Flat roof mounting

General hints

The spread of photovoltaics means increasing importance of electric parameters, durability, warranty periods, etc. and also the mounting details become more and more important. In the early days of photovoltaic installations, small numbers of modules were installed on roofs, now there are numerous mounting variants for all kinds of roofs and installation forms up to big surface roofs of industrial buildings or open area installations. With the ever increasing number of plants, insurers try to gain influence on the quality standards of the plants due to the statistic increase of damage cases.

Flat roof mountings and especially loading solutions are particularly relevant for the evaluation of damage risks. Whereas mounting faults on pitched roofs that can lead to roof leakages, module damage or yield losses only represent a limited damage risk, insufficient loadings on flat roofs can easily result in damage to third parties, and if the loadings are too heavy, even the danger of structural collapse of the roof has to be taken into account.

The following hints are supposed to help to limit the risks for the planner or installer and allow for a safe and professional project planning.

1 Loading or fastening
   General hints on flat roof mounting

In many cases, especially in case of PV-installations on flat roof, the respective roofs are not sufficiently considered from a technical point of view in the process of offer creation. All-inclusive kW-offers often include a standard loading solution without previous determination whether the weight of the loading is realistic or if the respective building can be loaded with the additional weight of the modules and the supporting structure, not to mention additional loads for the fixation of the PV-plant. Often it is not sufficiently considered that loading weights increase the complete load of the construction by a multiple and therefore can not be applied on many roofs.

In the course of a professional offer creation, the fixation of the PV-plant to the roof substructure definitely should be checked first, because it is the better option in most cases. Customers do not have to have any reservations about penetrations of the roof cladding, as the mounting details are ever more professional and include reliable sealing solutions. In fact, the planner should inform the customer about the much bigger risk of faulty project planning respectively the loadings that are really required.

If a loading solution should really turn out to be the better option for the respective object, the loading has to be dimensioned by calculation considering all relevant norms and all individual parameters. If necessary, an optimization of the mechanical construction details as well as a minimization of the required loading is possible.

Combinations of loading solutions and fastening solutions are generally not recommendable. Due to the elastic deformations in the system, this would require a painstaking structural analysis in each individual case.
Risk potential for the planner and the installer

Whereas mounting faults on pitched roofs represent a limited damage risk in individual cases, insufficient loadings on flat roofs can easily lead to dangers to third parties. If the roof is overloaded by loads that are too heavy, even the risk of an overloading and collapse of the roof has to be taken into account. Faulty dimensioning of loadings can easily lead to danger for "life and limb" of third parties. Usually such potential damage cases are covered by the liability insurances, but this only applies if there is no case of gross negligence. It can be interpreted as gross negligence if a flat roof is loaded with concrete weights without a previous check of the structural load-bearing capacity.

Therefore, the specialized company that carries out the installation has to dimension the loading considering all parameters (roof height, wind zone, terrain category, module size, etc.), so that any danger of lift-off, sliding or overturning can definitely be ruled out. Especially in the last years, increasingly extreme weather conditions have shown the top priority of of a technically thorough and safe project planning.

The information compiled here is supposed to demonstrate the possibilies of a professional project planning.

2 Technical limits of fastening solutions

Risk potential for the planner and the installer

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2.1 Allowable point loads

The allowable pressure loads on the roof insulation in combination with the sealing membrane that is laid on it, usually limits the maximum allowable point load (usually in kg/m² or kN/m²). When dimensioning the constructional loading weights, it has to be made sure that the maximum point load is not exceeded.

Possible dangers in case of exceeding the maximum point load are

- Caving in of the insulation
- Sinking in of the loading
- Overstretching of the roof cladding
- Brittling of the roof cladding
- Untightness

By means of a suitable laminar distribution, the point load can be limited.

2.2 Allowable distributed loads

The allowable distributed load (usually in kg/m² or kN/m²) usually relates to the complete roof area or to parts of the roof area. The maximum distributed load is determined by the load-bearing capacity of the structure. It has to be considered that the roof also has to bear the snow load according to the local standards besides the weight of the modules, the substructure and the potential loading weights.

On the basis of the structural analysis, the installer has to check thoroughly, whether the roof construction can really bear the additional weight of the PV-plant. After the serious events that took place in the winter 2005/2006, the importance of the dimensioning guidelines should be clear to anybody. It has to be considered that often very heavy loads are required to load a plant according to the guidelines of the new DIN 1055.

Possible dangers in case of an exceeding of the allowable distributed load are

- Partial caving-in of the roof construction
- Complete caving-in of the roof construction
- Collapse of the building
- Damage to persons

Possibilities to limit the distributed load

- Reduction of the number of modules laid
- Purposeful arrangement of the module rows above roof girders
- Optimization of the construction
2.3 Protection of buildings in view of the changing of the standards

Another important aspect after the change of the DIN1055 is the architectural conservation that were planned before the new set of standards was published. According to the new standard, a location in the south of Germany for example now may have to be calculated with a snow load of 1.6 kN/m², instead of 1.2 kN/m² (this corresponds to 120 kg/m²) until now. A hall that was built before the standard were changed with a load bearing capacity of 1.4 kN for example, still has architectural protection and does not have to be refitted necessarily.

But if an expert company installs a PV-plant on a roof with architectural conservation, the new load guidelines apply for the structural analysis, the architectural conservation becomes invalid if additional installations or constructional changes are carried out. The whole dimensioning has to be carried out according to the new standards.

3 Dimensioning criteria for loading solutions

3.1 Relevant standards

- DIN 1055 Load assumptions for buildings, part 4: Wind loads, edition 03/2005
- DIN 1055 load assumptions for buildings, part 5: Snow- and ice loads, edition 06/2005
- DIN 1055-100 Impacts on supporting structures, basics of the planning of supporting structures, safety concepts and dimensioning guidelines, edition 03/2001
- Eurocode 1: Impacts on supporting structures, edition 06/2002

3.2 Special wind loads

According to the standards mentioned above, no project plannings based on standard parameters can be carried out for projects in special terrain shapes. This especially applies for loadings, too. In case of such terrain formations (for example building on hills, etc.), a specific individual structural analysis has to be created.

3.3 Parameters for loading calculation

The required parameters for a loading calculation consist of the construction details of the intended module elevation (support geometry, beam configuration, inclination angle, module arrangement, additional measures for wind resistance, support distance, etc.) and the geographic data of the intendend location:

- Windzone acc. to DIN 1055
- Terrain category acc. to DIN 1055
- Height above sea level
- Ridge height above top ground surface
- Height of roof parapet (if there is any)
- exposed location (if this is the case)

The geographic data must be specified for a calculation (please also see geographic checklist, Schletter GmbH)
3.4 Load determination

The determination of the wind zone according to the norm can only be carried out by means of the accordant wind zone map. But as this is rather unexact and almost impossible with the resolution of the available norm, the Schletter GmbH provides an Internetservice for a load determination that is based on postal codes (wind loads, snow loads).

3.5 Dimensioning of the loading

Load case 1 - wind suction

The dimensioning of a loading against lift-off by wind suction represents a minimum requirement. If an air flow impacts an inclined surface with the respective presumable wind velocity, a dynamic pressure difference is created due to the different flow speeds on the upper and the lower surface. The power that is created by the pressure difference on the surface must be compensated by means of loading, so that the arrangement does not lift off.

For a long time, the dimensioning of the loading against lift-off was the only criterion for the selection of the loadings. This has partly been tolerated by testing institutes, as this kind of dimensioning results in rather high loads anyway. Structural analysis charts provided by system producers in most cases state this minimum requirement, a chart like that can be sufficient for optimized constructions. In any case, a chart like that can be used for a rough determination of the minimum loads. Using this chart, the installer can determine without painstaking calculation, if the flat roof is suitable for this minimum load, if a loading solution is reasonable at all, or if an alternative solution has to be chosen in the first place.
3.6 Dimensioning of the loading
Load case 2 - sliding

Besides the uplifting force, the air flow creates an impact pressure on the inclined surface. By vectorial subdivision of the arising pressure force, a pressure force that is parallel to the surface can be determined. In case of a complete loading solution, this pressure force must be compensated only by the friction on the roof surface in order to make sure that the module rows are not shifted on the roof. Due to the friction coefficients of the roof cladding that are often unfavourable and uncalculable, the required load can amount up to a multiple of the load against wind suction. The need for this additionally required load can possibly be avoided by securing the rows or by connecting the rows.

3.7 Dimensioning of the loading
Load case 3 - overturning

Especially in case of wind from behind, if the support base is short, or a high center of gravity, a single row on the roof can overturn. In order to make sure that wind from the north does not become a problem, this case also has to be considered thoroughly. The required load to avoid overturning can amount to a multiple of the load against wind suction. A minimization of the required loadings for the individual row can be carried out by means of well distributed loads, wide ground contact areas or wind deflectors, another constructive possibility is the coupling of several rows.
4 Optimization of the loadings  
Constructional options

The loading values determined according to the standards mentioned above are often not feasible due to the limited load-bearing capacities of the roofs. A limitation of the required loadings can be realized by means of different constructional modifications.

4.1 Interconnection of single rows  
(Construction example Schletter CompactVario)

By the interconnection of the single rows with load distribution beams, the overturning of single rows can completely be ruled out. The loading against tilting can be completely ignored in this case. The load distribution beam has to be dimensioned in such a manner that the potential tilting moment of a single row can be absorbed without plastic deformation. The risk of sliding of individual rows is also reduced with this construction, due to the mutual wind shading of the rows, the loading against sliding could be reduced by 20% and possibly even by 40%, depending on the specific number of rows.

A dimensioning solely with the loading against wind suction is only possible, if gliding can be prevented by constructional securing on the roof (for example by direct contact of the load distribution beam to the roof parapet).

4.2 Optimization of the angle and prevention of overturning by means of wind deflectors.  
(Construction example Schletter WindSafe)

The dimensioning of a loading against tilting is not required for rows that are closed at the back, because "wind from below" is avoided in these cases. Moreover, the required load can be further minimized by optimizing the inclination angle.

4.3 Optimization of geometry and load distribution  
(Construction example Schletter SolRack)

If the loads are placed in the gravel bed of a flat roof, the consideration of the sliding case can be omitted. Moreover, the proneness to overturning is reduced by the bigger support base which reduces the calculated loading against keeling over. A further reduction can be achieved by an unsymmetric distribution of the load burden (back 2/3, front 1/3). Thus, also in this example, loads that can still be carried by the roof are sufficient for the loading.
5 Software-aided calculation on the basis of the valid standards - calculation examples

After the introduction of new norms and numerous parameters, a professional project planning of fastening solutions on flat roofs is now only possible by using software tools. Here are a few examples to illustrate the way the system works. All examples are only for information without claiming technical correctness.

See attachment for example calculations.

Comparison of the calculation examples

The examples are supposed to illustrate the application of the loading data and the possibilities of constructional optimization.

In all examples, the other parameters (postal code, element height, module inclination, roof height, support distance, terrain category, etc.) are constant, in order to make other construction options possible.

Example 1
For example 1, a simple one-row elevation has been chosen.
• For a verification against uplift, 2x77.2 kg per support (according to chart at the front and at the back) would be required; this is also the value that is stated in a simplified form in the charts acc. to 3.5.
• The verification against sliding requires 2x129.5 kg.
• The verification against overturning requires 141.2 plus 251.4 kg. With a chosen support distance of 1.4 m that would be about 280 kg per running meter module row.
• The maximum load of these three verifications is the required loading.

Example 2
In example 2, "horizontal fastening" and "coupling of the module rows" are applied. This corresponds to the construction according to item 4.1.
• Only a loading of 2x77.2 kg per support has to be applied, this corresponds to about 110 kg per running meter/module row.

Example 3
In contrast to example 1, in this case no individual weights are used, but a fixed weight is applied centrically below the support. In this case, the subdivision of the weight that was already optimized in example 1 must be compensated by an additional weight.
• In this case, 502.8 kg are required for the verification against overturning (instead of 141.2 plus 251.4 like in example 1). With a chosen support distance of 1.4 m that would be about 360 kg per running meter of module row.

Example 4
Example 4 corresponds to example 2, but in example 4 there is an additional wind deflector.
• Only a loading of 2x77.2 kg per support has to be applied, this corresponds to about 53 kg per running meter/module row.
The reduction of the load due to constructional optimizations is obvious in this case.

6 Summary

The present project planning aid is supposed to facilitate the selection of suitable fastening options on flat roofs. To limit the risks both for the planner and the installer, an absolutely professional project planning is compulsory especially in case of flat roofs! But in many cases it has to be taken into account that flat roof fixations by means of loading solution are impeded by the limited load bearing capacity in spite of the possibility to optimize the construction, and thus definitely must not be implemented! In such cases, either a fastening solution has to be chosen as an alternative, or some projects simply cannot be realized.

It has to be the aim of all common efforts, to improve the quality of mounting in the long run, to reduce the liability risk of the plant installer as far as possible and especially to keep up the high level of acceptance of solar energy plants in public.
Example 1

Kalkulationsblatt Anlage 6: Auflastberechnung

Stand: 01.04.2006
Version: 4

Vorbemerkungen

Die nachstehenden Berechnungen gelten für regale Bedingungen. Bei Standsorten mit speziellen
Geländeformationen sind ergänzende Untersuchungen bezüglich der anzusetzenden Windlasten erforderlich.

Kunde: Mustermann
Auftrag 015
Postleitzahl Baubort: 83537 Haag in Oberbayern
11, 1762 nörd. Breite
12, 1729 westl. Länge

Elementneigung

Elementhöhe: 1,60 m
Höhe ü.N.N.: 500 m
Firsthöhe über GCK: 3,00 m
Abstand Stützrahmen: 1,4 m
Überstand Querträger: 0,50 m
Bastlänge B: 1,545 m
Sockelstandabstand: 0,822 m
Attikahöhe: 0 m

Ballastierung

Panklotz

Lastannahmen nach DIN 1055

Elementgewicht: 0,15 kN/m²
Schaufelast: 1,28 kN/m²
Geländebedingungs Kategorie (nach reibenden Bildern)
Stadtgebiete, bei denen mindestens 15% der
Fläche mit Gebäuden bebaut sind, deren
mittlere Höhe 15 m überschreitet.

Böingengeschwindigkeit: 0,41 kN/m²

erforderliche Ballastierung

Vorn

Hinter

Auskragung der Basis

Kippachweis

112,1 kg
251,4 kg
0 cm

Gleitachweis

129,5 kg
129,5 kg
0 cm

Nachweis gegen Abheben

77,2 kg
77,2 kg

Die ausgewählten Ballastierungsgroßen gelten für die jeweils erste Innenstütze von Durchlaufträgern

Reduzierung der Ballastierung bei weiteren Innenstützen auf: 80 %

Reduzierung der Ballastierung bei Randstützen auf: 76 %
Example 2

Kalkulationsblatt Anlage 6: Auflastberechnung

Vorbemerkungen


Kunde: Mustermann
Auftrag: 85
Postleitzahl Bauort: 83527 Haag in Oberbayern
6.1762 nördl. Breite
10.1729 westl. Länge
Elementneigung: 10°
Elementhöhe: 1,60 m
Höhe U.N.N.: 508 m
Firsthöhe über GCK: 9,80 m
Abstand Stoßrahmen: 1,4 m
Überstand Querträger: 0,50 m
Excitebreite: 1,545 m
Schwerpunktstafstand: 0,822 m
Attikahöhe: 0 m

Geländearten

Ballastierungs

Lastannahmen nach DIN 1055

Elementgewicht: 0,15 kN/m²
Schnee last: 1,28 kN/m²
Geländeart: IV
Stadtgebiete, bei denen mindestens 15 % der Fläche mit Gebäuden bebaut sind, deren mittlere Höhe 15 m überschreitet

Erfor derliche Ballastierung

Gleitbeiwert μ: 0,4

Kippnachweis

Gleitnachweis

Nachweis gegen Abheben: 77,2 kg 77,2 kg
erl. V = 10 cm³ (Grundräger)

Die ausgewiesenen Ballastierungsgrößen gelten für die jeweils erste Innensäule von Durchlaufträgern

Reduzierung der Ballastierung bei weiteren Innensäulen auf: 80 %
Reduzierung der Ballastierung bei Randrätern auf: 70 %
Example 3

Kalkulationsblatt Anlage 6: Auflastberechnung

Stand: 01.04.2008

Vorbemerkungen


Kunde: Mustermann
Auftragsnr: 1234
Postleitzahl Bauort: 83527 Haag in Oberbayern

Elementneigung
- Elementhöhe: 1,60 m
- Höhe U.N.N.: 500 m
- Firsthöhe über GCK: 3,00 m
- Abstand Stützrahmen: 1,4 m
- Überstand Querträger: 0,50 m
- Basisträger B: 1,545 m
- Schwerpunktabstand: 0,822 m
- Attikahöhe: 0 m

Geländekategorien

Ballastierung

Lastannahmen nach DIN 18055
- Elektroanlage: 0,15 MN/m²
- Schnee- und Schichtbelastung: 1,28 MN/m²
- Geländekategorie: IV (nach statischem Bildner)

Stadtgebiete, bei denen mindestens 15 % der Fläche mit Gebäuden bebaut sind, deren mittlere Höhe 15 m überschreitet

Erforderliche Ballastierung

Streckenlast
- Kippachweis: 502,8 kg
- Gleitachweis: 259,8 kg
- Nachweis gegen Ableben: 154,4 kg

Auszug der Basis

Die ausgewiesenen Ballastierungsgrößen gelten für die jeweils erste Innenseite von Durchlaufträgern

Pendelung der Ballastierung bei weiteren Innenseiten auf: 60 %

Pendelung der Ballastierung bei Randstützen auf: 70 %
Example 4

Kalkulationsblatt Anlage 6: Auflastberechnung

Stand: 01.04.2003
Version: 1

Vorbemerkungen

Kunde: Mustername
Auftrag: 570
Postleitzahl Bausort: 82527 Haag in Oberbayern
48,1762° nördl. Breite
12,1729° westl. Länge
Elementneigung: 20°
Elementhöhe: 1,60 m
Höhe U.N.N.: 509 m
Firsthöhe über GÖK: 2,09 m
Abstand Stützrahmen: 1,4 m
Überstand Querträger: 0,50 m
Basisbreite B: 1,545 m
Schwerpunktabstand Φ: 0,822 m
Atikonhöhe: 0 m

Geländekategorien
I
II
Ballastierungstyp:

Lastannahmen nach DIN 1055
Elementgewicht: 0,15 kN/m²
Schneelast: 1,28 kN/m²
Geländekategorie: IV

Stadtgebiete, bei denen mindestens 15 % der Fläche mit Gebäuden bebaut sind, deren mittlere Höhe 15 m überschreitet

Böschungsdruck: 0,41 kN/m²

erforderliche Ballastierung
Gleitbeiwert µ: 0,4

vorn
hinten

Auskrümmerung der Basis
Küppnachweis
Gleitnachweis

Nachweis gegen Abheben:
37,3 kg
37,3 kg
ert V = 2 cm² (Grundriss)

Die ausgewiesenen Ballastungssgrößen gelten für die jeweils erste Innenstütze von Durchlaufträgern.

Reduzierung der Ballastierung bei weiteren Innenstützen auf:
80 %

Reduzierung der Ballastierung bei Randstützen auf:
76 %

SCHLETTER
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