HEATING ENERGY IN DOUBLE SKIN FAÇADE BUILDINGS

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Abstract: In the following field study a long-term monitoring was performed in 13 buildings with double skin façades (DSF) distributed among several cities in Germany. The aim is to determine the heating efficiency of DSF buildings under real operation conditions. The evaluation of energy efficiency is carried out mainly by comparing the heating consumption with the target or limit values from different standards or guidelines. The results show that energy savings due to DSF buffering effect could not be verified in this research and the heating consumption within the investigated DSF buildings is usually higher than the consumption previously stated in publications or the demand calculated during the planning process.

Keywords: empirical evaluation; energy efficiency; double skin façades; heating

1. Introduction

Double skin façades have been used on a larger scale since the nineties for technical and aesthetic reasons in “innovative” office buildings in addition to renovations. Due to the recent pervasive design of transparent building envelopes, various publications have been distributed since then; one example is about the Post Tower, published by Helmut Jahn [1]. These publications contained unenlightened comments, calling these glass buildings "ecological skyscrapers" [2] and “the maximum, nowadays, that can be reached in office and administration buildings” [3]. Remarks like these seem to denote the exemplification of art and other forms of "well equilibrated architecture" [4]. Simultaneously, there were several criticisms that argued that so-called solar office buildings were neither energy efficient nor comfortable in relation to buildings with a smaller window to wall ratio. Gertis [5] summarized this discussion with a special focus on DSF already in 1999 and has postulated "that instead of a great number of descriptive reports" the need of "measurements under real conditions" exists. This requirement comes only after the comprehensive investigations of Mueller [6] (four office buildings) and Fisch [7] (one façade). The debate reached a new and highly technically questionable point, when in 2004 the article entitled "Life in the sweatbox" [8] clearly showed that the "big experiment" with glazed office buildings failed without a consolidated and comprehensive basis. The author even admits that he was looking for information on the "wall of silence" and laments the lack of meaningful data about the operation of those buildings. The article was a typical debate about innovative buildings in which numerous "experiences," "opinions" and cited data could be found; exactly what Gertis [5] had previously criticized. At this point, starts the research project “TwinSkin - double skin façades under test” [9], determining scientifically reliable data from DSF and validating concepts.

2. Research Concept
In TwinSkin [9], several DSF office buildings in Germany were analyzed regarding energy efficiency, comfort and functionality. The aim of the project was to analyze the potential for optimization of those office buildings during work operation. The planning and documentation of modern office buildings often ends with the building completion, so that little knowledge is available concerning the actual performance of the building and its components in full operation during most of their life cycle. The research project compared the planning objectives with characteristics and operating experiences in DSF, which built the basis for a comprehensive assessment of the functionality of DSF and energy concepts (Figure 1).

![TwinSkin planning concept](image)

Figure 1 TwinSkin planning concept

As part of the research project TwinSkin, these aspects are analyzed for some selected office buildings. Thus, knowledge is developed to optimize the operation of those buildings. Operational experience acquired from DSF facilities built in the last 10 years may be used as a basis for planning. However, in this paper only the heating energy is demonstrated and discussed.

### 2.1 Energy efficiency

One of the fundamental questions associated with DSF, especially on the controversial published opinions, is the required heating or cooling energy of the building. Despite the technical press strongly criticizing the increased cooling energy demand in highly glazed buildings, the DSF is repeatedly justified by the second skin as heating energy efficient. The energy efficiency is indicated according to the required energy and the proportion of the building (e.g. gross net area (GNA), number of workplaces or gross room volume (GRV)). The needed energy amount has to be distinguished between calculated energy demand and measured energy consumption. In this paper the calculated demand and the building consumption under operation are compared with each other. In the energy efficiency evaluation, the energy consumption offers some advantages to the energy demand. First, the consumption is not based on the planning intention (corresponds to the effectively erected building). Secondly, it takes into account the user’s influence and operation (e.g. partially occupied and operational error). Thirdly, it may be continuously assessed during the work time (e.g. annual and monthly) and finally, it is a financial aspect of the building’s operation; a component of building management. On the other hand, there are some disadvantages to energy consumption. For example, the type of the building and the specific utilization promote strong influences on the energy consumption and therefore are not completely standardized and comparable. The energy measurements are costly and require a high degree of technical competence.
Currently, the legal and normative general requirements of the erection process regulate, almost exclusively, the energy demand side of the buildings, the planning and construction. For energy consumption, only a few records are available and they are partly difficult to compare. In most studies, results like the characteristic energy value related to the respective buildings are not mentioned; comprehensive data on individual objects are usually missing. For the comparative assessment, the energy demand due to its precision seems to be at the first sight more appropriated. However, the determined values are not always calculated with the same boundary conditions and accuracies (studies on residential buildings give an uncertainty of about 25% [10]). Nevertheless, the energy consumption offers good opportunities for the continuous monitoring of existing building and the identification of uncommon energy inefficient buildings.

The 13 buildings of TwinSkin were chosen depending on the availability of the data, usage type, approximated construction age and magnitude. The heating energy of these buildings is assessed by comparing the recorded values with the Swiss standard (SIA) 380 [11]. During the project running time (07.2003 - 03.2007) the EU Directive “on total energy efficiency in buildings” [12] has been converted into DIN 18599 [13], which rates, limits and compares the total energy consumption of non-residential buildings in Germany. Initial field tests were performed on IGS (Institute for Building Equipment and Energy Design) in cooperation with the BMVBS (Federal Ministry of Transport, Building and Urban Affairs) and the DENA (see [14]). As a result of this field test it can be expected that future energy consumption and demand, according to EnEV 2007 [15], will be more publicly accessible. These calculation methods were also applied to the TwinSkin buildings to increase with the standardized procedure the comparability of the buildings.

3. Methodology

The evaluation of energy efficiency is carried out by comparing the characteristic annual heating consumption values. As reference values, the target or limit values from different standards or guidelines are applied. These are usually a result of empirical investigations on the building’s energy consumption or were defined as legal standards, for example, ordinance WSO 1995 [16] after which most investigated TwinSkin buildings were planned. In this project the demand value for 12 buildings have been calculated according to the ordinance WSO 1995 [16] and one in accordance with WSO 1984 [17]. It should be noted that these standards determine the buildings energy demand according to certain defined rules, producing only approximate values for the effective consumption. For the data to be comparable, they shall be corrected for effects due to outdoor temperature, and whenever the measurement period of one year does not comply with VDI 3807 [18]. In order to compare the buildings, the annual energy consumption for heating was corrected by time and outdoor temperatures.

To classify the energy demand, the investigated buildings were divided in three building categories according to climate control system:

Type “1” (Natural Ventilated): Building with low operation of technical equipments in order to influence the thermal comfort in most offices (e.g. window ventilation and static radiator).

Type “2” (Mixed conditioned): Building with increased operation of technical equipments in order to influence the thermal comfort in most offices (e.g. ventilation systems and concrete core activation for cooling).
Type “3” (Air Conditioned): Building with high operation of technical equipments in order to influence the thermal comfort in most offices (e.g. air conditioning with humidification, dehumidification and cooling ceilings).

These three categories are in line with the target values established by SIA 380 [11] and have been converted into gross net area (GNA). Within the project TwinSkin no building was classified as Type “1”, all objects in this classification are at least in the category Type “2”. Thus, it is possible in the evaluation to embrace the different devices of the building, providing reliable cross comparison. However, please consider that most buildings in their energy-related functions are not identical and the operation and utilization have significantly different influences on the energy consumption. The following graphics use identification codes instead of building names to prevent a direct identification of a single building with high consumption. This aims to protect the company name.

3.1 The buildings
This field survey, concerning the energy efficiency, evaluated 13 buildings (mixed conditioned and air conditioned) located in several cities in Germany: Berlin (3), Hamburg (3), Hannover (2), Bonn (1), Leverkusen (1), Mannheim (1), Stuttgart (1) and Kronsberg (1). In accordance with most classifications [19], the DSF buildings here evaluated are divided into four façade types: box window, box façade, multi-storey façade and corridor façade.

4. Results and Discussion
First of all, the heating demand and the heating consumption of the investigated buildings are compared. Since the data from thermal insulation certification are usually the only statement that deals with the future heating energy consumption, no new calculations according to DIN 18599 [13] are used at this point, indeed the old data are presented. Figure 2 shows the comparison of these planning data with the actual consumption.

The comparison between demand and consumption values (Figure 2) shows in average for DSF buildings a consumption approximately two times higher than the previously calculated demand (minimum 1.3 and maximum 3.8 times). For two buildings, no evidence of thermal insulation specification was found and one building initially consumed less than previously calculated (factor 0.6). However it receives a part of its heating through Heat Pumps by the extracted air and the Energy Piles. These heat values cannot currently be quantified; it is included in the total electricity consumption.
or rather in the Primary energy consumption of the building. The observation through demand and consumption do not initially permit conclusions about the quality of the technical execution of the building. Often, the quality of the planning, the building operation or the flow of information between those two are the decisive factors in increased consumption.

In the Figure 3 the annual energy consumption values are presented for the investigated buildings corrected by time and outdoor temperatures. The energy values were obtained from the building operator and/or the invoice from the utility supplier. The consumption values of DSF buildings vary from 32 kWh/m²a to 182 kWh/m²a (GNA). The average heating energy consumption from all TwinSkin buildings is calculated at 110 kWh/m²a (GNA).

![Figure 3 Annual heating consumption related to GNA (m²)](image)

In comparison, stand 8 from 13 buildings in the referenced area of the SIA 380 [11] (gray zone on graph); only three buildings exceed their consumption values with the recommended limits. The building K10 utilizes a Desiccant Cooling system; which means a portion of its heating flows into the cooling process. At this point, it should be noted that for the balance limits of the project, the energy for the air conditioner’s heater or for hot water preparation may be included in the heating values. In this assessment, the consumption is neither significantly higher, nor significantly lower than the reference values based on SIA 380 [11]. On the other hand, despite the provable buffer effect of the DSF [9], no heating energy savings were exhibited. Apparently, the variables with dominant influence are the user and the operation mode of the building and less the building elements.

5. Conclusions

The investigated DSF buildings usually consume more energy than that previously stated in publications or than the calculated demand during the planning process. This outcome is more aptly proven for heating energy than for other forms of End energy, which were not measured or recorded in the buildings in the same way.

Energy savings due to DSF buffering effect were not verified. One evaluated building that exhibits this is the Deutsche Messe Hannover. Despite the demonstration of a comparatively strong thermal buffer effect, no reduction in the heating energy consumption was seen. However, a one-dimensional causality between the façade and the thermally induced energy consumption is not determinable. The causes are varied and extend from early design phases to different usage conditions.
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摘要：本研究针对分布在德国境内多个城市的13座双层表皮建筑进行了长期监测。目的在
于确定实际使用中双层表皮建筑采暖能效。通过将建筑采暖能耗与各种相关标准和规范的目
标值或限制值进行比较来评价能效水平。结果显示，双层表皮的缓冲作用所带来的节能效果
并未被研究证实，被调研的双层表皮建筑采暖能耗常常高于以前文献中的值，或是高于设计
过程中的能耗计算值。

关键词：经验评估；能效水平；双层表皮；采暖

References