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Wind loads on the photovoltaic roofing system ilzoeasy with module inclinations of 11° and 15° of Ilzhöfer GmbH Lasertechnik

Determining the characteristic values for uplift and sliding

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Wind tunnel tests were conducted on the PV flat roof system **ilzoeasy** of **Ilzhöfer GmbH Lasertechnik** in accordance with chapter 1.5 of DIN EN 1991-1-4:2010-12 and the guidelines of the *Windtechnologische Gesellschaft* – WtG e.V. (German society of wind technology) as specified in the national appendix. The tests were performed at I.F.I. Institut für Industrieaerodynamik GmbH (i. e. “Institute for Industrial Aerodynamics”), Institute at the Aachen University of Applied Sciences. The PV-system consists of PV-modules angled at 11° as well as 15°, which are fixed on support assemblies. The support assemblies are installed on profile rails which connect the rows. Wind deflectors cover the modules at the backside and at each row end, as can be seen from Figure 1.1. Figure 1.2 shows a wind tunnel model.

Figure 1.3 shows the ilzoeasy system in comparison to the **ilzosave** system at 15° module inclination. Both systems share the same geometry, wind and side deflectors as well as the same ventilation gaps for module inclinations from 11° to 18°. As only the support assemblies which do not affect the aerodynamics differ between both systems, the results given in the report IHS02-3-2 may be applied for the dimensioning of the structure and for ballast calculation of the ilzosave system as well.

Pressure and/ or force coefficients were derived from the measurements. These coefficients may be multiplied by the design velocity pressure $q_{p,}$ determined depending on the wind zone, the exposure category and the building height in accordance with the European standard EN 1991-1-4 and the corresponding national annex to determine the wind loads on the PV system. From these results and under consideration of the partial safety coefficients determined according to EN 1990 it is possible to calculate the necessary ballast for uplift and sliding safety - sliding of PV elements occurs if the aerodynamic lift has decreased the down force due to deadweight sufficiently so that the drag forces are larger than the frictional forces - on flat roofs with pitch angles up to 20°.

For the present analysis, I.F.I. created a calculation tool in Excel which can be used not only for further programming or the dimensioning in a project, but also for purposes of documenting the ballast calculation. The tool presents a summary of the values calculated on the safe side from the tests for all wind directions and the roof zones H, G and F. In addition, it contains correction formulae taking into account the positive effect of a parapet on the wind loads in the edge and corner regions.

The results are given as quasi-steady characteristic values. As stated in EN 1991-1-4 where local load coefficients for an area of 1 m² to 10 m² are given, the force coefficients do not apply to modules placed individually, but only to arrays with at least 10 m^2 module's surface where at least four modules in a row and two rows are statically joint to one another. This is important as the simultaneity of smaller turbulences on the analysed field of 10 m² has to be excluded and only bigger turbulence effects have to be taken into consideration. Thus, smaller arrays may have to carry more ballast depending on their situation on the roof.

Figure 1.1: PV flat roof system ilzoeasy

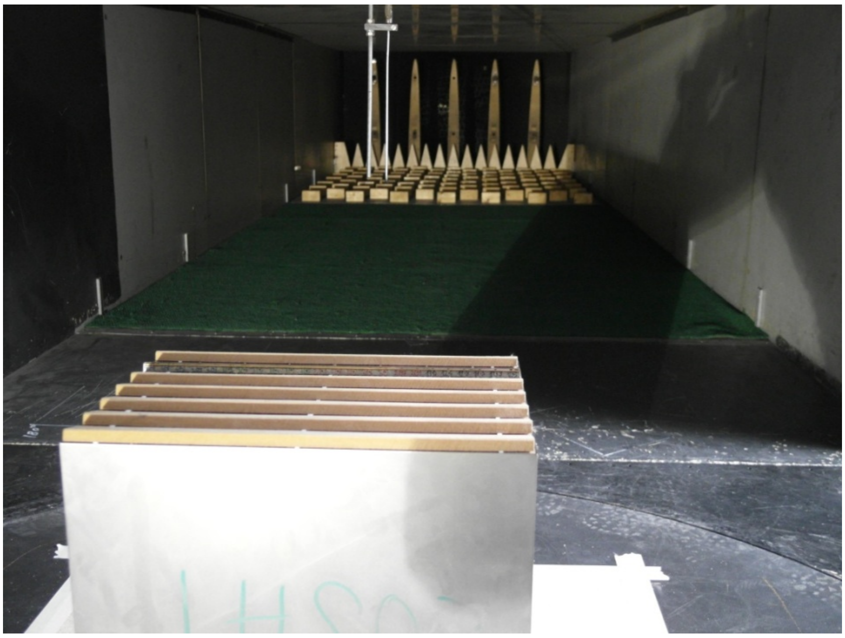

Figure 1.2: Wind tunnel model of the type building with the system ilzoeasy and with covered edge zones

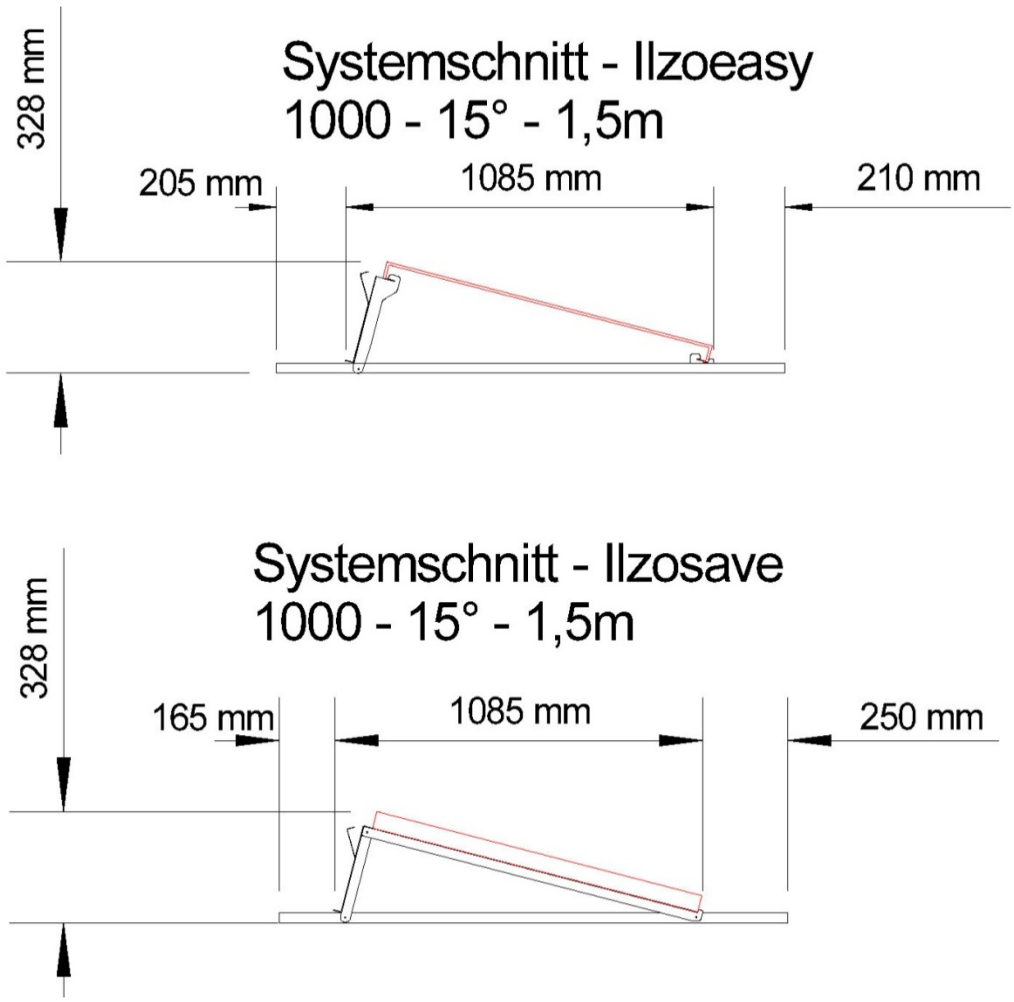

Figure 1.3: Comparison between PV flat roof systems ilzoeasy and ilzosave at 15° module inclination

For buildings with roofs at different heights, the maximum roof height has to be taken into account for calculating the wind loads on the safe side. The results apply without restriction for isolated buildings or buildings surrounded by buildings of the same or a smaller height. If a building is twice as high as the mean height of the surrounding buildings, the wind load calculation of those surrounding buildings has to be corrected according to appendix A.4 of EN 1991-1-4.

The results were determined for a set-up where the rows were aligned from east to west. However, the results are applicable for any row alignment with the points of the compass.

The coefficients extracted from the wind tunnel tests may also be used in accordance with the information given in EN 1991-1-4 and the corresponding national annexes.

The values show that the system in question needs very little ballasting in the centre of a field. The sliding and uplift loads exerted by the wind on the modules are very small due to the arrangement in rows. Higher loads were only observed in corners and in exposed edges of the field, and these have to be taken into account. On the basis of the measurements carried out, this may be done directly by increasing the ballast locally on the edge or corner elements as well as – in the arrangement of rows and space between the rows – by distributing the loads under consideration of areas less submitted to them and the dead load of the modules. However, in the latter case, higher structural demands are required for the load transfer by the supporting assemblies since, theoretically, a suspended corner module has to be held in place by the adjacent modules.

The analysis of the maximum loads in the different roof zones for the module inclination of 11° resulted in a maximum lift coefficient of $c_{fz} = 0.08$ [-] in the inner area of the roof and $c_{fz} = 0.38$ [-] in the corner zone of the roof, these results being based on the module's surface area. At the same time, sliding forces appear, their coefficients reaching $c_{fx,y} = 0.03$ [-] in the centre of the field and $c_{fx,y} = 0.24$ [-] in the corner zones.

For the ilzoeasy system with 15° module inclination the resulting maximum lift coefficients are $c_{fz} = 0.07$ [-] in the inner area of the roof and $c_{fz} = 0.32$ [–] in the corner zone of the roof. The maximum sliding forces have to be applied with $c_{fx,y} = 0.05$ [-] in the centre of the field and $c_{fx,y} = 0.30$ [-] in the corner zones.

Details of the tests and of the analysis can be found in the long version of the report IHS02-3-2.