Dr. Zapfe GmbH

**Engineering office for structural engineering and solar planning**

**Metal construction expert publicly appointed and sworn by the IHK* (Munich)**

**Dr.-Ing. Cedrik Zapfe**
Mobile: 0176 19191280
E-Mail: cedrik.zapfe@ing-zapfe.de

Alustrasse 1
**83527 Kirchdorf/Haag i.OB, GERMANY**

**Tel.: +49 8072 9191 280**
**Fax: +49 8072 9191 9280**

**http://www.ing-zapfe.de**

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## Expert report: Fastening of solar modules on membrane roofs and bitumen roofs by bonding respectively welding

A planner of photovoltaic plants on flat roofs always has to deal with the conflicting priorities of cost minimization for the rack technology and the building owner´s justified insistence on the integrity of his building. This applies both to the structural safety of the building and its serviceability. In this context, the term "serviceability" means that the deformation limits of the roof are not exceeded, and the water tightness and the durability of the roof are not affected, either. Especially with regard to water tightness, fastening systems with superimposed loads that do not require any perforations of the roof have prevailed. Due to aero-dynamic optimizations in the wind tunnel, the required calculated load could be reduced so much that they can also be used on flat roofs that only have little excess load-bearing capacity. It is compulsory to check the excess load-bearing capacity that can be used for a solar plant including the sags that might be caused by the solar plant before the solar plant is set up.

Fastening solutions where the mounting rack is connected to the roof cladding with glued membrane lugs (figure 1) or welded bitumen sheet strips (figure 2) are used especially with buildings that have little excess load-bearing capacity, but these fastening solutions are increasingly used also in normal conditions. In these cases, usually no superimposed loads are put on the rack.

**Figure 1** Fastening with glued lugs on membrane

**Figure 2** Fastening with welded lugs on bitumen

*Chamber of Industry and Commerce

Even though this fastening technology seems to be pragmatic at first glance, the following aspects must be considered.

1. There are no generally accepted rules and standards of technology that can be used for the verification of a sufficient load-bearing capacity. Thus, an experimental verification seems to be the appropriate procedure.
2. Punctual fastening leads to tension peaks at the glued edges which in turn lead to a peeling strain on the bonding. Usually, this leads to a drastic increase of tensions compared to a load transfer through the whole surface area.
3. Both plastic materials and glues have a time and temperature-dependent load deformation behaviour. With high temperatures, plastic components deform much more under the same load than they would in cold conditions.
4. Both bonded connections and bitumen weldings can become brittle as a result of ageing processes in the course of the solar plant´s service life. When an experimental verification is carried out, these effects must be considered.
5. During the service life of the solar plant, it is very likely that there will be tensile forces with different intensity at the glued/welded connection. There is no sufficient knowledge about the fatigue resistance of bondings/weldings.
6. Depending on the wind impact, roof membranes or Bitumen sheeting are only put loosely onto the cladding or the thermal insulation. Mechanical fastenings against uplift sometimes are used in the roof-edge and in the corner zones. The set-up of an inclined solar plant usually increases the uplifting forces significantly.

In the last months, many fastening systems that were bonded to the roof cladding were damaged by heavy winds. In extreme cases, the complete solar plant was torn off the roof. In view of such a damage case, in 2010, the German building authorities realized that they had to deal with the subject. Thus, the "Deutsches Institut für Bautechnik" (German Institute for Civil Engineering) was given the order to create an information brochure which summarizes all aspects regarding production, planning and design of solar plants. This was published in July 2012 and can be found at the following link:
www.dibt.de/de/Fachbereiche/Data/Hinweise_Solaranlagen_Juli_2012.PDF

In chapter 2.1.5, it says explicitly:

***The usability of fastenings by adhesive connection (bonding/welding) to the roof cladding must be verified by a general technical approval. With this type of fastening, the tensile forces and shear forces must be transferred reliably into the supporting structure of the building through all layers of the building envelope.***

When a general technical approval is created, the aforementioned items 1-6 must be comprehensibly verified on the basis of scientific examinations and special calculations considering all climatic conditions and ageing processes before the approval can be granted. As there is no basic research for such matters like for other materials and types of construction, this can be a long and painstaking process.

Quite often, people argue that bonding or welding of roofing membranes already have been the state of the art for roofers for several years. This applies insofar as these bondings and weldings are not subject to systematic loads except evenly distributed loads resulting from thermal expansion. However, punctual load transmissions with local tension peaks cannot be regarded as the state of the art.

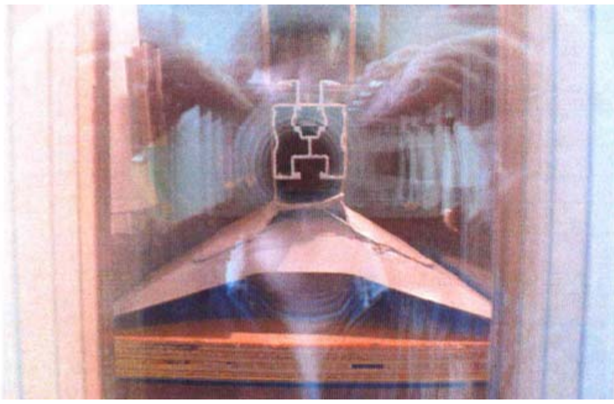

**Figure 3** Tensile test at a temperature of 80° C

Figure 3 shows a tensile test in a climatic chamber at a temperature of 80°. The main result that can be derived from that is that loads combined with high temperatures lead to considerable deformations that most probably are irreversible. Furthermore, the deformation figure clearly shows that there are tension concentrations with a distinctive peeling effect at the connection between the glued lug and the roof membrane. The terms used above will be explained using the example of a damage case from autumn 2013. As shown on picture 4, it is an aerodynamically optimized system with rear plates with rows arranged behind one another that are connected with metal straps. A glued lug made of membrane is arranged over the complete length (figure 5). In the first and the last row, the metal connections are laid into a special kind of membrane pocket.

**Figure 4** Inclined system

**Figure 5** Glued lugs over connection sheets

**Figure 6** Connection detail

**Figure 7** Local detachment of the glued lug due to peeling

Figure 6 shows the transition between the glued lug, the metal strip and the rack in the connection zone. In the figures 7-9, 3 different general types of failure are shown. Figure 7 shows a local detachment of the glued lug, which surely was facilitated by the low bending stiffness of the plain sheet. In figure 8, an extensive detachment of the glued lug is shown. With regard to the bright colorings on the lower side of the glued lug, it can be assumed that this state was preceded by the state shown in figure 7. Figure 9 shows a failure by a rupture of the membrane lug. Also in this case, a detachment due to peeling tension probably preceded the rupture. Effects like soilings in the bonding joint or ageing processes of the membrane surface before bonding can promote the detachment.

**Figure 8** Extensive detachment of the glued lug

**Figure 9** Failure by rupture of the glued lug

Summing up, it can be stated that bondings of solar modules to membrane roofs or weldings to bitumen sheets represent a considerable risk as there is only very insufficient experience with systematic tensile loads and shear loads. As the building law prescribes reliable structural safety, this risk is not acceptable! In Germany, a general technical approval by the "Deutsches Institut für Bautechnik” (German Institute for Civil Engineering) is compulsory.

Apart from the local load-bearing capacity of the connection, the danger of an extensive uplift of the complete roof cladding including the solar plant is to be considered, as far as it is not bonded completely without interruptions.

C. Zapfe

BAYERISCHE INGENIEUREKAMMER-BAU KÖRPERSCHAFT DES ÖFFENTLICHEN RECHTS
Dr.-Ing. Cedrik Zapfe
BayIkaBau
Beratender Ingenieur
12688