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Simulation of very high snow loads on solar thermal collectors

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Abstract

A new test device for the simulation and testing of very high mechanical loads on sloped roofs for a realistic rating of the snow load resistance of solar thermal collector systems was developed. Several sensors and cameras visualize the occurrence of snow load-induced damages during the test to identify structural weak points of a collector and its mounting system. In collaboration with the Swiss building insurances, a test and certification procedure was established aiming at a reduction of snow load cases.

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Keywords: Collector testing; Building codes; Snowload;

1. Introduction

Mountainous regions are preferred locations for solar thermal applications owing to the high irradiation levels, the dry atmosphere and the snow induced high ground reflection in winter times. However, in prolonged periods of bad weather such places may from time to time encounter massive snowfalls leading to very high snow loads on the collectors. From a building insurances point of view, these rare conditions define the minimum requirements given by the building codes [1] for such regions. As an example: The Swiss valley Engadine with the famous city of St. Moritz is located at approximately 1900 m altitude above sea level, the snow loads according to the applicable building codes [2] may easily exceed 10 kN/m^2 on the ground, without considering any safety factors.

For these regions the current standard test procedures for collectors as defined in the standard ISO 9806 are not suitable anymore to rate the resistance to these loads for several reasons:

- The recommended standard test loads are too low and the collector inclination is not considered at all.
- No minimum test duration is defined and mechanical fatigue effects are ignored.
- The interfaces between collectors, mounting systems and the substructures are not thoroughly considered.
- Test rigs for large collectors are not available.

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The effective snow load on a building is calculated in most national building codes on the basis of the snow load on the even ground multiplied by several factors considering wind, geographical location and the roof shape which is described by a form-factor. This form-factor is usually set to zero for inclination angles above 60° (Fig. 1) assuming that under high angles snow will slide down from the roof anyway, hence that snow load is not possible anymore. Experience with damaged collectors installed under almost 70° inclination indicate that this assumption might be wrong for some surface elements such as the well-insulated solar thermal collectors (Fig. 2). Furthermore, snow slides usually have to be prevented for safety reasons, thus further increasing the snow load on the roofs. It is also for safety reasons that in some alpine regions flat roofs are common or even mandatory, so that solar thermal collector systems have to be installed on stands.

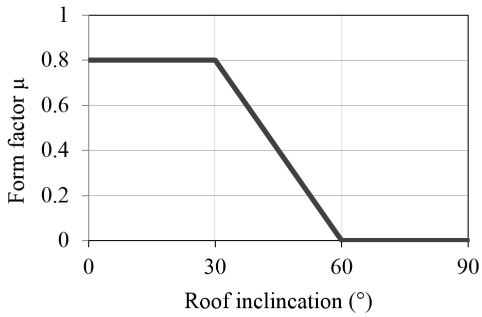

Fig. 1: Form factor for the roof inclination

Fig. 2: Balustrade mounted collectors damaged by snow load

As a result of the inadequate product standards and building codes, manufacturers, installers and building insurances operating in this alpine market notice an increasing number of damage cases over the last years. As there are no tools available to assess, investigate and rate the snow load resistance under controlled extreme conditions, there is currently a distinct risk that building owners, architects and planners refuse installing solar thermal systems in certain regions. To close the gap between product standards, building codes and the reality of alpine regions, a new test rig was developed, addressing the above-listed inadequacy of the current standards for solar devices.

2. Technical setup of the new snow load test rig

Different approaches to simulate snow loads on sloped roofs are known and have been evaluated. The standard test method is based on an extension of the standard test apparatus using pneumatically actuated suction cups. This approach is basically limited by the adherence of the suction cups on the sloped collector surface and is not really applicable for evacuated tube collectors. Furthermore using these suction cups under bigger angles may induce unwanted spots of high forces or tilting forces on the surface. Mainly for this reason, the method was considered as inadequate for our purposes. Other simple methods such as piling up sand bags reach their limits, not only for safety reasons, when testing with snow loads of several hundred kilograms. As a consequence of our review of different test methods and after several unsatisfactory attempts to modify our own standard test facilities a completely new test rig developed.

The core idea of the new system is to divide the required resulting force on a sloped collector into a parallel and a perpendicular component with respect to its surface (Fig. 3). The collector is installed with its mounting kit on a horizontal ground, simulating any roof structure. The forces perpendicular to the surface F_N are applied with a pressure-controlled air cushion, made of a thin polyurethane foil (Fig. 4, right). The flexible material is perfectly suited to provide a homogenous load corresponding to evenly distributed snow, without inducing local peak forces potentially causing early glass breakages. Furthermore the pressure remains homogeneous even if the sample is already being deformed by the load. Although basic physics, it is worth noting that pressurizing a cushion to provide all thinkable real snow loads requires only very low pressures in a range of less than 200 mbar. The whole test rig is enclosed in a very stable and stiff enclosure made of a steel frame with honeycomb sandwich structures to absorb these forces.