned tile producer are supposed to help to realize problems:

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

Flat roof pantile MZ3
- are usualy recommended for roof inclinations of 22 degrees or more.
- are only recommended for inclinations of at least 16 degrees in special cases (tight sarking membrane, glued if necessary)

Plain tiles
- like grooved tiles

Frankfurter concrete tile
- like MZ3

In case of 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.
An intense coordination between the producers of the different components of the plants (modules, mounting systems, etc.) and a consistent information transfer to the installers in the form of documentations, workshops, etc. will help to cooperatively serve the market in the long run and to promote the transition to renewable sources of energy.

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