

Transparent solar collectors

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A new type of combined solar collector and glass roof structure has been developed in Norway. The system uses heat-absorbing girders fitted with moveable, reflective flaps which are controlled automatically according to the prevailing conditions. Its feasibility is being demonstrated in an experimental greenhouse.



The PV façade.

Introduction

Ordinary glass roofs create climate-control and energy consumption problems in the areas below them. This is because of extreme variations in solar radiation and ambient air temperature, combined with the relatively poor insulation capacity of the glass cover. These problems are

usually solved through permanent or variable shading, natural ventilation or mechanical cooling, and extensive artificial heating during cold weather and cold nights. The new transparent glass roof structure solves these problems in a unique way. Features include active and passive solar collectors, daylight source, variable solar shading, night insulation, and large, load-bearing girders.

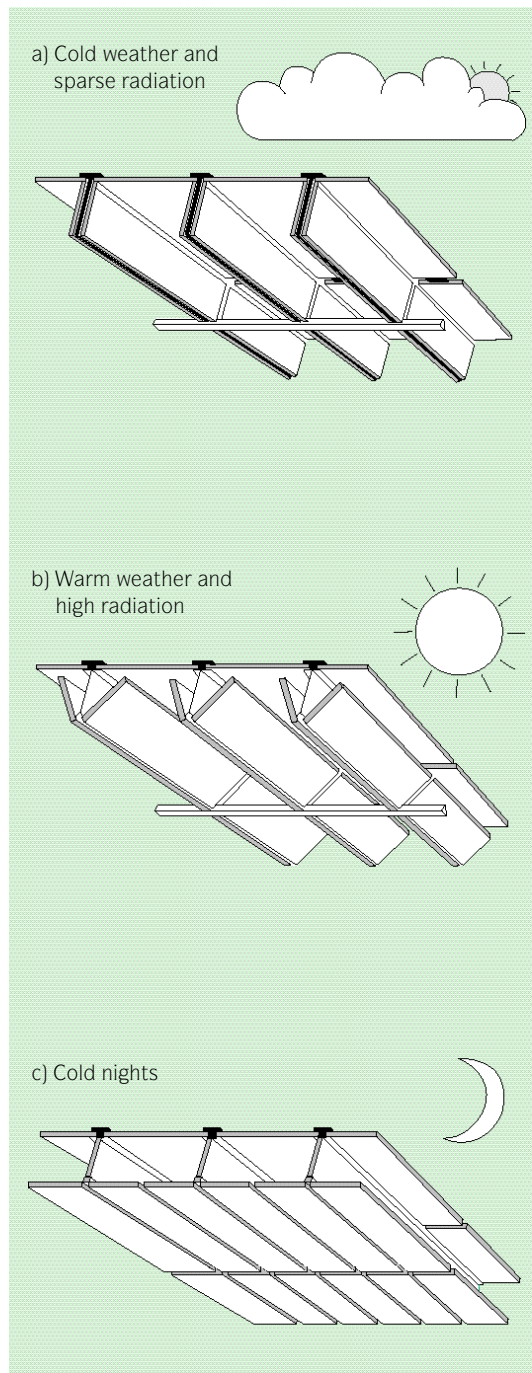
The new structure

The new roof structure has large, extruded-aluminium girders with a black coating which absorbs solar radiation. Pipes integrated in the girders are connected to circulation pumps and a heat storage facility. Hinged flaps are attached to both sides of each girder. These have skins made of thin aluminium mirrors, enclosing a core of insulating material, such as mineral wool or foam plastic. The flaps are interconnected in such a way that it is possible to move the flaps on each side of a girder independently.

The new structure has three main operational modes. During overcast or cold weather with moderate direct solar radiation, the flaps are positioned in parallel with the girders. In this position, the roof operates as a passive solar collector. Transparency is as high as in an ordinary glass roof, except for minor absorption by the mirrors. The position of the flaps is triggered by ambient and interior temperature sensors, and by monitoring the solar radiation (see figure).

During strong solar radiation, the flaps are activated and move out from the girders when the interior temperature below the structure exceeds a pre-set threshold. An astronomical clock, or a cluster of solar cells with different orientation, keeps track of the sun's position and helps the control system to choose the optimal position of the flaps. Generally, they are positioned to reflect direct solar radiation onto the girders and diffuse radiation into the space below the roof. The heat generated on the girders by direct radiation, and indirectly from the flaps, is transported to a heat storage facility just like an ordinary active solar heating system.

During cold nights and cold days with negligible solar radiation, the flaps are positioned at 90° to the girders to provide additional roof insulation. The rims of the flaps are lined with rubber gaskets to prevent air circulation between the upper and lower sides. This position is also triggered by ambient and interior temperature sensors, and by monitoring the solar radiation.



Modes of operation.

The prototypes

Two prototypes of the new roof structure have been built. The first, a small roof on an office building, aimed to develop and test the mechanical components. The second was an experimental greenhouse with a floor area of 250 m² and a single-glazed saddle roof of 290 m², which slopes 30° with one half facing south.

Located to the north of the experimental greenhouse is an ordinary greenhouse with the same floor and roof area, roof and wall sheets, to serve as a reference point for monitoring. Surplus heat generated in the south-facing girders of the experimental greenhouse is accumulated in a storage tank situated between the two greenhouses and is delivered to each greenhouse when heat is required. During the summer, excess heat is exported to an adjacent heating plant which provides heat to local school buildings and commercial greenhouses.

Monitoring of the greenhouses' heat consumption and production started in 1998. From 13 August to 13 November, the reference greenhouse imported 16,015 kWh, compared to 10,170 kWh for the experimental greenhouse. This corresponds to a 36.5% saving. This difference in heat consumption is due to the combined effect of the night insulation and the collected and accumulated solar heat. The monitoring uncovered some air leakage between the flaps in the night insulation position and a weakness in the fluid circulation system. With these repaired, the savings are expected to be much higher.

Future potential

Originally, the new structure was developed for large-span glass roofs above courtyards, streets, office buildings, supermarkets and educational buildings. In these applications, it is expected to be competitive because the high, strong girders replace the primary steel structure. Excluding the cost of the moveable flaps, the new structure may be cheaper than an ordinary large glass roof. In a cold climate, the night insulation function pays for the additional cost of the moveable flaps within a few years. In hot, sunny climates, the value of this

function may be low or negligible; however, the structure may be competitive if the girders are used to provide heat for absorption cooling. Solar absorption cooling can be a suitable option, because peak solar radiation and cooling needs almost coincide, so minimal heat storage is required.

The structures of ordinary commercial greenhouses are extremely cheap compared to architecturally-designed glass roofs, mainly due to standardisation and mass production for the large greenhouse market. If the new structure is to compete in this market, it will have to be standardised and mass-produced in a similar way.

The new structure may compete with ordinary opaque roofs in buildings where the value of the variable control of daylight and solar heat outweighs the additional costs. Several investigations have shown that a high daylight level without overheating can increase productivity and product quality in factories and workshops.

In sports halls, a high daylight level without glare helps both competitors and spectators. In large, glass-covered football stadiums, where shadows can prevent proper grass development, the new structure may be especially suitable because the flaps can be tailored and controlled to reflect direct solar radiation onto the playing area. A stadium equipped with this type of roof could also be a big exporter of surplus heat.

The ultimate application of the new structure could be as a large, transparent communal roof above structurally independent buildings below. The solar energy, collected in the girders and combined with seasonal heat storage, may make the whole structure and compound of buildings self-sufficient in heating and cooling. If thin-film PV cells are attached to the girders, the structure could even provide some of the electricity consumption in the buildings.

For more information contact the CADDET Norwegian National Team at Rud.