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Upgrading of Panel-Built Residential Houses

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Summary

The majority of the apartment houses in Slovakia were built in the 1960-1985 period. These residential buildings have been implemented, in more than 70 % of cases, by the construction systems using concrete panel blocks. The outer shells of apartment houses were constructed as single layer jackets and, only after introduction of new buildings standards with tougher specifications covering thermal technical properties of buildings objects in 1983, the multi-layer building jackets with polystyrene thermal insulation layer came in use. As seen by current standards, all constructions have low thermal insulation quality. As a result of reduction of indoor temperatures to 20-21 °C, the thermal insulation inhomogeneous begin to influnce mildew develops. The obtaining of thermal comfort conditions in the flats is energy-intensive. A complex refurbishment of building structures is necessary (depending on the form factor of a building) which can bring as much as 50 % savings in heat energy consumption of the building.

Keywords: residential buildings, U-value, energy consumption for heating, hygenic problems, in-situ-data of existing buildings

1. Assessment of Thermal Insulating Properties of Building Structures

1.1 Thermal Resistance of Building Structures

The outer walls and roofing jacket of buildings have been designed according to the applicable thermal insulation specifications of the constructions. The changing requirements set on the thermal resistance and/or U-value of building outer jacket, have influenced the application of the materials. The ever more demanding refuirements have influenced the technologies used in the building outer jackets constructions.

The design value of the densitivity of cellular concrete used for outer wall structural elements in designs was 1.350-1.450 kg/m^3. However, the actual value as confirmed by the diagnostic tests performed on the existing buildings was 1.630-1.920 kg/m^3 which means that the thermal insulation parameters of the outer jacket are similar to those of normal concrete. For example, by taking the design value of the densitivity of 1.450 kg/m^3 for slagpemseconcrete used by panel blocks outer jacket, we arrive a theoratical value of $\lambda = 0{,}66$ W.m^{-1}.K^{-1}. The actual measured value of densitivity of built-in panel blocks is 1700 kg/m^3, which in turn gives an actual value of $\lambda = 0{,}84$ W.m^{-1}.K^{-1}. In this particular example the change in thermal insulation quality of material caused the thermal resistance value drop of 30 %. Through this effect the calculated temperature of building indoor surfaces (for the assumed outdoor temperature t_e = -15 °C) would be equal to the dew point temepratutre 12 °C. For buildings located in the temperature zone with t_e = -18 °C, the indoor surfaces would be even lower. Thus the panel block construction of houses does not meet the hygenic criterion (considering the samllest possible safety margin, the indoor surface temperature should be at least t_{ip} = 12,2 °C).

The influence of thermal inhomogenity is more pronounced in multilayered building outer jackets. Thermal conductivity of foam polystyrene is $\lambda = 0{,}044$ $W.m^{-1}.K^{-1}$. As consequence of protruding reinforcement bars of the „M" anchors (for multi-layered panel blocks of P1.14 type used in building constructions in 1965-1970 period) made from stainless steel bars of 8 mm diameter, pins of 2 mm diameter and cement milk and concrete spills poured into thermal insulation layer, the thermal conductivity attains higher values up to $\lambda_{ekv} = 0{,}07$ $W.m^{-1}.K^{-1}$. The increase in the thermal conductivity value by almost 60 % would mean, at the same time, that thermal resistance of the insulatiom layer is 60 % lower. The value of thermal resistance of panel blocks for bulding structures with inhomogenous layers is equal R = 1,07 $m^2.K.W^{-1}$. If a homogenous thermal insulation layer, which is exposed to unidirectional heat flow, is considered, then the thermal resistivity of panel block would be as high as 1,86 $m^2.K.W^{-1}$. The assessed thermal resistivity values of individual peripheral wall jacket and roofing structure, based on the performed diagnostic testing are given in the following table. The inhomogenity of the structures for the respective building types was verified by the thermovision diagnostics.

Table 1 : Assessment of Various Building Types of Housing Blocks

Construction System	Thermal Resisitivity R ($m^2.K.W^{-1}$)	U-value ($W.m^{-2}.K^{-1}$)	% [1] of Heat-Exchange Surface	Form Factor (row-rise houses) (m^{-1})
PV - 2	0,694	1,16	70	0,43
G - 57	0,280	2,23	57	0,41
BA	0,550	1,39	81	0,31
LB	0,390	1,79	51-66	0,31
T06B KE	0,503	1,49	46-62	0,42
T06B ŽA	0,414	1,72	57-72	0,27
T06B NA	0,923	0,92	51-54	0,45
T06B BB	0,450	1,62	52-60	0,43
ZTB	0,353	1,92	63	0,39
T08 B	0,923	0,92	49	0,32
BA - BC	0,802	1,03	70	0,38
B - 70	0,990	0,86	61	0,37
BA NKS	0,960	0,89	57-65	0,40
P1.14	1,07	0,81	65-75	0,31
P1.15	1,08	0,81	65-75	0,31

1) The values given for stand-alone and in-line attached houses, subject to construction system used for the selected building

The real thermo-technical properties of the building roofing jacket are influnced by the moisture contents of individual layers. The results of diagnostic tests have shown that the increased moisture contents is not caused by the water vapour condensation in the thermal insulation layer in winter period, but it is consequence of the rain water pouring into the structure, due to workmanship defect in construction details and due to damaged hydroinsulating foils.

Mold Fungus Formation in Large Panel Buildings with Subsequent Applied Thermal Insulation

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Summary

Thermal insulation of large panel buildings which are errected in the 60's up to the 80's is from the present point of view, insufficient. Major thermal bridges are also present in a large number of these buildings. Furthermore, the window constructions are untight and mostly partially damaged. For these reasons the exterior walls of such buildings are subsequently thermally insulated and new windows are installed. In connection with these rehabilitation works it is frequently claimed, that the new airtight windows to an air exchange lead, which is much less than that of the old untight windows, with the consequence of mold fungus formation in the dwellings. Furthermore, it is claimed, that due to the application of the thermal insulation, the exterior walls cannot "breath" anymore. These claims are wrong! Through sensible heating and functional ventilation mold fungus can be prevented.

1. Problem

Thermal insulation of large panel buildings which are errected in the 60's up to the 80's is from the present point of view, insufficient. Major thermal bridges are also present in a large number of these buildings. Furthermore, the window constructions are untight and mostly partially damaged. Today, in order to save heating energy, the exterior walls of such buildings are subsequently thermally insulated and the old windows are replaced through new tight windows which have better thermal insulation properties. Within the rehabilitation measures, the following two claims are made:

- Due to the new airtight windows, the air exchange in the dwelling is majorly reduced in comparioson to the old windows with the result, that the formation of mold fungus can take place.

- The application of a thermal insulation - especially an external thermal insulation composite system - leads to a lasting disturbance ot the "breathing activity" of exterior walls. Health consequences cannot be excluded.

Both arguments are not correct!

2. Conditions for the growth of mold fungus

Mold fungus can grow and spread only in the presence of suitable living conditions (fig 1). Based on the spurs, fungus layers begin to grow on the walls. These layers may be green, black or red. In order to prevent the growth of mold fungus, no condensed water ore moisture should format on the inner surfaces on rooms. For this, the minimum surface temperatur in rooms sholud never be less than + 14 °C.

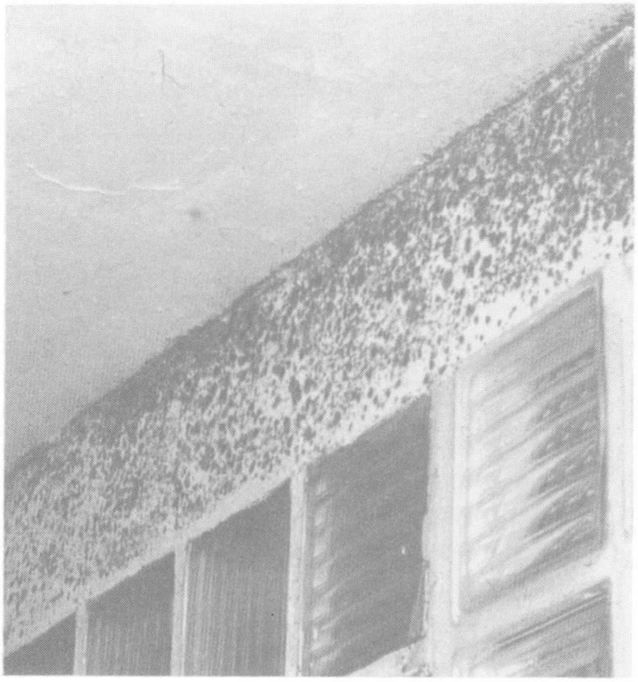

Fig. 1: Mold fungus

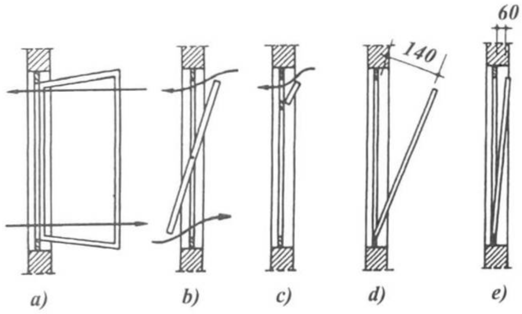

Fig. 2: Types of Window ventilation

Thermal bridges can be excluded as a reason for the formation of mold fungus as long as a thermal insulation system is applied on the outer walls beside the renewal of the windows within the rehabilitation measure.

The ventilation of dwelling due to air exchange through the new tight window joints is not enough in order to prevent the formation of condensed water. Window ventilation leads on the other hand to an extreme unnecessary air exchange between the interior and exterior and consequently to high energy losses. A cleave ventilation according to fig. 2e is enough to prevent a harmful humidity formation in dwellings.

3. "Breathing" of the exterior walls

Now a days, frequently the "breathing" of exterior walls is related to the permiability of walls to water vapour. It can be numerically proved, that the draw off of water vapour from a room through diffusion is much less than that through ventilation.

4. Summary

Thermal insulation measures and tight windows which have good thermal insulation properties do not influnce the humidity budget of a dwelling in a harmfull manner. On the other hand, thermal insulation measures are meaningful measures in order to save heat energy and to improve other properties of the walls.

Thermal Protection and Moisture Proofing of Exterior Walls of Existing Buildings

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Jürgen Dreyer, born 1941, graduated (Dr.rer.nat,Dr-Ing.habil.) at the Technical University Weimar, worked at the Universities in Dresden, Cottbus, Wismar and Vienna. His field of research is heat and mass transfer in building construction.

Summary

In this paper possibilities are represented to receive in situ data of the current thermal protection level. In the practical part several checkups of buildings and measurement data of elements and materials are figured out the level of heat and moisture protection and the strength of existing buildings in Mecklenburg/Vorpommern. .

Keywords: in-situ-testing, thermal resistance, moisture content, mechanical strength

1. Introduction

The thermal properties of building materials are of great importance for many technical questions, like utility value, running costs in housing and public buildings and so on. The moisture content, the strength and other qualities point to the general state of constructions.

2. Steady-state methods

Steady state methods to measure the thermal resistance are well known and described in standards. In this paper further possibilities are represented to obtain thermal properties of used buildings. This methods work with a heating system transmitting a definite steady heat flux through the object. The generated temperatures determine the thermal resistance and conductivity. In this way the determination may be carry out independent from climatic condition in a relative short time period.

3. Determination of the Thermal Resistance with Unsteady Methods

The measurement of thermal properties in the steady state mode of heat transfer is a method of high accuracy, allowing an easy utilization of the measured data. Unsteady state or transient methods have the advantage of shorter measuring times. Furthermore it is important to determine the state of a wall more exactly to get information of the distribution of thermal qualities in the cross section of the wall respectively about the properties of each layer of a multi-layered construction. Supplementary it is possible to determine the thermal diffusivity and the thermal capacity of heat storage. Figure 1 shows measuring results of two constructions.

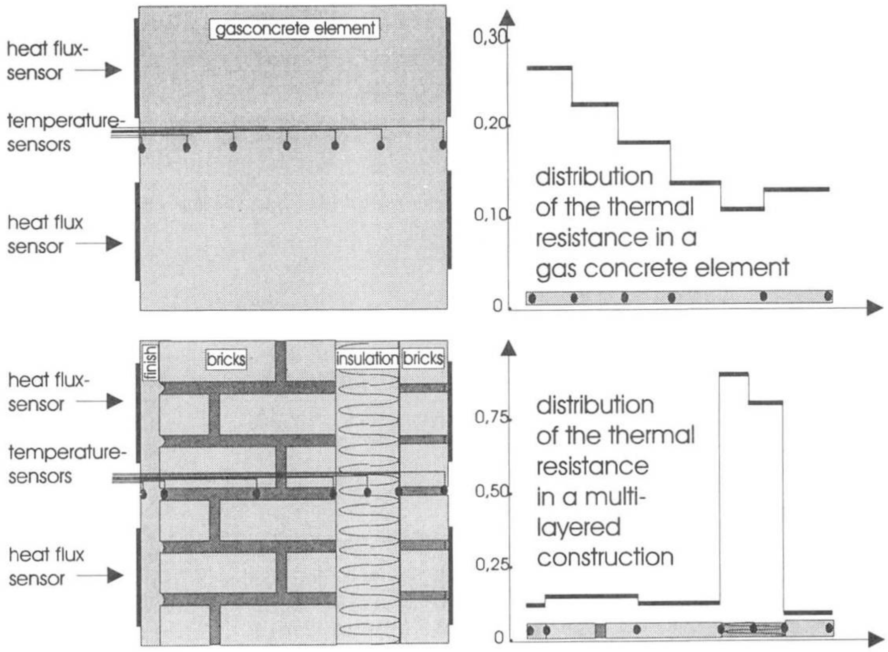

Fig. 1: Measuring arrangement for the determination of the distribution of thermal resistance in constructions

4. Evaluation and Analysis of Existing Buildings

The described methods were applied for measurements at existing buildings needing to be reconstructed in Germany, especially Mecklenburg/Vorpommern.. Additional to the thermal quality the mechanical and moisture qualities have been determined to select the right method of reconstruction. Table 1 shows results gained at several buildings describing some essential properties during the life cycle of these buildings and materials.

Table 1 : In-situ-data of exterior wall construction

number and product	**wall construction**	**compression strength**	**k - value**	**moisture content**
6 brick walls	plaster 24 und 36 cm brick plaster	15 - 25 N/mm²	1,71-2,48 W/m²*K	1,0-4,0 M-%
11 gas concrete blocks or panels	plastic finish, 24 und 30 cm panel, plaster	1,4 - 3,6 N/mm²	0,73 - 1,63 W/m²*K	1 - 40 M-%
7 panels of Light Weight Concrete	cement-lime finish, 28 cm panel, plaster	4,2 - 23,7 N/mm²	1,21 - 2,54 W/m²*K	1,7 - 5 M-%

The heat protection of these wall constructions in the analysed buildings varies a lot and is often very bad. The gas concrete elements have high moisture contents and low strength. The analysis shows that a lot of exterior wall elements have to be reconstructed due to the bad physical state the weathering process will be accelerate. A lot of these damages may advantageous and complex be repaired by extra heat insulation at the outside of the constructions.

Rain Screen Cladding Based on Steel Structures - Thermal and Moisture Physical Behavior of Repaired Wall Structure

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Summary

The thermal and physical behaviour of a rain screen cladding system with a steel structure was studied with field measurements in a block of flats, whose lightweight aerated concrete facades were repaired with the system. The building was located in central Finland. The results of the field measurements and numerical calculations show that with the system an old external wall structure can be dried out to a level at which further deterioration due to reinforcement corrosion is low under northern European climate conditions. The new, external thermal insulation layer also raised the temperatures of the old wall structure so that further deterioration due to frost is unlikely.

Keywords: Thermal and moisture physical behaviour of external walls, facade repair methods

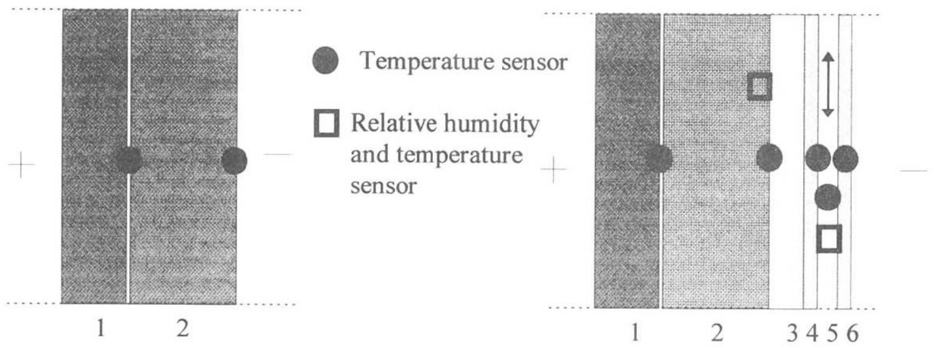
1. Field measurements and numerical analysis of facade repair

In the field measurements the thermal and moisture physical behaviour of the rain screen cladding system was studied foe example with temperature and relative humidity sensors placed in the wall structure. The time step in the continuous measurements was 30 minutes. The measurements began in January 1995 approximately one year before the actual repair and have now continued for 2.5 years. The objective of the field measurements was to find out how the cladding system, with its additional external thermal insulation layer and ventilated air gap, improves the thermal and moisture physical behaviour of the external wall structures.

The unrepaired and repaired external wall sections are shown in figure 1. The field measurements include continuous measurements of temperature and air relative humidity of the air, moisture content measurements of samples and local effective heat transfer coefficient measurements with heat flow meters.

In addition to the continuous measurements, the U-value of the unrepaired wall section was measured with heat flow meters combined with room temperature regulation. The moisture content of the lightweight aerated concrete of the old wall structure was measured by taking samples before and after the repair.

The magnitude of the apparent thermal resistance was estimated with transient numerical calculations using the measured outdoor temperature and the temperatures between the inner, load bearing concrete layer and the lightweight aerated concrete layer as boundary conditions. The apparent thermal resistance was defined using iterative calculations. The calculations were made using temperatures in January 1996 and 1997 since the effect of solar heat radiation is lower than at other times of the year.



1. Concrete (gable-end walls) 160mm 3. Thermal insulation layer 70 mm 5. Ventilated air gap
2. Lightweight concrete 300 mm 4. Thermal insulation layer 25 mm 6. Steel cladding

Figure 1. The unrepaired (a) and repaired (b) test wall sections and the locations of the temperature and air relative humidity sensors in wall sections.

2. Thermal and moisture physical behaviour of repaired facade

The initial moisture content before the repair of the tested facade was, at its highest, 26 $kg \cdot m^{-2}$. The old wall structure started to dry out once the daily mean temperature of the ventilated air gap rose above 0°C. After one year, the additional moisture had dried out and the moisture content of the old lightweight concrete layer corresponded to material exposed to normal climate conditions. The corresponding relative humidities were 40-60 RH%, which indicates that further deterioration due to reinforcement corrosion would be very slow.

The exterior mineral wool thermal insulation layer raised the temperature of the old facade so that the temperature of the lightweight aerated concrete dropped below 0°C for only a few days on the first floor when the outdoor temperature was around -20°C. This indicates that further deterioration of the old facade due to frost is unlikely.

The measured apparent U-values of the facade before repair were 0.42-0.46 $W \cdot m^{-2} \cdot K^{-1}$. These values were lower neighbouring values since the mean moisture content was lower, 5.3 w-%, than in the case of facades exposed to a greater amount of driving rain, the highest measured mean moisture content was 17 w-%. One year after the repair the apparent U-value was estimated to be at a level of 0.18 $W \cdot m^{-2} \cdot K^{-1}$ according to numerical simulations. Taking the simulations into account, the thermal conductivity of the lightweight aerated concrete layer improved from a level of 0.18 $W \cdot m^{-1} \cdot K^{-1}$ to 0.14 $W \cdot m^{-1} \cdot K^{-1}$ due to the drying of the layer. In the numerical simulation the effective thermal resistance of the ventilated air gap was also studied. The effective thermal resistance was found out to be at a level of 0.5 $m^{-2} \cdot K^{-1} \cdot W^{-1}$. This effective thermal resistance is taken into account in the apparent U-value shown above.

The results support the use of the tested type facade repair method as a means of saving energy. In addition, when the structures are carefully designed and the cladding is properly installed, the old external wall structure dries out to a level that considerably extends the service life of the external wall structure.

Rehabilitation of Large Panel Buildings using ETICS

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Summary

For large panel buildings in Central and Eastern Europe with three layer elements it is useful to apply thermal insulation to increase thermal protection, weather-resistance and to guarantee durability. The most economic form of such additional measures are external thermal insulation composite systems (ETICS). However, these ETICS are loaded on three layer panels in the area of the element joints due to the joint movements from the thermally and hygrically induced face concrete deformation. The investigations described below show that ETICS with suitable materials have sufficient bridging capabilities in order to be used on three layer walls.

Remaining Joint Movement

After applying ETICS the still remaining joint movement is due to

- thermal influence - daily and yearly
- hygric influence - yearly and long-term drying.

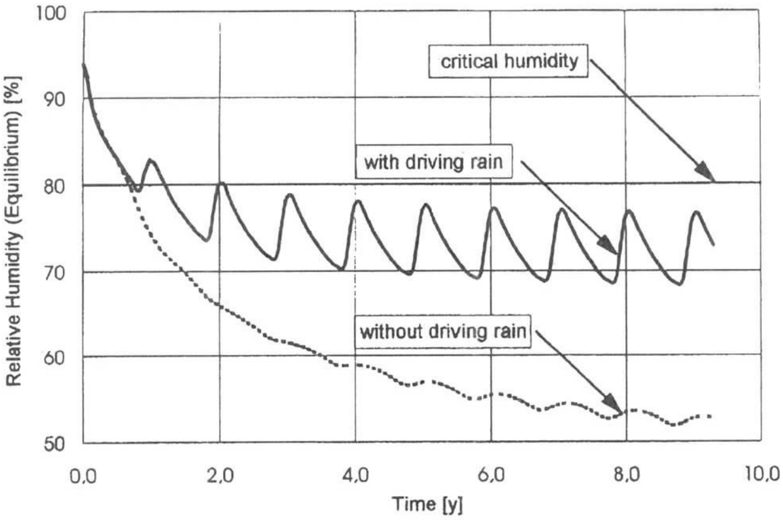

Figure 1: Hygric influence: Relative humidity (equilibrium) of the outer layer concrete after applying ETICS (here: mineral system)

In order to determine the magnitude of movement it is necessary to find the characteristic values of the outdoor climatic conditions. These results were used to calculate the influential condition values of temperature and balance humidity (Fig. 1) for the facing layer using unsteady heat and moisture flow computation. The deformation of the outer layer was calculated and thus the magnitude of joint movement was determined. These results were confirmed by calculations using in-situ recorded data. For a regular three layer panel an expansion of the vertical joint between two outer layers of 6.2-m-elements max $\Delta w_{tot} \cong 2.5$mm can be assumed.

Bridgeable Joint Movement

On top of the widened joint, the plaster of each ETICS suffers strain from shrinkage as well as from changes in temperature and moisture. Shrinkage tests have shown that fully strained plaster releases 85 – 95% of its theoretical restrain stress by creeping.

Based on the FE-method and using the "Fictitous Crack Model" according to Hillerborg, Bazant and Duda the bridgeable joint movements were estimated for the above loading cases. The calculation results were verified during joint extension tests.

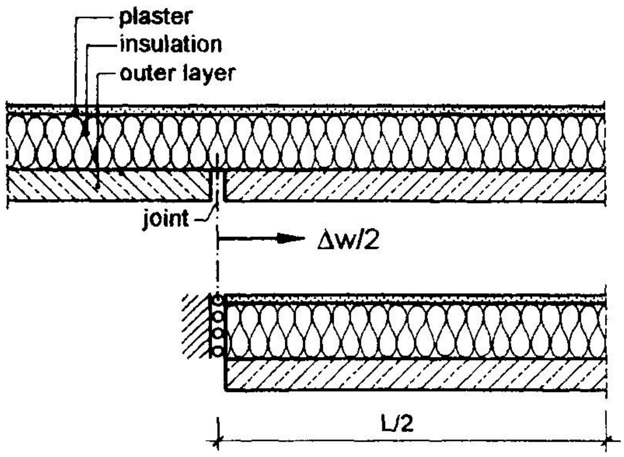

Figure 2: System of FEM-calculation

The result of the calculation is:

- Bridging properties improves with increasing thickness, decrease in shaer modulus of the insulation as well as increased stiffness of plaster.

- Conventional, mineral-based ETICS are unable to withstand under uncracked condition. Crack widths can be reduced to a harmless measure by coordinating plaster matrix and glass fabric (wire lath).

- Conventional, mineral thin plaster systems behave more favourably than mineral thick plaster systems (light plaster).

As a rule, ETICS with insulation thickness from 60 mm upwards and conventional, thin plaster systems or those using resin-based mortar have satisfying bridging properties.

Saving of Sacral Stained-Glass Window against Moisture Condensation

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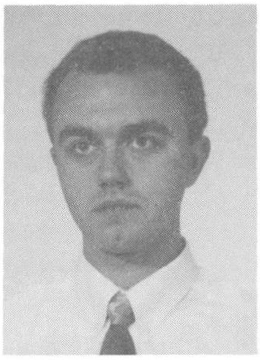

Summary:

This paper presents the analysis of possibilities of preserving historical stained-glass windows and historical windows from negative effects connected with the condensation of moisture. There were two models examined of this protection with inside and outside ventilation of the cavity between the original and protective glazing. It was proved that using additional window at the outside of the existing one or moving the existing protected window to the inside increases temperature on the protected window. It was found that in the case of the fixed protected window - the first solution - the outside ventilation is more effective. However, in the second solution with the protected window from the inside, the inside ventilation is more effective - the surface condensation does not take place on the protected window.

1. Introduction

The phenomenon of moisture condensation on the inside surfaces of transparent partitions and the problems connected with this issue is not anything new. However, recently the researches relating to this damaging process have been very significant considering the intensity of the inconvenient consequence, particularly in monumental and sacral buildings. The negative effects of that phenomenon are created principally by the influence of the aggressive pollution of the environment; including very polluted atmosphere, particularly in cities, agglomerations and industry regions. The aggressive pollution which is dissolved in the water from rainfall and which exist in the air causes, that the moisture which is condensed on the surface of transparent building partitions has a destructive and aggressive impact. It is confirmed by numerous observations in historical buildings, particularly in shape of destruction and corrosion of window-frames, frosting of windows and stained-glass windows, dump patches mainly under windows and so on.

Because of that a lot of researches relating to moisture condensation on the surfaces of windows and stained-glass windows in historical and sacral building were carried out in Western Europe [1,2,3]. These researches included the recognition of that phenomenon and the description of the ways of protecting windows by using ventilated spaces from the outside or from the inside of the existing partition. The clear choice of the proper way of inside or outside ventilation is not made because there are different opinions on this subject [3,4]. Therefore, for example the outside ventilation of the cavity between transparent partitions has been chosen in England while in Holland and Germany the inside ventilation appears to be more effective [1].

2. Model of Transparent Partition with Ventilated Spaces

The issue of ventilation of the cavity between two-layer of a transparent building partition can be described as two different models of ventilation. The acceptable models of different are shown on the fig. 1.

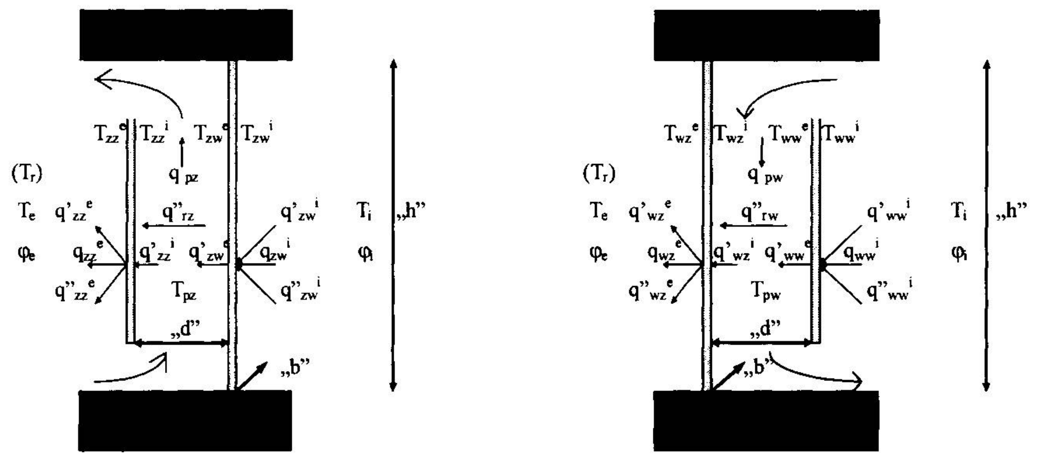

Fig. 1 The transparent two-layer partition with outside and inside ventilation, where:

q, q', q'' - total / convection / radiation heat flux density [W/m^2],

q_{pz}, q_{pw} - heat flux density; the result of warming or cooling the air in the space between layers [W/m^2],

T_i, T_e, T_r - the inside and outside air temperature, environmental radiation temperature [^{0}C],

T - the temperature of surface of the layer [^{0}C],

φ_i, φ_e - inside and outside air humidity [%].

In the situation, in which the protected window is undetachable and the additional window is placed in its inside or outside (the first solution) the outside ventilation is most favourable. In this way the temperature on the surface of the protected window is higher than when the inside ventilation is used; also the dimension of moisture condensation on the protected window is slighter. This fact was confirmed in our own researches [5]. The additional window causes that the temperature on the surface of the protected window is higher. In this way, the surface moisture condensation can be fragmentary reduced.

In the researches made in Western Europe there were applied other approaches (the second solution) to the inside ventilation of the cavity. In this instance of inside ventilation the protected window was moved to the inside and the additional window replaced it [1].

In this case, on the basis of our own researches, it was confirmed that the inside ventilation of the cavity is more favourable than outside ventilation. Though the quantity of condensed moisture is always greater than in the case of outside ventilation, the surface condensation occurs on the additional window and the process of destruction of the protected window is stopped.

Concept of Energy Restoration of Residential Buildings in Slovenia

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Summary

Since 1992 there have been more studies done concerning improvement of energy efficiency in Slovenian residential sector. In the framework of these studies energy saving potential in residential buildings in Slovenia has been assessed. Further more energy efficiency measures and possible ways of implementation were suggested following the results of public opinion analysis detecting appartement owners attitude and plans. In 1996 incentives for additional loft insulation, drought proofing and oil burner adjustment were implemented. The goal of the paper is to present the expectations in improvement of energy efficiency in building and accomplished results of grant subsidy scheme for energy saving measures in households.

1. Technical and economically viable energy saving potential in residential buildings in Slovenia

The analyses showed that expected energy savings in Slovene residential building sector are in range from 45% to 76% with average technical energy saving potential of 64%.

According to previous studies energy saving measures with payback period lower than 10 years that are socially acceptable can reduce energy consumption up to 30%. Further more most of the buildings need to be refurbished anyway that means that only a smaller part of the whole investment in refurbishment is on behalf of the energy restoration. Considering that payback period for the most extensive and therefore expensive but the most efficient energy saving measures (outer wall insulation, new windows) is much shorter.

To investigate public opinion on implementation of energy saving measures in buildings or households a public opinion analysis was completed 1996.

As it was predicted buildings in Slovenia built before 1980 are poorly thermal insulated. More than 60% of residential buildings have bad loft insulation ($k > 1.0$ W/m^{2}K) (Fig. 1), more than 64% have draughty windows and more than 42% of them have heating system older than 15 years. Majority of the questioned households are interested in implementation of energy saving measures, especially those with short payback period (up to 10 years). The main barrier proved to be lack of money.

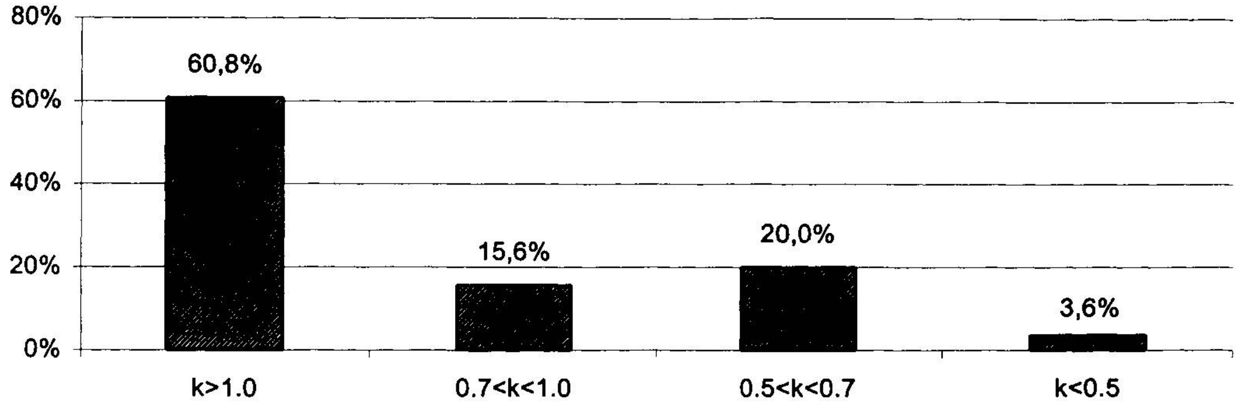

Figure 1. Present situation in outer walls k value (W/m^2K) in Slovenian residential buildings

2. Incentives

A pilot project of grant subsidy scheme was formed in 1996 where the Ministry of Economic Affairs allocated the founds for the incentives for implementation of energy saving measures in 2800 households in Slovenia. The following energy saving measures were subsidised:

- ***loft insulation*** (in 355 households) - 350 SIT/m^2 with max. 28.000 SIT/household, i.e. aprox. cost of insulation material for unused attics in average building,
- ***window tightening*** (in 944 households) - 400 SIT/m' of window frame with max. 10.000 SIT/household, aprox. cost of window tightening in smaller apartment,
- ***oil burner adjustment*** (in 1229 households).- 5.500 SIT, i.e. cost of the service.

In frame of the "Loft insulation" project average k value for the 355 lofts and attics before implementation was 1,75 W/m^2K (varying from 0,7 to 4,5 W/m^2K). After the implementation average k value is 0,29 W/m^2K (Fig.2). Such enormous difference in heat loss through loft/attic signify reduction of energy demand in household from 7% (single family house built after 1980) to 24% (single family house built before 1970) or in average 800 oil per household depending, of course, on condition before implementation. Payback period of the state investment in energy efficiency is less than one year, but for the whole investment considering different ways of realisation of additional loft/attic insulation pay back period varies from 1 to 5 years.

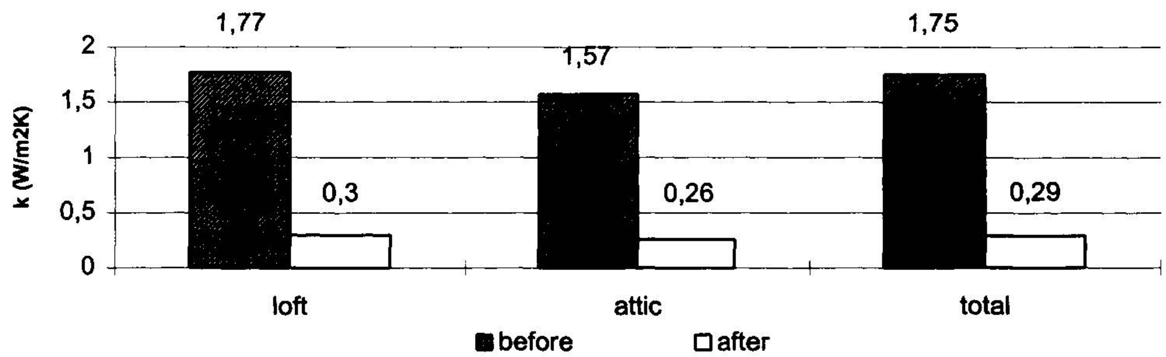

Figure 2. Average k values(W/m^2K) before and after implementation of additional loft/attic insulation

Fully Automatic, Decentralised Ventilation System with Heat Recovery

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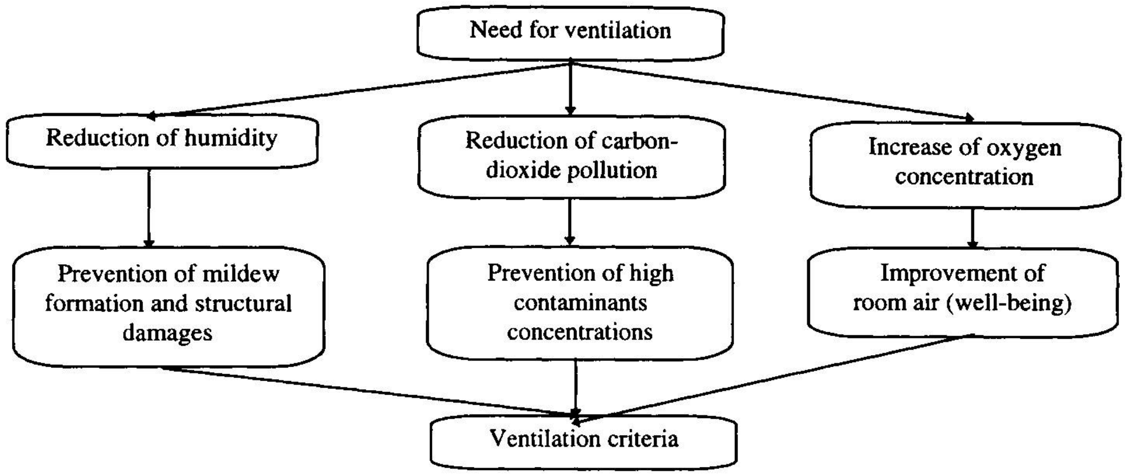
1. Need for Ventilation

Almost all flats in the Federal Republic of Germany are ventilated by opening the windows. Free ventilation can only hardly fulfil the demand for sufficient air quality as well as for energy-saving ventilation. No air exchange corresponding to the demand can be reached with free ventilation. In some cases, there is too much ventilation (e.g. windows that are permanently in the bottom-hung position). On the other hand, there are cases in which ventilation is too low. The damages arising therefrom are defrost water scale and mildew formation. Apart from the visible damages an enrichment of unhealthy contaminants takes place from building materials and from chemicals being used at home (e.g. detergents and cosmetics, glues).

Each kind of free ventilation is uncontrollable, because the air exchange depends on wind and thermic drive conditions.

In the Federal Republic of Germany, roughly a third of the whole energy consumption is applied on heating private households.

Due to the growing heat insulation standard, the losses of ventilation heat are very much increasing in relation to the transmission heat losses (see chart: comparison of heat losses). These energy losses can be reduced considerably in case of being constantly used today with the market of available equipment. In the demand for ventilation heat there is a remarkable potential for saving energy in the future. If there will be a building with good thermal insulation, the **demand of ventilation heat** can amount **up to 50 per cent** of the whole heat demand.



2. Health

Today, the subject matters ´outdoor air´, ´room air´ and ´health´ belong inseparably together. Thus the number of people suffering from allergies is growing from year to year in an alarming manner. Numerous environmental influences cause for many people partly grave health troubles. But here, in particular, many dangers are looming up.

Due to the continuous air exchange of the system THERMO-AIR the allergens are reliably removed through special filters and - depending on the individual requirements - both from the existing air and the fresh air which is delivered from outside. In a clean condition the air is taken to the room. And the system works in a decentralised manner. Thus the corresponding rooms can be equipped with THERMO-AIR individually and according to one´s own requirements.

3. Structural Defects

Not only the ventilation of old buildings, above all, the mode how to deal with ventilation and heating of modern buildings, rises increasingly bigger problems for room hygiene. Caused are these complications by too small an air exchange often prevailing in such rooms. The untightness of doors and windows felt to be a defect in former years, however, had a decisive advantage: it provided a continuous forced-air ventilation of the rooms. Waste air and the resulting air humidity were steadily removed to outside. This type of forced-air ventilation is practically not existent any longer, because modern door and window systems are employed. In inner rooms more air humidity is coming up as, for instance, by human breathing, by water vapour from bathroom and kitchen, by plants, etc. This humidity, however, cannot be taken off to the outdoor air sufficiently owing to the low air exchange. The moisture precipitates on exterior walls and ceilings. Damages caused by moisture, mildew and mould are coming up. The result is a considerable demand for rehabilitation in most cases. The system here ensures a permanent air exchange, thus creating a healthy room climate. It is indeed a reliable protection against moisture-conditioned damages and fungal invasion.
Moreover, modern systems have to fully guarantee sound control.

Complex Room Acoustics Analysis Methodology for Large Lecture Theatres

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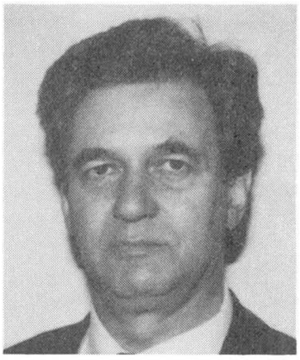

Hans-Peter Tennhardt, born 1942 studied at the Technical University Dresden from 1962 until 1968. Research Scientist and vice head of department at the Building Academy of the GDR, Berlin from 1968 until 1990. From 1991 group leader Room Acoustics at the Frauenhofer Institute of Building Physics. Since 1992 head of Building Physics section at the Institute for Maintenance and Modernisation of Buildings (IEMB e.V.) in Berlin.

Summary

The room acoustical function securing of important concert halls and large auditoriums is tied to the achievement of optimal audibility parameters the realising of which assumes a direct influence upon shape, surface and furnishing of the presentation room. To avoid bad investments and cost intensive remedial works, a quality safeguarding complex-method was developed further, which is based upon fundamental analyses of the primary structure of the auditorium by means of a computer simulation and detail analyses of the secondary structure through a measuring method with the aid of a size reduced model of the interior on the basis of the system theory.

1 Complex room acoustics analysis methodology

The complex analysis methodology for the design of large auditoriums (e.g. concert halls, music and speech theatres, congress centres) determines on the basis of the system theory in advance the room acoustical parameters of an unknown room (black box) with an adequate degree of accuracy. With the room acoustical design of large, high class auditoriums or with rooms of complicated shape (e.g. cylindrical rooms) a combination of two methods for the determination of the room pulse response, the mathematical and the physical model technique is applied. For the principle clarification of questions of the primary structure of the room (basic shape) the for this purpose more efficient computer simulation is applied. The questions of the secondary structure (surface creation, shaping) can with the required accuracy be clarified on the physical model only by means of the metrology.

Comparable objective and subjective analyses in the completed room show that the achieved accuracy of the room acoustics criteria between model and actual room is below the significant threshold of perceptibility.

1.1 Design method of the computer simulation

The methods applied at present are based upon the geometrical room acoustics:
-Image source method:
Each reflected sound ray originates from a secondary sound source which reproduces the image of the original sound source.

-Ray tracing method:
From the position of the original sound source numerous sound particles are reflected which describe the spreading of a sound energy pulse in energy quantum's according to the intended directional characteristic.

- Some methods can allow for diffuse sound reflections, but not the frequency dependent sound refraction.
-The fundamental disadvantages of the above mentioned individual methods have led to the development of efficient combinations.

1.2 Design method of the model metrology (physical model)

The room pulse response is obtained in the reduced interior room model (suitable scale 1:20) of the presentation room by application of the model laws. At the location of the sound source (stage, rostrum, orchestra pit, loudspeaker) a sound pulse is reflected. At the reception positions the acoustical reaction (response) of the room is simultaneously received through an artificial head with ear replica (see fig. 1). Special scale loudspeakers serve as simulations of a speaker or singer, of an orchestra with the instrument groups and as loudspeaker
The analysed frequency range is between 5 kHz to 200 kHz at model scale, i.e. 250 Hz to 10 kHz within the original range.
All physical sound processes like, amongst others, refraction and dispersion are shown frequency true.
The achieved accuracy is at present far above computer accuracy. The methods can answer questions of balance analyses in music presentation rooms, of the electroacoustics and of the directional effect of wall and ceiling textures equally at model scale.

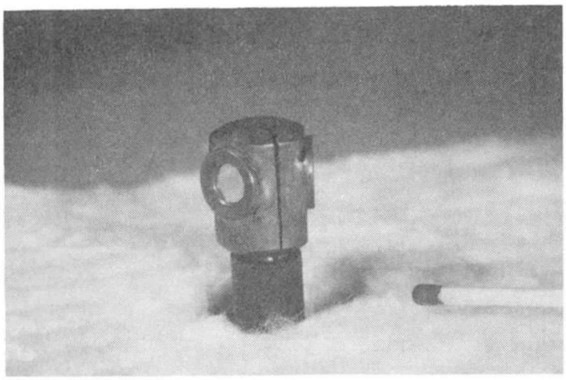

Fig. 1: artificial model head

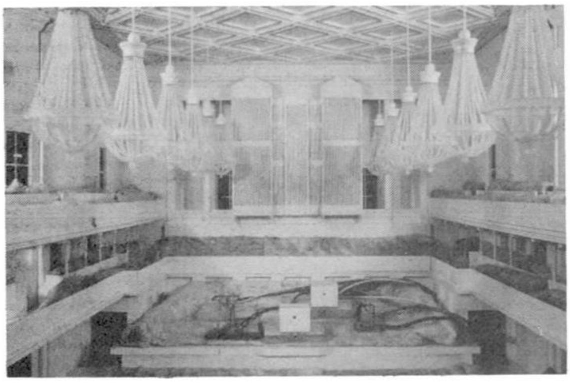

Fig. 2a: model " Konzerthaus Berlin"

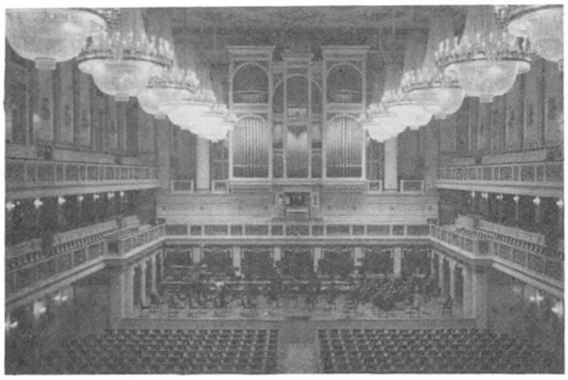

Fig. 2b "Konzerthaus Berlin" large auditorium

2 Auralisation

The binaural and head related room pulse responses obtained from the analyses on the mathematical and physical model can with the aid of music and speech programmes be "folded" and thus facilitate a "listening in" into the in reality not yet existing room. The derivation of building construction changes is not yet altogether possible.

Rehabilitation of Concrete Walls using Thermal Insulation

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Summary

Exterior walls of concrete buildings frequently exhibit surface deterioration due to corroding reinforcement. Laboratory and field experiments show that it is possible to arrest the rebar corrosion in exterior walls of concrete buildings in Central or Eastern European or similar climates by additional thermal insulation. This method makes it possible to arrest the rebar corrosion without the usual concrete repair and at the same time to save heating energy.

1. Introduction

Exterior walls made of reinforced concrete often show surface deterioration due to rebar corrosion. Hand-applied concrete repair of these walls is expensive and the results may be imperfect. On the other hand the thermal insulation of these walls often is not sufficient according to today's standards. It can be demonstrated by diffusion calculations that it is possible to dry the exterior walls of concrete buildings in Central European or similar climates by attaching an additional thermal insulation to the outside of these walls. To verify this theory the following laboratory and field experiments were made.

2. Experiments

Accelerated carbonated concrete specimens with in advance weighed steel bars were stored in different relative humidities. Later the specimens were investigated for steel corrosion (fig. 1):

- All steel bars showed a basic corrosion caused by the carbonation of the concrete specimens.
- After four years of investigation the basic corrosion level did not change in specimens which were stored in climates with a relative humidity of 60 to 80 %.
- When stored in 90 % relative humidity the rebar corrosion in the specimens showed a significant growth over the time.

To verify the above mentioned theory long-term field tests were made at a dwelling in Berlin. Temperatures and moistures in the concrete sandwich exterior walls with and without additional thermal insulation were recorded for more than five years (fig. 2): The outer layers as well as the bearing layers of the sandwich walls were drying behind the additional thermal insulation. After a few years the concrete moisture was in an equilibrium to the measured relative humidity of 30 to 70 %.

3. Conclusions

The above mentionded experiments show that steel corrosion in reinforced concrete walls with additional thermal insulation can be arrested because after some years of drying the concrete moisture is in equilibrium to not more than 80 % relative humidity to the surrounding atmosphere (fig. 3). Another corrosion protection (as used in usual concrete repair) is not necessary.

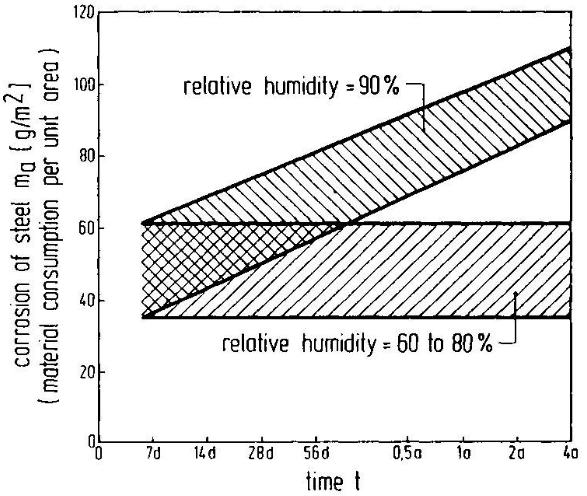

Fig. 1 Mass losses of rebars in carbonated concrete specimens stored at different r.h.

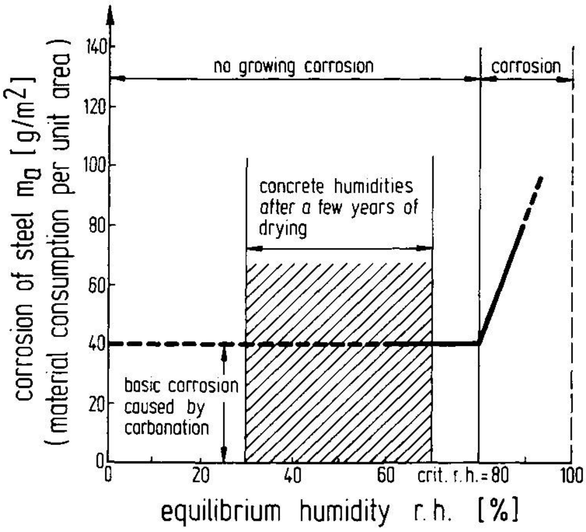

Fig. 3 Scheme of arresting rebar corrosion in concrete exterior walls using additional thermal insulation

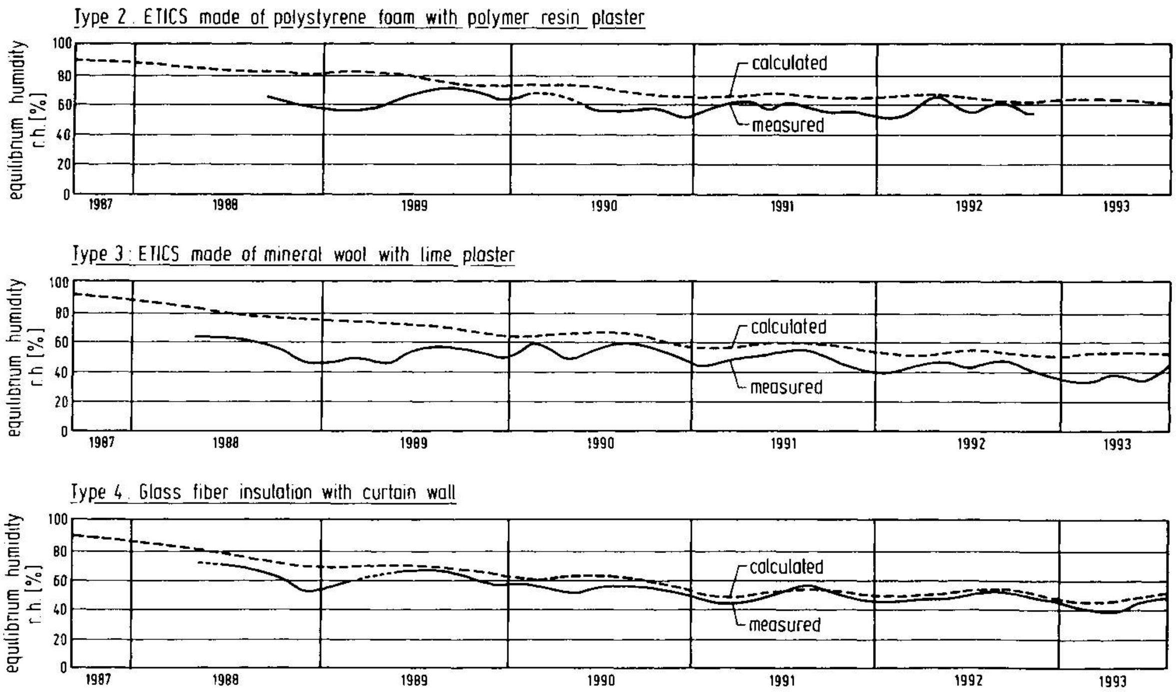

Fig. 2 Measured and calculated equilibrium humidities in the outer layers of concrete sandwich exterior walls with additional thermal insulation

Mineral-Wool Based, Glased Curtain Walling with Solar Energy Use

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Summary

A new type of curtain walling for architectural design consisting of a rockwool insulation material laminated with a coloured felt and a glass cladding with open joints will be presented. Research results concerning the thermal bridge effect of a new facade mounting system and the achievable passive solar energy gains of a rockwool insulation are discussed.

1. Concept of curtain walling

For improved cost reduced architectural design of facades combined with passive solar energy gains three industrial partners, VEGLA Vereinigte Glazswerke GmbH, G+H Montage Fassadentechnik GmbH and G+H ISOVER AG, have developed a new ventilated glazed curtain walling. This curtain walling can be used for new building and for retrofit of multiple dwellings and office buildings to secure the necessary hygrothermal, acoustical and fire protecting performance of the facade. The external cladding is a single pane safety glazing which for design purposes can be printed with different half-dot pattern.

The facade mounting consist of single, thermally separated fasteners which are fixed to the wall through the horizontal open joints of the cladding. Behind the glazing rockwool boards with laminated coloured felt are glued or fixed using dowels. The coloured laminated felt offers in combination with the half-dot printed glass panels multiple design possibilities.

Beside the architectural aspects the new facade system allows to improve the insulating performance of the mineral wool insulation by use of passive solar gains.

2. Passive solar energy gains

The principle effect of achieving passive solar energy gains by the glazingand rockwool insulation material has been already observed by the Fraunhofer-Institute for Building Physics during a research project of the BMFT „Light transparent, energy gaining insulation system for building application LEGIS" and shortly described.

Solar radiation falling through the glazing will penetrate some centimeter into the insulation material due to the fact that mineral wool forms a porous translucent material. The penetration depth of the radiation depends on fibre density, orientation and diameter as well on the surface composition. Inside the insulation the absorbed radiation is transformed to heat and gives the effect of a counter heating during the heating season which significantly reduces the thermal losses of the facade.

Due to the effect that the effective transparency of the mineral wool is restricted and only a small amount of radiation is transmitted to the wall, the problem of overheating of the facade and building in summer is neglegible compared to high transparent insulation system. Therefore no need exists for costly shading devices and the new system can be applied to the whole facade.

3. Influence of thermal bridges

Beside the utilisation of polar radiation the new ventilated curtain walling has been optimised with respect to the thermal bridge effects of the facade mounting system. The effects can dramatically reduce the effectiveness of the thermal insulation of a ventilated facade has been shown in several recent research projects. For the new system therefore a thermally optimised fastener has been developed.

The computer simulation of the influence of the fastener composed to in situ measurements on a facade are given in this lecture.

4. Results

At a research building of the Fraunhofer-Institute for Building Physics Holzkirchen and at the G+H research building Ladenburg the new curtain walling are installed and outdoor measurements were made about 2 years.

Previous results of the obtained solar gains and the achieved reduction of the effective thermal transmittance U are shown in table 1.

U-value (calculated)	0,266 W/m^2
calculated mean density of heat flow rate (climatic data 18.3.-22.5 and 1.9.-10.12.1997)	3,81 W/m^2
measured mean density of heat flow rate (climatic data 18.3.-22.5 and 1.9.-10.12.1997)	2,33 W/m^2
effective U-value (climatic data 18.3.-22.5 and 1.9.10.12.1997)	0,163 W/m^2

Table 1

Further results of outdoor measurements on solar gains of the new curtain walling at the Fraunhofer-Institute for Building Physics Holzkirchen and at the G+H research building Ladenburg are presented and discussed with respect to the thermal bridge effects and the total energy balance of the system will be evaluated at the IABSE Colloquium.

Influence of the Glass Paned Areas on the Closing Walls of Buildings

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Summary

With a look on establishing an adequate value of the thermal transmission resistance, the study analyses the necessary of heat for an area considering separately the losses of heat through the opaque area of the wall, the losses through the glass pane area and the necessary heating for the cold air infiltrated through joinery leaks and their weight in the entire heat necessary for different percentages of the glass pane area in relation with the total area of the wall.
This way a good thermal insulation will be achieved by diminishing, at first, the losses of heat of great weight in the total heat necessary.

Introduction

The glass pane elements must meet some functional demands concerning illumination, thermal protection, architectural plasticity, etc.
In order to respect the minimal illumination index, which takes values between 10 - 16 % for dwellings, in relation with the rooms' purpose, minimal dimensions must be established for windows. But the glass paned surfaces are parts with much lower thermal resistance than the opaque parts of the walls, the thermal energy lost through the windows (by direct transmission and by heating the infiltrated cold air) having an important weight in the building heating.
In this context, the problem of reducing the heat losses through the glass paned parts of the walls naturally imposes.

The hygrothermal behaviour of glass paned closing walls

The thermal energy losses per hour can be expressed by the relation:

$$Qp = \left[\left(\sum KosSs + \sum KoFSF\right)\left(1 + \frac{\sum A}{100}\right) + \sum Ljijv^{4/3}\right]\Delta T \qquad (1)$$

where S_s and S_f are the opaque surfaces of the windows, having the thermal transfer coefficients K_{OS} and K_{OF}; L_j is the length of the joinery spaces through which the cold air infiltrates, with the infiltration coefficients i_j; v is the calculation speed of the outside air. $\sum$ **A** represents the sum of the additions (for the orientation, the cold surfaces' compensation and the special addition), and Δ **T** is the difference between internal temperature (T_i) and external temperature(T_e).

For a temperature difference of one degree, the relation (1) becomes:

$$q = K_{OS}S_S + K_{OF}S_F + Lq_i = q_S + q_F + q_i \qquad (2)$$

Considering, for example, a wall with a window having R_{OS}=0,92 m^{2}K/W, R_{OF} = 0,33 m^{2}K/W, the calculation speed of the outside air v = 4 m/s and the infiltration coefficient i=0,093W/(m/s)$^{4/3}$K (corresponding for timber double windows), for a total wall surface of 9,72 m^2 (3,60 m x 2,70 m) and diverse window sizes, **Table 1** presents the heat losses q_S, q_F and q_i , and their weight in the total heat loss.
We mention that the partial losses (q_S, q_F, q_i) aren't real losses, being obtained by multiplying by ΔT, but their weights are real.
Analysing the values in **Table 1** we find that the increasing of the thermal resistance of the opaque parts of walls with large windows is not enough . The increasing of the thermal resistance of the glass pane part , too , becomes obviously necessary.

S_s [m^2]	L_f [m]	H_f [m]	S_F [m^2]	L [m]	q_S [W/^{0}C]	q_F [W/^{0}C]	q_i [W/^{0}C]	q 5+6+7 [W/^{0}C]	$\frac{q_S}{q}$ [%]	$\frac{q_F}{q}$ [%]	$\frac{q_i}{q}$ [%]
9,72	-		-	-	10,57	-	-	10,57	100,00	-	-
8,28	1,20		1,44	6,00	9,00	4,36	3,54	16,90	53,25	25,80	20,95
7,92	1,50		1,80	6,60	8,61	5,45	3,89	17,95	47,97	30,36	21,67
7,56	1,80	1,20	2,16	9,60	8,22	6,54	5,66	20,42	40,25	32,03	27,72
7,20	2,10		2,52	10,20	7,83	6,82	6,02	20,67	37,89	32,99	29,12
6,84	2,40		2,88	12,00	7,44	8,73	7,08	23,25	32,00	37,55	30,45
7,92	1,20		1,80	6,90	8,61	5,45	4,07	18,13	47,49	30,06	22,45
7,47	1,50		2,25	7,50	8,12	6,82	4,43	19,35	41,96	35,25	22,89
7,02	1,80	1,50	2,70	11,10	7,63	8,18	6,55	22,36	34,13	36,58	29,29
6,57	2,10		3,15	11,70	7,14	9,54	6,90	23,58	30,28	40,46	29,26
6,12	2,40		3,60	13,80	6,65	10,91	8,14	25,70	25,88	42,45	31,67
5,67	2,70		4,05	14,40	6,16	12,17	8,50	26,93	22,88	45,56	31,56

***Table 1**: The partial thermal fluxes weight in the total flux in case of walls with diverse window dimensions.*

Conclusions

The conclusions that draw from the heat flow analysis are really important in establishing the necessary resistance of the closing elements. Therefore , we can see that the increase of the thermal resistance of the opaque part is less efficient in the case of walls with large windows and, hence , for obtaining a real efficiency of the thermal protection , the increase of thermal resistance for the glass paned parts also becomes necessary.
These considerations can lead to a few concrete ways of increasing the thermal transfer resistance efficiency for the glass paned parts of the walls. These are:

- -avoiding the use of simple windows for heated rooms;
- -using windows having better thermoinsulating qualities (thermoreflecting, IZOVIT), with the thermal transfer coefficient lower than the usual by 50 - 100%;
- -using, as an alternative to special windows, three or four glass sheets with air spaces of 15 - 20 mm between them;
- -improving the joinery design by using a metallic joinery with a reduced section and equipping it with thermal insulation, using supplementary thermoinsulating on the outline spaces, in the fixing part of the windows;
- -increasing the tightness of the joinery, thus, decreasing the amount of infiltrated air.

Energy Audits of Schools in the Town of Kamnik

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Summary

In order to lower energy consumption and the costs for energy used for heating, lighting and hot water supply in primary schools in the municipality Kamnik an energy audit has been carried out. The energy consumption and current state of building envelope and heating system have been established for each of 17 schools in the municipality. A list of energy saving measures has been determined regarding cost efficiency and energy saving potential in order to give the investor a professional basis to plan necessary investments in energy restoration and building maintenance. As a result of this audit an integrated energy conservation plan was then prepared and implemented in 1996. The first year of energy consumption monitoring shows approx. 265 MWh (39 %) reduction.

1. Introduction

An important part of expenses for the operation and maintenance of buildings are expenses for energy used for suitable living and working conditions. Expenses for the maintenance of public buildings are in the large scale charging the local communities and the state budget. The expense for energy is one of the largest that can be supervised and lowered by implementation of the energy efficiency measures. The biggest number of buildings, which operation is based on the municipal budget are the primary schools. Systematic financing of the energy restoration of existing buildings offers possibility to decrease energy consumption and expenses and, with the means saved, to create a fund for investing into more intensive actions of the energetic refurbishment or into modernisation of the activity.

Municipality Kamnik is located 20 km north from Ljubljana, capital of Slovenia at the base of Alps. The heating degree day number for town Kamnik is approx. 3500 degree days, with the average temperature in winter around 0 °C and lowest temperatures in winter down to -25 °C. The Kamnik municipality methodically decided to arrange the energy politics when starting the energy plan of the town Kamnik.

2. Energy Audit of Fran Albreht Primary School

Fran Albreht school building is one of the 17 audited schools in municipality. It is an early 1960's "H" shaped four storey structure, with total heated floor area of 3280 m^2 (11,000 m^3 heated volume). It has a concrete roof and wood-framed double glazed windows. Space heating and hot water services were provided by two light-oil fired boilers. The average fuel consumption in the heating season for the Fran Albreht Primary School (1991 - 1995) is 66.000 l, average annual consumption of electrical energy is 53.400 kWh. Specific energy use for the school is 194 kWh/m^2a.

As a result of this audit an integrated municipal energy conservation plan, aimed at reducing the energy consumption by reducing heat loss through the roof and windows, and to improve comfort conditions by improving the heating control, was then prepared.

3. Measures Implemented

A detailed energy audit recommended a series of measures and the final package included the following measures:

- loft insulation
- replacing the remaining original windows with new plastic framed windows with argon filled Low-E double glazing,
- connection to district heating with sub-station,
- Building Energy Management System (BEMS) with heating zone control and weather compensator,
- thermostatic radiator valves (TRVs) and hydraulic regulation,
- variable speed drive pumps

Table 2. Breakdown of estimated savings at Fran Albreht elementary school

Measure	Energy Savings (MWh/year)	Pay back Period (years)
Loft Insulation	122	2.9
Low-E Double Glazing (1)	53	2.3
Connection to DH(2)	24 (est. 5%)	4.0
Building Management System (BEMS)	48 (est. 10%)	4.9
Thermostatic Radiator valves (TRVs)	48 (est. 10%)	14.2
All Measures	295	4.6

(1) The difference between Low-E double glazing and normal double glazing - the air exchange rate was also improved, but these savings are small and are not included here
(2) The difference between new boilers and connection to the local district heating (including heat sub-station and the main pumps)

4. Results

Achieved energy savings were fing Measured energy consumption in the heating season 1996/1997 was 410 MWh. Compared to average light oil fuel consumption of 66.000 l oil (660 MWh) it presents reduction of 250 MWh or 38% in energy use. Taking into account also heating degree day number - average for 1991 - 1995 was 3490 degree days and for the season 1996/97 it was 3571 degree days, the consumption should be 67.500 l, so the savings are 265 MWh or 39 %.

5. Conclusions

Measurements of energy consumption during one heating season after the implementation of the measures show 39% reduced energy use. The results achieved matched the investors expectations.

6. Acknowledgements

The paper is based on a study "Energy audits of elementary schools in municipality of Kamnik", 1995 and on a project funded by European Commission DG I PHARE programme "Demonstration projects of energy efficiency investments in building and industry sector", 1996.