Recent Advances in Transparent Insulation Technology

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1. Introduction

Transparent insulation is an attractive technology to meet the targets of decreasing the heating demand of buildings. As a complement to thermal insulation it gives the architectural community a wider range of design options. However, commercial market penetration has been slow. The first decade of transparent insulation has been characterized by research, development and demonstration of the system. In spite of the economical risk and high costs associated with a small market, an increasing number of companies are taking up the developments and presenting products.

2. New Materials and Components

Since the last TI-meeting a number of new products and developments have turned up. Some of them are just alternative material options, others are real advances in technology. In short, the market has become more competitive.

The company LES (Licht- und Energie-Optimierungssysteme GmbH), Rednitzhembach, Germany, produces transparent insulation glazings from polycarbonate honeycombs. As many applications deal with daylighting and light-guiding, the material is used also in a modifiied form: The honeycomb cells need not to be perpendicular to the glazing surface, but may be also inclined, usually with 45 degree. Also honeycombs parallel to the glass sheets is used.

The principle of inclined honeycombs was theoretically presented already at a previous TI-conference, but this is the first commercial realiziation. Typical layer thickness of the honeycomb is 12-50mm for daylight applications. Perpendicular honeycombs for solar wall applications are available with larger thickness.

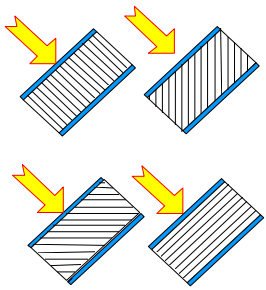

Fig. 1: Different orientations of the honeycomb layer within a LES glazing give flexibility for the application e.g. in roof-lights and sheds

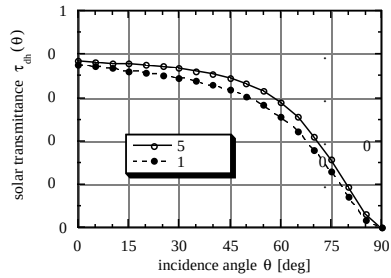

Fig. 2: Characteristic solar transmittance for 50 and 100mm honeycomb layer between two glass sheets; U=1.3 W/m2K and 0.9 W/m2K (estimated from literature data)

Just recently a manufacturer of air-to-air heat exchanger and sandwich layer materials in honeycomb form has started to go transparent. The first steps toward a decrease of density down to 40 kg/m^3 with polycarbonate structrures have taken place resulting in transparent layers with good heat insulating properties. The product of Tubus Bauer, Bad Säckingen, Germany, is flexible to produce and it seems possible to produce with demand tailored specifications.
Although the solar and light transmittance is negligible, a honeycomb material made from recycled cardboard claims to be a transparent insulation material. The company ESA Energie Systeme Aschauer, Bad Kreuzen, Austria, markets the so-called "Solarfassade" as a complete low-cost solution which obviously needs no solar shading for overheating protection. The systems utilizes a cheap wood construction with one protective glass cover in front of the open cardboard honeycomb. In a recent comparative investigation the energy gains of the system proved to be rather low but not negligible. Due to solar absorption within the material the averaged yearly total solar energy transmittance is around 13%. The U-value of the facade construction is about 0.9 W/m^{2}K for 126mm total thickness. Thus small solar gains may even be achieved leading to the situation that the heat loss over the heating season is around zero.
The transparent exterior insulation finish system (TEIFS) of the company Sto AG, Stühlingen, Germany, has received much attention as being a potential candidate for a low-cost system. The principle is shown in fig. 3. Several innovations improved the product, which has gone commercial since March 1996, when compared to the prototype production. The transparent plaster protecting the capillary structure utilizes only a minimal single layer thickness of glass spheres. Therefore solar transmittance could be increased. The application to walls within a conventional opaque insulation finish system as frame has been rationalized with prefabricated elements of arbitrary shape. The unpacked elements are fixed in recesses with the help of the black absorber glue. Overlapping glass fibre reinforcements of the plaster are embedded in the opaque part of the insulation system. Clean and fast mounting is possible.

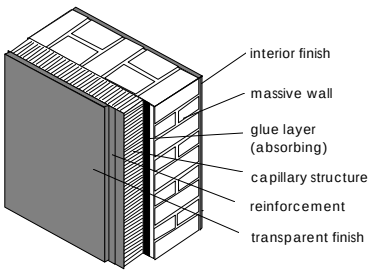

Fig. 3: Principle of StoTherm®

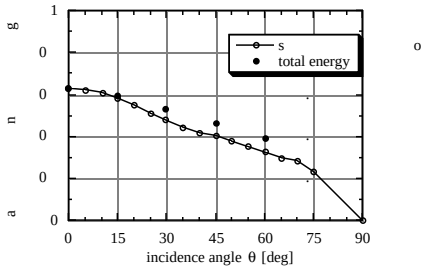

Fig. 4: Transmittance of 100mm StoTherm-Element
(total solar energy transmittance includes effect of absorber α=95%)

The first transparent insulation glazing utilizing low-e coatings and noble gases for minimizing heat loss with slim elements have been introduced into the market by the Okalux company. The so-called Okalux-H uses conventional edge-seal techniques in

order to obtain a hermetically sealed unit. As the gas volume per m^2 is 40l, the pressure build up due to a temperature rise is appreciably and leads to bulging glass surfaces. Therefore maximal allowed temperature are 60°C, the sizes of the panel are restricted. However, the slim elements may be used in connection with standard commercial profiles and need no extra TI-solution. The following table gives product data estimated from manufacturer's data for standard conditions.

Table 1: Product data OKALUX-H (U=0.8 W/m^2K)

property	symbol	direct irradiation	diffuse irradiation
light transmittance	τ_v	0.73	0.59
solar transmittance	τ_e	0.59	0.46
total solar energy transmittance	g	0.77	0.61

Since the last TI-meeting the technology for producing transparent insulation modules from glass tubes has made a big step forward. The company Schott Rohrglas Gmbh, Mitterteich, Germany, developped with a funded project both new cutting and filling technologies for glass tubes produced with diametres of 7 to 10mm and wall thicknesses around 100µm. Fractures at the tube ends could eb avoided without loss in optical transmittance. The automatic filling process allowed Schott to present a product with the brand name Helioran™ at the beginning of this year. The module has very high optical quality and may be used for the solar wall and for daylighting application.

Table 2: Product data Helioran™ (U=1.1 W/m^2K)

property	symbol	direct irradiation	diffuse irradiation
light transmittance	τ_v	0.82	0.68
total solar energy transmittance	g	0.82	0.67

There are a number of other development projects going on dealing with transparent insulation, however, no definite results are available at the time being. In any case it seems promising that an increasing number of parties try to spur their activities in this field.

3. SYSTEM TECHNOLOGY

The main interest in all investigations is on lowering costs and increasing applicability. Some demonstration projects had problems with humidity and condensation within the TI-facade (e.g. Greenpeace), with fire resistance (e.g. school building Leipzig). Usually costs are driven up by special requirements and construction. In this respect it is vital for the technology to find cheap and reliable solutions for overheating protection. Some new options are presented here.

Venting a TI-collector facade can remove the heat from the absorber in summer time, while closing the air gap yields a typical TI solar wall in winter time. The idea has been taken up recently by different parties. A Swiss architect has built two completely covered TI-houses realising the concept with a own constructive solution. For two commercial developments more detailed work is necessary. The optimisation of modules, temperature resistance of the TI-layer, air flow characteristics, heat

resisitance of the shutters or flaps, flexibility of the system, and the control strategy for the flaps have to be investigated.
Apart from the usual static shading options for South facades, overhangs and balconies, the idea of metall sheets transmitting selectively radiation from specific parts of the sky has been developed further by the company Schweizer Metallbau AG. Several geometries and production techniques have been investigated in a project. Although there always is a reduction of efficiency of 20-30% for winter time, the results were quite encouraging. The figure below shows the transmittance against direct solar radiation for different sheet options.
One of the promising developments for cheap overheating protection are thermotropic layers. Dependent on the temperature of the thin layers embedded in glas the layers are clear or reflective white due to scattering. In the scattering state for higher temperature the solar transmission drops to less than 10%.
Current activities concentrated on optical and thermal properties, principal system integration and production of large area units. The feasibility of efficient overheating protection for TI-facades and windows has been shown. Future work should deal with the questions of durability, application standards, system design, aesthetical and practical systems aspects.

4. BUILDING REGULATIONS

In the building regulation field progress has been slow. A draft version prEN 832 is dealing with calculating heating energy demand for dwellings. TI-facades are included in the method, but the precise definition of the parameters within the formulae is not given. The question of utilization of solar gains is not satisfactorily as no regard is given to the positive influence of thermal wall capacity. Similarly the German DIN4108 part 6 has its drawbacks. For example, it is not defined, what a g-value (total solar energy transmittance) exactly means in this context. Neither is it prescribed how to measure this quantity. Nor does the procedure give a solution how to proceed from product properties to system performance (c.f the question of seasonal variability of efficiency). A very important obstacle against market penetration is the fact that transparent insulation is no classified regular building product according to the European building product regulation.

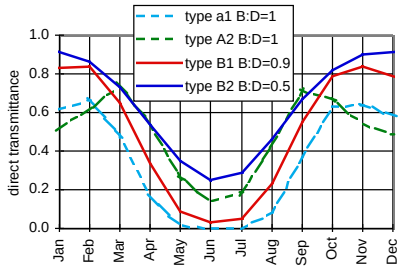

Fig. 5: Monthly direct solar transmittance of different shading metall grids

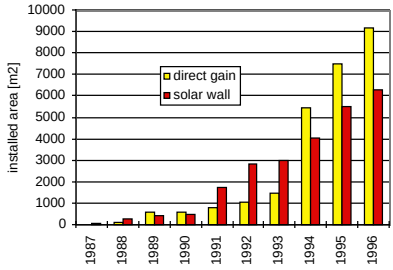

Fig. 6: Accumulated installed area of transparent insulation systems

5. MARKET DEVELOPMENT

From a questionaire sent to companies active in the field of transparent insulation it can be estimated that more than 85 buildings in the three countries Germany, Austria and Switzerland, which covers more or less the marketplace today have been equipped with about 15000 m^2. The situation is characterized in general by few larger projects utilizing transparent insulation as daylighting glazing and smaller projects with solar wall application. More than two thirds of the installed area is from 1994 onwards, and also new prducts have been introduced into the market. Fig. 6 shows the yearly installed areas in the fields of daylighting and solar wall application, which is fluctuating, but with a strong positive trend.

A number of new competitors have recently come into the market play. The L.E.S. company sells polycarbonate honeycomb glazings for daylighting applications. Holz- und Leichtmetallbau, Leipzig, Germany, has developed a low cost TI-module for use in modular facade systems with the help of the German ministry for research and science. The Swiss company Schweizer Metallbau has founded a German daughter called Schweizer Deutschland, also active in the field of transparent insulation. The company Capatect of the Deutsche Amphibolinwerke, Oberramstadt, Germany also is in the process of developing a facade module and has built up test facades with alternative design options. The Swedish Isoflex AB sells their products in the German and Swiss markets via the AGI group with the product name Agicell/Moniflex, mainly for the application in direct gain systems (shed roofs, industrial buildings, swimming and sport halls). 3-4 other companies are active in product development but not yet ready to go publish results. This shows that transparent insulation is becoming an commercially interesting product. Nevertheless dthis does not imply that a market breakthrough has been achieved. Several obstacles like the building legislation, low energy prizes and lack of wide spread information keeps sold quantities low up to now. The abandonnement of the production of the Basogel® product is an indication, that it is not easy to reach sufficiently high positive sales figures. It shows that the efforts in marketing are especially important in this area. It cannot be expected that the product is can be sold with only little promotion.

The costs of TI-systems are difficult to rate because of two main reasons: Firstly the prize certainly depends on the project size, as it is the case for all building products. The consulting work is unproportional high for small projects. Secondly the production usually is only a marginal business sector of the producing companies. Small and not optimized production lines keep manufacturing costs high. Often manual labour is still used to a large extent. Thus costs could certainly decrease appreciably with increasing sales. The following table show prices estimated from manufacturers and project information.

Table 3: Price estimates and performance data for different TI-facade options

	thickness [mm]	U-value [W/(m^{2}K)]	g_{dif} [%]	price estimates [DM/m^2]	
TI-systeme				TI-element	Ti-system
Okalux Kapilux H	49	0.8	63	400,-	1000,-
LES honeycombs	26-100	1.9-0.9	no inform.	no information	1000,-
Schott Helioran	90	1.1	67	600,-	1200,-
Schweizer SolFas	110	0.9	60	-	800,-
Sto ThermSolar	104	0.8	48	-	400,-
Cardboard honeycombs	126	0.8	13	200,-	400,-

6. CONCLUSION

The situation is promising but not satisfactory. The small market grows and even becomes a bit competitive. On the other hand information dissemination, broad access to easy planning tools, product development into a regular building product and still cost reduction is a necessary prerequisite to a further stimulation of the technology. Many activities may be parallel for different products, thus concerted actions might bundle the energies to step forward into a brighter, more transparent and ecologically better future.

LITERATURE

An overview over the historical development of transparent insulation materials is given in :

W. J. Platzer, "Transparent insulation materials: A review", SPIE Conf. Proc. 2255 Optical Mat. Techn. for Energy Eff. and Solar Energy XIII (1994) 616-627
Many of the systems mentioned within this article are described in a more detailed version within this conference by a series of authors.