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Modern façade and roof constructions with photovoltaic panels

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Glass as a building material is used in a multitude of new applications like modern glass facades or roof constructions. Important points in these times are a contribution to a positive energy balance. So the application of solar panels becomes more and more important. Until now most applications are standard applications with framed panels on roofs or installations on fields. More and more attractive applications from the architectural point of view are built or are under construction. There are on the one hand side different techniques to combine the photovoltaic element with the glass pane. The possible glass sizes are increasing, so there are many new ways of application. On the other hand side there are different possibilities of the fixing of the solar panel: Linear or in points. First some basics about the topics glass and solar are explained. The "traditional" systems for fixing of solar panels and also new systems are presented very short. In addition technical aspects like principle design rules, static calculation of solar panels and substructure are presented. Built examples with solar panels are presented.

Keywords: solar, glass structure, linear fixing, point fixture, solar clamp

1. Introduction

For a positive CO2 balance glass can also play its role in several applications. Special coated glass, insulating glass elements or use of glass panels in term of double facade are more or less well known and topics of other papers. The mentioned methods base on minimizing the cost for energy due to thermal climate control in the building (looking at moderate climate of northern hemisphere this means heating in winter or cooling in summer).

Beside this another interesting contribution for a positive balance of CO2 has to be considered: gaining energy by using photovoltaic panels. As the wish or demand for a bigger portion of renewable energy is realized more and more the use of photovoltaic panels also increases. At present different methods for fixing solar panels on superstructure are used. As each of them show also some disadvantageous attribute a new development was made.

The price of the whole system consisting of solar panel and fixing method (hardware and labor cost!) is important (or maybe the most important point) for the acceptance in the market and by this a success of this method to improve our CO2 balance.

Subject of this paper are the technical aspects (different kinds of products, static calculation, regulations, testing) of panels and fixings and not a quantification or qualification of the related CO2 balance. With increasing use of photovoltaic for architectural applications and not only for functional reasons, e.g. as cover of large roofs of industrial buildings or farmhouses, these technical aspects are getting more and more important.

2. Basics

Photovoltaic panels and solar cells respectively can be classified in many ways like e.g. thickness, material or production process. A common feature of most solar panels is the fact that they are placed between two layers of glass or on a surface of one glass to which a second layer is laminated. So every solar panel can be seen as laminated glass; depending on the material of the interlayer it in some cases can be classified as laminated safety glass. So the basic principles for calculation and design of laminated glass can be applied also for solar panels. In addition specific topics like e.g. adhesion of photovoltaic cell and interlayer have to be considered.

To get the electric power from the cells to a collector usually cables are necessary. And these usually run through holes near edges or corners of the lower (horizontal installation) or back (vertical installation) glass sheet.

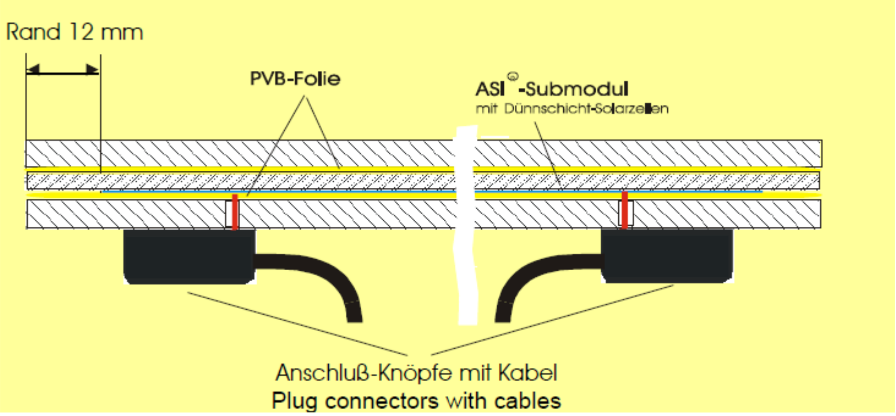


Figure 1: ASI-Submodul Arnold Glaswerke.

3. Support of glass

3.1. General

As stated above, solar panels can be considered as laminated glass or laminated safety glass. So for fixing the laminated glass panels with solar cells different methods can be used:

- - Linear fixing of two, three or four edges
- - Point fixing in holes of glass panels
- - Point fixing at edges of glass panels: solar clamp

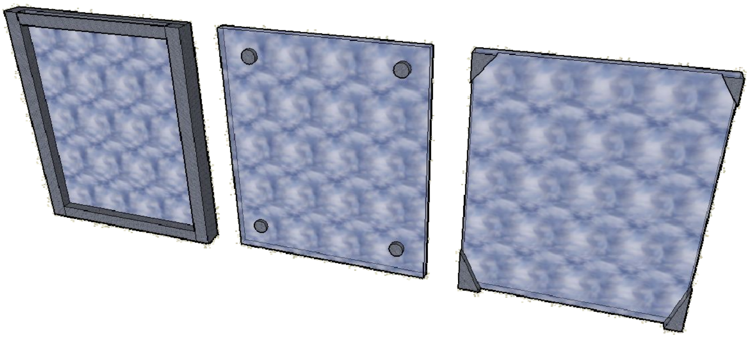


Figure.2: Examples for different fixing types for laminated glass panels.

3.2. Linear

Linear fixing is often done by using aluminium profiles. By this the edges are protected but a lot of material is necessary. Beside the holes for cables in the lower glass pane no additional holes in glass are needed. The top profile of a linear fixing has to take into consideration not to shade the active area of solar cells to avoid a decrease of solar power output.
In principle two different ways of installation are on the market:

- - solar panel with glued frame, which is fixed on superstructure
- - solar panel is clamped between EPDM-strip of a bottom profile and a top profile; bottom profile is fixed to superstructure.

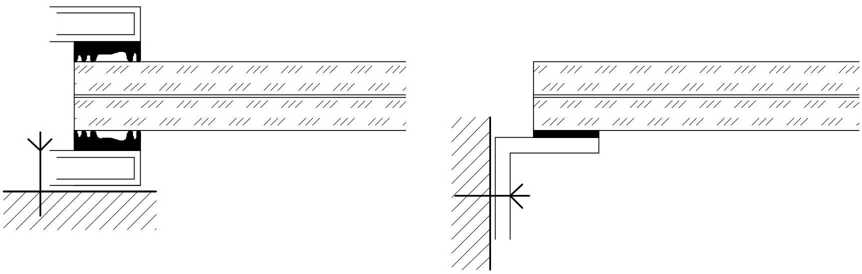


Figure.3: principle for linear fixing, section cut

In general this way of installation is easy to install, cables can run along profiles. But the optic appearance is considered as poor and sometimes not acceptable to architects.

3.3. Point-fixture in holes

Point fixings used for facades are a challenge for calculation, production and installation. For solar panels this is even a bigger challenge because of the solar cells in the interlayer. The price of the system consisting of solar panel and fixing method is important, so highly sophisticated point fixings like used in facades are only a solution for a few projects. Solar panels have to be produced a serial product with same location of holes for all panels. So in building usually existing tolerances have to be compensated by the point fixing, what makes this solution even more costly. Another aspect is that also the layout of photovoltaic cells is affected by the necessary holes.

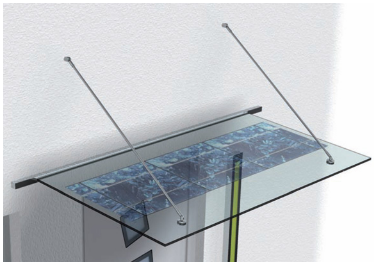


Figure.4: point fixing with tolerance compensating „spider“ which is fixed to superstructure. Figure 5: point fixed canopy with solar panel

So in conclusion point fixings in holes seem to be not a solution for a wide application in the field of solar panels.-Exceptions are small applications like canopies.

3.4. Clamps

Tolerances – especially for mounting on existing structures – are a very important point. As the solar clamp is independent from the panel, the mounting position can be shifted along the edge according to the superstructure. This makes it also possible to use the system on older buildings with e.g. different spacing of rafters. Easy installation guarantees low cost for installation. This is valid for first installation as well as for change of eventually broken or not working panels. A sophisticated technology makes mounting also on curved surfaces, convex and concave, possible. By this the field of application can be widened – an interesting aspect for architects, thinking of spacial structures covered with solar panels.

Depending on the size of panels and to be considered load the number of fixings can be enlarged, even locally like e.g. near edges of roofs where higher values of wind suction have to be taken into consideration. Another system is designed for architectural sophisticated facades. Here the German regulations like clamping area are matched, it is possible to change the photovoltaic elements very easy in case of breakage or electric problems.

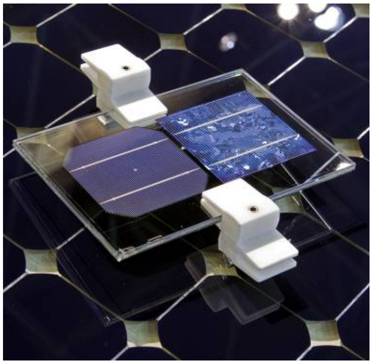


Figure 6: Design of solar clamp, Figure 7: Prototype of solar clamp.

Figure 8,9 : Exhibition booth with prototype

Figure.10: Clamp for facades

4. Demands

In addition to electric demands aspects of safety like static calculation of the glass and remaining load carrying capacity have to be considered. Depending on the application different points are important. Of course, a static calculation of the glass is necessary. Depending on the kind of support, this can be very easy or very difficult.

It must be sure that a glass construction cannot collapse in case of breakage of glass, so that the safety of people, e.g. falling against a glass façade or standing under a glass roof at the moment of breakage, is guaranteed. Depending on the kind of application the testing of remaining load carrying capacity is done with different testing methods. In case of glass-panes of facades a pendulum impact test like shown in Figure 12 is done. The behavior after breakage of a glass pane depends on many factors. The kind of glass (thermally toughened or heat strengthened glass) or the geometry of the point fixing have influence. The interlayer between the glass panes are not only PVB-foils but also EVA foils or cast in resins. The remaining load carrying capacity is not the same using "standard" laminated glass ore laminated glass with photovoltaic cells. So often tests in laboratory are necessary. Figure 13 shows a Remaining load carrying test and figure 14 an Impact test at high temperatures.

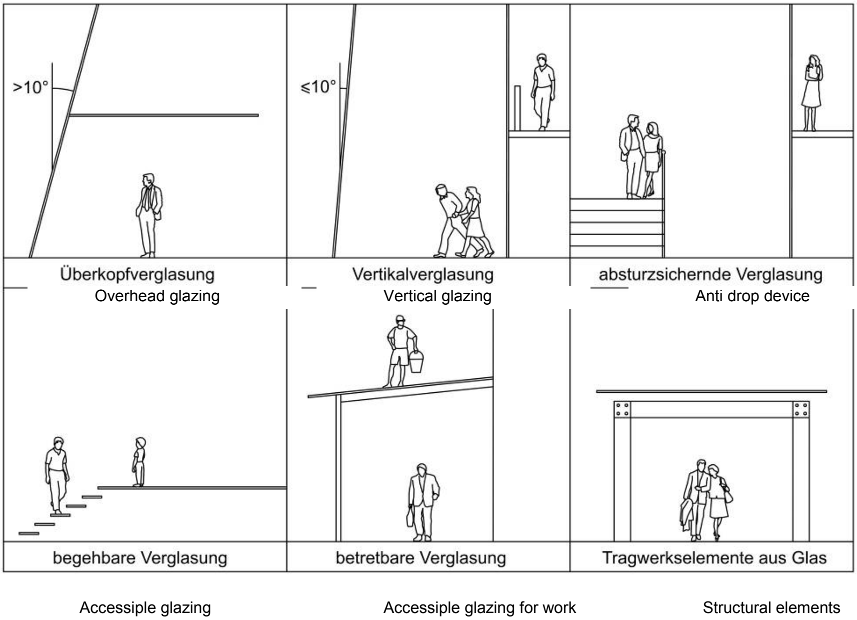


Figure 12: pendulum impact test.

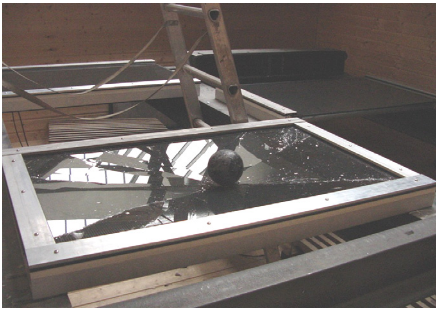


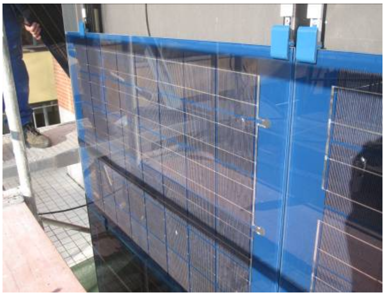
Figure 13: Remaining load carrying capacity test [15], Figure 14: Impact test at T= 70°C [15]

5. Solar Facade in Landshut

2009 a photovoltaic facade in front of a stair case in Landshut was finished.
The size of the glass panes is 1210 mm x 835mm, the glass panes are fixed at 4 points with clamps. To match the German regulations, some changes were necessary; of course a static calculation was done.

6. Roof construction in Haar

At present a roof in front of an outdoor swimming area in Haar near Munich is under construction. The fixation of the solar panels is linear but not in the classical way with aluminium frames: clamping profiles made of stainless steel are used for fixing solar panels with thin layer technology. The size of the panels matches to the substructure.



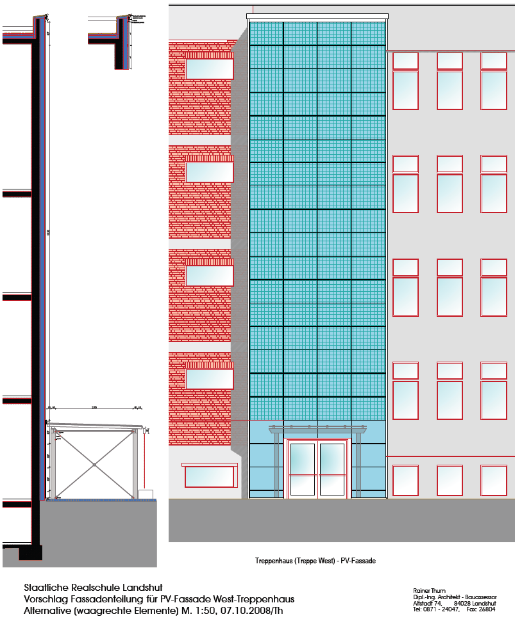


Figure 13, 14, 15: Solar façade in Landshut

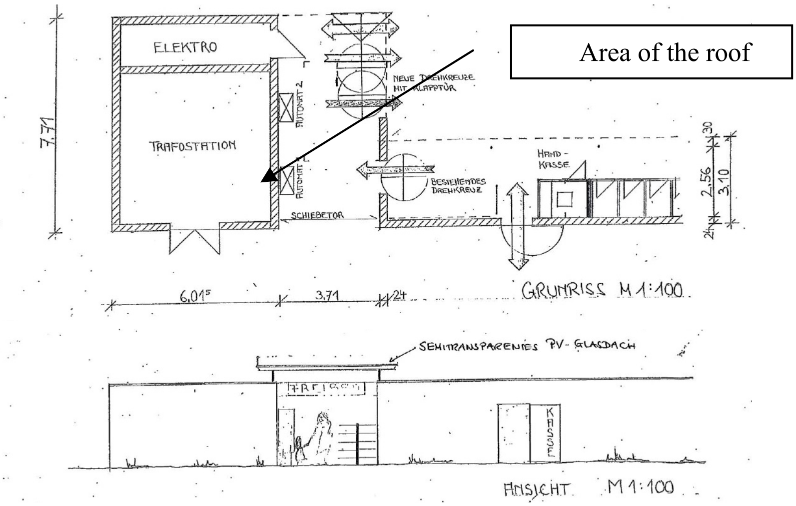


Figure 16: Solar roof in Haar

7. Discussion, Conclusions and Acknowledgements

The architectural use of solar panels helps to save energy and reducing CO_2 output. Design and building such constructions several points are to be considered: Not only the electric aspects and aspects of the efficiency are important. Because of the fixation and the application like overhead glazing additional points like static calculation or remaining load carrying capacity are necessary.

The presented solar clamp (patent pending) as new fixing system for solar panels makes installation and application of solar panels more easy, from the financial point of view interesting and widens the field of possible and easy to use applications e.g. to curved surfaces. By this the portion of renewable energy hopefully will increase in the future.

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