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ScienceDirect

Energy Procedia 91 (2016) 49 – 55

Energy Procedia

SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry

Enameled glass panels for solar thermal building envelopes

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Abstract

The paper presents a novel concept of solar thermal panel specifically intended for building integration, aiming at a higher architectural quality and at a reduction of installation costs. The panel consists of a low-emissivity enameled flat glass as solar absorber and a metallic heat exchanger, which are glued together by an adhesive layer. It features high design flexibility and can be used as roof or façade cladding in combination with common frames and profiles. We analyze the potential of the panel both as uncovered and covered collector by means of efficiency measurements on large-sized prototypes according to ISO 9806. Our results show that panels equipped with black enameled glass can achieve performance values competitive with those of commercial available products (uncovered panel: η_0 = 0.75, b_1 = 8.05 W/m²K, b_2 = 1.64 J/m³K, b_u = 0.043 s/m; covered panel: η_0 = 0.74, a_1 = 4.26 W/m²K, a_2 = 0.013 W/m²K²). As reported by our optical measurements on small samples, colored glass can exhibit solar absorptance up to 0.93, thus representing an aesthetically appealing alternative to black panels. For its implementation, system integration, operating conditions and design aspects have to be taken into consideration.

Peer-review by the scientific conference committee of SHC 2015 under responsibility of PSE AG

Keywords: solar architecture; building integration; flat plate collector; glass; enamel; low-e coating

1. Introduction

Building integration has long been recognized as a promising approach for a more successful dissemination of solar thermal systems for domestic hot water and space heating.

An improved architectural and constructional quality of the installation can increase the acceptance among architects and end-users and at the same time reduce the system cost thanks to synergic effects. Up to now, however,

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Peer-review by the scientific conference committee of SHC 2015 under responsibility of PSE AG
doi:10.1016/j.egypro.2016.06.170

building integration represents the exception in the realization of solar plants and is still far from becoming an established practice. The different motivations for that have been analyzed in detail in earlier as well as in more recent studies [1; 2]. The lack of suitable products, able to offer aesthetical quality and sufficient design freedom is identified as one of the decisive factors.

After current integration approaches the solar panel typically replaces part of the building envelope by adapting to the existing circumstances (type of construction, materials, surface finishes, colors, etc.). Many manufacturers offer their own solutions, with appropriate mounting kits, frames and covering strips. Some other solar companies have special products with modular design in their portfolio, which can be produced in a large variety of formats and sizes, thus ensuring architecturally more appealing installations [3; 4].

A second, less common approach consists in modifying the components of the building envelope themselves to enable the active use of solar energy. Examples can be found particularly in research works [5; 6; 7; 8] but also on the market [9]. This approach is technically more demanding and presupposes the definition of new scenarios in the development and marketing of the products as well as in the planning and realization of building projects, but it can open up new success chances for the solar assisted heat generation in buildings.

The paper presents a novel glass panel, which follows this second development principle and is conceived as solar thermally activated version of glazed components for façades and roofs.

Nomenclature

a_1	heat loss coefficient (covered collectors), [W/m²K]
a_2	temperature dependent heat loss coefficient, [W/m²K²]
a_{40}	heat loss coefficient at a temperature differential of 40 K between fluid and ambient air, [W/m²K]
b_1	heat loss coefficient (uncovered collectors), [W/m²K]
b_2	wind speed dependency of the heat loss coefficient, [J/m³K]
b_u	wind speed dependency of the zero heat loss efficiency, [s/m]
G	hemispherical solar irradiance in the collector plane, [W/m²]
G”	hemispherical net irradiance in the collector plane, [W/m²]
T_{Air}	air temperature, [°C]
T_{Fluid}	mean collector fluid temperature, [°C]
T_{Sky}	sky temperature, [°C]
α	solar absorptance, [-]
ε	thermal emittance, [-]
η	collector efficiency, [-]
η_0	zero heat loss efficiency, [-]
τ	solar transmittance, [-]

2. Concept, design and integration

The new solar panel results from the combination of a tempered glass pane with a heat exchanger: To ensure the mechanical and thermal coupling of the two components we are investigating different approaches, but focusing on adhesive bonding (s. Figure 1).

The glass pane takes over the static and aesthetical function in the compound, but is also responsible for the absorption of the incident solar radiation: Absorption can take place either in the bulk (colored glass) or in the underside of the pane (enameled glass). The wide range of geometries, sizes, colors, patterns or surface finishes enables an almost unlimited design freedom. This ensures optimum adaptation to the architecture of the specific building, which is not the case with common commercially available solar panels. Furthermore, the glass surface exhibits a perfect planarity not yet achievable by metallic absorbers, independently of the manufacturing technology used (laser or ultrasonic welding, gluing, etc.). The application of a low emissivity (low-e) coating on the front side of the glass pane can significantly reduce the heat losses by radiation and enhance the performance of the panel, in a similar way as with spectrally selective solar absorbers. For this purpose transparent conductive coatings based on