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BUILDINGS AND ENVIRONMENT 2016

INTERNATIONAL CONFERENCE PROCEEDINGS

22nd – 23rd September 2016

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FACULTY OF CIVIL ENGINEERING

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enviBUILD 2016 - Buildings and Environment

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Preface

The 11th International enviBUILD 2016 Conference held in Brno focused on specific issues related to buildings and environment especially in Central Europe. We hope that it provided good opportunity for discussion and publishing of most recent findings from scientific and academic community in the field of building physics, sustainability and healthy built environment.

In these digital proceedings you can find conference papers and abstracts of selected peer reviewed papers that are published in special issue of Applied Mechanics and Materials Journal (full-texts available on http://www.scientific.net/AMM). The proceedings include nine sections:

- Building Materials and Structures
- Energy Performance of Buildings
- Smart Buildings, Smart Cities, Sensors
- Retrofitting and Revitalization of Buildings
- Sustainable Building and Environmental Assessments
- Hygrothermal Performance of Buildings
- Indoor Climate, Thermal Comfort and Ventilation
- Daylighting and Insolation
- Acoustics and Noise Protection

Before you start browsing the content of this proceeding, let us express many thanks to everyone who spent their time and contributed to the organization of the conference: authors, reviewers, members of the Scientific and Organizing Committees. We highly appreciate the time you devoted to the enviBUILD 2016 conference. These proceedings present one of the results of your effort.

Miloš Kalousek
Karel Struhala

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Section 1: Building Materials and Structures

Development and Experimental Verification of Sliding Elements of Transparent Loggia Enclosures in High-rise Building

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Keywords: High-Rise Building, Aerodynamic Study, Transparent Loggia Enclosures, Experimental Verification, Pressure Chamber, Acoustic Camera.

Abstract. Originally open balconies and loggias of high-rise residential building showed a significant aerodynamic load - discomfort for users. Subject of the contract cooperation with the investor was therefore development, experimental verification and optimization of the strength and functional parameters of sliding elements of transparent loggia enclosures from the effect of the dynamically changing wind pressure (pressure - suction), as well as the elimination of undesirable acoustic expressions. This paper introduces the aerodynamic study of the building with the objective of quantifying the maximum load on sliding elements from the effects of wind as the boundary condition for their dimensioning. It describes the final design of transparent sliding elements and their experimental verification in a large pressure chamber in laboratory. The elimination of undesirable acoustic expressions was successfully implemented through design optimization with use of acoustic camera.

Grate-Free Ventilated Thermal Insulation Systems

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Keywords: Reconstruction, Composition of Circuit Design, Substrate Moisture, Humidity Masonry, Uneven Surface, Ventilated Thermal Insulation, Thermal Transmittance, Mineral - Stone Wool, Hard Plate, Grate-Free Mounting Plate, Special Plate Anchor Price, Entire System, Fire Resistant, Ventilated Space, Ruggedness.

Abstract. Grate-free ventilated thermal insulation systems. Description of the using a complex system grate-free aerated insulation of buildings using plate anchors "michno-system" and Gigapan boards. This is a new way of insulation, which will be financially viable for a wide range of buildings. The system responds to common problems with traditional contact system. These are primarily the effect that the house called "breathe", then there will not be a risk, that the birds will be peck insulation. The system is suitable method for solves the problem of uneven walls for reconstruction, disparate and sometimes wet outer shells of old buildings.

Introduction

At present, we assess the quality of the indoor environment. Contact thermal insulation systems ceases to perform in foreign countries more than 20 years. Finally, even here the professional community admits the unappropriateness of contact thermal insulation for interior comfort staying of people in residential and public buildings. For people with high sensitivity are being developed health problems related to staying in these objects. These are primarily respiratory diseases. The formation of mold and bad air exchange in addition the growth of bacteria building with contact insulation almost not breathing, if not invest considerable funds into the ventilation system and recuperation. These measures are completely opposed to the very idea of energy savings. This gives rise to again energy costs for the operation of these devices. So why not insulated so that the subject is still breathing and there was no need at all to some manifestations of the formation of mildew and bad internal environment to deal with.

According to applicable standards CSN 73 0540, which is binding, valid for the recommended external wall heat transfer coefficient $U_N \leq 0.2$ $W \cdot m^{-2} \cdot K^{-1}$ and heavy exterior wall is $U_N \leq 0.25$ $W \cdot m^{-2} \cdot K^{-1}$. Additionally in the assessment shall include the influence of thermal bridges, which then eliminates the increasing thermal insulation.

The proposed system of ventilated facades is considering a combination of mineral wool (rockwool) anchored to the existing masonry to dry without sticking (refer with: Figure 1). Stone wool products are made of natural materials, recyclable and environmentally friendly. Stone mineral wool is an excellent non-flammable insulation material that absorbs noise from outside, long keeps its shape, keeps the breathability of the walls and contributes to the fire safety of buildings [1]. Now rock mineral wool complies thanks to its unique characteristics strictest criteria, requirements and standards for building insulation.

It is also a assembly of special anchors for fixing so. Super Slabs of MGO, and the subsequent installation of the contact safety waterproofing mineral wool (stone wool). The entire system is covered by boards at a distance of at least 30 mm of mineral wool.

Superboard is a large-format structural building board white with dimensions of 1.22x2.44 m (refer with: Figure 3). The board contains magnesium oxide MgO, which is fireproof. The plate has a high resistance to water and moisture. The board is therefore suitable for buildings with problematic masonry - mixed or brick which exhibits increased moisture. From the viewpoint of

acoustic properties it has excellent sound insulation properties. flexibility and strength. An important property of the plates is their resistance to pests, mildew and rot and rodents. The board is sterile and protects against fungi and bacteria, it helps to conserve energy thanks of high-reflectance infrared spectrum.

Composition of the board: The core of the board consists of 48.9% of MgO, further 25.4% MgCl 2, 5.1% SiO2, 13.3% wood pylons, 6.3% cements and fillers based on cement. Nominal density: 0.77 - 1.2 $g \cdot cm^{-3}$. The surface of the board consists of mutually glass fiber mesh of 1%, the coating is formed of MgO.

Boards are not pecking by birds and any subsequent repairs to the surface are inexpensive. The boards are screwed into the anchor using a special hardened screws MGO size 3.5x35mm over distances of 200-250 mm. Class of reaction of fire the board is A1 [3]. Bulk density of the plates is about 779 $kg \cdot m^{-3}$.

The finish of plates is possible, first coating facade paint or by coating the through-colored silicate or silicone plaster rendering grain size up to 1.5 mm (possibly up to 3 mm).

Airborne sound insulation of exterior Super Slabs of MGO is 44 dB. Fire resistance is assessed according to CSN 73 0804 - with this type of ventilated facades is best to use mineral hydrophobized insulation in combination with the proposed board, which has declared reaction to fire classification A1.

MGO board meets the hygienic requirements, does not contain formaldehyde, ammonia nor other hazardous substances. MGO is a natural material. CO2 has a negative value, and conversely it absorbs from the atmosphere. Mechanical resistance against damage the facade is high - in the base plate 8 mm thick (BASIC) has strength perpendicular to the plane of bending 10 MPa and tensile strength in bending in the wet state of about 7 MPa.

Ventilated facades ensuring comfort object with respect to the ongoing ventilated gap between the top plate and insulator. Ensure proper ventilated gap thickness. 30 mm over the entire height of the facade. For window frames, in window and door door head and other parts to the height of one floor (maximum to 3.05 m may be allowed a minimum the ventilated space 20 mm).

Supply and discharge must have a minimum cross-sectional area of 50 $cm^2 \cdot m^{-2}$. In places where it is expected a larger amount of snow is necessary to ensure an adequate supply of air into the ventilation gaps. Inlet and outlet openings is appropriate to protect the grid against intrusion of pests.

The supporting structure for the cladding plates of the MGO consists of a system of plate anchors - "Michno - System " (refer with: Figure 2). The anchors are formed by anchoring threaded rod, dowels and plate. The whole anchor can be adjusted and it is ideal for leveling uneven substrates. Simply screw individual anchors to a desired distance from the wall, regardless of its flatness of them. Anchors create a planar substrate for assembly plates. Distances of anchors between them is at least 612.5x612.5 mm grid.

Main advantages of ventilated facades:

1. Installation using the dry process - time flexibility.
2. Removal of condensation in the walls.
3. Ventilation insulation system with high comfort for a living and stay in buildings.
4. Ideal way for construction of uneven substrates and possibly wet - the reconstruction of buildings.
5. Reliable thermal, mechanical and fire protection facilities.
6. Simple repairability final finishes.
7. Reduce the penetration of noise from outside.
8. Dimensional stability and mechanical resistance of pecking birds.
9. Possibilities architectural finishes in terms of shape and color.

10. The price is approaching the price of contact thermal insulation in principle is similar – price range from 1250 - 1550 CZK·m^{-2} Mineral wool insulation product with a long grain of tl.140 mm. Impact on cost is in addition to the thickness of the insulator and the articulation of the facade and the amount of detail.
11. Decreasing diffusion resistance to the exterior.
12. Permanent protection of the interior from overheating.
13. Ensure constant drying of thermal insulation.
14. Any of insulation thickness.

Disadvantages of ventilated facades:

1. Requirements for technical performance and adherence to quality implementation of details.
2. Possibility partial from getting wet of isolation.
3. Slightly higher cost of implementation than for the contact facades.

Figure 1. *Anchoring insulator - mineral boards.*

Figure 2. *Grate-free anchors for attaching of plates.*

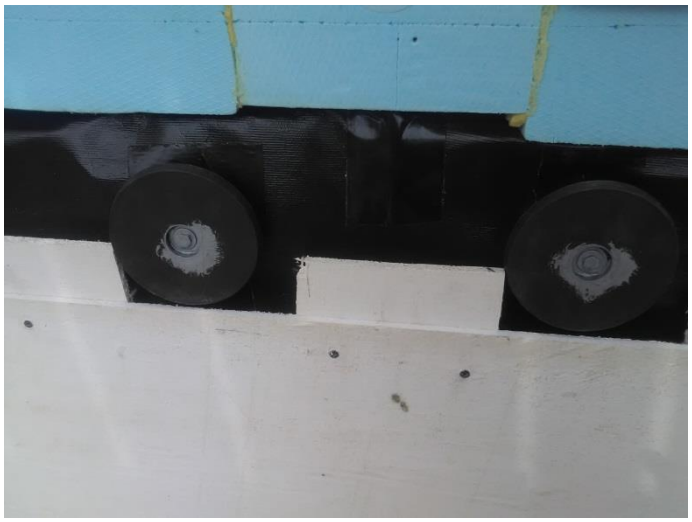

Figure 3. *Super MGO board for system suitable thickness 8 mm.*

Summary

Design is always determined for all layers as a whole (with ventilated structures to ventilated gap and with the intended effect of thermal bridges due to anchoring), even if the design thickness sufficient thermal insulation, thermal design according to our technical requirements generally obliges. Very good insulating mineral wool insulation for ventilated facades that meet heat transfer coefficient $U \leq 0.20$ $W \cdot m^{-2} \cdot K^{-1}$ to a thickness of 180 mm, without considering the influence of the substructure and considering the declared value of thermal conductivity λ_D, which is necessary for an accurate calculation to convert the design, according to EN ISO 10456 and ČSN 73 0540-3.

[2] But it is important, how it works and ventilated facade as thermal insulation in construction behaves, what it works, how it changes its characteristics due to the influence of influencing factors etc. These questions cannot be answered simply, it is always necessary to assess each case individually The system of ventilated facades is thus based on the ventilated air gap between the thermal insulation and self facade plate. For the system to work properly, the air flow in the gap.

The air from the outer facade heated (in winter due to the heat loss from the interior) rises and this leads to an average speed of flow of 0.5 to 1.0 $m \cdot s^{-1}$ [2]. With such speeds, then usually leads to laminar flow, whereas turbulence occurs rarely in several places due to other factors (height and shape of the building, the nature and type of grate solution supply and discharge openings etc.).

What has this effect on the flow of heat insulation? The warm air has a great feature in itself absorbs significantly higher amount of moisture than cold air. When the air temperature in the room drops below the critical level (ie. Dew point), relative humidity begins to approach 100%.

Thanks to this surface condensation (drops) appear on the inner surface of the structure, the inner surface temperature is lower than the dew point temperature of the internal air. Important in this case is a condition where the warm air can on the contrary this moisture into itself absorb. We are interested especially in a situation where no thermal insulation dry (summer early morning precipitated on the surface dew drops or there is a blowing-water wind into the space etc.) and through subsequent moisture are during this period its thermal insulating properties worse than considered (thermal conductivity λ is then significantly higher values of the declared value of the thermal conductivity $\lambda D = 0.035$ $W \cdot m^{-2} \cdot K^{-1}$ may be a value up to 40% less). With ventilation, the thermal insulation is relatively quickly dried and is again perfectly heat insulating material. Moving air removes moisture from mineral thermal insulation that into it diffuses from the interior through its own supporting structure (mostly in the winter, but in theory it is happening almost any time when the temperature outdoors is lower than indoors), thereby contributing to a healthy vlhkostnímu mode the whole structure . However, we can be sure that the structure is properly designed, it needs to always check and calculation.

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Experimental Preparation of Magnesium Oxide Board

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Keywords: Magnesium Oxide Board, Experimental Preparation, Composition of MgO Board, Tensile Strength in Bending

Abstract. In the present, global production of magnesium oxide (MgO) boards comes exclusively from China. However, Slovakia is one of the leading countries in the mining of magnesite. Therefore, an experiment of MgO board preparation from local resources was realized. The experimental board was made from the calcined magnesite mined out in Hačava in Eastern Slovakia. The paper describes the production process of the MgO board in laboratory conditions. In order to compare the experimental MgO board with a MgO board from China, the tensile strength in bending was examined. The experiment demonstrates that the tensile strength of the experimental MgO board in bending in one direction is higher than the declared strength of the commercial board, but in the second direction it is nearly a half of the declared strength of the commercial MgO board. The results of this paper confirm the potential of the MgO board production from local resources.

Material Optimization of Wooden Window Structures to Increase Their Thermal Properties

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Keywords: Wood, Windows, Thermal Properties, Optimization.

Abstract. This contribution is dedicated to an alternative solution of wooden window structure in order to achieve better thermal properties. The proposed window with a sandwich material composition will conform to the requirement of the norm STN 730540 valid from the year 2016. Subsequently, production technology of the given structure will be described.

Characterization of Lightweight Concrete Produced from Plastics Waste – Polystyrene and EVA

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Keywords: Lightweight Concrete, Waste, Plastic, Polystyrene, Ethylene Vinyl Acetate, EVA.

Abstract. In this paper, the lightweight concrete made from polystyrene and ethylene vinyl acetate (EVA) waste was studied. EVA waste from footwear industry and waste polystyrene were used as an aggregate in the lightweight concrete. Each of the plastic wastes was used alone (as a sole aggregate) or in combination with the other in a ratio of 1:3, 1:1 and 3:1. The water-cement ratio of 0.50 and the dose of cement – 175 kg·m-3 were used for all mixtures. Test results showed that the bulk density and the thermal conductivity of lightweight concrete tended to increase with increasing EVA waste content. The maximum compressive strength of lightweight concrete was reached with the waste materials in a ratio of 1:1. Based on the results, the application of EVA waste as lightweight filler showed a good possibility for use in the lightweight concrete.

Examination of Mechanical Properties and Temperature Resistance of Epoxy Coatings Filled with Secondary Raw Materials

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Keywords: Epoxy Coating, Waste Glass, Tensile Strength, Shore Hardness, Temperature Resistance.

Abstract. Epoxy coatings are used mainly in the construction especially where it is necessary to increase the resistance of concrete floors against mechanical wear, to increase chemical resistance, to prevent dusting and to ensure hygienically clean environment. Epoxy coating is a composite material that consists of epoxy resin cured mainly by polyamine hardener and filler. As a filler is currently used pure silica sand Dorsilit ground to below 0.063 mm and for more demanding applications fine glass flakes with a high proportion of SiO2. The aim of this work is to experimentally examine the possibility of using secondary raw materials as fillers into three types of polymer epoxy coatings, where it seems the most appropriate utilization is waste glass with a high content of SiO2. Based on the evaluation of the test results of tensile properties, Shore hardness and temperature resistance the possibility of replacing the commonly used filler by finely ground waste glass is assessed.

The Development of Lightweight Thermal Insulation Plasters and Experimental Analysis of Their Moisture Behavior

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Keywords: Thermal Insulation Plasters, Moisture Transport, Lightweight Aggregate, Hydrophobic Agent, Porosity, Thermal Conductivity.

Abstract. The development of lightweight thermal insulation plasters containing alternative binders as a partial cement substitute opens the possibilities of using new, eco-friendly materials in civil engineering. The substitution of cement significantly reduces the energy consumption these materials' manufacturing. In addition, they contribute to the overall energy performance of buildings, which represents another environmental benefit. Concerning the negative effect moisture has on the thermal insulation properties of plasters, the investigation focused on the influence of various hydrophobic agents on the hygrothermal behaviour of the newly developed porous materials. The goal of the research was to develop eco-friendly thermal insulation and rehabilitation silicate materials and to analyse their moisture transport.

Analysis of Unreinforced Ceramic Wall Panels in the Mounting State

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Keywords: Prefabricated Ceramic Panel, Mounting State, Shapes of Panels, Bending in its own Plane, Static Issues.

Abstract. Properties of building materials used for the construction of surrounding structures significantly contribute to creating a healthy and comfortable microclimate inside the rooms. Ceramics belong among materials which exhibit very suitable properties for the formation of the healthy environment. It is also one of the reasons that the fired clay structures remain popular among builders and that recovery of ceramic prefabrication can be seen in the Czech Republic. The important step towards rediscovering the benefits of the prefabricated ceramic elements is forthcoming production of unreinforced ceramic wall panels made of fired clay masonry units with tongue and groove, connected in the bed joints by two-component adhesives. Conventional analytical model for vertical loads is used in the operating state. However, in the transport and mounting state it is a structure stressed by bending in its own plane. This paper is focused on the issue of load-bearing capacity of structures with masonry units cross-sections that are not filled in head joints and therefore are unable to transfer either tensile or compressive stresses. On the segment of the wall panel is performed numerical model analysis using the finite element method in the computing program ANSYS and comparison of this analysis results with the results of the experimental tests.

Current Importance of Glasses and Influence of the Weakening of Glass Surfaces on Glass Strength

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Keywords: Glass, strength, tears, linear elastic fracture mechanics, weakening of surface.

Abstract. Purpose of this work is of current importance and failure due to surface cracks in glass. This significance has risen compared to past. The nowadays tendencies are stated and the glass functions, which infiltrated to the top in terms of technology and architecture, are summarized. At its peak the glass also applies to a significant failure rate due to its extreme sensitivity to breaching of the surface quality. In connection, the comparison of strength of an undistorted almost perfect element and element surface subjected to external influences, in which can be seen more slight weakening in its surface, is presented. The processes under stress which could, in the extreme, lead to the weakening of the surface to total fracture are reported. Knowing the processes and locating the first crack we can see significant sensitivity of glass quality, even the smallest cracks on the surface, which may lead to significant minimization of the total capacity. Summarizing of allegations stated in the text shows that its sensitivity causes a sudden fracture resulting in weakening of the glass surface. Weakening of surface due to normal wear cannot be eliminated. Cited theory of the process of stress and fracture of the glass highlights the significant influence of surface quality even at an affordable and technically sophisticated system that might even with the slightest cracks suddenly fail.

Current Importance

In comparison to the past the significance of glass has incomparably risen lately. It can be stated that in addition to lighting the glass is substantially applied in the load-bearing capacity and for creating comfortable climate housing. Using glass can bring an attractive style to the area and the interior microclimate adapts to the overall comfort of living. With current technological processes, the glass can be adequately and effectively adapted to its functions. In the context of the current technological peak in this area the application of glass and with it the numerous manifestations of disorders and sudden failure has increased.

Solar and Load-Bearable Glass

Solar Spectrum. Solar spectrum traveling through space to the earth surface varies in a wide range of wavelength 100 nm and 1 mm, as can be seen in Figure 1. The entire solar spectrum does not penetrate to the earth's surface. On the way it gets absorbed or reflected by the atmosphere and clouds.[3] Solar spectrum of 300 - 2500 nm wavelength reaches the Earth’s.[3]

Significant is the spectrum of light passing through the atmosphere to the actual glass. If it concerns technically innovative glasses the parameters monitored are related to the input of solar energy and visible light as well as minimal UV entering the atmosphere. Currently, we want to technically eliminate solar energy and eventually UV with simultaneous nearly 100% visible light transmittance.

Solar Glass. Due to transparency and technological adaptability of glasses an entire spectrum of types appears. The glass itself now constitutes the overall climatic comfort indoors.

Interior lighting has a very significant influence on the microclimate in the area. Humans are sensitive to many forms of lighting and general harmony with the surroundings. Nowadays the glass

is, in connection with the microclimate in projects, an important topic and the centre of a quality project. With this idea the rate of fitting glasses and with it the amount of incoming solar energy has risen. [8] However, a significant impact of this phenomenon on the microclimate of comfort can be seen. In this situation we can use glass, which eliminates exactly these effects of extreme input the solar energy during intense shine. Innovating the glasses we can reduce the extreme heat entering from outside, alongside with the necessity of designing air conditioning and eventually shielding glasses on sunny days.[11] In addition, the glasses minimize energy loss in winter, while simultaneously transmitting the maximum out of that low solar gain in winter. With this fact and the fitting system is also connected the climate of the area, the layout of the building to the ground and the property in relation to northern unlit or other intensely illuminated sides according to the time of the year. Due to the climate, the glass is exposed to extreme conditions. At the same time we can reduce the cost of creating an optimal indoor climate throughout the year. [11,16]. These connections relate to the whole design process.

In the context of minimizing the impact on the surrounding area we may encounter the certified glasses „Green“, which are according to the environmental assessment friendlier to the environment.[11]

According to the projected microclimate conditions the interior features often overlap. Currently, we can find a wide assortment of glasses, which are selected according to the situation.

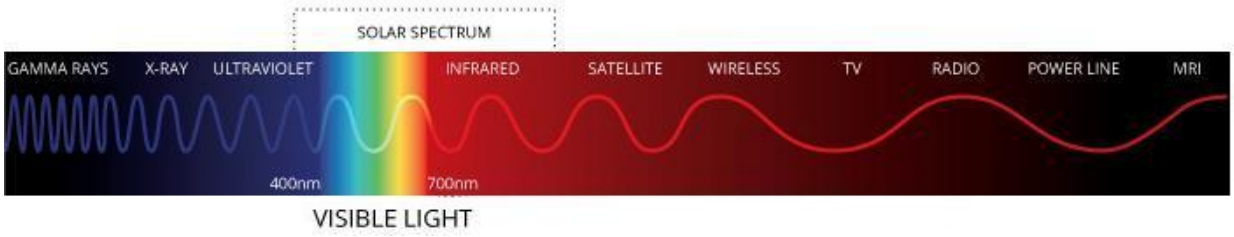

Figure 1. *The solar radiation spectrum includes bands between 100 nm and 1 mm, which encompasses ultraviolet, visible and infrared radiation. [3]*

Load-bearable Glass. Glass has undergone an important process of innovation even in the load bearing capacity. Due to current trends and contemporary processes we can encounter glasses that are compatible with stress resulting from given situations. In these systems the glass forms a support element itself. With this in mind may be mentioned the so-called safety glass and security glass. Safety glass is projected to load and at the same time eliminate injuries caused by sharp shards given by a possible failure. For this purpose a tempered glass, which shatters into thousands of little dull so called cubes is fitted. If the glass is situated in areas, where we wish to eliminate their release, a laminated glass is fitted, in which these cubes will stick to a moulded transparent film. Concerning the security glass, this laminated glass is fitted with the intent to eliminate penetration through or falling on glass and eventually to prevent the level of forced entry. Fragments of a breach of glasses can be seen in Figure 2.

In the context of the current setting of the strength glass, faults and sudden failure may occur. This fact is closely related to extreme sensitivity as to the weakening of the surface, and in addition, system installation and fixing of glass. Wide range of glasses is comparable to their failure rate due to the weakening surface and eventually wrong fitting system.

Nowadays we can encounter glass with given solar and light transmittance, which simultaneously fulfils the given level of load bearing capacity.

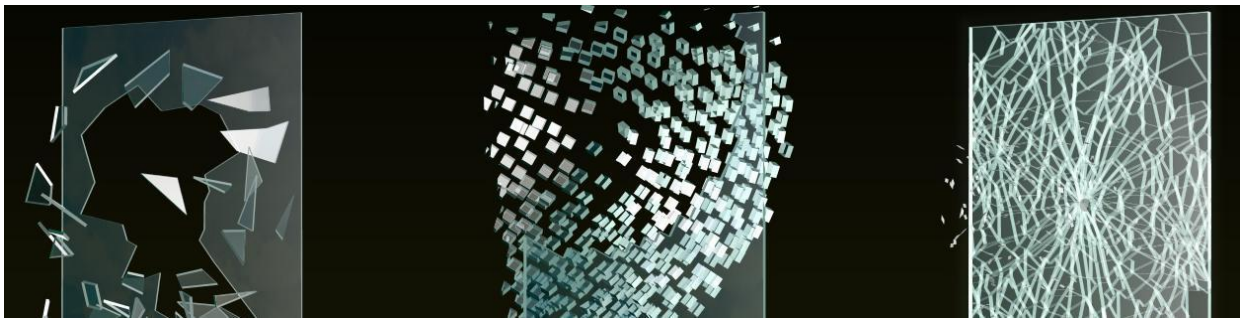

Figure 2. *Fragments of annealed, tempered and laminated glass.* [17]

Solar, Light and Optical Parameters of Glass

Due to technical transparency and adaptability of the glass itself a whole spectrum of alternatives is formed. The glass itself now forms the overall climatic comfort indoors. The parameters of glasses adapt according to the projected conditions. The parameters of soda lime silicate glasses are stated in table 1.

Table 1. *Solar, light and optical parameters of soda lime silicate glass according to the Standard.* [1,11]

Parameter	**Symbol**		
Index of refraction compared to refractive index of air	n	1.5	
Overall thermal transmittance of solar energy (solar factor)	g	0.87	
Emissivity	ε	0.837	
Light transmission coefficient	τ_v	90	%
Light reflection coefficient	ρ_v	8	%
Colour rendering index	R_a	99	%
Shading coefficient	SC	1.01	
Transmission coefficient of ultraviolet light	τ_{UV}	70	%
Selectivity	τ_v / g	1.02	
Transmission coefficient of direct sunlight	τ_e	87	%
Reflection factor of direct sunlight	ρ_e	8	%
Absorption factor of direct sunlight	α_e	5	%
Thermal conductivity coefficient	λ	1	$W \cdot m^{-1} \cdot K^{-1}$

Actual and Theoretical Strength of Glasses

In addition to the unique features of the lighting a significant parameter of glass strength is stated. However, the theoretical strength in reality is not relevant for applications. [10] Due to its unstable strength and specific refraction we abandon the usually applied stress models. Theoretical strength even reaches 10 GPa [4], however the real strength of glasses is stated in percentage. Strength of the same elements of glasses is more or less far much lower, i.e. up to 10 - 30%.[5,6] Tensile strength, according to the European standard provides a mere 1% of the theoretical strength and over time gradually decreases to 0.1%.[5] Characteristic strength value for soda-lime glass $f_{g,k}$ is 45 $N \cdot mm^{-2}$.[19] This effect is determined by the impact of weakening of the surface elements.

Glass always fails due to the low tensile strength. Through the process of vertical stress the stress profile extends linearly in the glass, while the upper surface is reflecting the stress at the lower thrust and tensile cracks. The cracks and stress grow until fracture occurs. Summarizing that gives

the glass strength high modulus E in conjunction with low tensile strength, which can be found in the strength parameters in table 2. Due to stress the glass does not bend, but small local camber of glasses significantly increases stress in the glass. This stress concerns inequalities, anomalies, micro-cracks and leads to an overall fracture. Significant concentrated stress is reflected further in locally mounted handles and notional contact of glass and air, which concerns the edges and local weakening passing through the glass. Strength is further subjected to the influence of climate, load duration and age of the element. [4].

Currently, exists technically innovative load-bearable glass, tempered glass. In this glass is situated artificially applied stress on its surface, which can be seen in Figure 3 and Figure 4. In this glass tension arises on the bottom surface much later.

Table 2. *Strength properties of soda lime silicate glass according to the Standards* [2, 11].

Parameter	**Symbol**		
Density at 18 ° C	ρ	2500	$kg \cdot m^{-3}$
Hardness according to Mohs	HMo	6	GPa
Young's modulus	E	70.10^{10}	Pa
Poisson	μ	0,2	
Coefficient of linear thermal expansion 20°C - 300°C	α	9.10^{-4}	K^{-1}
Strength of soda lime silicate annealed; tempered glass	$f_{g,kk}$	45; 70-120	$N \cdot mm^{-2}$
Compressive strength	$f_{c,k}$	1000	$N \cdot mm^{-2}$
Tensile strength	$f_{t,k}$	80	$N \cdot mm^{-2}$
Bending strength	$f_{m,k}$	100	$N \cdot mm^{-2}$
Specific thermal capacity	c_p	720	$J \cdot kg^{-1} \cdot K^{-1}$

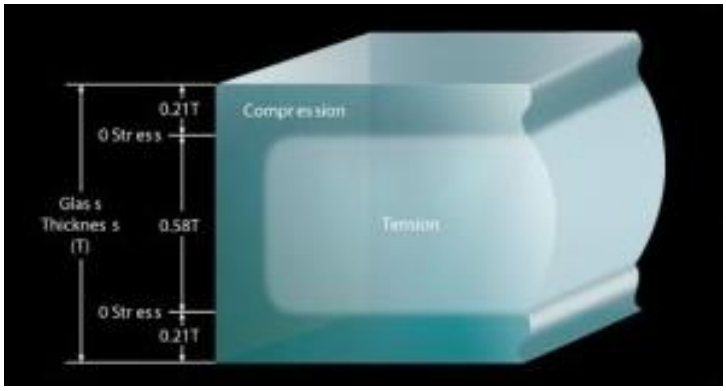

Figure 3. *Stress profile of tempered glass*. [17]

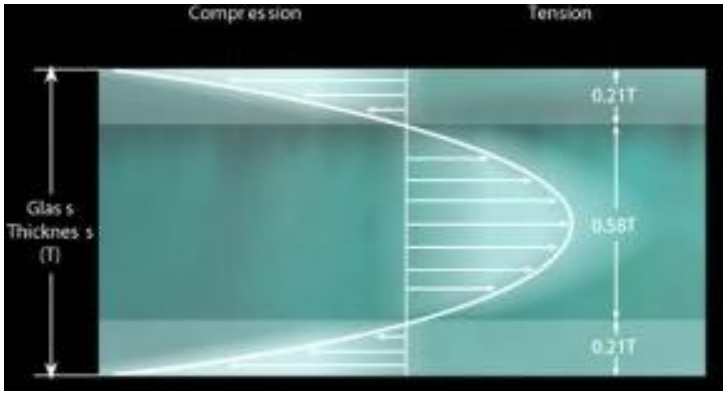

Figure 4. *Compression and tension zones in stress profile of tempered glass. [17]*

Standard Strength and Projecting

The limits and procedures related to designing are mentioned in drafts and standards. According to these we can analyse the resulting stress in relation to the limit deflection and strength of the element.

The project comprehensively analyses the tensions in the bending tensile of glass while weakening the surface, fitting, geometry, environmental and climatic conditions and duration of stress. [7]

According to given situation with a vertical or a walk-on glass the stress of wind, snow, people and things and climate with temperature is reflected. Climatic stress of exterior temperature and meteorological pressure is stated right in relation to the insulating glass with a gap.

The Standard strength and allowable effective stress is stated in soda-lime glass according to

$$f_{g,d} = k_{mod} \frac{f_{g,k}}{\gamma_M k_A} \gamma_n, \quad (1)$$

Where k_{mod} modification factor based on the duration of stress,
$f_{g,k}$ characteristic bending strength; 45 $N \cdot mm^{-2}$,
γ_M strength factor,
γ_n national factor,
k_A size factor of the stack area A [m^2]. [7, 9]

Characteristic strength $f_{g,d}$ [$N \cdot mm^{-2}$] is for the strength glass stated by the standard according to the definition

$$f_{g,d} = \left[\frac{(f_{b,k} - f_{g,k})}{\gamma_V} + k_{mod} \frac{f_{g,k}}{\gamma_M k_A} \right] \gamma_n, \quad (2)$$

Where $f_{b,k}$ characteristic bending strength of glass; thermally toughened safety glass 120 N/mm^2,
γ_V pressure area stress factor.[9]

Apart from these glasses a laminated stack, where the glass is compressed together with a transparent foil, is rather applied in many situations.

Deflection w_{lim} and tension σ_{lim} caused by stress are determined according to the fitting and mounting system. We can state definitions according to literature. [15].

The Standards than compare the strength of the external limit stress of the element σ_{lim} according to definition

$$\sigma_{lim} \leq f_{g,d}. \quad (3)$$

Apart from strength $f_{g,d}$ deflection w_d is stated in the quoted standards, which is compared to the limit deflection of glass from stress w_{lim} according to

$$w_{lim} \leq w_d. \quad (4)$$

Linear Elastic Fracture Mechanics (LEFM)

Due to the almost perfect elasticity of glass is the linear elastic fracture mechanics (LEFM) ideal for process modelling theories of stress and breach of the glass. [10].

Fracture mechanics is dedicated to the limit state of the element with cracks, fracture spreading of the crack and fracture processes. Crack is called the theoretical idealized model of glass breakage with a given geometry almost always located in the surface of the element. Linear elastic fracture theory area is based on the assumption of an almost linearly elastic process. This means that the

element is bent linearly until failure fracture. Linear elastic nature of refraction concerns glass precisely.

Due other strengths the series of otherwise identical glass elements associated with sensitivity to environmental conditions, pressures and weakening of the surface, forms a linear elastic fracture mechanics by mere default method of analysis.

In relation to low tensile strength and given modulus of elasticity E cannot eliminate the local extremes of tension and always yield a tensile cracks spreading through the surface.[9]

The theoretical analysis of cracks in the element according to the linear elastic fracture mechanics we can find a theory stating occurrence of cracks in this element even before stress. Theoretical small fractures are local spots in the surface area of the element where there is an extreme stress. They simulate extreme tension arising from disruption of the surface. Extremes and local tensions in the element exist in addition to cracks even on sharp lines, i.e. where the adjacent glass alone is eventually in contact with air or another environment. Theoretically, the process of glass breakage occurs by reducing the total extreme tensile stress in the element. This decrease applies to the formation of a new quarry of adequate surface area [10] according to the definition

$$\gamma = \frac{d\Gamma}{dS} \tag{3}$$

Where γ fracture surface energy of surfaces; surface tension; elastic energy,
dS fracture surface,
$d\Gamma$ fracture energy.

Significant Role in Weakening of Surface of Glass

Under normal circumstances the glass has almost perfect elasticity and then breaks by brittle fracture while under strength. This fracture comes with glass almost always precisely localized micro cracks and other disruptions. According to these claims, it can be seen that in glass an extreme susceptibility to this small weakness that initiates cracking is reflected. It can therefore be noted that according to many studies and researches the strength of the whole element is given by the strength of the weakest spot in its surface, by strength glass-only minimally. In this context it may be noted, that neither the tension in the element at the time of failure is not corresponding the projected strength, otherwise written this tension is closely related to the degree of relationship of cracks or other defects to the overall system load. [7] Besides weakening forms the centre of the crack initiation also locally with handles and notional contact of glass and air. In these areas the extreme concentration of stress is reflected. In researches of strength any series of otherwise identical glass elements are showing significantly different strengths related almost always locally concentrated in the surface tension. In this context it may be noted that the actual strength compared to the theoretical strength is significantly lower. The actual fracture is always produced by pulling due to significantly lower tensile strength, always based on the surface of located at a local weakening, weakening throughout the entire glass and contact of glass and air.

Summaries, Tendencies, Research

Summarizing all the facts and context, we can see the extreme sensitivity of glasses in relation to the weakening of the surface. Almost invisible scratches and micro cracks due to wear, weakening ongoing through glass or local areas with concentrated stresses in the glass related to its fitting and using are normal phenomenon visible on the surface. If we take a look at the situation in terms of fracture mechanics, the weakening of the glass surface are later the centre of overall failure.

Nowadays there is a very wide range selection in connection to glass. According to the current tendencies we can state its significance in the following period. Therefore are fractures, failures and processes in glass a particularly topical issue of scientific research. Due to the sensitivity of glass

forms linear elastic fracture mechanics just a default method of analysis. A large amount of data and found connection are based on scientific research and experiments.

A narrower topic and centre of research of glasses could be analysing of elements compared to the current of strength to of strength according to standards specified at the time of the project. Throughout the entire fitting time there are influences of environmental effects eventually even the influence of unexpected situations. The research would cover analysing of the strength and the surface and would lead to seeking local tension centre in the element due to weakening by a non-projected weakening. It would also lead to analysing the overall strength compared to the projected strength due to the projected stress. In addition it might be able to show the effects of age according to the time of fitting. The research can be analysed alongside the theoretical real degree of influence on the weakening strength. Aside the theoretical degree of influence the real degree of influence of weakening the strength can be analysed.

Acknowledgement

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Design and Numerical Modelling of Prefabricated Roller Blind Lintels

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Keywords: Roller blind lintel, window, masonry, static, thermal, analysis, FEA.

Abstract. The prefabricated roller blind lintels have become common solution, particularly for the single-leaf masonry structures without external thermal insulation system. These lintels, representing simple system solution, are designed to interrupt thermal bridges in a place of above the window lintel and simultaneously to provide sufficient reliability of load transfer. The actual outdoor blinds contribute to increase the thermal stability in the room in summer and winter season. They prevent overheating of the room in the summer months and reduce heat transmission through a window in the winter. This paper is focused on the design and numerical modelling of the prefabricated roller blind carrier lintels solutions. Methods of elimination of the thermal bridge are demonstrated on the example of a real produced prefabricated lintel. At the same time this paper deals with its structural analysis. Analyses were carried out using the method of numerical modelling, using finite element method and computing software ANSYS.

Modern Electrical Measurement of Alkali Activated Slag Mortars with Increased Electrical Conductivity

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Keywords: Electric Measurement, Alkali-Activated Slag, Building Materials, Carbon Admixtures, Dissipation Factor.

Abstract. Slag mortars belong to the new promising alternative construction materials. Conventional cementitious materials are harder to measure by electrical test methods. It is being researched if the dopant atoms in the form of powder improve the mechanical properties. This article describes how the test slag mortars with addition of carbon by electrical impedance spectroscopy measurement methods and their extensions in the form of using ZNC vector analyser with a coaxial probe from Speag. Impedance spectra of samples were obtained in the 40 Hz to 1 MHz. Declines of impedance by adding more carbon were expected and confirmed. Electrical conductivity and permittivity were measured by vector analyser for the 100 MHz to 3 GHz. The permittivity was varied from 4 to 20, depending on the addition of carbon, the conductivity of the samples from 1/2600 to 0.3 S·m-1.

Testing of Fire Retardants

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Keywords: Fire Retardants, Testing, Wood Modifications, Fire Protection.

Abstract. The authors deal with the importance and significance of fire retardants for fire protection in practice. The main aim of this paper is to inform the readers about the possibilities of wood modifications by fire retardants. The authors present the experiment of testing wood specimens applying the experimental scientific method of test for limited flame spread on the test bench under laboratory conditions. The results of the experiment represent fire-technical characteristics that describe the wood behavior during the process of combustion. Different types of fire retardants are evaluated according to the selected evaluation criterion - the weight loss of test specimens. The conclusion summarizes the results of the experiment and recommendations for fire retardant modification in practice.

Research on Slaked Lime as Ecological Moisture Retardant on Sheep Wool and Straw

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Keywords: Slaked Lime, Moisture Retardant, Sheep Wool, Straw.

Abstract: This paper is about an experiment which should prove that slaked lime is suitable as an ecological moisture retardant. Therefore, the performance of straw, sheep wool, hemp and directed hemp covered with slaked lime was monitored over a long period. The other half of the probes were uncovered to serve as reference data. The main focus of this experiment is to determine the moment when the probes start to mold as extreme humidity in reality only lasts for a short time. During the experiment the used material is continuously exposed to moisture whereas under non-experimental conditions exposure to moisture would last for a much shorter period of time (cooking, cleaning, etc.) This paper only covers the performance of straw and sheep wool covered with lime. Also the spreading of mold will not take place.

Finite Element Analysis of Composite Ceramic-Concrete Slab Constructions Exposed to Fire

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Keywords: Finite Element Analysis, Thermal Simulation, Computational Fluid Dynamics, Elevated Temperature, Fire Safety, Hollow Ceramic Slabs.

Abstract. In this research, conjugated thermal and fluid dynamics simulations are presented on a modern hollow clay slab blocks filled pre-stressed reinforced concrete beam slab construction. The simulation parameters were set from Eurocode standards and calibrated using data from standardized fire tests of the same slab construction. We evaluated the temperature distributions of the slabs under transient conditions against standard fire load. Knowing the temperature distribution against time at certain points of the structure, the loss of load bearing capacity of the structure is definable at elevated temperatures. The results demonstrated that we could pre-establish the thermal behavior of complex composite structures exposed to fire using thermal and CFD simulation tools. Our results and method of fire resistance tests can contribute to fire safety planning of buildings.

Fire Safety of Apartment Buildings Fabricated from Glued Sandwich Panels Compared with the more Frequently Used Structural Systems

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Keywords: Fire Safety of Buildings, Timber Structures, Light Buildings, Fire Resistance, Panel, Timber Frame, Insulation, Flammability.

Abstract. At present, the trend in new building techniques in the Czech Republic is to move towards light structural systems, and efforts are also being made to use such techniques with multi-storey buildings. It is a characteristic of the light building structural system that a substantial part of the structure of a building is made up of thermal insulation, and heavy and wet processes are eliminated. The article focuses on the options for the use of a specific new technique which utilizes the advantages of large-format structural panels composed of 15 mm thick OSB board glued using a polyurethane adhesive directly onto rigid thermal insulation, which is most frequently made from façade polystyrene. No other reinforcement is used. The consistency and load-bearing capacity of the panels are exclusively provided by the gluing of the insulation to the cladding using a polyurethane adhesive. The contribution focuses on the prospects for the use of this interesting technique from the aspect of the fire safety of apartment buildings; so far it has only been used for family homes. The contribution also contains a comparison of structure-related technical and financial indicators of use of this technique with standard structural systems employed for timber structures and also with traditional ceramic masonry from the viewpoint of the fire resistance of individual structures.

Optimization of Mineral Dry-shake Topping Dosage in Industrial Concrete Floors with Respect to Selected Quality Parameters

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Keywords: Industrial Floor, Mineral Dry-Shake Topping, Abrasion Resistance, Absorbing Power, Cohesion.

Abstract. For the final quality of the industrial floors with mineral dry-shake toppings is a decisive factor amount of the mineral dry-shake topping in the course of its implementation. Amount of the mineral dry-shake topping affects mainly on the abrasion resistance, which is critical for the real life of the floor. Another important property is the absorbability of the finished floor and mineral shake-layer coherence with the concrete base. This paper summarizes a study on the ideal amount of mineral dry shake toppings when considering the resulting wear resistance of floor surface finish as well as its water absorption and also the adhesion properties of the studied layer to the concrete base.

Analysis of Fire Protection with Focuse on the Specific Conditions of the Historic Roofs

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Keywords: Wood Truss, Sprinkler, Firefighting Arrangements, Inhabited Area, Cultural Monument.

Abstract. Protecting of historic roofs is an important part of efforts to protect our cultural heritage. These wooden structures carry a lot of information about the authentic tools, technologies and construction processes. Trusses are generally endangered by many risks that could cause irrecoverable damage and loss of information. In addition to the threat wood destroying insect and fungi, should not be forgotten on fire threats that may start from lightning, through electrical installations, to the burning of the surrounding dry grass areas. Historical wooden trusses are with respect to the old wood, indoor climate, the unavailability or the fact that many national cultural monuments are located outside of the inhabited territories, very susceptible to fires. Nevertheless, there are many methods, which are used for new buildings, but unusable for historical truss, and others were proved to be unsuitable by the time. This article analyses the possibilities of modern firefighting arrangements in the historic truss with regard to the specific construction conditions and with regard to the very rare substructure, which should not be damaged.

The Economic Analysis of Building Structures with Fair-Faced Self-Cleaning Concrete

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Keywords: Self-Cleaning Concrete, Fair-Faced Concrete, Titanium Dioxide, Construction Cost, Cost Analysis.

Abstract. The study presented in the paper deals with fair-faced concrete having a self-cleaning effect. This effect is induced by photo catalytic forms of titanium dioxide (TiO_2) in concrete. The characteristics of TiO_2, its production and application in construction are discussed in the paper. The economic analysis of building structures with fair-faced self-cleaning concrete is intend to point out that despite higher costs on such concrete production, its durability is longer compared to conventional concrete. The economic analysis is aimed at estimation of costs on self-cleaning fair-faced structures with smooth and textured finish facade area.

Introduction

Using the self-cleaning building materials presents a new approach into environmental protection. The self-cleaning is due to photo catalysts in the materials. The photo catalysts in a natural way accelerate the process of organic materials decomposition by using the sun or ultraviolet radiation. Research on photovoltaic properties began in the thirties of the last century. The self-cleaning building materials have not only self-cleaning ability, but also can relieve air waste substances. When a photo catalyst is used in the concrete, it becomes a self-cleaning concrete. TiO_2 - as the most common titanium compound - belongs to the main representatives of photo catalysts. Research on TiO_2 in construction began in the late eighties of the last century [1]. Its specific weight is between 4.13 to 4.25 $g \cdot cm^{-3}$. The melting point is 1825 °C. It occurs in the nature as the mineral rutile, brookite or anatase. From industrial point of view, the most of TiO_2 is obtained from $FeTiO_3$ ilmenite, which contains 31,6% of TiO_2 [2, 3, 12].

TiO_2 is used as a pigment due to its suitable properties, which are for example a strong light, a high refractive index, a high reflectance and colour stability. This form is used in various industries as part of painting materials, plastics, in the rubber industry, in papermaking, in the manufacture of inks and in the pharmaceutics. The photo catalytic activity is its very important feature. Thanks to the feature, in the presence of air, moisture and UV rays, TiO2 is able to decompose various organic and inorganic compounds. It is mainly used in a variety of surface finishing of materials. Moreover, TiO2 has a chemical stability, very good durability and it is nontoxic. It is therefore preferred over other types of photo catalysts [4].

Another benefit of the photo catalytic reaction consists in reduction of pollutants in the air. The concrete structures modified with TiO_2 cause a 15% reduction of nitrous oxide produced by the exhaust gases. According to some sources, the urban air quality could be improved by 80% if the building structures such as roads, sidewalks and building surfaces have been treated with this system. TiO_2 can be applied directly into concrete or only as surfacing of concrete structures. It can be added to the grey and white cement and used in the monolithic concrete structures as well as in the production of prefabricated elements. Similarly, it is possible to apply only thin surface layers of concrete containing cement with TiO_2, for example top layers of prefabricated elements and surfacing of vibro-pressed elements. Among typical applications belong small-scale road elements, prefabricated large-scale facade elements, noise barriers, reinforcing elements in tunnels and elements of small architecture [5].

Nazari and Riahi [6, 7, 8] have dealt with the influence of TiO_2 on properties of concrete using ground granulated blast furnace slag as binder, of self-compacting concrete and of high-strength concrete. The results of the three individual experiments were consistent. All the results indicated change of concrete strength (an increase of strength, however the strength decline in case of certain value exceeding).

Moreover, Nazari and Riahi [7, 8] tested the absorbing power change of self-compacting concrete with the admixture of TiO_2 0 – 5 wt. %. The samples were placed in an aqueous medium, and the water absorption was determined after 2, 7 and 28 days in the aqueous environment.

As well, Nazari and Riahi [6, 7, 8] searched for the effect of TiO_2 on the rate of hydration and the level of hydration heat of cement applied in three types of concrete: concrete with blast furnace slag as an additive, self-compacting concrete with blast furnace slag and high-strength self-compacting concrete.

When using the TiO_2 photo catalysis in building materials, it is important to achieve the above mentioned self-cleaning ability and ability to reduce pollutants in the atmosphere. The great advantage of these materials consists in the fact that in addition to TiO_2 only sunlight, oxygen and water are necessary to activate their self-cleaning ability [9].

Shen et al. [10] argue that using of self-cleaning concrete presents one from possible approaches into cleaner cities, an approach reducing air pollutants. They examined the photo catalytic concrete with ultra smooth surface in the study. The results demonstrate that the concrete surface coated by CeSeH and TiO_2 was very smooth and rain can easily wash off impurities thanks to photo catalytic properties.

Most studies have examined in details the technical characteristics of concrete structures using TiO_2 nanoparticles and have demonstrated the positive impact on the environment. Only few studies advise of economic barriers that keep from wider application of concrete with TiO_2 in practice but there is no detailed quantification. For example, Martins et al. [11] presented the results of experimental investigation of mechanical characteristics and durability of high performance concrete (HPC) based on TiO_2 particles and fly ash. The results have pointed out high mechanical strength. The authors have only briefly mentioned that the cost of TiO_2 is responsible for the severe increase in the cost of concrete components.

Although the photo catalytic cement needs UV radiation for its activity, its using is possible in the interior. When the interior is illuminated by the light of a suitable wavelength, the air cleaning by photo catalytic surface can be used to improve the quality of the indoor environment [5]. In this case is also questionable if it is economical to implement concrete containing TiO_2 or concrete surface applied with a transparent coating containing TiO_2 in order to construct the fair-faced concrete in the interior. The paint must be renewed during the life cycle of structure. Good-class unstructured surfaces of the fair-faced concrete in the interior are difficult to implement from technology point of view. This is particularly if they are designed for closely reinforced thin-walled monolithic structures. Such surfaces must often be adapted by plaster imitating concrete surface.

As the complex photo catalytic reaction is carried out only on the surface of the structure, use of the concrete with TiO_2 is not economical in case of its overlapping by the cement, gypsum or concrete plaster. Therefore, all the risk factors must be considered before the structures construction if some environmental requirements are established.

Methodology

On the basis of data from the building practice a cost analysis of materials and building elements for concrete structures with the following application of TiO_2 was made:

- Ready-mix concrete with photo catalytic cement TioCEM
- Ready-mix concrete with the admixture of TiO_2 4 wt. %
- Ready-mix concrete with the admixture of TiO_2 6 wt. %

- Application of TiO_2 by Detoxy Color coating [13]
- Fair-faced concrete plaster with admixture of TiO_2 [14]

The cost of materials are calculated as the unit cost of 1 m^2 or 1 m^3 of several shape variants of the final concrete structure: without application of TiO_2 as well as with admixture of TiO_2, as part of photo catalytic cement TioCEM, coating or fair-faced concrete plaster containing TiO_2.

Variants of vertical concrete structures that were the subject of the economic analysis were evaluated in terms of application of the above applications of TiO_2. Concrete walls variants differ in both size and surface finish as the fair-faced concrete or fair-faced concrete plaster or coating. In case of selected vertical concrete structures, the costs of formwork, labour and material were calculated. It was calculated for 1 m^3 or 1 m^2 of the concrete area as well as for 1 m^2 of active fair-faced surface.

The results presented in tables provide the economic comparison of the variants and can serve as the basis for selection of appropriate concreting technology.

Results

The Materials Cost. In Table 1 are presented the cost of materials for concrete structures production calculated as the unit cost of 1 m^3 of concrete volume or of 1 m^2 of concrete structure area. The costs include 20% VAT.

Table 1. *The cost of selected materials for concrete structures production.*

Material	**Cost** [EUR/measure unit]
Ready-mix concrete (without TiO_2) STN EN 206-1– C 30/37 –XD4, XD2 (SK) – Cl 0,2 –Dmax 16– S4	74.67 EUR·m^{-3} of concrete
Ready-mix concrete with photo catalytic cement TioCEM STN EN 206-1–C 30/37 –XD4, XD2 (SK) – Cl 0,2 –Dmax 16–S4 – fair-faced	138.21 EUR·m^{-3} of concrete
Ready-mix concrete with admixture of TiO_2 STN EN 206-1–C 30/37 –XD4, XD2 (SK) – Cl 0,2 –Dmax 16–S4 – TiO_2 4 wt.%	133.40 EUR·m^{-3} of concrete
Ready-mix concrete with admixture of TiO_2 STN EN 206-1–C 30/37 –XD4, XD2 (SK) – Cl 0,2 –Dmax 16–S4 – TiO_2 6 wt.%	165.35 EUR·m^{-3} of concrete
Self-cleaning coating FN2 Detoxy Color	1.524 EUR·m^{-2}
Self-cleaning coating FN2 Detoxy Color including coating application as a subcontract [13]	6.72 EUR·m^{-2}
Fair-faced concrete plaster with admixture of TiO_2 - thickness 2 mm	32.4 EUR·m^{-2}
Fair-faced concrete plaster with admixture of TiO_2 - thickness 2 mm including coating application as a subcontract [14]	39.8 EUR·m^{-2}

Currently in Slovakia, the market price of the ready-mix concrete with TiO_2 is approximately double compared to common concrete. Similarly, materials of the plaster imitating the fair-faced concrete (even without TiO_2) are relatively expensive compared to surface working.

The Variant Proposals of Vertical Concrete Structures. A monolithic vertical structure presents the subject of the economic analysis. It is reinforced with steel mesh, diameter of bar 8 mm, mesh size 400 x 400 mm, formed by double-sided frame formwork.

The texture of the fair-faced surface of vertical structures can be:

- with smooth surface (texture "R0"),
- with moulded surface; the formwork shell forms a matrix with a shallow (Figure 1), medium (Figure 2) or deep raster (Figure 3).

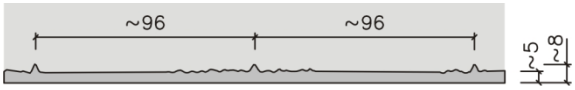

Figure 1. *The fair-faced surface with the texture "R1" – shallow raster, e.g. wood imitation.*

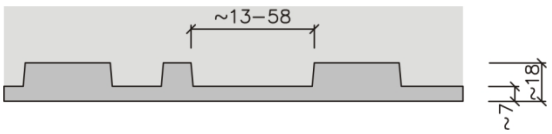

Figure 2. *The fair-faced surface with the texture "R2" - medium raster, e.g. masonry imitation.*

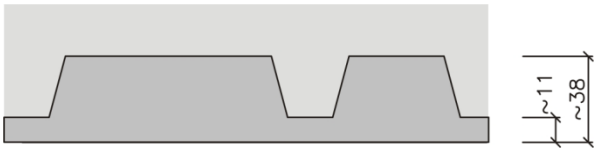

Figure 3. *The fair-faced surface with the texture "R3"- deep raster, e.g. stone masonry imitation.*

Table 2 presents the shape characteristics of the variants of monolithic wall structures.

Table 2. *The characteristics of analyzed variants of vertical structures.*

Dimensions of monolithic wall structure (length/height/thickness) 3850mm/2600mm/100mm	**Volume of concrete** [m^3]	**Adapted fair-faced surface** [m^2]	
		coated	**concrete plaster**
Smooth surface of the fair-faced concrete „R0“	1	10	10
The fair-faced surface with the texture “R1”	1.003	10.6 to 11	-
The fair-faced surface with the texture “R2”	1.008	11 to 14	-
The fair-faced surface with the texture “R3”	1.015	13 to 15	-

The Variants of the Concrete Structures According to Materials. The variants of concrete structures that were the subject of economic analysis are according to applied technology of TiO_2 divided into following groups:

I. Monolithic structure from standard ready-mix concrete (without TiO_2),
II. Monolithic structure from ready-mix concrete with cement TioCEM,
III. Monolithic structure from ready-mix concrete with admixture of TiO_2 4 wt. %,
IV. Monolithic structure from ready-mix concrete with admixture of TiO_2 6 wt. %,
V. Monolithic structure from standard ready-mix concrete painted with self-cleaning FN2 Detoxy Color coating,
VI. Monolithic structure from standard ready-mix concrete coated with fair-faced concrete plaster with admixture of TiO_2 (the technology may be applied only on smooth surface of concrete).

Calculation of the Cost Variants of Vertical Concrete Structures. Tables 3 and 4 present the cost of the wall structure with smooth surface as well as with the relief. The cost involves the cost of material (ready-mix concrete and reinforcement), rental of frame double-sided formwork (5 days working cycle), including the purchase of relief matrices (matrices are applied at least 10 times) and workers wages (formwork mounting and dismantling, reinforcing, concrete processing, concrete treatment after formwork dismantling). In case of additional arrangements of the self-cleaning surfaces by the coating or the concrete plaster, the cost involves the cost of the material and the cost of the labour. From the table is evident, which cost is changed after change of the concrete volume depending of the change of the wall thickness by Δa (m).

Based on the data, which are presented in Table 3 and Table 4, it is possible to compare the various technologies of the monolithic wall structures with the requirement of the self-cleaning concrete surface supported by the photo catalytic reaction. It is possible to derive which TiO_2 technology is the best from economy point of view. It is possible to deduce for various thickness of the structure.

Table 3. *Data to calculate the cost of the variant vertical concrete structures.*

The cost of the variants of monolithic wall structures [EUR·structure^{-1}]						
Dimensions of the wall structure length d=3.85m; height v=2.6m; thickness a=0.1m		**The fair-faced surface with the texture**				**Cost change after thickness revision** Δa (m)
		„R0“	**“R1”**	**“R2”**	**“R3”**	
Ready-mix concrete	without TiO_2	74. 67	74.89	75.27	75.79	± Δa*d*v* 74.67
	with photo catalytic cement TioCEM	138.21	138.62	139.32	140.28	± Δa*d*v* 138.21
	with admixture of TiO_2 (4%)	133.40	133.80	134.46	135.40	± Δa*d*v* 133.40
	with admixture of TiO_2 (6%)	165.35	165.84	166.67	167.83	± Δa*d*v* 165.35
Reinforcement (0,6t)		46,8				-
Formwork rental		250				-
Formwork matrices		-	12. 32	14.48	23.46	-
Wages		182	272			± Δa*d*v*10.4
FN2 Detoxy Color coating including labour		67.2	from 71 to 74	from 74 to 94	from 87 to 101	-
Fair-faced concrete plaster including labour		398	-	-	-	-

Table 4. *The cost of the variants of monolithic vertical concrete structures.*

The cost of the variants of monolithic wall structures [EUR·structure^{-1}]						
Dimensions of the wall structure length d=3.85m; height v=2.6m; thickness a=0.1m		**The fair-faced surface with the texture**				**Cost change after thickness revision** Δa (m)
		„R0“	**“R1”**	**“R2”**	**“R3”**	
Monolithic structure	standard ready-mix concrete	553.47	656.01	658.55	659.07	± Δa*d*v* 85.07
	ready-mix concrete with cement TioCEM	617.01	719.74	722.6	732.54	± Δa*d*v* 148.61
	ready-mix concrete with admixture of TiO_2 4 wt. %,	612.2	714.92	717.74	727.66	± Δa*d*v* 143.80
	from ready-mix concrete with admixture of TiO_2 6 wt. %,	644.15	746.96	749.95	760.09	± Δa*d*v* 175.75
	standard ready-mix concrete painted with self-cleaning FN2 Detoxy Color coating	620.67	from 727 to 730	from 733 to 753	from 747 to 770	± Δa*d*v* 85.07
	standard ready-mix concrete coated with fair-faced concrete plaster with admixture of TiO_2	951.47	-	-	-	± Δa*d*v* 85.07

For example in case of the wall with the relief fair-faced surface of the deep grid, only when the wall thickness is approximately from 0.12 m (or from 0.15 m), the cost of the structure from ready-mix concrete with cement TioCEM is higher than the cost of the structure from standard ready-mix concrete painted with self-cleaning FN2 Detoxify Colour coating. In case of smooth surface, the cost of these two technologies is comparable when the wall thickness is 0.113 m.

Summary

There are several possibilities for application of titanium dioxide in building structure, as an admixture of concrete or as a material component of cement, plasters or coating mixtures

of building structures. The self-cleaning concrete is used in the exterior as well as in the interior of building and civil engineering structures and in the production of concrete accessories.

The fair-faced concrete with TiO_2 nanoparticles has super hydrophilic nature of the surface which increases its self-cleaning ability. In terms of economy, on the one hand, higher cost of material presents one from disadvantages of such concrete production, on the other hand, the durability of concrete structure is extended and the cost of maintenance is reduced in this way. The results of the economic analysis of TiO_2 application in production of building structures using the fair-faced self-cleaning concrete are presented in the paper.

One of the first applications of the fair-faced self-cleaning concrete in Europe is the church „Dives in Misericordia" in Rome, constructed in 2003. Positive environmental characteristics of self-cleaning concrete are confronted with economical barriers. In Slovakia, a unique example of application of "white" fair-faced concrete with TiO_2 is known in a significant cultural centre in Košice incurred by conversion of the former barracks in 2015. The architect has preferred the fair-faced concrete in the interior. From technology point of view, it was possible to achieve only by additional concrete plaster. The results of the cost analysis of various technologies of TiO_2 applications in building structures can contribute to better relationship between construction cost and functional characteristics of concrete structures.

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Multiple Aspects of Comparing Surface Properties of Ceramic Tiles Regarding Slip Resistance

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Keywords: Ceramic Tiles, Slip Resistance, Friction, Surface Roughness, Cleanability.

Abstract. The objective of this study was to determine the affecting factors that can possibly change slipperiness of flooring. Laboratory slip resistance tests were conducted under different surface conditions. Two different methods were used to measure 6 different ceramic tiles. This article has its focus mainly on the required security and its quantification during the service life of floor coverings. Slip resistance of ceramic tiling can change with use. It is worth to investigate the effect of cleaning agents on slipperiness of floors, because it could be more dangerous when the cleaning process is in progress, so the surface is still in wet state or partly covered by liquid. This paper makes a comparative analysis on the different measurement methods and sliders that rub against the surface. In case of public and residential buildings slip resistance and surface roughness associated with cleanability, all have influence on safety in use and durability. The results showed that the perceived surface roughness parameters could be used as indicator of slipperiness and supplement objective measurement of this performance.

Constitutive Laws Assessment for Unconfined Concrete under Compression

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Keywords: Constitutive Laws, Concrete, Structures, Microplane, Continuum Damage.

Abstract. Nowadays, the rehabilitation of buildings takes more importance due to sustainability reasons. This involves working with existing building structures and the precise calculus of the building to guarantee the adequate strength and safety, from structures with change of use to deteriorated or damaged structures. Concrete is the most common material in building structures, but it is a heterogeneous and non-linear material. The concrete constitutive law, relation between strains and stresses in different directions, is very complex, and different in tension and compression. In the case of new construction project, the linear relationship between stress and strain has been proved safe enough, but it is unable to simulate the behaviour of used and damaged structures, where it is necessary to study the entire load range. In this work, the most widely used constitutive laws of concrete are compared, parameterizing the necessary constants for their professional application in advanced simulation structures software. Some of the evaluated constants are the Young's modulus, Poisson's ratio, stress cracking and crushing, failure energy or the law of damage evolution. Linear-multilinear behaviour, Willam-Warnke crushing and cracking criteria, continuum damage and microplane options are the assessed constitutive laws, showing the differences between the behaviour models and the tightest values of these material constants along the entire load range.

The Effect of Aggregate Type on the Properties of Lime Mortars

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Keywords: Lime Mortar, Aggregate, Limestone, Quartz, Strength, Porosity, Carbonation.

Abstract. Lime mortars represent indispensable building materials that have been used for centuries in civil engineering. Considering the necessity of numerous restoration work on historical buildings, a research of the applicability and suitability of various types of plasters for repairing the historical plasters has been developed. This work presents the applicability of limestone aggregate and limestone fines to aerial lime-based mortars. The role of aggregates on the properties of lime mortars is examined in this paper by comparing pure quartz sand and limestone aggregate and its quantity in the mortar. It was found that limestone aggregate produced the comparable or higher mortar strengths than quartz aggregate and slightly increased porosity, water absorptive capacity and carbonation rate of the mortars. Partially replacement of aggregate by limestone fines has caused dramatic growth in strength, especially in mortars with high content of binder. The applied limestone aggregate is convenient to lime-based mortars and the addition of limestone fines contributes to better mechanical properties of lime mortars.

Section 2: Energy Performance of Buildings

Performance Simulation of External Metal Mesh Screen Devices: A Case Study

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Keywords: Solar Shading, Building Performance Simulation, Modelling Approach, Energy Demand, Adaptive Thermal Comfort.

Abstract. Early design decisions with regard to building facade characteristics play a significant role in the resulting building's thermal performance. In this context, external metal mesh screens - used as a permanent second facade skin- are a rather new shading alternative, particularly in non-residential buildings. It has been suggested that such products can filter excessive incident solar radiation while maintaining the facade's transparent quality. Given the multifaceted implications of this shading device for building energy performance, we undertook a detailed simulation-based study to evaluate the impact of metal mesh screens on annual energy demand for heating, cooling and electric lighting in different European climate zones. Possible design variations were considered in terms of mesh screen translucency, window to wall ratio and facade orientation. The feasibility of using such a shading strategy to provide passive cooling during summer was also explored, along with suitable ventilation scenarios. Toward this end, we examined a number of existing approaches to simulate metal mesh screens and identified their capabilities and limitations. A typical office space was tested in three European locations, taking local building construction standards into account. The results of this study can help planners in their choice of the appropriate shading strategy and provide recommendations for the application of metal mesh screens according to the climatic and architectural criteria.

The Effect of Boundary Conditions to Specify the Energy Performance of Buildings

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Keywords: Energy Performance of Buildings, Boundary Conditions, Impact of Energy Specialists.

Abstract. The overall energy performance of buildings is determined not only based on structural and material solutions of the building. Boundary conditions affect the results of evaluation of the energy performance too. This paper deals with buildings in the Czech Republic. The paper is devoted to the evaluation of energy performance of buildings under changing boundary conditions. This means the change of the intensity of ventilation, changes in the structures' accumulation and influence of thermal connections.

Simulation Study on Thermal Performance of a Ventilated PV Façade Coupled with PCM

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Keywords: Building Integrated Photovoltaic/Thermal System, Ventilated Façade, Phase Change Material, PV Temperature.

Abstract. This paper presents a dynamic thermal model based on DesignBuilder simulation software platform, for a simple office building model with an integrated ventilated PV façade/solar air collector system in climatic conditions of Bratislava, Slovakia. Thermodynamic simulation has been applied in order to express thermal performance of a ventilated PV façade coupled with phase change material through the whole reference year. Attention is focused on simplified approaches which capture the important elements of the problem. The results of simulation show that natural ventilation of PV façade with added phase change material have ability decrease temperatures of PV panel during extreme days more than 20 °C and shift time of peak temperature even more than 5 hours.

Energy Aspects of Gravitational Ventilation in the Heating Season

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Keywords: Heating, Gravitational Ventilation, Energy Demand, Indoor Air Quality, Thermal Comfort.

Abstract. Natural ventilation is currently widely used in existing buildings in order to assure the fresh air needed by occupants. The low investment and operational costs are the most important advantages of this type of ventilation. However, the dependency on the meteorological parameters has to be considered as disadvantage of the natural ventilation. In case of buoyancy-driven ventilation, the variation of the outdoor temperature results in the variation of the infiltrated air flow, CO2 concentration in the indoor air and energy demand of the ventilation. The air inlet and outlet orifices have to be properly chosen in order to meet the indoor air quality and energy requirements at the same time. In this paper the CO2 concentration and energy aspects of gravitational ventilation are discussed in case of a typical block of flats.

Effect of Glazed Ratio on Indoor Comfort and Energy Need for Heating

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Keywords: Energy Need for Heating, Operative Temperature, Glazed Ratio.

Abstract. According to the current national regulations appropriate operative temperature must be provided in premises. Nevertheless simplified calculation methods of heating built-in capacity and energy need for heating are based on indoor air temperature: to have the same output in function of operative temperature requires a series of iteration or dynamic simulation. Experience in existing buildings shows that higher glazed ratio is accompanied by decreasing Mean Radiant Temperature to be counterbalanced with higher indoor air temperature in order to keep the prescribed operative temperature. Nevertheless, in well insulated buildings this effect is weaker. Moreover, it turns into opposite: high Mean Radiant Temperature should be compensated with lower indoor air temperature which considerably decreases the heat loss – especially the ventilation heat loss. Energy need for heating of a sample building is analysed in the function of thermal insulation, glazed ratio and thermal mass.

An Impact Of Air Permeability On Heat Transfer Through Partitions Insulated With Loose Fiber Materials

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Keywords: Air Permeability, Loose Thermal Insulations, Mineral Wool, Heat Losses, Infiltration.

Abstract. The paper presents the problem of windwashing in partitions including air permeable thermal insulations. There are technical solutions, which deliberately accept the filtration of air in the insulating layer, guided by the necessity of possible drying of building materials. Some scientific papers even suggest that the air infiltration decrease the heat losses through ventilation. In result there occur heat losses in building heat balance which are underestimated and therefore difficult to take into account during calculations. Heat changes on the inner surface of the building partition occur with a delay to the initiation of the wind. However, even the short-term local wind speed loads on thermal insulations result in temperature decreasing and therefore possible condensation on the inner surface of the building partition. The article presents laboratory measurements of air permeability of loose mineral wool and laboratory investigation of the impact of air filtration on heat transfer in lightweight partitions filled with loose thermal insulation.

Analysis of Energy Sources on Energy Indicators Performance

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Keywords: Energy Performance, Energy, Building, Energy Classes, CO_2.

Abstract. In the members states of the European Union, portion of buildings in the total consumption of energy represents 40%, and their portion in CO2 emissions fluctuates around 35%. The European Union is trying to protect the environment by reducing energy demand and releasing CO2 emissions into the air. Energy performance is the quantity of energy, which is necessary for heating and domestic hot water production, for cooling and ventilation and for lighting. Based on results of energy performance, individual buildings are classified into energy classes A to G. A global indicator (primary energy) is the decisive factor for final evaluation of the building. The new building must meet minimum requirements for energy performance, i.e. it must be classified to energy class A1 since 2016, and to energy class A0 since 2020. The paper analyses effect of the use of different resources of heat in a family house designed according to requirements valid since 2020, and its subsequent classification into an energy class.

Glazing with Low-Emissivity Layers and its Performance Simulation

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Keywords. Low-Emissivity Layer, Surface Emissivity, Glass, Performance Simulation.

Abstract. The contribution deals with the importance of low-emissivity glazing layers in improving the energy balance of building interiors. It describes the effects of changes in surface emissivity of glass, depending on the position of low-emissivity layer. It also discusses principles, advantages and disadvantages of the most common glazing combinations with regard to interior visual and thermal comfort and also slightly misleading interpretations caused by complexity of the matter. The discussion (and comparison) is based on methods and tools used in computer-aided building performance modelling and simulation and on recent information from glass industry.

Experimental Full-Scale Test Cell Optimizing for Research of Novel Concepts towards Climatically Active Solar Façade Design

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Keywords: Test Cell, Full-scale Testing, Dynamic Outdoor Testing, Optimization

Abstract. The passive solar test facilities have recently been created in many research centres all over the world to analyse dynamic outdoor phenomena on buildings and their components. The main objective of these research activities is primarily to evolve a methodology, improve test methods, validate numerical models and measure real thermodynamic properties of building components under outdoor climate conditions. An integration of advanced material solutions into buildings need to be investigated within specific conditions related specifically to outdoor test methods. A research project on Contemporary concepts of climatically active solar facades at the Brno University of Technology does have an ambition to create an experimental full-scale test cell for research of thermal aspects in progressive advances of future solar façade concepts exposed to the real climate conditions. This paper describes the design optimization phase preceding the test cell assembly. This phase includes the analysis of energy and thermal properties based on parametric study features. Computer simulations based on finite element and volume methods are involved in the optimization process. The proposed optimized test cell design is confronted with parameterization of typical thermal aspects to present final test cell demonstration.

Material of Thermal Insulation affects Heat Gains in the Summer Period

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Keywords: Pitched Roof, Attic Room, Thermal Inertia, Heat Transfer.

Abstract. Buildings with light-weight roof structures tend to suffer from overheating of attic spaces during the summer period. One of the methods for improving the indoor thermal comfort with no energy consumption is reducing the heat flux passing through the building envelope. In particular, this can be achieved by increasing the thermal inertia of the roof, specifically, by choosing materials with relatively high density and high specific heat capacity. This article focuses on evaluating of the roof assembly of an inclined insulated non-ventilated roof which meets the requirements for the passive house standard. A dynamic Comsol simulation with harmonic fluctuation of the exterior temperature was used to express the impact of the structure on the temperature damping and the time lag. The period of 7 days was screened. As a result temperature profiles of several material variants are compared.

Section 3: Smart Buildings, Smart Cities, Sensors

Environmental Simulations and Their Role in the Research of Human Responses to Environmental Stimuli

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Keywords: Environmental Simulation, Web Application, Material, Environmental Setting, Colour, Surface, Preferences, User, Virtual Reality.

Abstract. The paper is aimed at the problematics of environmental simulations as one of the efficient methods of behavioural research for exploring the reactions of respondents to certain environmental settings. It explores the contemporary situation of the development of simulation at different levels within the environment, serving as visualizations of designed spaces, for games and simulation /testing of subjective and objective responses to different environmental stimuli. In our long-term research at the BCDlab, we are focused on body conscious design, which means exploring relationships: body/nervous system and the environment with an aim to design human friendly solutions through spatial design. To gain our own experiences with environmental simulations and their impact, in 2015, the Faculty of Architecture BCDlab, developed an interactive application, BCD-APP, which works as a web interface and also in virtual reality. The paper presents the process of setting research methods and results of the first pilot tests of the app as a research tool, with a small controlled group of respondents. They were confronted with pre-selected settings of materials, colours and surface finishing, and with the setting of their own choice, the subjective and objective physiological reactions (brain waves and respiration) were measured by EEG sensors and evaluated in a Labchart environment.

An Inquiry into the Current Practice of Building Product Data Handling by Different Stakeholders in Austria

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Keywords: Building Product Data, Stakeholders, Questionnaire, Building Product Representation, Repositories.

Abstract. The timely availability and quality of building product information is critical prerequisite for a successful building delivery process. However, little is known about the processes by which stakeholders acquire and use such data. This contribution documents the results of recent relevant surveys, addressing the building product data processing by planers, clients, and the industry. Web questionnaires and interviews with opinion leaders were conducted. Altogether, over 100 participants provided pertinent insights regarding strengths and weaknesses of the current data representation practices. A comparison of the obtained data with that of an earlier study allows for the documentation of the evolutionary trends in web-based data provision. Most importantly, the results facilitate the formulation of strategies for a more effective presentation and distribution of building product data.

Building Monitoring and Diagnostics: A Web-Based Approach

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Keywords: Building Monitoring, Building Performance, Building Diagnostic, Data Analysis, Embedded Systems.

Abstract. Efforts toward optimized building management and operation require monitoring data from multiple sources. Experiences from previous research projects underline the need for an easily adaptable, low-cost, and easy to set up monitoring infrastructure that could provide data for modelling and performance evaluation. The increasing availability of small and powerful development boards (e.g. Raspberry Pi BeagleBoard or Arduino) facilitates the implementation of a cost-efficient infrastructure for data collection and building monitoring. For the purpose of the present contribution, the Arduino Yún was used to create a data logger that obtains data from wireless sensors, stores it locally, and syncs it with a data repository. Toward this end, we have developed a web-based user interface that enables the user to evaluate various aspects of the monitored building's performance. The communication between the software components is implemented via RESTful interfaces and enables the user to integrate also other data sources such as web services. The paper includes an actual implementation of the above approach. Thereby, we illustrate how the constitutive system components can be integrated in terms of a versatile monitoring system with multiple utilities in terms of building performance assessment and building diagnostics.

Rule Based Building Construction Generation: An Approach Based on Formal Language Methods

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Keywords: Formal Modelling Approaches, Building Constructions, Layered Compositions, Thermal Building Performance, Automation in Construction.

Abstract. The composition of efficient and appropriate building constructions is a key agenda in the building delivery process. While this process is regularly considered to be of highest importance for the final quality of a building, many involved stakeholders regard it as a cumbersome and repetitive routine. Therefore, approaches to facilitate this process should be investigated. Toward this end, we address the layer-wise building component composition via formal language methods. These are regularly used in computer science to formalize real-world processes into a language that can be processed by a computer. Regarding building component generation, relationships and interdependencies between different layers need to be considered. While these are easy to understand for a skilled human planner with pertinent domain knowledge, the exact formulation of building composition rules is far from trivial. Thus, automated building part generation requires collection and formalization of the required knowledge regarding building component composition, so that it can be readily transformed into a processual form. After collection, definition and structuring of such rules, the overall process of component generation can be expressed in Pseudo-Code. This offers three major advantages: I. Pseudo-code is vendor and platform neutral and is a widely used concept in computer science; II. Potential mistakes and issues can be easily identified, III. Flexibility, extensibility and editing ease is ensured. In this contribution we illustrate a general approach, define certain rules and thresholds, and introduce a formalized method for building part generation. Furthermore, we demonstrate the concept via a limited number of constructions and discuss potential application scenarios.

Section 4: Retrofitting and Revitalization of Buildings

Experiment Based Analysis of Complex Posterior Waterproofing Systems

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Keywords: Posterior Waterproofing, Chemical Injection, Rising Damp, Hygrothermal Analysis.

Abstract. In connection with the problems of aging European building stock, the opportunity of posterior waterproofing methods emerges as a relevant solution. There are different technologies which are suitable against rising damp in walls, but the chemical injection system through injection boreholes is the most commonly used method due to its extensive usability and fast implementation. The aim of the experimental research was to measure the efficiency of the chemical injection method by the penetration of the injection agents. There were built several specimens of small size solid bricks and some further ones of coarse lime stones. The three months long research allowed determining the moisture content of the specimens before and after the injection process. The received results were mass-based and moisture content data was measured by Protimeter. Surface coating and renovation plaster give additional moisture protection and along with the chemical injection provide a complete posterior waterproofing system. The elements of posterior waterproofing cause changes in the vapour diffusion of renovated structures. However, diffusion-open orders of layers can solve the problem of evaporation, as environmental friendly reconstruction solutions. Based on the measured results of rising damp and known characteristics of cement-based waterproofing and renovation plasters, thermal simulations and hygrothermal analysis and thus building physical conclusions have been performed.

Economic Analysis of Energy Saving Measures in Current Prefabricated Panel Buildings

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Keywords: Prefabricated Panel Buildings, Energy Consumption, Energy Saving Measures, Investment Costs, Operational Costs, Operational Savings, Economic Return on Investment.

Abstract. The paper focuses on analysis and assessment of economic efficiency of measures taken in order to lower energy demands of prefabricated panel residential buildings. For this purpose, a group of buildings with previously made modifications with potential to lower the energy and heating consumption were selected. Next, the development of their energy consumption and their costs was monitored. The assessment of achieved figures was made with regards to amount of costs which were paid for these measures and also with regards to their service life, amount of gained subsidy and decrease of consumed energies and operational costs of the buildings after the measures were taken. It was found that there had been a significant difference in investment returns for constituent technical measures. For some of them, it is not even realistic to expect reaching the return of investments during their service life period.

Energy Balance Concepts of Apartments Dwelling Houses Renovation

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Keywords: Renovation, Apartment Dwelling Houses, Energy, Building, CO_2

Abstract. In members states of the European Union (EU), portion of buildings in the total consumption of energy represents 40%, and their share in CO_2 emissions represents 35%. Taking into account dependence of the EU on import of energy, this represents a large quantity of energy and CO_2 in spite of the fact that effective solutions for the reduction of energy demand of buildings exist. The EU adopted three main commitments for fulfilment of criteria by year 2020 in the 20-20-20 Directive. On the basis of the aforementioned directive, the Slovak Republic (SR) declares support for the renovation of apartment dwelling houses (ADH). Taking into account the fact that the state support can be obtained only once, and energy requirements of the EU are increasingly stricter, it is inevitable to approach to the renovation of buildings comprehensively. At the same time, it is inevitable to propose the renovation of buildings taking into account requirements for buildings until 2020. The paper divides ADH in the SR into three categories according to the existing renovation state. There are ADH without any renovation, after partial renovation and after comprehensive renovation. Within the case study, energy balances and CO_2 emissions were compared for all categories. Based on results it is obvious that energy saving up to 50% is achieved after the partial renovation in comparison with the solution without any renovation. In the case of comprehensive renovation, energy savings exceed 80% in comparison with ADH without renovation.

Introduction

New buildings represent the increase by 1% to the existing housing stock (Schmidt, 2012). In the SR, 48% of apartments are located in ADH (Statistical Office of the SR, 2011). Demographic curve of the number of inhabitants in the SR has been stabilized in the last 10 years. The total increase of inhabitants has even the decreasing nature (Statistical Office of the SR, 2011). It is possible to include up to 95% of inhabitants living in the SR into lower and middle classes (Median, AISA, 2005). Up to 58% of inhabitants of the SR receive less than average monthly wage (platy.sk, 2014). Need for housing is very important problem of each class of inhabitants. The existing housing stock, mainly in the form of the panel construction in the period of 1970 – 1990 offers great potential for the solution of the housing question for the dominant group of inhabitants of the SR. In spite of this fact, the housing construction is oriented towards minority groups of inhabitants at the present time. The European Union specifies in its strategies for the period of 2020 – 2050 need for the renovation of existing buildings with the stress put on energy saving, the environment or natural resources (Directive 20/20/20, Agenda 21, EIA, SEA).

Figure 1. *Ratio of family houses and apartment dwelling houses in Slovakia. [1]*

Apartment dwelling houses in construction systems until 1970: T 11 – T21, T 01 B – T 03 B, G 57 (Gottwaldov); SG 60, BA, LB (float concrete); MB (prefabricated concrete), MS 5; MS 11 (prefabricated system), PV – 2, PD – 62 (66), NMB, K 61 (version of Kosice), T 05 B – T 08 B (region versions) [2].

Apartment dwelling houses in construction systems since 1970: T 05 B – T 08 B (region versions), ZT (unified type); ZTB (unified type Bratislava), BA - BC (Bauring - Camus), B 70, BA - NKS I/1; BA - NKS I/2, P 1.14; P 1.15; P 1.24/25, PS 82 (region versions PP, ZA, BB, TT), U 65 (version of Banska Bystrica) [3].

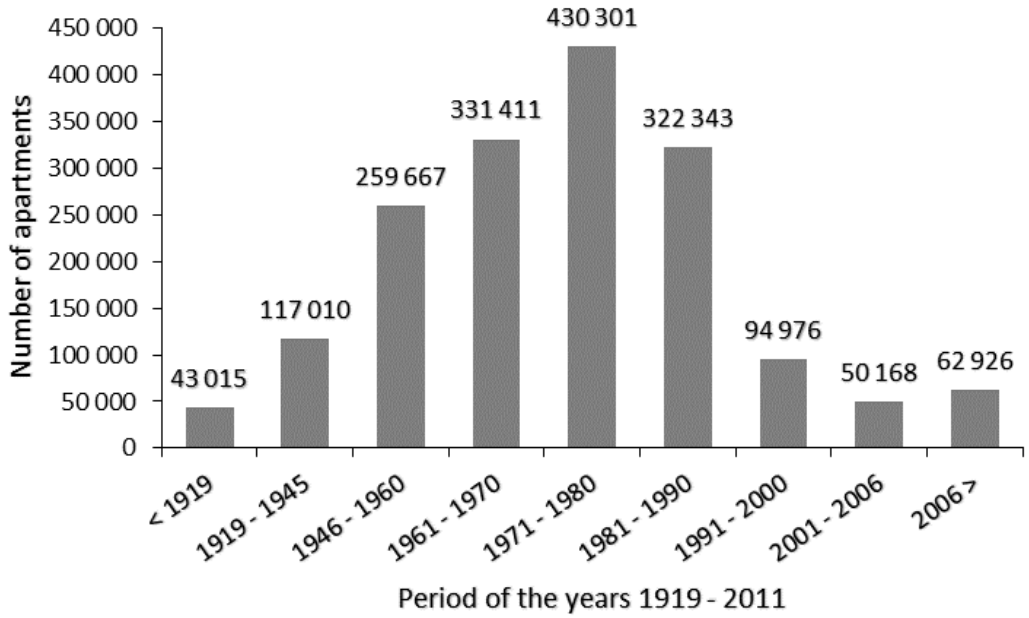


Figure 2. *Numbers of apartments by period of construction. [1]*

Years 1961 – 1990s can be included between the years with the highest concentration of apartment construction (family houses, apartment dwelling houses). Specifically, the largest representation of the construction was achieved in 1971 – 1980s.

The recommended values are in force since January 2016. Recommended target values will be valid since 2020.

Table 1. *U-value requirements. [4]*

Type of construction	**Transmission heat loss coefficient U-value (W/m^2.K)**			
	Maximal value	**Normalized value**	**Recommended value**	**Recommended target value**
	U_{max} [W·m^{-2}·K^{-1}]	**U_N [W·m^{-2}·K^{-1}]**	**U_{r1} [W·m^{-2}·K^{-1}]**	**U_{r2} [W·m^{-2}·K^{-1}]**
The external wall and sloping roofs of residential space heating with a slope > 45°	0.46	0.32	0.22	0.15
Flat and angled roof with a slope ≤ 45°	0.30	0.20	0.10	0.10
The ceiling above the external environment	0.30	0.20	0.10	0.10
The ceiling above unheated spaces	0.35	0.25	0.15	0.15
Ceiling heat flow from the top down to 15 K	1.60	0.95	0.60	0.35

Table 2. *The scale of energy classes for specific energy used for heating in kWh·m^{-2}·a^{-1}. [5]*

Classes of energy performance of buildings						
A	B	C	D	E	F	G
≤ 27	28 – 53	54 – 80	81 – 106	107 – 133	134 – 159	> 159

Table 3. *The scale of energy classes for specific energy used for domestic hot water production in kWh·m^{-2}·a^{-1}. [5]*

Classes of energy performance of buildings						
A	B	C	D	E	F	G
≤ 13	14 – 26	27 – 39	40 – 52	53 – 65	66 – 78	> 78

Table 4. *The scale of energy classes for total specific energy use in building in kWh·m^{-2}·a^{-1}. [5]*

Classes of energy performance of buildings						
A	B	C	D	E	F	G
≤ 40	41 – 79	80 – 119	120 – 158	159 – 198	199 – 237	> 238

Table 5. *The scale of energy classes for primary energy as global indicator in kWh·m^{-2}·a^{-1}. [5]*

Classes of energy performance of buildings							
A0	**A1**	B	C	D	E	F	G
≤ 32	**33 – 63**	64 – 126	127 – 189	190 – 252	253 – 315	316 – 378	> 378

The designed building must be classified to energy classes A in Slovakia since 1 January 2016. In primary energy as a global indicator new building must be classified to energy class A1.

Approaches to the Renovation of Housing Stock

The renovation of apartment dwelling houses can be divided into three basic groups as follows:

I. Apartment dwelling houses without any renovation,

II. Apartment dwelling houses after partial renovation,

III. Apartment dwelling houses after comprehensive renovation.

Apartment Dwelling Houses Without any Renovation. A common feature of buildings older than 30 years (Figure 1a – b), which were built in the SR mainly in the period of 1960 to 1992 in mass forms of the construction, is high wear of building equipment, which must be quickly replaced with elements having the quality and properties creating required safety and internal comfort of these buildings for the next longer period of time. Static and technical deficiencies of building structures are other common negative features, which are affected by the original technical design, method of construction, but mainly by insufficient maintenance and repairs. In some cases, we can speak about the emergency conditions of ADH [6].

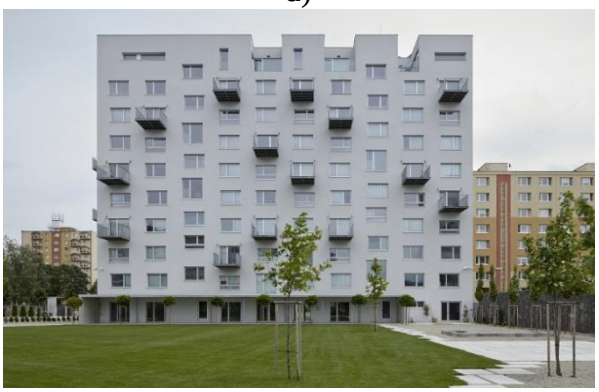
a)

b)

c)

d)

e)



f)

g)

h)

Figure 3. *Examples of apartment dwelling houses a) ADH without renovation – Lunik VIII, Kosice [7], b) ADH without renovation – Lunik IX, Kosice [8], c) ADH after partial renovation, LB panel system – Kosice, d) ADH after partial renovation – PS-82-PP, Kezmarok, e) ADH after comprehensive renovation – Vajnory, Bratislava [9], f) ADH after comprehensive renovation – Rimavska Sobota [10], g) ADH after comprehensive renovation – Prague, Czech Republic [11], h) ADH after comprehensive renovation – Lorient, France [12].*

Apartment Dwelling Houses after Partial Renovation. The targeted renovation of the housing stock older than 20 years has been taking place since 1992 in the SR, mainly by thermal insulation and removal of static deficiencies. The construction of panel ADH was terminated in 1993. All these ADH should be gradually renewed. This is based on knowledge that the housing stock younger than 20 years is subject to cyclic maintenance and repairs; the housing stock older than 20 years must be renewed [6].

This type of renovation is related to ADH and their building structures forming mainly the thermal exchange envelope (Figure 1c – 1d). This is the replacement of original filling structures with new ones, mainly plastic, with better thermal-technical properties with the application of external thermal insulation contact system (ETICS), either on the basis of EPS or mineral wool or other thermal insulation materials with new painting. In this case, it is also necessary to regulate the heating system [13].

According to the Statistical Office of the SR [1], 50% of apartments in ADH and 33% of apartments in family houses have been renewed in the SR by 2013. In total, it represents 42% renewed apartments. By 2020, 72% of apartments in ADH and 49% apartments in family house (FH) should be renewed. In the case of the aforementioned extent of renovation, ADH should be renewed in the SR by 2029, and FH by 2043 [1].

Comprehensive Renovation. The comprehensive renovation should relate not only to ADH, but it should solve the entire urban settlement (US), (Figure 1e – 1h). In the case of this type of renovation, hidden potential should be used in full extent. Enlargement of useful areas in apartments; interconnection of several apartments into one apartment, either horizontally or vertically; modernization of architectonic aspect of ADH; utilization of renewable energy resources in ADH (application of solar and photovoltaic system on the roof of ADH, or integration of this system directly into the façade; utilization of heat pump, ...); application of the unit with the recovery of heat; application of intelligent control systems and others. All of this was related to ADH. In order US would be functional, and no ghetto would become from it, medium and higher classes of inhabitants should remain in it. But this means that residents should feel well, in comfort and safely in US.

Method

The objective of this paper is to compare values of primary energy as a global indicator in three approaches to the renovation of ADH. Approaches to the renovation of ADH are as follows: ADH without renovation, ADH after partial renovation and after comprehensive renovation. The calculation was carried out according to STN EN ISO 13 790 [14] and STN EN 15 316 [15]. The classification into energy classes was carried out according to Regulation No. 364/2012 Coll. [5].

Inputs

The assessed ADH is located in Kosice. The altitude of the area solved is 208 m above the sea level. Model example illustrated in Figure 4 is represented by the ADH of the PS-82-PP construction system, which had been constructed since 1982. This is the existing ADH with 9 over-ground storeys. Useful premises are located on the first over-ground storey. The second and higher storeys are typical storeys intended for housing. The ground plan of house is of a rectangular shape. Filling structures are oriented to the east and to the west. The built-up area is 203 m^2, specific floor area is 1624 m^2, built-up volume is 4633 m^3, and building shape coefficient is 0.39 $l \cdot m^{-1}$. The building is connected to the central heat supply, where black coal is considered as a source of energy.

Figure 4. *Schematic 3D model of designed ADH PS-82-PP.*

Table 6. *Input data for envelope structures.*

Structures	**A** **U-value [$W \cdot m^{-2} \cdot K^{-1}$]**		**B** **U-value [$W \cdot m^{-2} \cdot K^{-1}$]**		**C** **U-value [$W \cdot m^{-2} \cdot K^{-1}$]**	
External wall	0.53		0.32		0.15	
Flat roof	0.40		0.20		0.10	
Ceiling structure	0.53		0.53		0.35	
Filling structures	2.85	g = 75%	1.40	g = 67%	0.67	g = 51%

Boundary conditions are as follows: winter external design temperature θ_e = -13 °C, external relative air humidity ϕ_e = 84%, indoor design temperature θ_i = 20 °C, interior relative air humidity ϕ_i = 50% [4]. Natural ventilation is planned in variants A and B. Forced ventilation with unit of

reverse obtaining heat with efficiency of 80% is planned in variant C. New distribution systems for heating and domestic hot water in the apartment dwelling house are planned in variants B and C.

Results

Resulting values of specific heat use for space heating, primary energy and CO_2 emissions are illustrated in Table 7.

Table 7. *Resulting values of specific heat use for space heating, primary energy and CO_2.*

Specific heat use for space heating $Q_{h,nd}$ in kWh·m^{-2}·a^{-1}		
A	B	C
77.59	46.12	13.50
Primary energy, global indicator in kWh·m^{-2}·a^{-1}		
154.57	102.96	53.55
CO_2 emissions in kg·m^{-2}·a^{-1}		
51.18	34.09	17.73

The difference between resulting values of specific heat use for space heating (variants A and B) is 40%, between variants A and C, it is 83%. The difference between resulting values of primary energy and CO_2 emissions (variants A and B) is 33%, between variants A and C, it is 65%.

Conclusion

Apartment dwelling houses are renewed in Slovakia. This is mainly partial renovation from resulting values of specific heat use for space heating of individual variants it is obvious that by this renovation saving approximately of 40% will be achieved in comparison with the existing state. In the case of comprehensive renovation, saving of at least 80% will be achieved. The difference between individual resulting values of primary energy is je 33 – 65% and for CO_2 emission, it is 33 – 65%.

Acknowledgements

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Section 5: Sustainable Building and Environmental Assessments

Case Study of the Straw Bale House

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Keywords: Straw, Straw Bale House, Specific Heat Use for Space Heating.

Abstract. Straw is renewable material both from the ecological and environmental point of view. It is almost always available at construction sites. Straw is used mainly as filling thermal insulation in structures. This paper deals with design of a two-generation family house. The family house is located in the eastern Slovakia. There is the temperature zone -14 °C. The first goal of this project was to specify the optimal ratio between solid and glazed surfaces in distribution of the specific heat use for space heating. The second goal was to achieve the specific heat use for space heating lower than 15 $kWh \cdot m^{-2} \cdot a^{-1}$. The specific heat use for space heating has been calculated according to STN EN ISO 13 790 Energy performance of buildings. The project analysed forced ventilation with the heat recovery unit, orientation towards cardinal points, optimal ratio of glazed and solid surfaces of the designed house and their impact on energy performance of buildings. Individual parameters were mutually combined and required goal has been achieved. The specific heat use for space heating was less than 15 $kWh \cdot m^{-2} \cdot a^{-1}$ in 13 of the evaluated combinations.

Criteria and Indicators for Assessment of NZEB in Slovakia

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Keywords: Indicators, Energy Need, Energy Use, Primary Energy.

Abstract. Building energy design is currently going through a period of major changes. One key factor of this is the adoption of nearly zero energy buildings as a long term goal for new buildings in most developed countries. To achieve this goal a lot of research is needed to accumulate knowledge and to utilize it in practical applications. Paper summarizes criteria and indicators prepared in law and technical documents in Slovakia.

The Impact of Decisions Made in Various Architectural Design Stages on Life Cycle Assessment Results

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Keywords. LCA; Building Life Cycle Assessment; Early Design Phase; Parameter Analysis.

Abstract. Life Cycle Assessment (LCA) is an advantageous tool for the analysis of the overall environmental effects of a building. Most of the decisions that influence the final result of an LCA are made during the design process of the building. Therefore, LCA in early design stages is crucial, because the changes in this period of design are cheaper and more effective. However, there are many other aspects that influence the design of a building. During the design process a high number of variables have to be defined, and in each design stage a specific number of variables have to be fixed depending on various engineering considerations. In this paper we investigate the effect of decisions made in each design stage on LCA results. Within this paper the available possibilities are compared with the variant that was actually selected in each stage, and it is evaluated how environmental indicators evolve during the whole design process. The approach is demonstrated on a case study of a realized single family house.

Environmental Assessment of Buildings Constructed by Modern Methods of Construction

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Keywords: Environmental Assessment, Modern Methods of Construction, Life Cycle Assessment, Construction, Case Study.

Abstract. Currently, we are witnessing the significant impact of industrial activity on the environment. A recent study shows that construction is the third largest industry sector in terms of environmental pollution. One option to reduce these negative effects is environmental assessment of buildings, as well as the used building materials. One of the most comprehensive environmental assessment methods is LCA (Life Cycle Assessment), which includes the assessment of impacts within mode ”Cradle-to-gate” which is focused on assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (i.e., before it is transported to the consumer). The aim of this paper is a comparison of the environmental impact of selected material variants applied within modern methods of construction. The comparison will be processed through the results of the case study containing three material variants of family houses construction in term of three selected parameters - embodied energy, global warming potential and acidification potential.

Facility Management in Sustainable Building Construction

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Keywords: Facility Management, Sustainable Building Construction, Optimization of Buildings, Operational Costs, Energy Efficiency, Quality of Indoor Environment, BIM.

Abstract. The aim of the paper is to analyse the demands on design and management of modern buildings. Namely, it is the assessment of benefits of facility manager's role in various stages of building's preparation and life cycle. The requirements on production quality, technical equipment and operational efficiency are getting stricter and stricter. Growing demand for energetic efficiency and quality of indoor environment are being analysed together with flexibility and usefulness of modern buildings, including their administration. The analysis of indoor environment quality assessment was carried out by the users of selected modern buildings in relationship to the manner of their management and maintenance. Next, the paper discusses the benefits of facility management not only during the actual using of the modern buildings but also during the project preparation phase in order to meet the users' and owner's requirements.

Introduction

Operational demands of modern buildings designed in strict limits of sustainability are assessed during the course of preparation by means of different methods (LEED – Leadership in Energy and Environmental Design, BREEAM – Building Research Establishment Environmental Assessment Method) which assume that forthcoming management of these buildings will be done in an optimal manner. That presumes highly professional administration of services and management for the whole life-time of such buildings. Their aim shall be achievement of maximal cost efficiency in environmental, social and hygienic regards. Also, the facility management should respect individual needs of the users. Application of conservative approach in administration and management of modern buildings is not sustainable anymore. It is necessary to establish cooperation with a facility manager as early as in during the project preparation phase of building and its modern management in order to achieve maximal environmental and economic efficiency and to guarantee true sustainability.

Development of modern construction materials, technologies and requirements on buildings motivates but, on the other hand, it also calls for changes in long-used traditional procedures of their design and managements. Growing pressure on sustainability has pushed the life-cycle operational costs of buildings into the centre of the attention while the costs of production are no longer emphasised. Conducted analyses and current practice have shown that building's production costs are roughly equal to operational costs after 10 or 15 years of usage [1]. It is quite a significant dispersion of values. This period gets longer together with operational efficiency of the building. However, this does not have to be directly proportional – even production costs may grow. And it is the facility manager who greatly influences the ratio between production costs and building's performance.

The scope of facility manager's key activities is, in modern point of view, very varied and broad. Besides general property administration, it also includes coordination and integrated management of services which directly support the users of the building [2]. International Facility Management Association (IFMA) states that facility management includes principles of business administration, architecture, humanities and technical sciences. Its objective is to reach long-term sustainability of building's use – optimal arrangement and use of its space, provision of function and efficient

functioning of technical equipment, quality indoor environment and other needs of the users and, last but not least, clear management of the whole system. It focuses on obtaining comfortable indoor environment while reaching maximal efficiency in terms of consumption of energy and other resources, necessary for building's operation. In fact, there is no difference if a building is residential, administrative or industrial or even if it is a complex of buildings. What is important is quality support of clients' primary activity by means of efficient use of their property. The responsibility for these requirements should be accepted by a facility manager as early as during the preparatory phase of the project of a new building or of reconstruction, in case of an existing one. Therefore, a facility manager should belong to project team and they should actively participate on emerging project.

This paper is partially based on the results of research, focused on analysis of users' and administrators' individual requirements on properties of energy/operationally efficient residential and administrative buildings [3]. The assessment included their demands and satisfaction with the various aspects of quality of the indoor environment – heat-humidity, acoustics, lighting, layout and maintenance. Special attention was paid to facility management of energy efficient buildings e.g. – whether the building has been put into facility manager's keeping, since which stage and to which extent the management is performed.

Traditional Approach in Facility Management

It is currently common practise that the building project is created by a team assembled around the investor and an architect (structural engineer, technical equipment specialist, technologist, construction estimator etc.) so the contractor usually receives a finished project, without any possibility to influence it by his experience. Subsequently, the project is often edited or corrected which results in alteration in terms of technical and material solutions which leads to extension of finishing of the project. The facility managers usually find themselves in even more unfavourable position – if there is such a specialist hired by construction management. It is typical that a facility manager receives a completed building and they have very limited options to influence the efficiency of its usage and the amount of costs during its life-cycle. Such an approach is utterly unacceptable for modern professional facility managers.

In the Czech Republic, a facility manager's competencies are simplified and limited only on building's management and maintenance of the infrastructure. Facility management is typically not part of property management and operation management. There is not a clear definition of facility manager's authority and of requirements on their performance. As a result, the services are provided chaotically and inefficiently, current needs are not catered for in timely manner, there are failures in productivity of services and also in users' primary activity which leads to growth of energy consumption and operational costs. During the phase of building's use, the principle of planned (precautionary) maintenance is not sufficiently upheld. Most of building and equipment maintenance is done only if it is actually necessary. It focuses on elimination of apparent problems and failures but it is not interested in their causes. Consequently, the frequency of repairs and amount of maintenance cost increases. It becomes clear, that these costs are four times higher than costs of precautionary maintenance and the building operation is interrupted by uncoordinated interferences [3].

Role of Facility Manager during the Creation Phase of the Building

During the project preparation stage, the presence of a facility manager is vital, especially for corrections of architect's design. Obviously, there may be a clash of different philosophies concerning the concept of the building in which, a facility manager should secure an optimal operationally-technical and economic demands of the buildings at its highest possible usefulness. It appears that a facility manager's experiences with real operation of the buildings tend to differ substantially from architects' visions. The operational optimization is the easiest and, at the same

time, the most effective during the project preparation phase. The property investors and owners need to realize that continuous and professional management and maintenance is the best way to avoid unintentional disruptions of the operations and also, it minimizes the risk of damages and wear.

Modern building of 21st century must, besides architectonical, technical and environmental qualities, be extensively flexible and useful. In reality, it has been proved that the chances for building optimization are decreasing as the progress of its realization is getting further. Thus, the best opportunity is during its project preparations, in fact, at the very beginning. When the project work is finished and the realisation has begun, the amount and the structure of future operational costs is virtually fixed from 80%. Only about 20% of operational costs is possible to influence during the usage of the building (see Figure 1) [4].

In case of traditionally designed building, even if it was calculated as energy efficient, the opportunities for its adoption for different needs are very limited. It usually requires extensive technical interventions into its design. That means both some initial costs to pay for the realisation of construction changes and also secondary losses connected to restrictions in building's operation. Considering that, if we define maximal efficiency of property usage and its operational optimization as a primary factor of sustainability, it is necessary to fulfil a large number of individual parameters which are especially [3, 5]:

- high productivity and mental or physical condition of building's users (e.g. employees, residents etc.);
- efficient, complex and clear organisation of services and processes which are necessary for provision of optimal functioning of the building;
- optimization of used area by maximisation of utilization of actual floor area (real optimization, not just minimisation of working area per one employee);
- minimization of energetic demands and environmental effects of building while, at the same time, provision of optimal quality of indoor environment (not at the lowest acceptable limit);
- minimization of resources necessary to provide optimal functionality and development of the property.

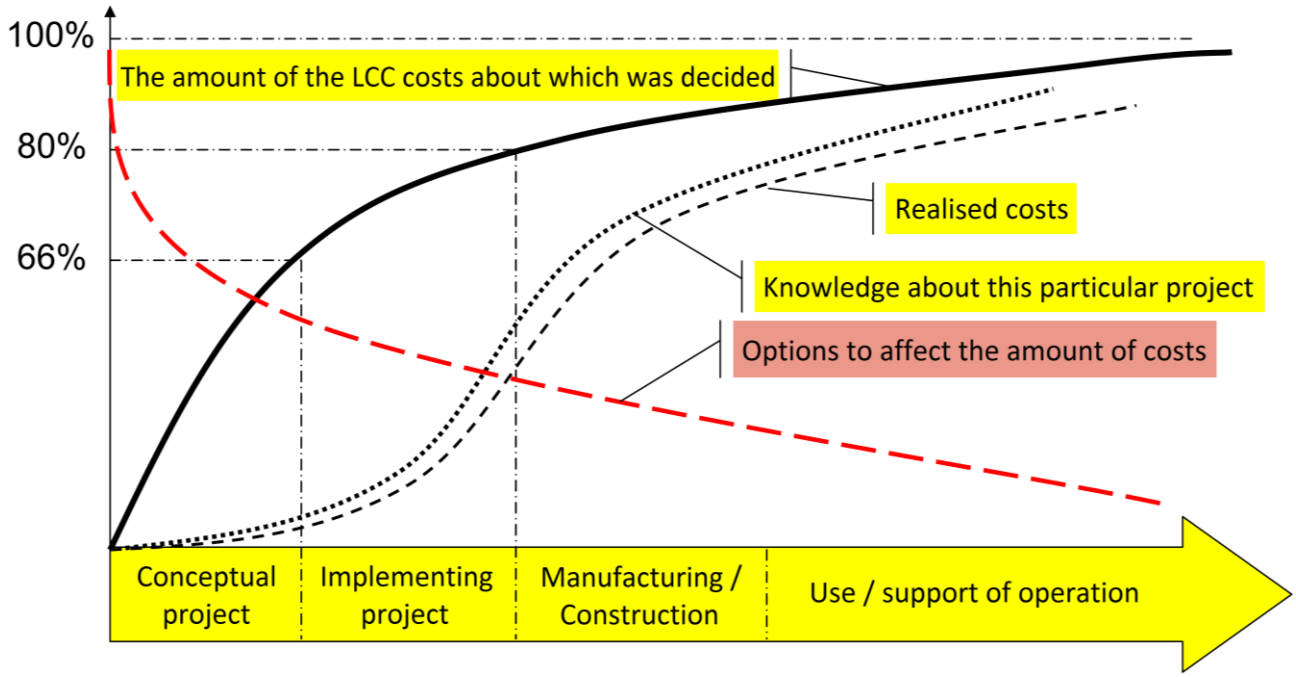

Figure 1. *Graph of development of opportunities to influence overall costs during the building's life-cycle [4].*

In modern practice of building design or even extensive reconstructions, it is essential to leave traditional approaches, based on separated modelling, calculations and drawing of project documentation. It is more appropriate and later indispensable to integrate all of them into one process and to add further software applications used for construction optimization and implementation of potential changes. In the traditional process of information exchange, it is common that part of the data is lost or deformed or the volume of the data is so big that it is not possible to process it and apply it in further phases of building's life-cycle. Subsequently, more time is needed to understand the aims by other participants. It appears that it is vital to include information environment BIM (Building Information Modelling / Management) for sharing of data about the buildings and their usage since the moment of building's creation. This way, a fluent transition between the individual phases is provided, together with substantially more efficient information sharing among the participants (see Figure 2) [6].

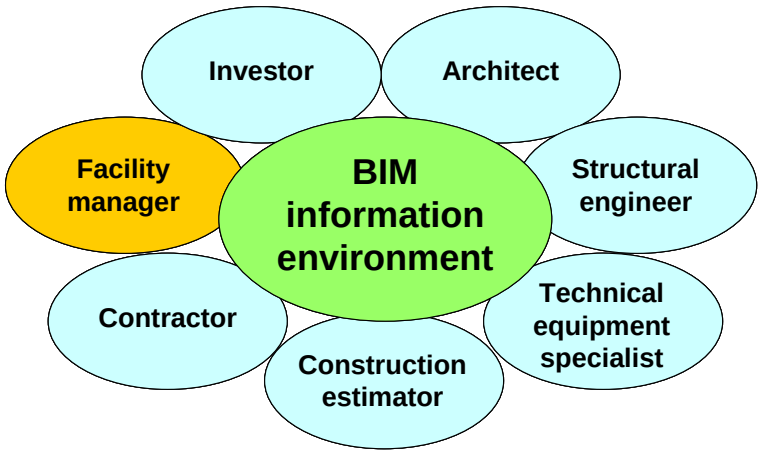

Figure 2. *Process of information sharing in BIM environment during building design process [6].*

Stanford University Center for Integrated Facility Engineering has researched 32 projects in which BIM was applied [7]. As a result of more efficient data usage and their coordination by the participants, the length of design and realisation phases were shortened and the management of such buildings have become more effective. Another significant effect is also 40% reduction of costs outside the budget and 10% of total costs as a result of collision elimination during pre-realization and realization phase.

Role of a Facility Manager During the Phase of Building's Use

The performance of facility management is, especially in terms of commercial buildings, a continuous activity which focuses on permanent observation of individual needs of building's users, changes in real estate market, existing parameters of the building and its parts and equipment. Facility manager's work is much easier in case of maximal beneficial effect (typological versatility for satisfaction of market demands), flexibility (ease of adaptation to new needs or even different purpose) and long service life. It is also important how attractive the building is for its future users (e.g. tenants). Namely, it is a facility manager's task to provide:

- quick availability and analysis of information regarding the building's operation, exact and detailed overview of operational costs;
- efficient management of indoor space or area, together with connection and distribution of technical equipment and their flexible adaption to current needs;
- simple and effective planning of maintenance and cleaning, high quality and longevity of used materials and elements, accessibility of individual surfaces and elements;

- high level of safety of building and its users;
- efficient usage and optimisation of consumption of energy/media which are necessary for provision of building operation;
- optimization of demands on extent of servicing, inspections and modernisation of technical equipment by application of suitable components in sufficient number and of long service life;
- economical modernisation and regeneration, optimisation of overall costs of building's operation;
- high level of life-cycle management of the building.

Legislative regulations stipulate the assessment and documentation of energetic demands of the building at the moment of issuing construction permit or, possibly even, each 10 years of its operation by means of Energy Performance Certificate. However, the figures in this document are gained by calculations which are based on projections but these may be different from the reality – yet in the initial phase of the building's life-cycle. Moreover, in case of insufficient management, the real energy performance may be much worse than the expected one. The reasons for that could be both worsening of the parameters of the technical equipment which is responsible for energy management and also deteriorated quality of insulation of building's envelope.

User of Building and Facility Management

Subjective perception of the indoor environment quality, different for each user, is an important fact which immediately influences their psychological comfort and physical fitness, health or work performance. It is vital to respect that both while designing and managing the buildings. For variable and adjustable parameters of the indoor environment, it is essential to find such levels which are acceptable for all the users. It does not have to be only the temperature, ventilation, daylight or artificial lighting controls but especially in administrative buildings or other commercial buildings, the change of indoor arrangement and placement of the workers with similar preferences to the same workplace may be suitable. It is evident, that all the subjects which are related to the given building – the designer, owner, construction company, the facility manager, the main user (employer) as well as single employees must participate in this process.

Research conducted within [3] between more than 100 participants demonstrated the need to give a high level of care for the operation of energy efficient and sustainable buildings and their users. The reason is, among others, quite contradictive attitudes and requirements of the actual users (employees, tenants) and of the owners (lessors) resp. facility managers. That may be alarming especially in the cases where it has a negative influence on health or work performance of the users. The employers and facility managers prefer large open space offices which are, on the contrast, perceived negatively by the employees. The main reasons are either noise accumulated from the individual work positions, insufficient natural light conditions by the workplaces which are further from the external walls or, on the contrary, excessive insolation of the workplaces which are closer to the glassed side walls (shading by means of window blinds worsened the intensity of natural interior light even more), usually unified temperature and humidity setting regardless to individual needs of each employee. The owners and the facility managers tend to make these problems relative.

The fact, that the quality of indoor environment is perceived as an important priority of using operationally efficient buildings, is shown in Table 1, containing results of research conducted among the owners, users and facility managers of low-energy and energy passive buildings. In order to research the level of user's satisfaction with indoor environment, 11 parameters of the indoor environment quality were formulated. The centre of the interest are not the parameters which should not appear at this type buildings or those which the users are not able to rate objectively (the

presence of thermal bridges, moisture condensation on the inner surfaces of structures or on glass fillings of the openings, moulds etc.).

The users of energy and really operationally efficient buildings perceive and respect the necessity of paying higher acquisition costs in order to obtain these buildings. For these money, they expect to get a quality indoor environment together with quality building surroundings and contact with it. This factor is logically more important for the users and owners of residential buildings and family houses. However, it is also important even for the personal comfort of the users of the administrative buildings. At residential buildings, the highest level of satisfaction was expressed by those users who actively participated on the building design even during the project phase. Less satisfied were the users who obtained the building from a previous owners, despite the following construction adjustments. As the least satisfying were rated the buildings which were realised by a developers.

Table 1. *Rating of satisfaction with the parameters of indoor environment quality (R – residential buildings, A – administrative buildings); rated from 0% (absolutely inconvenient) to 100% (absolutely convenient), step 5%.*

Ranking	Parameter	Rating of satisfaction [%]							
		Minimum		Maximum		Average		Median	
		R	A	R	A	R	A	R	A
1.	Modernity level of indoor equipment	50	80	100	100	84	89	90	90
2.	Intensity and the layout of interior artificial illumination	45	50	100	100	85	82	90	90
3.	Intensity of daylight interior illumination	15	40	100	90	80	77	90	90
4.	Interior cleanliness and demands on its provision	55	50	100	100	81	79	85	80
5.	Interior air cleanliness	60	30	100	100	87	69	90	70
6.	Interior air temperature and humidity parameters	60	20	100	100	82	59	85	60
7.	Visual contact with the building surroundings and its quality	50	40	100	100	85	56	90	50
8.	Interior layout, orientation to the cardinal points	10	30	100	90	78	61	80	50
9.	Draught intensity in the interior	15	20	100	90	75	59	85	60
10.	Acoustic comfort and interior noise level	40	30	100	90	80	53	80	50
11.	The resistance against overheating of the interior during very sunny days	20	20	100	90	74	54	75	50

An important parameter of building's comfort is, how the owners resp. the facility managers care about the interior and the indoor environment – the frequency of inner surfaces painting, cleaning of glassed surfaces, inspections, cleaning and regulation of building technical equipment etc. It is necessary to say, that the users of energy efficient buildings perceive this factor very sensitively. Although, in some cases of the residential buildings, it is regarded as bothering, especially, in comparison with common buildings which are mostly maintenance-free. A noteworthy fact is that medium-vivid or dark colour shades predominate at colour arrangements of the interior surfaces, structures and equipment. They excessively absorb the daylight and they worsen the illumination conditions in the interiors.

Especially in relation to the heating and indoor air humidity, the facility manager should be interested in the rating of employees' perception of indoor environment quality at least 2 times a year – after the beginning of the heating season and during the summer. In case of increased number of unsatisfied users, the facility manager must react by changing the settings of related systems and technical devices of the building. It is also essential to keep these devices in a perfect technical and hygienic state. There is a significant amount of the users who consider simple control and noiseless operation of technical and technological devices to be an essential factor of user-friendly operationally efficient building. Semi-annual, or even better, annual intervals of filter-changing, cleaning of solar or photovoltaic panels or large glassed fillings are acceptable. More frequent or extended service procedures required by technical equipment are considered as bothering, costly and value-lowering.

The influence of the indoor environment of operationally efficient buildings on the users' fitness was examined in 3 areas – health, psychical well-being and work performance. The owners and managers of administrative buildings were intentionally excluded from this rating. The summary of the data gathered from the group of users (workers) of operationally efficient administrative buildings and the owners resp. users of operationally efficient residential buildings are shown in graphs in Figure 3.

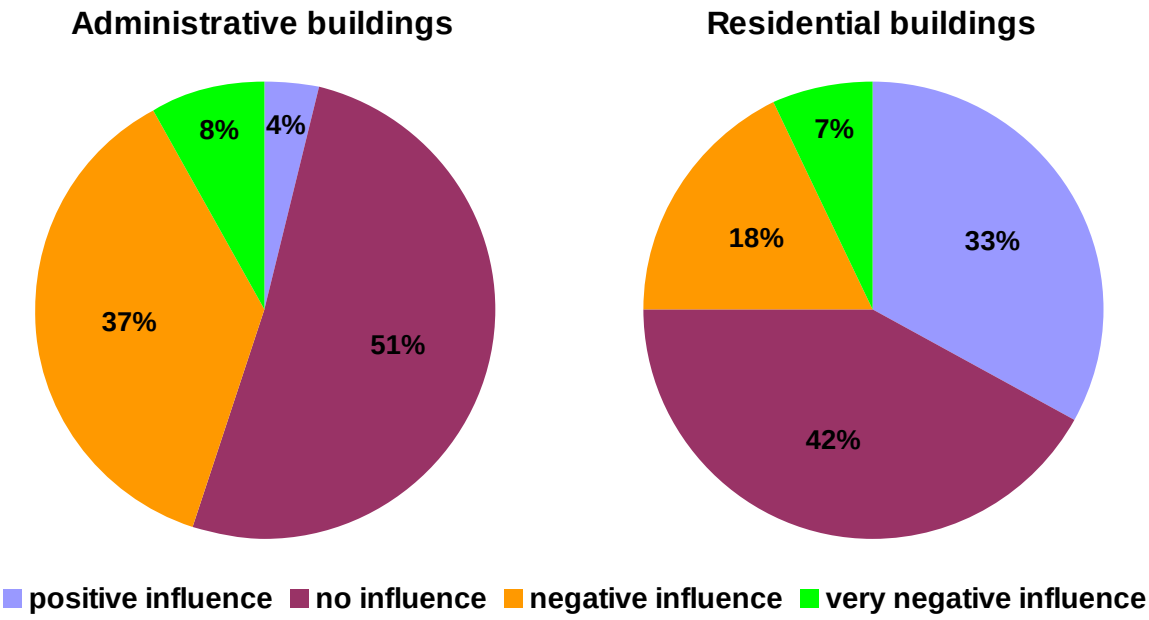

Figure 3. *The rating of the influence of operationally efficient buildings on the fitness of their users.*

It is possible to say that the buildings which are ventilated in a natural way, without ventilation devices, are rated as without any influence on the users' health. This group includes large part of operationally efficient family houses and apartment buildings. Part of residential buildings which are equipped with ventilation device have, according to their users, a positive influence on their health, namely, if these devices are regularly and properly maintained. On the other hand, negative rating was given to a few factors of indoor environment quality with potential effect on the users' fitness (see Tab. 1). Large open space offices are also rated negatively in terms of lowered work productivity. With regards to their subjective feelings, the users of these buildings are very sensitive to the character of dispositional arrangements of the interior, including the room orientation to the cardinal points. It is necessary to emphasize that this perception is not unified. Individuals who prefer sun are not satisfied when placed on a workstation inside the building's disposition or alongside less insulated frontages. On the contrary, the employees who prefer shading feel uncomfortably at the workplace which is directly exposed to sunlight. In summary, facility manager must respect very broad needs of the users of energy efficient buildings, with regard to the sustainability of construction.

It is necessary to assess operational efficiency of the buildings in a wider context – not only from costs and energy consumption points of view. It is necessary to include also personal costs. They consist of significantly varied items as e.g. employees' personal and sickness payments, loss of income in case of employees' work incapacity or in case of their fluctuation. The residential buildings costs include also users' health costs to pay for necessary extra clothing owing to unsuitable interior heating regime etc. The amount of these costs is definitely related to the quality of the environment inside the buildings which is influenced by their structural and technical properties, by the quality of used equipment (e.g. furniture) and of course, by the care given to the buildings, their equipment and their indoor environment. If the quality of the building's indoor environment reaches certain level, which positively affects users' psychical and physical fitness, health and work performance, it results in a very favourable contribution into the balance of operational economic demands of such building.

Summary

Generally, it is possible to view facility manager's presence while administrating modern, energy-efficient buildings as beneficial or even essential. The problem is, that in the Czech Republic, this role is often reduced to mere cleaning and simple maintenance. The user's and owner's level of satisfaction with the quality of indoor environment and operational efficiency grows together with the intensity and professionalism of the facility management.

The main benefits of intensive and professional facility management of modern energy-efficient buildings are – from owners' point of view – fluent, uninterrupted and efficient operation and so – maximal continuous utilization. Moreover, good facility management may secure preservation of its flexibility together with current and future financial values at the real estate market. The users of such building will probably appreciate high quality of indoor environment, physical and mental fitness and extended working productivity or subjective satisfaction with its usage.

However, failure to provide professional facility management may lead to unexpected breakdowns of essential appliances which are responsible for building's operation, increased energy demands and insufficient utilization of indoor areas. This causes financial losses to the owner and to building's credibility. Similarly, the users' may suffer from physical and mental discomfort and their health is also put in jeopardy by possibility of "sick building" syndrome, unpleasant feeling or interrupted productivity.

Acknowledgements

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Biomass Use for Low Energy Buildings and Retrofits

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Keywords: Solid biomass, boiler and system efficiency, primary energy conversion factors.

Abstract. Based on the EPBD 2010 directive and the mandated method of cost-optimum calculation the forthcoming national regulations require "nearly zero energy buildings" which have high energy performance, significant share of renewables in covering the low energy need and harmonizing the requirement system and the cost-optimum. Known intention of Member States as well as some research reports create the impression that predominant use of biomass in the forthcoming years will be the right way to fulfil the above requirements of nearly zero energy buildings. Nevertheless a brief analysis proves that these expectations are exaggerated due to either cost problem or seasonal system efficiency whilst some "secondary" environmental problem must not be forgotten.

Section 6: Hygrothermal Performance of Buildings

Long-time Measurement of Experimental Walls Suitable for Low Energy Buildings Exposed to the Outdoor Climate - Hygrothermal Durability and Thermal Performance

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Keywords: Lightweight Wall, Wooden Frame, Zero Energy Building, Experiment, Simulation, HAM, Heat-Air-Moisture, Long-Term, Thermal Conductivity.

Abstract. Five lightweight timber-frame wall sections with various thermal insulations, vapour barriers and outdoor coating colours were exposed to the real outdoor climate since 2011. The indoor boundary conditions were maintained by the air conditioning unit. After five years of exposure, the experimental wall was dismantled. The samples from thermal insulations were collected and the mass moisture content and thermal conductivity were found out. This article compares designed and measured values of thermal conductivity and the temperature inside five sections to simulation in WUFI Pro. The wall sections differ from each other with thermal insulation: mineral wool, glass wool and hemp and by the colour of the outer surface: white, grey and yellow. Considering the vapour transport in composition, there are three variants: without the vapour barrier, with the classic vapour barrier and with the vapour barrier with changeable diffusional resistance. There are thermal sensors located in each section. Samples of the thermal insulation were taken from the sections and the water content was measured by the gravimetric method twice – before and after the winter period.

Introduction

The experimental external wall fragment was designed and realized according to the thermal-technical standard for passive buildings. This relates to all sections of the wall. The structure differs from the usual ones through the inverse order of layers. Taken Nordic countries as an example, the thermal-accumulating layer is located from the exterior side and the thermal-insulating layer from the interior side of the wall. It is expected that in the near future, buildings on basis of wood with natural insulating materials will be used more because of their suitability for low-energy buildings. Good examples come from advanced countries, e. g. Czech Republic [1], Nordic countries, Austria and Germany. Wooden buildings suit well to the requirements for passive buildings. We used hemp insulation as a natural material in section 3. The monitored experimental external wall fragment from our laboratory centre is defined by its dimensions of 3670 x 2670 mm. It is divided into five sections, which differ from each other in material composition and colour of the final surface [2]. The experimental wall fragment is fixed as a part of the external wall of existing building of the University of Zilina. Sections no. 1, 2, 4 and 5 are made as diffusional closed constructions and the section no. 3 is diffusional open (Figure 1). The wall fragment is a part of external wall construction of climatic chamber of pavilion type in the laboratory centre belonging to our department. Measured temperatures of the fragment (exterior surface, under the coating, on the internal surface of the MDF board and interior surface of the thermal insulation) were recorded in the 30-minutes steps. Some temperature sensors are placed at the wooden columns, too. More detailed description explains [3]. The mentioned experimental wall fragment is exposed to real boundary conditions from the exterior and to determined boundary conditions from the interior maintained by the air-conditioning unit (20 ºC and 50% relative humidity).

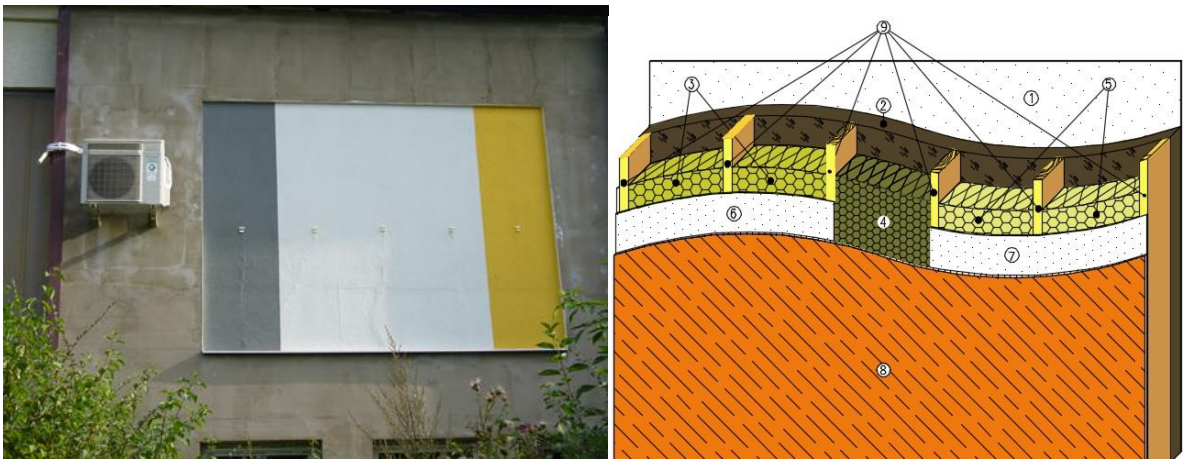

***Figure 1**. View at the experimental wall fragment with visible location of the measuring sensors, right: view from the exterior, left: layer arrangement, 1 – external coating 4 mm, 2 – MDF fibreboard Hofatex 100 mm; 3 – stone wool 220 mm; 4 – hemp mat 220 mm; 5 – mineral wool 220 mm; 6 – PE vapour membrane; 7 – vapour barrier with changeable diffusional resistance 8 – OSB board 12 mm; 9 – wooden columns 60 x 220 mm.*

Parameters of the external environment were recorded by the detached experimental weather station at the chosen time step (30 minutes). We measure and record meteorological variables, such as external air temperature and humidity, wind direction and velocity, global radiation on horizontal and vertical plane (identical to the orientation of the experimental wall) [4]. The measuring device is fixed on the roof near the laboratory centre.

Before the cold period of the year (autumn 2014) and after the cold period of the year (spring 2015) there were taken samples from the thermal insulation to obtain mass moisture content (after four years of the wall sample being built in). The thermal transmission coefficient of individual materials was measured with assistance of Isomet 2104. Mass moisture content of the thermal insulation and MDF board was determined by the gravimetric method according to [5]. To obtain mass moisture content of wooden supporting parts, the resistance meter Greisinger GMH 3850 was used.

Results of Measurement and Their Evaluation

A one-week measurement in the cold period of the year [2] was chosen (reference week, 27.01.2012 to 02.02.2012 with recorded temperatures $\theta_{ae,\ min}$ = -18.9 °C, $\theta_{ae,\ max}$ = 4.6 °C) to show results from the long-term measurements. External surface temperatures of each section are shown in Figure 2.

As the sections of the experimental wall fragment have various material compositions, the measured values differed from each other due to parameters of individual layers. Also the natural environment and different light absorption and reflectance of various surface colours influenced the results of measurement.

The highest surface temperatures were recorded on the grey coloured surface – section 5 (as expected). Such a coating has the lowest reflectivity of solar radiation and absorbs the most short wave solar radiation. Recorded maximums during clear days were above 48 °C. This was by 30 °C higher in comparison to the other coloured surfaces. Selected from three sections with white coating colour, the section no. 3 reached the lowest surface temperatures. This was caused by higher heat flow. During nights of the whole reference week, surface temperatures in all sections were lower than the ambient air temperature due to the cold sky radiation. Minimum temperatures were recorded mainly in the section no. 4 with white-coloured surface and the section no. 1 with yellow-coloured surface [6].

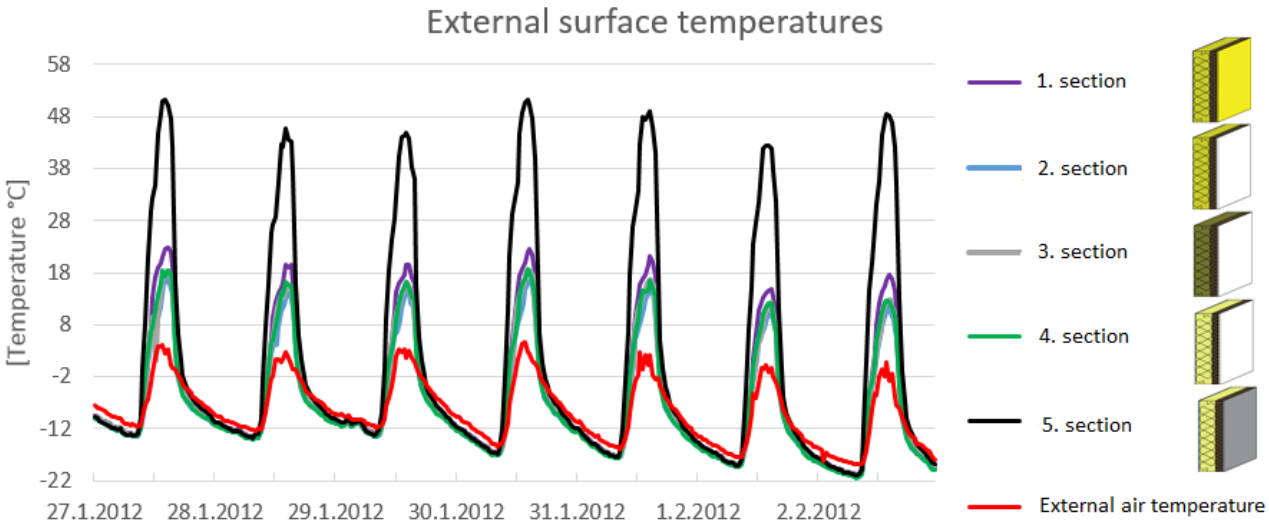

Figure 2. *Temperature courses at the exterior surface of the wall fragment (time period from 27.01.2012 to 02.02.2012), yellow (1. section), white (2., 3. and 4. section) and grey (5. section) coloured surface*

Significant influence of deviation of external conditions at the temperature course in the construction was noticed in monitored positions closest to the interior under the additional thermal insulation MDF board Hofatex. The greater impact of the internal environment (air-conditioning unit to maintain the indoor climate according to the need of experiment) was noticed on the contact between the thermal insulation and MDF board. During the winter period, the mechanism of heating and cooling process had positive effect on heat losses of the experimental laboratory of pavilion type. Minimum temperatures under the additional insulating layer and therefore the largest cooling of storage layer was thanks to the thermal inertia and with it connected phase shift of the temperature oscillation recorded in time. Evaluating properties of individual thermal insulations after 4 years of measuring, we found out that by 24-hour measuring of the thermal conductivity coefficient of fibrous insulations these indicated changes during the day only minimally or insignificantly (Table 1). 24-hour evaluation of the additional insulation MDF board Hofatex showed that there were registered significant changes in all sections, particularly in the 5th section with dark grey coloured surface. It was also determined that while in the sections with diffusional closed layer compositions the thermal conductivity coefficient stayed nearly the same according to declared values, the thermal conductivity coefficient of the hemp thermal insulation increased by about 50% in the moisture transport. Measured and recorded values of thermal conductivity coefficient λ suited the interval <0.0621; 0.0637> $W \cdot m^{-1} \cdot K^{-1}$. According to this it would be more appropriate to use diffusional open structures.

Measurements of water content in sections 1, 4 and 5 in fibrous insulations confirmed the constant low content in both time periods of measuring (Figure 3). In other sections there were no measurements performed, because of the running measurement by use of optical fibres from another work place. On the contrary, the increased water content was noticed in the hemp insulation with the diffusional open composition. The water content at the MDF board oscillated in range from 8.50% to 13.42%. Lower values of the water content were noticed under darker surfaces (Figure 3 – section no. 1 and 5). The highest moisture content was recorded in the section with diffusional open construction again (section no. 3). Interesting would be results from section no. 2, but because other measurement was not possible to collect samples from that section.

The mass water content in wooden columns oscillated in a range from 10.00 to 15.20%. These are appropriate values for wood (Figure 4).

Lower values were obtained at fronts of the columns (from the interior side). Higher values were obtained from measuring at sides of the columns.

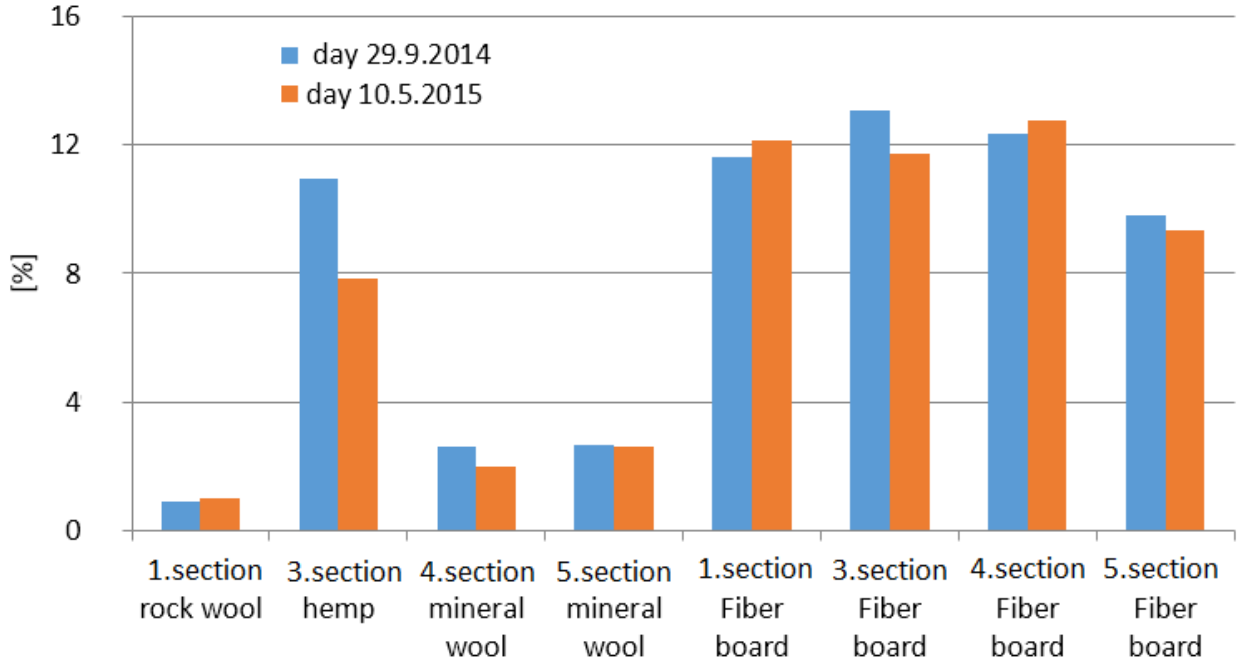

Figure 3. *Water content [mass %] in the thermal insulation of wall sections.*

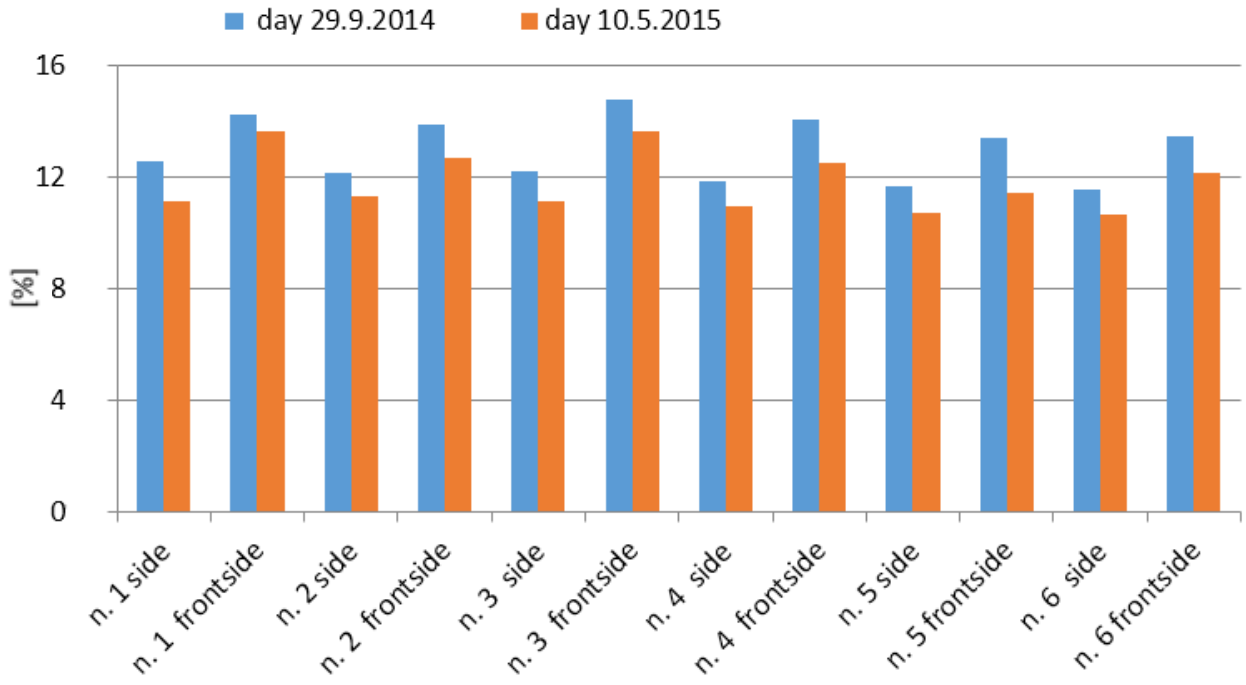

Figure 4. *Water content [mass %] in wooden columns.*

Table 1. *Measured thermal conductivities in the materials of wall sections.*

	Section no. 1			**Section no. 3**			**Section no. 4**			**Section no. 5**		
Area of Insulation	**min λ**	**max λ**	**Δλ**	**min λ**	**max λ**	**Δλ**	**min λ**	**max λ**	**Δλ**	**min λ**	**max λ**	**Δλ**
	[W·m^{-1}·K^{-1}]			**[W·m^{-1}·K^{-1}]**			**[W·m^{-1}·K^{-1}]**			**[W·m^{-1}·K^{-1}]**		
Infill Insulation	0.039	0.040	0.001	0.062	0.064	0.002	0.038	0.040	0.003	0.038	0.040	0.001

MDF Insulation	0.104	0.112	0.007	0.102	0.108	0.006	0.106	0.121	0.015	0.099	0.129	0.030

Table 2. *Properties of materials used in wall sections.*

Material	**Description**	**d** [m]	**λ** [W·m^{-1}·K^{-1}]	**ρ** [kg·m^{-3}]	**c** [J·kg^{-1}·K^{-1}]	**μ** [-]
External Plaster	StoSilco	0.004	0.7	1900	720	40
Woodfiber MDF Board	HofaTex SysTherm	0.1	0.045	210	2100	5
Stone wool Insulation	Rockwool MW W	0.22	0.037	40	840	1
Hemp Insulation	Cannabest Plus	0.22	0.040	36	1200	1.9
Glass Wool Insulation	Isover ENV	0.22	0.035	24	840	1
Vapour Barrier with Changeable Diff. Resist.	Isover Vario KM Duplex	0.0004	1	2000	1470	90000
Vapour Barrier	PE foil	0.0002	0.4	400	1470	10200
OSB 3	OSB 3 MUPF/PMDI	0.012	0.14	700	2100	240

Results of HAM Simulations

WUFI Pro in version 5.1 was used for heat-air-moisture (HAM) simulations. It is the software, which allows realistic calculation of the transient coupled one- and two-dimensional heat and moisture transport described by Künzel [7] in multi-layer building components exposed to real boundary (weather) conditions. It is based on the newest findings regarding vapour diffusion and liquid transport in building materials and has been validated by the detailed comparison to measurements obtained in the laboratory and on IBP's outdoor testing field. Material properties are described in Tab. 2. Instead of dry thermal conductivities the real measured ones were used (Tab. 1). Four of five sections (Fig. 2), which are described above were modelled and simulated for the time period from 04.10.2014 to 15.04.2015 with use of exterior boundary conditions measured by the detached experimental weather station [4].

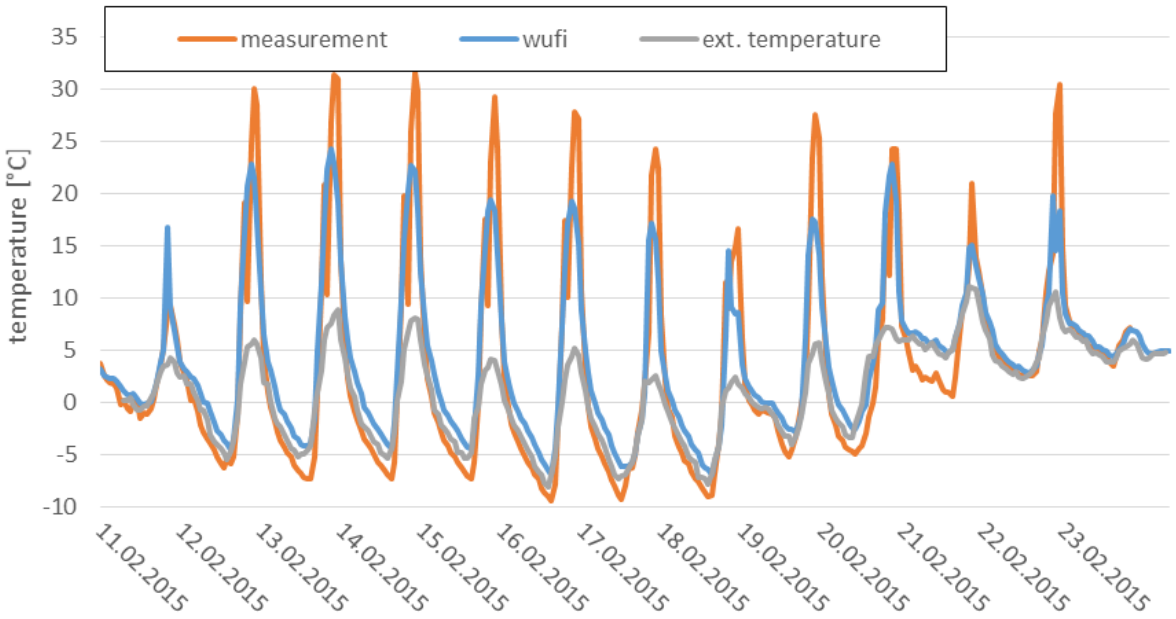

Figure 5. *Daily courses of measured temperature under the exterior coating, exterior air temperature and the course simulated in WUFI for the 1st section, sunny winter days (time period from 11.02.2015 to 24.02.2015).*

The courses of simulated and measured temperatures in selected boundaries in the wall sections were compared. The initial conditions for material properties were taken from the gravimetric measurement. At the end of winter period there were taken other samples of materials of the experimental wall. These results of water content in thermal insulations were compared to the simulated ones.

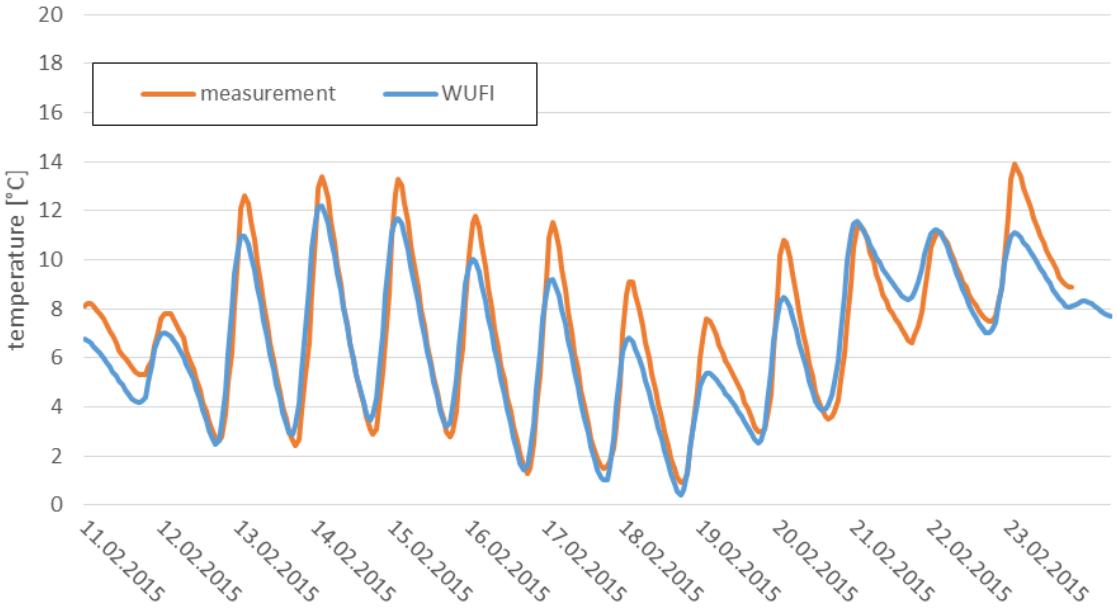

Figure 6. *Daily courses of measured and simulated temperature on the inner surface of MDF board for the 1st section, sunny winter days (time period from 11.02.2015 to 24.02.2015).*

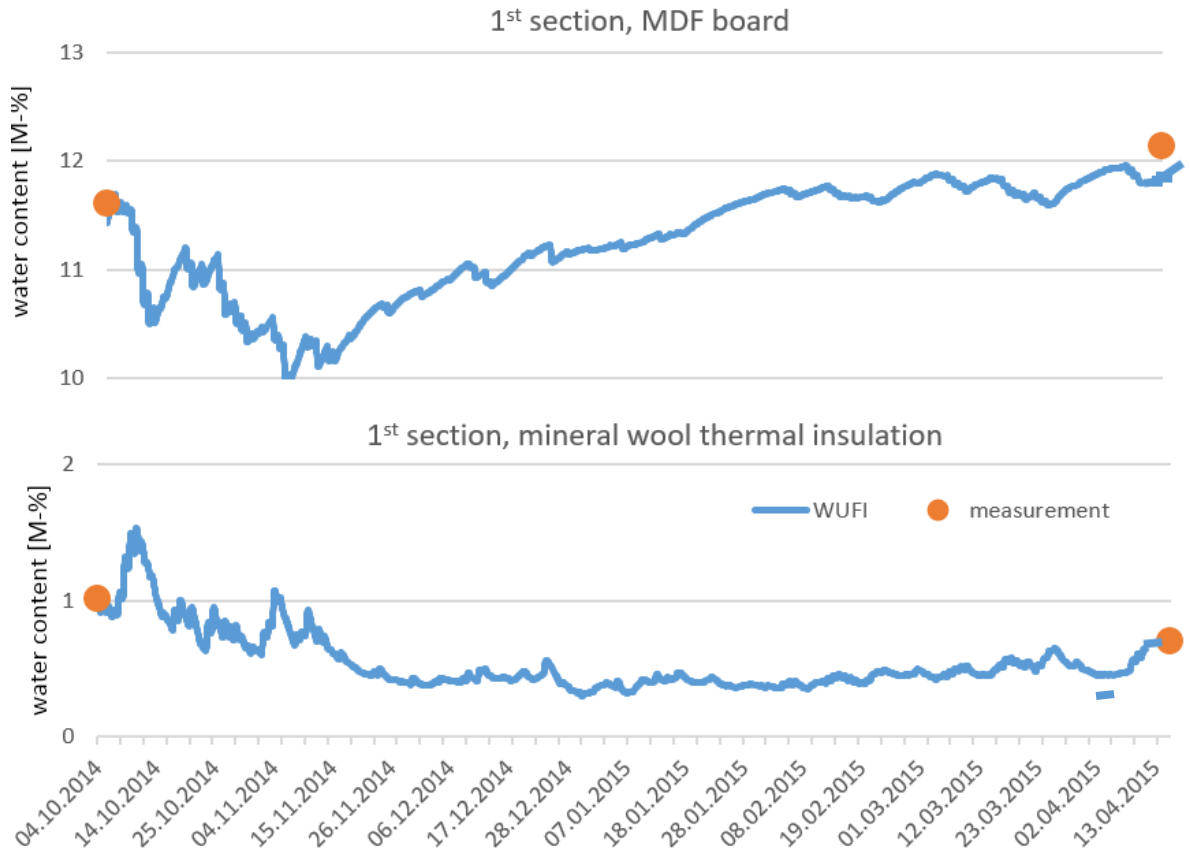

Figure 7. *Daily course of water content (according to the computer simulation) and results from the gravimetric measurement (from 01.10.2014 to 10.05.2015) for the 1st section.*

The temperature courses on the surface and material boundaries show quite good match between measured and simulated values with exception of the section no.3 with hemp thermal insulation. Temperatures measured on the surfaces reach higher values than the simulated ones. It could be caused by the dust and decreased surface reflectance after 4 years of test wall existing [8]. From the simulation period during the winter there was chosen the period from 11.02.2015 to 24.02.2015, which could be characterized by freezing temperatures during the night (up to -10 °C) and clear, sunny days.

From the simulated sections of the wall fragment, there was chosen the 1st one with yellow coloured surface (Fig. 5, 6), where we can see a good match with the measured temperature values. In the section no. 3 there are noticed higher differences. The results of the simulation are better than measured ones. The reason is in decreased material properties of diffusional open layer composition of the section (water content, thermal conductivity), which did not influence the simulation well enough.

Significant fact is that the measurement and simulation showed that the temperature courses did not fall below zero in the boundary between MDF board and filling thermal insulation. This means, that the wooden poles remain in positive temperatures.

Similar findings can be specified about the courses in the MDF board and mineral thermal insulation. The comparison of water content from gravimetric measurement and simulation can be realized only for boundary layer, because the samples were taken only from the interior surface. The simulation can be realized for different position inside materials of the construction or at the contact of layers. Figure 7 shows this course of water content from the section no. 1 for MDF board and mineral wool thermal insulation.

Conclusions

During long-term measurements it was shown as expedient to use the unconventional composition with inverse range of layers according to the model of Nordic countries in the climate zone of central Europe too. The thermal-accumulative layer was warmed during winter days. This caused the improvement of boundary conditions for heat transport and decreasing heat losses. Moreover, the negative influence of external environment on filling fibrous thermal insulations decreased (temperature extremes, UV radiation, dust, moisture, etc.). The thermal-insulating properties of thermal insulations have not changed significantly during the day due to this fact. Moreover, it was thus possible to avoid reinforcing OSB board from the exterior side. This has a positive impact not only on moisture transport through the structure, but in economic terms, the absence of one layer has positively influenced both – the amount of acquisition costs or labour content.

Comparison of measurement results to simulations showed favourable accord in diffusional closed compositions, while in diffusional open constructions there were determined significant differences. Based on the research, conclusions for actions in lightweight wall in real conditions were formulated. However, it is needed to remark, that these are valid for specific conditions of interior environment (air-conditioned room without presence of thermal gains from internal sources and without thermal gains from solar radiation through transparent constructions).

This experimental wall was disassembled in the spring. The measurement will continue with different – updated wall composition, updated measurement technology (temperatures, relative humidity and heat flux) and for different orientation (south and east). Also some defects from previous design were updated so the crucial layers are strictly divided between the sections (compared to the MDF layer in this case). This should avoid moisture transport between the sections, which is under further investigation of this experimental measurement.

Acknowledgement

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Determination of Capillary Conductivity Coefficient by Using Electromagnetic Microwave Radiation

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Keywords: Capillary Conductivity, Microwave Radiation, Moisture, Inhomogeneous Porous Material.

Abstract. Moisture in building structures affects negatively construction material physical properties, particularly thermally insulation properties. The porous structure of most building materials distinguishes by the ability to absorb water in liquid and gaseous state into its internal cavities, to fill the accumulative space of pores, to transport moisture and to re-transmit to the surroundings. The moisture characteristics of building materials are the base for evaluation of building structure thermal insulation properties. The moisture spreading via capillary conduction is the most significant material parameter of a moisture appraisal. However, it is necessary to incorporate also spreading the liquid phase into the moisture appraisal for certain structure material compositions. The article deals with determination of capillary conductivity coefficient by using electromagnetic microwave radiation. The radiation passed through a wet sample is detected and then the value of capillary conductivity coefficient is determined. The coefficient of capillary conductivity is property dependent on several physical parameters, but primarily on the moisture.

Comparison of Driving Rain Index Calculated According to EN 15927-3 to the CFD Simulation and Experimental Measurement

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Keywords: Measurement, TRY, Heat-Air Moisture Simulation, HAM, Wind-Driven Rain, Airfield Hourly Index, CFD, Slovakia, Bratislava.

Abstract. Wind-driven rain or driving rain is a rain which has given a horizontal velocity component by the wind. It can be the important moisture source for building façades and has been of the great concern in building science. In this article, the normative method described in STN EN ISO 15927-3:2009, was used for calculation of driving rain impact on vertical surfaces. This amount of rain was compared to the CFD simulation for selected location and to the experimental measurement carried out by wind-driven rain gauge.

Double Windows in Heritage Listed Buildings

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Keywords: Double Windows, Heritage Listed Buildings, Surface Temperatures, Relative Air Humidity.

Abstract. Heritage listed buildings, or their parts, are subject to the decisions of state authorities in the field of heritage preservation. When windows are reconstructed, the requirements concerning the new design are most often based on the original appearance of the windows. In the case of double windows - the traditional style with space and reveal in between - the outer window is installed with insulated glazing while the inner window has a simple glazing, in order to meet the conditions of thermal related technical standards. For this reason, the contact between the window frame and the reveal must be tight with very low air permeability. The article presents the measurements of surface temperatures of both of the window parts and explores the issue of thermal humidity condition in the area between the windows.

Incidence of Microorganisms on Insulated Facades in the Selected Location (Ostrava – Poruba)

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Keywords: Microbiotic Contamination, ETICS, Poruba Location, Ostrava.

Abstract. Incidence of microorganisms on thermal-insulated facades in the selected location (Ostrava-Poruba). Incidence of microorganisms on facades is more and more common. It benefits mostly from façade´s thermal insulation. This problem is not only esthetical. Incidence of microscopic fungi increased due to environmental changes. Every person is breathing spores (reproductive particles of mould) unknowingly. There is evidence that spores are closely related to respiratory illnesses. Objects that are vulnerable to microorganisms should be managed in a way, where there is no risk of harm to us or people around us.

Analysis Method for Studying Groundwater under a Church

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Keywords: GPR, Building Materials, Groundwater, Church, Capillarity.

Abstract. The Church of Asunción of Llíria (Valencia, Spain) is one of the best examples of the Valencian Baroque of the seventeenth century. This research is based on the study of the building from an urban, historical, and especially, a constructive view. The location of this particular church is unique because it is embedded in a mountain. First, some excavations were made into the mountain before the construction of the church started. Thus, there is a slope between the main entrance of the church and the rear. This research work provides the analysis of the ground humidity throughout the Ground Penetrating Radar (GPR) technique. We have analysed the subsoil of the whole church by various cuts or paths. Longitudinal and transversal measurements allowed us to produce a three-dimensional model of the land on which the church stands. We have also analysed the homogeneity or heterogeneity of the subsoil in each area and the presence of certain ground water routes. The rising moisture has been analysed on the walls and pillars of the church. To this end, a moisture analyser has been employed to monitor the moisture content over a period of six months. With this information, it was possible to identify points that are systematically more humid.

Dynamic Heat and Moisture Transport Modelling of Industrial Floors on Different Climates

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Keywords: Dynamic Simulation, Heat and Moisture Transfer, Industrial Floor, Building Physics.

Abstract. In this paper a conjugated heat and moisture transport investigation of industrial floors is presented. We have analyzed 2D general segments of wall and foundation connections in three different climatic conditions: Budapest (Hungary), Lisbon (Portugal) and Espoo (Finland). We also modeled the component with horizontal or vertical edge insulations with various thicknesses and lengths, and two different soil compositions under the floors. The design of the floor and wall components was performed according to the current standards. We examined 126 combination of the segment and the results shows difference both in relative humidity across the components and heat losses through the internal faces. In conclusion, the simulations and results can improve the energy efficient design of industrial buildings across Europe.

Reinforcement-Dependent Thermal Properties of Reinforced Concrete Columns and Slabs

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Keywords: Building Physics, Thermal Conductivity, Reinforced Concrete, Finite Element Analysis.

Abstract. Energy efficiency aspects are rarely considered during practical structural design. In building energetic calculations, thermal conductivity values from EN ISO 10456:2008 [1] are mainly used, although the standard define concrete's values only by taking into account the density and the approximate percentage of reinforcement. Details of the structure type (column or slab), reinforcement (e.g. direction, diameter, amount of rebar spacers) and other properties (e.g. concrete composition) are not mentioned. In this research, we uncover the possible relations between the steel content parameters and thermal properties by laboratory measurements of 1:2 scaled reinforced concrete specimens and validated finite element models of columns and slabs with different designed reinforcements. Results shows, that depending on the structure type, design and steel content, there is a difference in the structure's equivalent thermal conductivity. Our results and experiences of this research possibly can be used in energy conscious structural design practice.

Evaluation of the Dependence of the Parameters of Internal Environment of Wooden Truss on the Orientation of the Building

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Keywords: Relative Humidity, Wood Moisture, Fungi, Wood-Destroying Insect, Cultural Heritage, Historical Wooden Truss.

Abstract. Historical wooden trusses carry a lot of information about used tools, technologies or construction processes. Unfortunately they are generally threatened by many dangers, which could cause irreparable damage and loss of the carried information. Protection of historical roof trusses is an important part of efforts to protect our cultural heritage. Wood destroying insects and fungi are the most serious threats to historical roof trusses in our climatic conditions. Their spreading depends on several specific (interior) conditions. These include critical moisture content in the wood, relative humidity, temperature, etc. In addition to these commonly monitored parameters (and their critical levels) we also must not forget the influence of local geography, biotope or orientation to the cardinal. This paper describes temporal fluctuations of some of the mentioned physical parameters in a historical roof truss (in Brno, Czech Republic) with regard to external climatic conditions and orientation to the cardinal.

Drying of the Basement Spaces of the Faculty of Arts in Brno

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Keywords: Heating, Frequency, Microwaves, Electromagnetic, Moisture, Wall, Foundation.

Abstract. Drying masonry building structures using high-frequency electromagnetic radiation, so-called microwave technology in construction practice is becoming more common. It is an innovative method which can be used to remove excess moisture with significant speed. This article focuses on the description of physical phenomena that occurs during drying and compares the most commonly used processes for drying buildings. This article describes the heating of building materials (basement spaces built from full burnt bricks) using microwave radiation. It assesses the depth of the heating process achieved under different conditions while taking account of various moisture content of irradiated material and varied length of heating.

Moisture Monitoring of Built-in Wooden Elements

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Keywords: Build-in Wooden Elements, Wood Moisture Measurement, Resistance Method.

Abstract. This paper describes moisture monitoring of wooden elements, which are built-in to structures of building envelopes. This monitoring is helpful in proving long-term functionality of designed details or, conversely, in pointing out of an emerging problem, thus avoiding infestation of these elements by wood decaying fungi or insects, which is usually connected with excessive wood moisture. This can occur in these elements especially when they go through the building envelope from interior to exterior. The described long-term measurement is based on a resistance method and the text explains its principle, mentions factors influencing the accuracy of measurement and shows installation and development of probes, which were designed by author for this kind of measurements.

Cooling and Thermal Insulating Effects in Layers of Roof Garden

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Keywords: Intensive Green Roof, Roof Garden, Permitivity, Cooling Effect, Thermal Insulation Effect, Photosythesis, Transpiration.

Abstract. This paper presents partial results of measurements in the layers of roof garden in winter and summer. In winter, the roof garden acts as additional insulator for buildings, reducing energy needed to provide heating. Layer of soil on intensive vegetative roof in the winter can considerably reduce daily temperature fluctuations. On hot summer days, the roof garden can considerably reduce the heat flux through the roof. Transpiration in plants cools the surrounding air, thus lowering the temperature of the surface of the soil.

Effect of the Moisture in the Heat Storage Capacity of Building Structures

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Keywords: Building Structures, Moisture, Heat Storage Capacity.

Abstract. Buildings in Europe, account for about 20–40% of total final energy consumption. Therefore reduction of energy demand is crucial. It has become one of the most important issues to achieve energy saving at installations and refurbishments of buildings. Humidity in the wall structure of buildings produced by precipitate and other circumstances could modify the building's heat capacity, the heat transfer coefficient furthermore density and/or other factors. In this study, wall structures of buildings with nearly zero net energy consumption were examined that were built from different materials with different moisture load. By applying different experiments and calculations we presented the changes of the stored heat energy of different wall structures in relation to the duration of the wetting time. The external wall of the building is the interface between the interior of the building and the outdoor environment. From the perspective of sorption and heat capacity, knowledge of the behavior of structures in relation to their moisture content, can help us to select the perfect type of wall. We have found three major traits peculiar to the change in the stored heat of different building structures in relation to the moisture load.

Comparison of Meteorological Climate Data Sets from Greater Žilina And Their Influence On Temperatures Within The Experimental Wall

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Keywords: Exterior Temperatures, Weather Stations, Comparison of Data Sets, Real Boundary Conditions.

Abstract. The experimental wall fragment (consisting of five different sections) was completed in 2010. Temperatures inside the sections had been recorded since. The laboratory centre of our department is also equipped with the own detached experimental weather station. In this paper, the outdoor boundary conditions obtained from the experimental weather station are compared to the automated weather station Dolny Hricov and to the phenological weather station in Zilina (with registering period of three times a day), both maintained by Slovak Hydrometeorological Institute (SHMU). For the comparison, there were selected 14 days from the years 2014-2016, to find some extremes. Differences between the data sets obtained from the stations were computed to each other and analysed in terms of boundary conditions for the HAM computer simulations. Differences between the temperatures under finish of the experimental wall fragment were found out by use of ESP-r software.

Calibration Method of Cool Box used for Measuring of Thermal Conductivity Coefficient

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Keywords: Cool Box, Calibration, Thermal Conductivity Coefficient, Guarded Hot Box.

Abstract. One of the methods used for determining of the thermal conductivity coefficient value of building materials is the Calibrated and Guarded Hot Box method. This method is based on the principle of measuring the heat flux density that passes through the test specimen at a temperature difference between warm and cool parts of the measuring box. For measuring of thermal conductivity coefficient is at the Faculty of Civil Engineering of VŠB-TUO used the Cool Box. Measuring in Cool Box uses the same principle of measuring as Calibrated and Guarded Hot Box. For creating temperature difference during the measurements at the Cool Box is not used heat, but cold. Measurement of the thermal conductivity coefficient by a Cool Box is very complex in terms of measurement accuracy. That the resulting values as accurate as possible, it is necessary to calibrate itself refrigerated cabinets and all sensors that are used for measurements. This paper describes the principles of calibration of Cool Box and other components, which are used for measuring the thermal conductivity coefficient of selected natural building materials. Determination of the thermal insulation properties of selected materials is part of a long-term research focused on conventional and unconventional natural building materials.

The Risk of Humidity at Greened Façades

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Keywords: Façade Greening, Humidity, Civil Engineering.

Abstract. This paper shows the results of a project that investigated the humidity of the air in the ventilation gap of a green façade system. The systems which were investigated are made of aluminium troughs, aluminium modules, or fleece. These systems are mounted on metal rails. The metal rails connect the façade with the plants. This creates a curtain façade that is ventilated by air. The humidity of the air in the gap was investigated, and this paper shows the results of the investigation.

Section 7: Indoor Climate, Thermal Comfort and Ventilation

Optimization of Thermal Stability of Atrium based on Computational Modelling

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Keywords: CFD, Atrium, Thermal Comfort, Thermal Loads, Solar Radiation, Air Conditioning, Cooling.

Abstract. The article deals with analysis of the heat balance and temperature microclimate of indoor space of a four-storey building atrium. With regard to the anticipated thermal loads in all functionally connected rooms, investor made a request to verify the thermal stability of the atrium before the implementation stage. Atrium and adjacent rooms are a geometrically complicated inner space which cannot be solved by analytical methods to ensure the required temperature conditions in occupied zone. This led to the creation of a mathematical model of the atrium with the current project solution. The result of the simulation of the existing solutions is that there is not complied desired air temperature in the occupied zone. For this reason, it was developed optimization of existing variant. Optimization was performed in steps as changing temperature of the central air conditioning system, changing number of units and performance of local refrigeration air conditioning. The conclusion of this paper is to evaluate the thermal profiles of temperature stratification in the atrium area and request the required cooling performance of the ventilation system. The article attempts to use computer modelling as a tool for the placement and performance design of ventilation equipment.

Analysis of Thermal Comfort in Flat in New High Residential Building

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Keywords: Thermal Comfort, Heating Design and Architectural Design of Residential Interiors.

Abstract. This paper focuses on the analysis of thermal comfort in a flat in the new high residential building. Providing the optimal parameters of thermal comfort in each room of the flat is the basic prerequisite for the satisfaction with housing. Incorrect position and size of heating elements, incorrect positioning of the furniture and incorrect use of residential interiors may significantly disturb the thermal comfort. Residential areas in the new residential buildings are much more intensively used as in the other types of buildings. Surface of new flats is the most optimized. Experimental measurements were carried out in the winter season in 2016 in the residential rooms of the large flat in the new high residential building. Device Testo 480 with temperature and humidity sensor, globe thermometer and turbulence sensor was used for the measurements. Obtained values of air temperature, air relative humidity, air velocity, globe temperature and indexes PMV, PPD are presented in the graphs. Heating system of the flat and the possibility of its regulation, positioning and size of the heating elements in the individual rooms, positioning of the furniture and the utilization of rooms were evaluated on the basis of parameters of thermal comfort. In the conclusion of the paper, there are principles on the architectural design of the residential interiors and their heating in the new residential buildings.

Evaluation of Indoor Climate in Small University Lecture Hall

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Keywords: Parameters of Thermal Comfort, Operation and Design of Small University Lecture Hall.

Abstract. This paper is focuses on the evaluation of the indoor climate in the small university lecture hall. Providing the optimal parameters of thermal comfort in the interiors of a university is immensely important for the students of the university. Fulfilling these parameters is inevitable not only for the physiological needs of students but also for the required performance of students. Reconstruction took place in the small university lecture hall. The original windows were exchanged for the modern wood tight windows. Experimental measurements were carried out in the winter season in 2016 in this small university lecture hall in order to evaluate the thermal comfort after the reconstruction. The device Testo 480 was used for the measurements. Obtained values of air temperature, air relative humidity, air velocity, globe temperature and indexes PMV, PPD are presented in the graphs. Heating, operation and architectural design of the small university lecture hall were evaluated on the basis of the parameters of thermal comfort. In the conclusion of this paper, there are principles how to design new small university lecture halls. Furthermore, there are presented recommendations how to operate the existing small university lecture halls.

Recommendations for Automatic Opening Vents (AOV) in an Office Building in Terms of Thermal Instability in Relation to Natural Ventilation and Cooling

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Keywords: Automatic Opening Vents, Natural Ventilation, Building Simulation, Simulation Instability.

Abstract. One of the optimal and most economic ways of completing a thermal assessment of a building is with a precise dynamic thermal simulation, where a building envelope and its systems are simulated and evaluated in a virtual climate using real meteorological data. The simulation parameters can be exported to a Building Management System for a particular building, as simulation problems of natural ventilation reflects the real behaviour of a building. Instability of dynamic thermal simulation is a typical issue for certain conditions, as window operations can cause excessive interior temperature fluctuations and even trigger the heating system if the common ON/OFF or simple linear operation function is used. To solve the problem, reduction of the simulation time-step is usually used, though the principle of the air flow is not handled. Additionally this solution multiplies the simulation complexity, though the instability of the model is significantly reduced. The case model clearly showed a negative contribution of AOVs operated by linear function related to temperature or CO2 at initial simulations, by increasing the energy consumption of the building.

Impact of Inlet Boundary Conditions on the Fluid Distribution of Supply Duct

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Keywords: Ventilation, CFD, Flow Distribution, Inlet Conditions, Air Conditioning.

Abstract. Ventilation is important to maintain the indoor air quality and other comfort parameters in the occupied zone. The design of ventilation systems is based on one dimensional approach. When the air distribution is modelled in the ventilated space usually CFD simulation is performed and simplified boundary conditions are defined at the locations where the supply air enters the room. However, in some cases it is difficult to predict the duct flow by 1D methods. The flow in the duct system determines the outflow at the air terminal devices. The interaction between the multiple system elements is important, since many different combinations are possible, for instance multiple bends can create a special flow field which also influences the distribution performance of the duct. It is very important to determine this impact, because the room airflow depends on it. In this study the impact of the inlet boundary conditions on the fluid distribution performance of a special supply duct –which is designed to provide uniform distribution– is investigated with CFD. Three different inlet boundary conditions are defined: constant inlet velocity and turbulence parameters estimated from intensity and hydraulic diameter, diffuser after fully developed turbulent pipe flow, diffuser with one bend and a Venturi-tube upstream. In each case, the simulations are performed with the realizable k-epsilon model. The reliability of the results is estimated with the grid convergence index.

Monitoring of a Prototypical Free-Running Building: A Case Study in a Hot-and-Humid Climate

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Keywords: Thermal Comfort, Hot-and-Humid Climate, Long-Term Monitoring, Indoor Climatic Assessment, Sustainable Building.

Abstract. The provision of comfortable indoor conditions is widely considered as one of the key tasks of architecture. Hereby, different climatic regions require different concepts for the operation of buildings. Achieving thermal comfort in buildings in hot and humid regions without Air-Conditioning can be considered as a challenging task. In this context we present a monitoring study of the indoor conditions in a new prototype building, called the Zero Carbon Resort Demonstration Cottage. This building was designed according to passive cooling principles with the intent to reach a high degree of sustainability and to have little environmental impact. To explore the viability of this concept, we deployed a comprehensive monitoring of the outdoor conditions via a weather station and of the indoor conditions via air temperature and relative humidity sensors. Moreover, short-term monitoring of thermal comfort was conducted. In a first analysis step we compared the results of the indoor monitoring with the corresponding outdoor measurements. In a second step we conducted a standardized thermal comfort study. Thereby we considered the special circumstances of the thermal comfort in naturally ventilated buildings. Results suggest that acceptable indoor conditions can be maintained, if passive cooling methods are applied properly.

Evaluation the Contribution of Plate Enthalpy Exchanger in Air-Conditioning

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Keywords: Enthalpy Exchanger, Heat and Mass transfer, Ventilation, Air-condition, Humidity, Indoor Climate,

Abstract. This paper is focused on theoretic application of plate enthalpy exchanger in real environment. This paper is focused on advantages / disadvantages of these exchangers compared to heat exchangers used today. Plate enthalpy exchanger is able to realize heat transfer and mass transfer thanks to membrane, that is primary unit of construction of this exchanger. This paper shows problematics of low humidity of air in internal environment with forced ventilation during winter season. Thanks to properties of enthalpy exchanger is possible to achieve sufficient humidity of air in internal environment without necessity of other equipment.

Introduction

Currently, the vast majority of building construction is conceived as a very tight envelope of internal environment in which we spend a significant portion of time. Tightness of the envelope is a consequence of pressure to reduce heat loss of building construction. Thanks to the quest for reducing heat loss it occurs situations where indoor environment exceeds the permissible limits of some monitored pollutants (VOC, CO_2, relative humidity, etc.) very often, because of inadequate fresh air ventilation. Inadequate ventilation of the internal microclimate may lead to health problems of residents living in these areas. Problems associated with poor indoor air quality and subsequent health problems of the population are known as Sick Building Syndrome (SBS). This issue was solved by many authors such [1] and [2] and is not the aim of this article to devote this issue. The aim of this article is to highlight the problem of insufficient relative humidity during application of forced ventilation in residential construction in the winter and the transition period. Next point is to evaluate the possibility of using the system for the redemption of moisture for ventilation in residential construction (or similar space) available today. Enthalpy plate exchanger allows in addition to the heat transfer also moisture transfer and is now quite commonly used in smaller air-condition units. Thanks to the simulations, this work evaluates benefits and shortcomings of the application air-conditioning systems with enthalpy plate exchanger (hereinafter referred to ERV = energy recovery ventilation) on the real housing unit. ERV system is also compared with the HRV system (HRV = heat recovery ventilation)

Experimental Measurement

Authors own simulations and calculations are based on real data. Data were collected in a small housing unit with two rooms. The apartment is not fitted with a forced ventilation system and it is only naturally ventilated. During the measurement it was recorded air temperature and relative humidity when the recording interval was 2 minutes for a period of three weeks. The data-loggers were used as a recording device, and their accuracy of measurement of air temperature is ± 0.4 °C and relative humidity is ± 2.5% in the range from 5% to 95% of the actual relative humidity in the measuring space. From data are clearly recognizable temporal habits of residents and their use of the apartment. For presenting the results there are used data collected during the first week, which is taken as a reference.

The data needed to determine the efficiency (thermal efficiency, humidity efficiency) of ERV system and HRV system was obtained from records of previous measurements in another study. The results of measurements are available in [3]. These values were approximated and were determined by a linear equation, which determines in the required interval dependence of the efficiency on the difference of specific humidity between the supply and extract air side to the plate exchanger, see Figure 1.

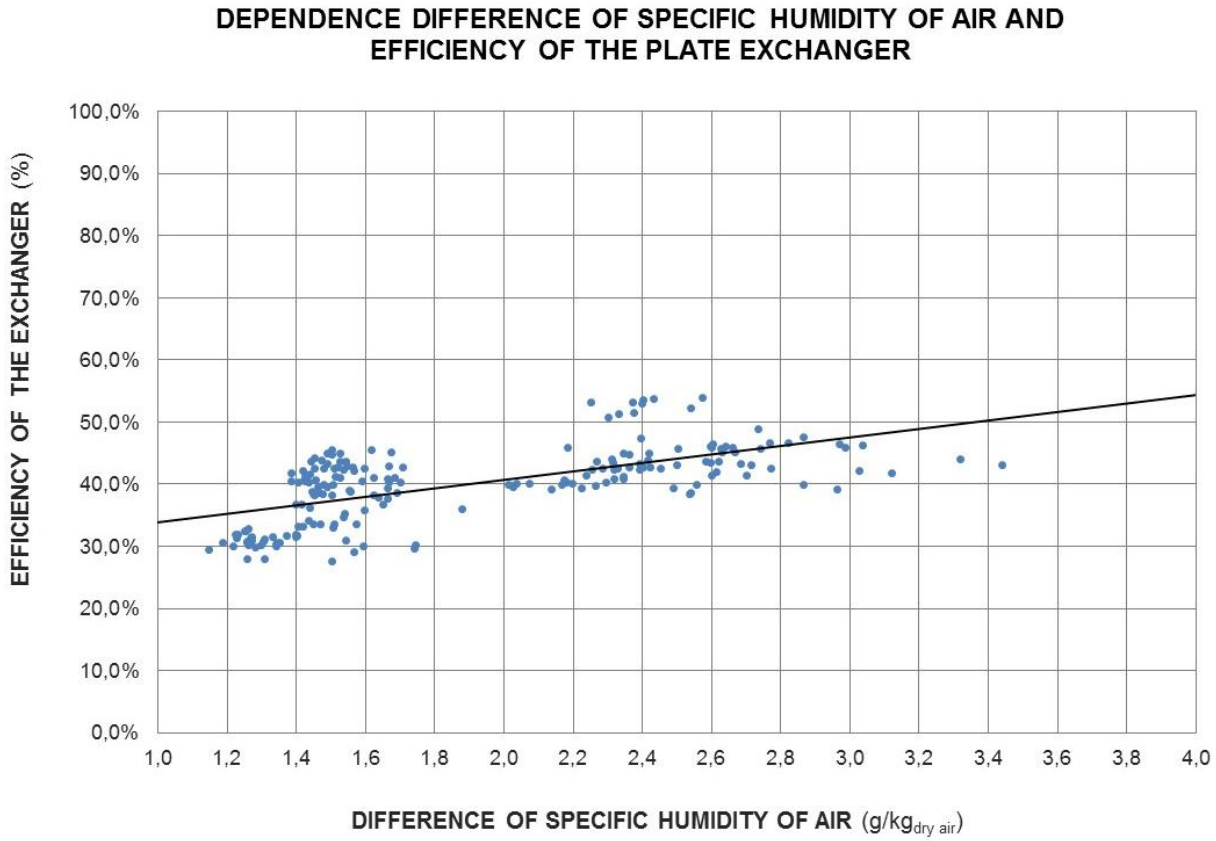

Figure 1. *Determination of the dependence of the difference of specific humidity and the efficiency of the plate enthalpy exchangers.*

Calculations and Simulations

The Basic Principle. The aim is to use the data collected from the living space and the exterior, which is no mechanical ventilated, and use them for subsequent calculations. This mainly deals with the moisture gains that are essential for this work. Outputs of this work are values defining moisture microclimate in the interior after installation of unit providing forced ventilation. The effectiveness of simulated ERV and HRV systems are calculated from actual values measured during actual operation. Calculations have been performed by using Microsoft Excel and Simulink / MATLAB. Thermal efficiency is not crucial for the simulation and it is considered the same value for both systems. From the outputs it is readable, as moisture microclimate changes in the reference room without forced ventilation, with ERV system and with HRV system.

The dynamic progress of development of the monitored pollutants (specific humidity) in the interior was simulated on the basis of balance equations in differential form (1).

$$\dot{V}_p \cdot C_p \cdot d\tau + \dot{M}_s \cdot d\tau = \dot{V}_o \cdot C_o \cdot d\tau + V \cdot dC \quad (1)$$

Differential equations were modified by variable separation and it was adjusted by integration (2), which is the basis for own calculations in this work. It was necessary to implement to equation certain limitations, e.g. maximum possible saturation of water vapor in the supply air.

$$C_i = C_{i-1} \cdot e^{-\Delta\tau \frac{\dot{V}_p}{V}} + \left(\frac{\dot{M}_s}{\dot{V}_p} + C_p\right) \cdot \left(1 - e^{-\Delta\tau \frac{\dot{V}_p}{V}}\right) \quad (2)$$

$\dot{V}_p$ - volume flow rate of supply air, $\dot{V}_o$ - volume flow rate of extract air, V – volume of room, C_p – concentration of water vapor in supply air, C_o – concentration of water vapor in extract air, C_i – concentration of water vapour in room in certain time, C_{i-1} – concentration of water vapour in room in previous interval, $\dot{M}_s$ - mass flow of moisture gains, $_{\Delta}\tau$ - difference of time interval.

Assumptions and Simplifications. It was required to reflect some simplification in calculation. It is considered the perfect mixing of supply air with the air in the interior. The air temperature is assumed equal to the value obtained from real measurements. Thus, it is believed that it will be supplied the air of the same temperature as the temperature of the interior air and will not formed heat loss by forced ventilation. It is also considered a ventilation system work with the same ratio of inlet and outlet volume flow rate. The ratio between volume flow rate on the inlet and outlet side of the air have a significant impact on the efficiency of plate exchangers.

Results

The whole course of humidity characteristics in the interior is seen at Figure 2. From the obtained values it is clear that the relative humidity of the air during natural ventilation moves above the minimum required level of 30% required by regulations [4]. In terms of moisture microclimate in wintertime the values are satisfactory, but in terms of other elements of microclimate as toxic and the odor microclimate is indoor air quality poor and it is therefore necessary to establish a system of forced ventilation.

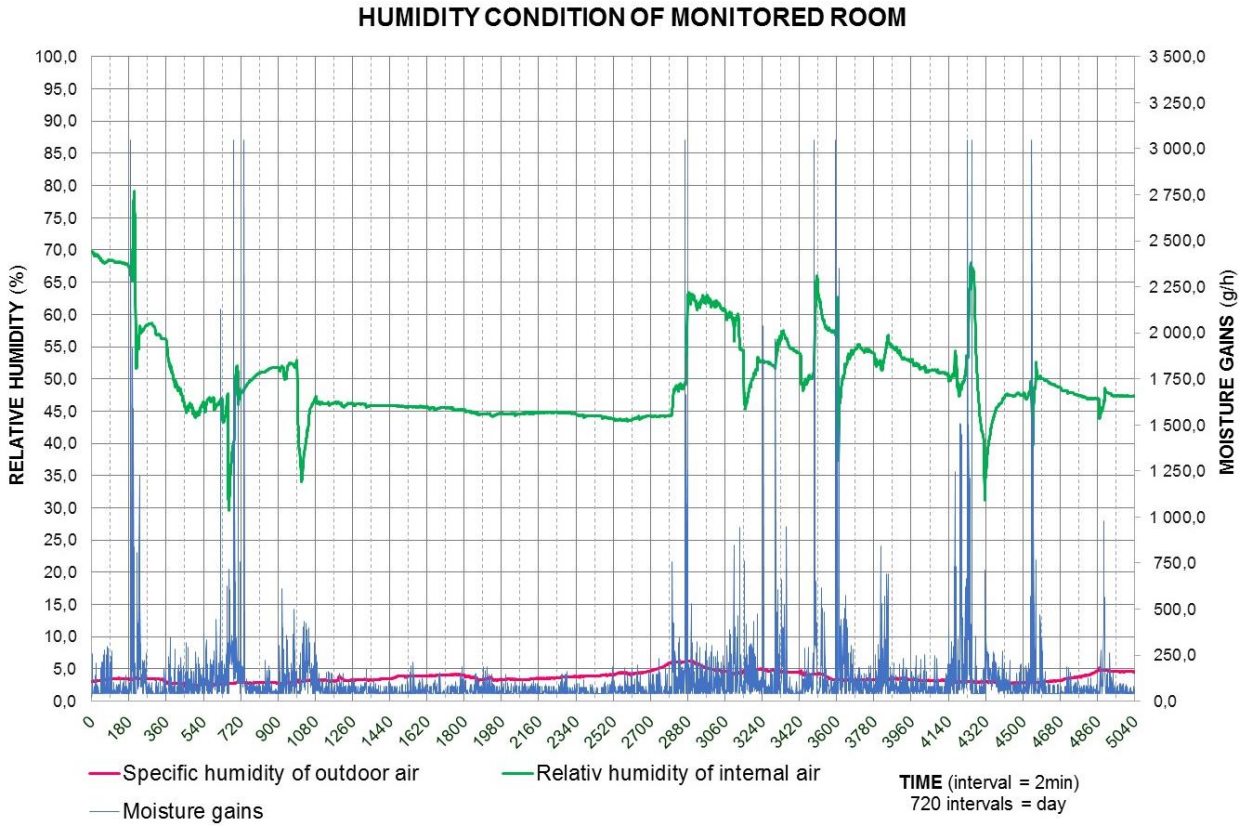

Figure 2. *The course of the relative humidity in the interior with natural ventilation.*

As an appropriate indicator of indoor air quality appears to be CO_2. In the investigated areas the CO_2 concentration was not measured, it was not intended to demonstrate the concentrations of toxic

and odor elements solved in residential zones. Other measurements demonstrating a lack of quality and substance of excessive concentration of CO_2 in the same type of residential construction and in very similar housing units is available in [6]. Limit concentrations of CO_2 is caused by inadequate dose of fresh air, thanks to a tightness of the building envelope. In [6] is demonstrate the need of forced ventilation in these types of building. Without forced ventilation is very often exceeded the value of CO_2 concentration in the indoor air 1500 ppm, which is referred as the limit of concentration in [5]. During the calculation was changed supplying of fresh air into the interior and sequentially adjusted to presented final values. The main tested variants are presented below.

Permanent Forced Ventilation. In initial setup there was considered a permanent forced ventilation of the constant flow of air and it was tested varying intensity of ventilation space solved. This setting is shown as unacceptable in terms of very low values of relative humidity in the interior and is presented in Figure 3. and Figure 4. Internal air in both considered systems are sequentially dried and the limit value of 30% is almost never reached aside from short intervals. In ERV system are values of relative humidity higher and the progressive decrease of specific humidity is slower, however, they are unsatisfactory. At very low values of volume flow rate was the boundary of values of relative humidity acceptable for both ventilation system, but in terms of supply enough fresh air for diluting the CO_2 concentration in the interior, appears low volume flow rates as insufficient.

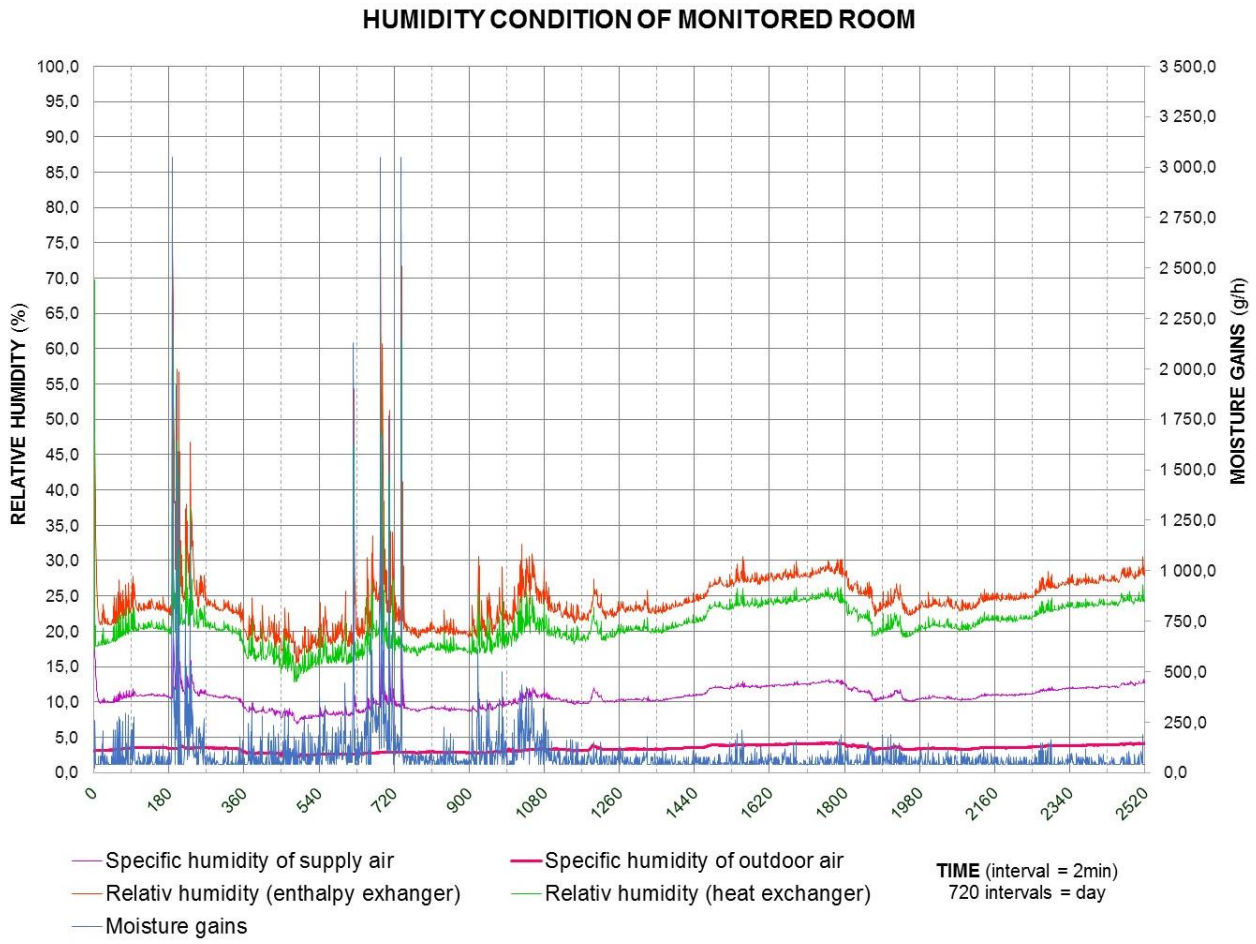

Figure 3. *The course of relative humidity with a permanent mechanical ventilation, 1 week.*

Percussion Ventilation with Damping Mode. Another tested option was a control setting on a percussion ventilation during crossing the relative humidity of 60% and a subsequent transition to damping mode at achieving a relative humidity of 45%. This variant has proved to be effective and is presented as a result on Figure 4. Full operation of the system is considered with volume flow rate 300 $m^3 \cdot h^{-1}$ and damping operation volume flow rate 40 $m^3 \cdot h^{-1}$.

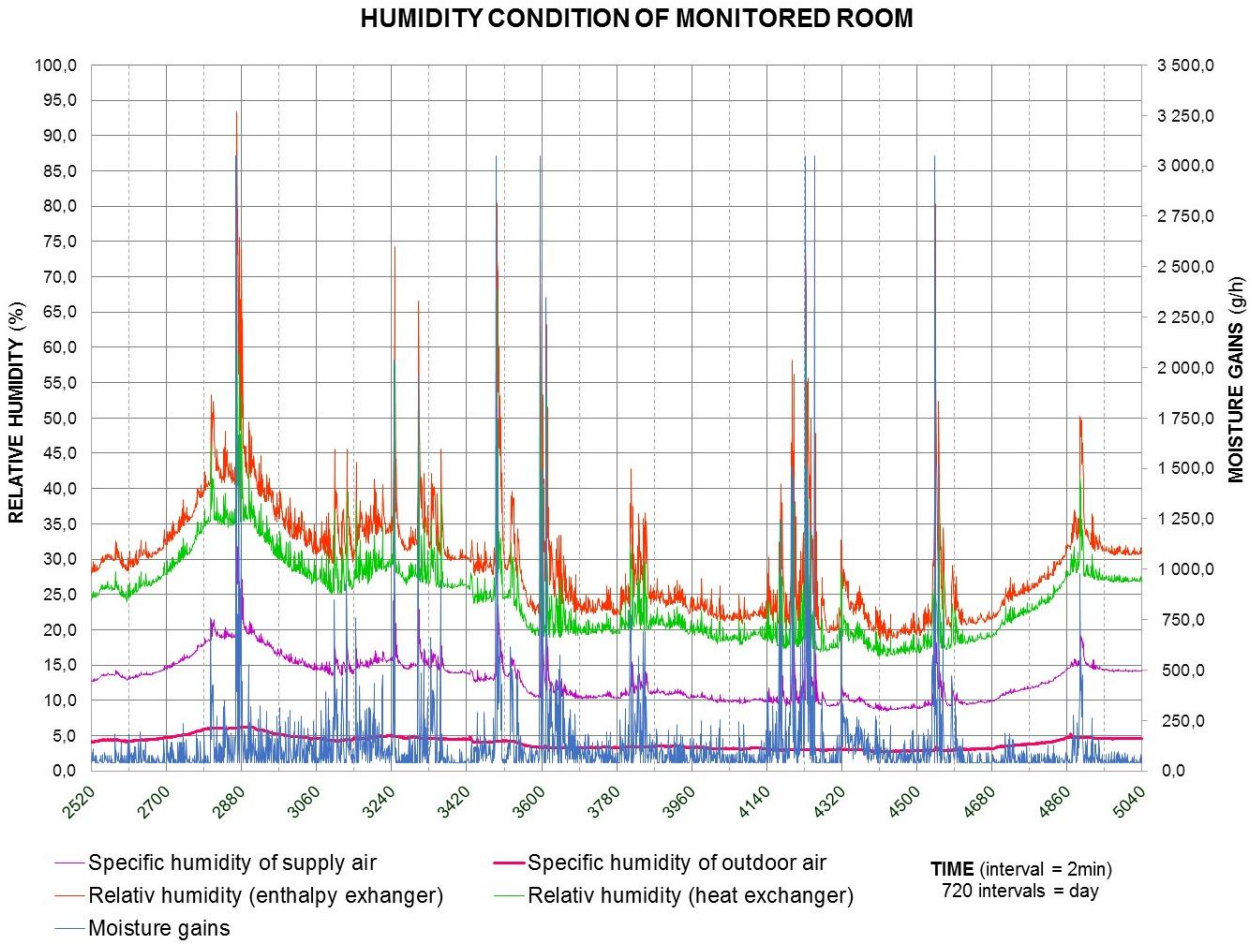

Figure 4. *The course of relative humidity with a permanent forced ventilation, 2 week.*

Final Variant. The resulting values of relative humidity in the consideration of HRV and ERV system are clear from Figure 5. and Figure 6. It is obvious that forced ventilation will significantly reduce the relative humidity in indoor air, compared to the initial measurement with natural ventilation. Insufficient relative humidity in winter is a common problem of forced ventilation in residential construction. Performed simulation confirms the issues with insufficient relative humidity in the indoor areas. The HRV system often reaches values of relative humidity below limit of 30% required by [4]. The ERV system can keep in our final variant the relative humidity in the interior of the order of 5 to 10% higher, than the system of HRV. However, it should be noted, that in a system with plate enthalpy exchanger is the lower limit of 30% is exceeded also, however, compared to the system with heat air to air plate exchanger is increment moisture component noticeable.

Conclusion

The contribution of enthalpy heat exchangers in residential ventilation and humidity microclimate in the winter is important. With proper draft is forced ventilation with enthalpy plate exchanger beneficial. Compared to heat plate air to air exchanger are enthalpy plate exchangers able to share humidity back and from the extract air. Unfortunately, due to a mechanism that enables sharing of moisture, there is also a transfer of some pollutants. But the ratio of the transmission of particles of certain pollutants in the supply fresh air is minimal. More information about the transfer of pollutants in studies [7, 8]. However, if we are not considering some special operations in the industry or health (e.g., clean rooms, chemical industry) the importance of the transfer of some unwanted pollutants is relatively insignificant. Due to the small transport of particulate of monitored pollutants (e.g. VOC, CO_2 and others) and therefore the low efficiency of transmission of these

particles, it will be supply fresh air always contain lower concentrations of the monitored pollutants than the concentration of pollutants contained and optionally formed in the interior. In the case of transfer of some pollutants from the extract air, it will therefore only lead to an extension of time until the limit of monitored concentrations in indoor air will be reached.

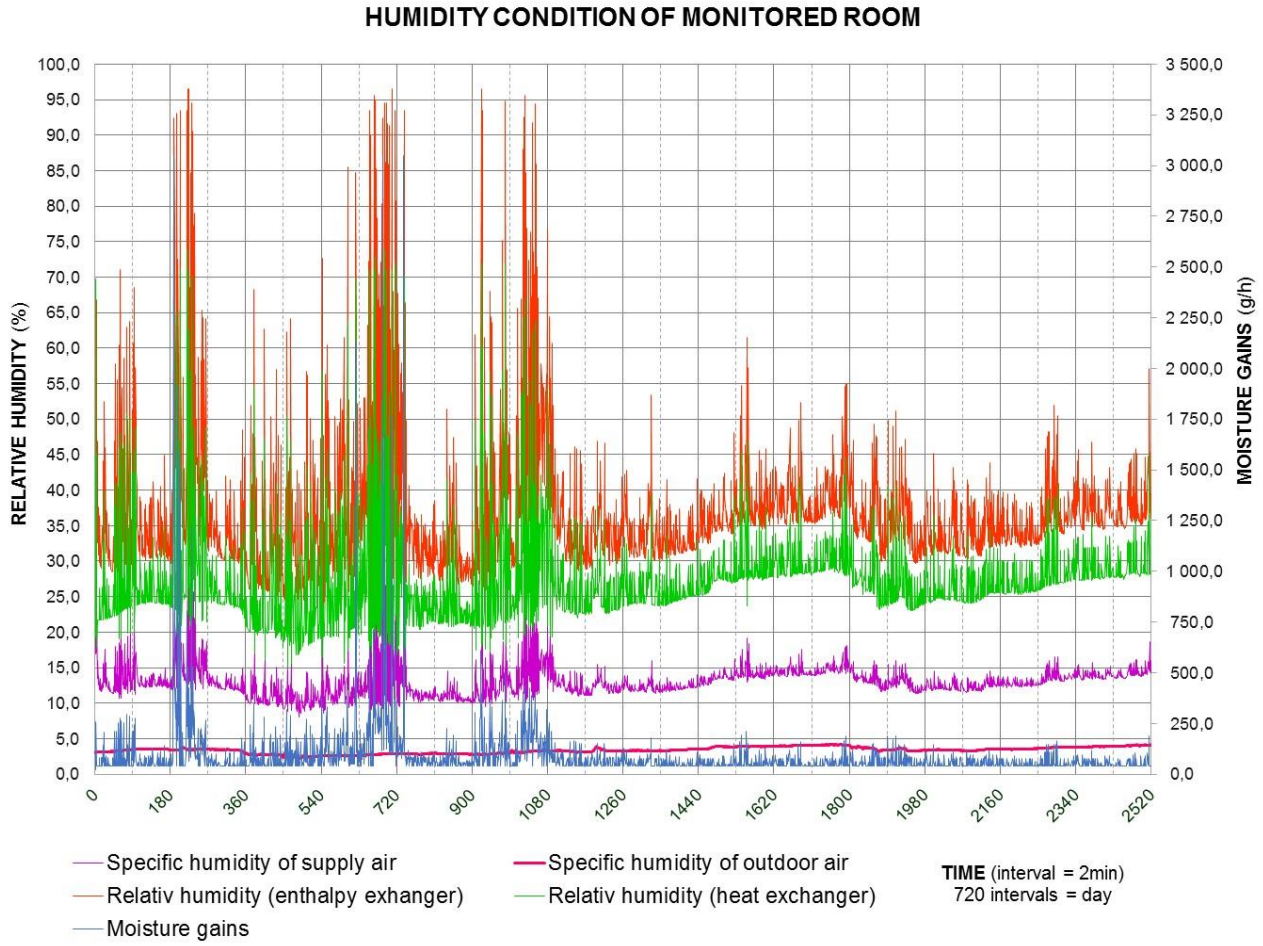

Figure 5. *The course of relative humidity with forced ventilation and damping operation, 1 week.*

More interesting issues in enthalpy plate exchanger seem to be the physical nature of water vapor condensation on the exhaust side followed by freezing exchanger. Detailed information about the possibility of condensation and freezing enthalpy plate exchangers are very modest and further studies are needed in this area. Many articles are focuses on plate enthalpy exchangers and moisture transfer, but in the vast majority of articles is addressed to the climatic conditions in Asia. There is used plate enthalpy exchanger to remove the problem of excessive moisture in the interior and freezing in these conditions does not occur. Acquired knowledge from these climatic conditions in our climatic zones may not be applied. Problematic of these exchangers in cold and frosty climates is not monitored and it is necessary to pay more attention to this topic and understand the physical nature in more depth.

It is also advisable to reduce the time interval (step), in which were measured input data and calculation is performed, compared with the original 2 minutes. The reaction of system of forced ventilation is in 2 minutes step relatively late, and therefore during the startup of forced ventilation at full regime is reached from 40 $m^3 \cdot h^{-1}$ volume flow rate of 300 m^3/h higher levels of relative humidity in the interior than it actually occurs. The result is a condition of the air reaching the peak of around 95% relative humidity, however, that the real not occur.

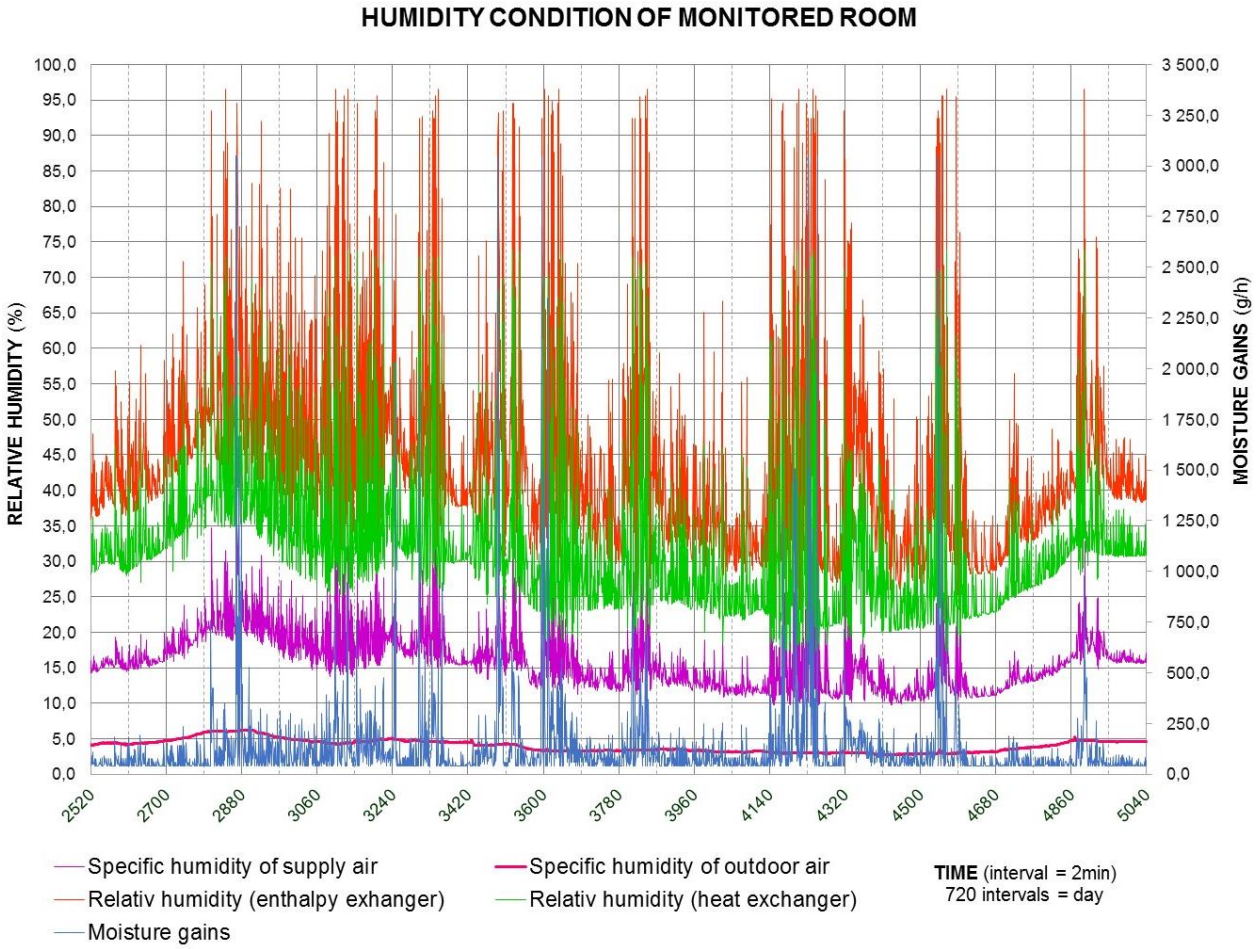

Figure 6. *The course of relative humidity with forced ventilation and damping operation, 2 week.*

The need of supply fresh air in residential construction is unambiguous. Forced ventilation systems help to solve these problems, but they also brings other problems (e.g. excessive dryness in the winter). Enthalpy plate exchangers can at suitable proposal to eliminate or substantially eliminate the problem of lack of moisture in the interior and it is possible through them to reach the limit values of relative humidity of 30-65%, which is mentioned in [4]. The final variant with occasional forced ventilation seems as appropriate. Benefits of ERV system for ventilation of residential buildings and houses are positive. The availability of this technology is already quite common and in the future it will continue to expand.

Acknowledgment

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Parametric Analysis of Floor Cooling

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Keywords: Floor Cooling, Parametrical Analysis, Nomogram, Numerical Simulation, Software CalA.

Abstract. This study is aimed at parametric analysis of floor cooling. Impact of several design parameters such as air temperature, temperature of cooling water, distance of cooling pipes, thickness and thermal conductivity of top layer on total heat transfer of cooling floor is studied. The issue is solved by steady-state 2D numerical simulation of heat transfer to the floor construction. These parametric simulations are performed in software CalA. Impact of variable input parameters on total heat transfer is observed. Results of parametric analysis are displayed in a nomogram. This nomogram is useful for faster designing of floor cooling.

Effect of Ventilation in Protected Escape Ways upon the Thermal Properties of these Spaces

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Keywords: Aeration, Protected Escape Way, Positive-Pressure Ventilation, Thermal Characteristics.

Abstract. Protected escape ways enable the rescuing of persons to the outside of a building on fire. They are characterized, in particular, by strict requirements relating to the aeration of such spaces. However, the fulfilling of these limits may impact the monitored thermal characteristics of the respective internal areas. The outlined dilemma will be illustrated by way of an example of a protected escape way aerated by positive-pressure ventilation.

Energy Saving Potential of Personalized Ventilation Applied in an Open Space Office under Winter Conditions

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Keywords: Computer Simulation, Ventilation, Office Building, Indoor Environment, Control Strategy.

Abstract. Mixing and displacement air distribution are the main ventilation principles applied in both residential and non-residential buildings. Recently, personalized ventilation when the fresh air is delivered directly to the occupants at a high ventilation effectiveness has become an alternative. Despite of this fact, little research has been carried out to quantify the energy saving potential of personalized ventilation. This study aimed to quantify the effect of ventilation effectiveness and control strategy on the energy performance and thermal comfort for an open plan office equipped by different types of ventilation systems, including mixing ventilation with constant air volume, demand control ventilation and personalized ventilation. A model was created in a program for dynamic energy simulations TRNSYS, representing one floor of a typical office building divided into four zones with different orientations and a core. Space heating and cooling were provided by ceiling fancoil units recirculating the room air, thus the tasks of ventilation and air conditioning were provided by two separate systems. The potential of personalized ventilation to save energy for fans and for the heating coil of the ventilation system presented about 70% compared to constant air volume mixing ventilation, however, the overall saving was only 20% when also the energy demand for space heating was considered. The energy benefit of demand control ventilation and personalized ventilation depends on the energy need for space heating and cooling, system configuration and operation, and occupancy.

The Importance of Cooperation between Heating and Ventilation in the Industry Buildings

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Keywords: Ventilation, Air Handling Recovery Unit, Radiant Heating, Industry Large Area Buildings

Abstract. Our national husbandry belongs among economies with the biggest energy consumption per an inhabitant. Slovak Republic consumes for making of product's unit approximately twice more energy than the average in forward European countries. Such a big reserves, that we have to achieve in the area of effective increasing of energy utilization are not possible only by administrative way, but by establishing of new technical solutions into a general practice too. In a part of large-area industry operations, the new technical solution lies in the combination heating system by radiant ceiling panels with ventilation by air handling unit with integrated device for heat recovery, which considerably reduces the operation costs. Paper shows also the basic principles of heat transfer main construction of the radiant ceiling panel and finally stated objective its advantages and drawbacks.

CFD Model of Thermal Plume Occurring above Hot Surface of Kitchen Appliance

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Keywords: Thermal Plume, Kitchen, CFD Simulation.

Abstract. During the cooking process, pollutant fumes are released into the ambient air by the convection plumes. These convective plumes - thermal plumes – are generated above hot surfaces and they need to be efficiently and ecologically ventilated in order to achieve appropriate internal climate. Calculation method for determination of volume flow rate of rising convective plumes is described in German standard DIN 18869 [1]. This article focuses on study of thermal plumes using numerical model in software Ansys Fluent, determinates volume flow rate of rising air and compares the simulation results with the results from known computational relations.

Consideration of Operative Temperature in Design and Operation

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Keywords: Operative Temperature, Automatic Control, Input Design Data.

Abstract. In order to provide appropriate thermal conditions current national regulations prescribe operative temperature as the base of design and operation. In simplified calculation procedure prescribed operative temperature can be provided using a corrected air temperature. Interrelation of operative and indoor air temperature has been investigated in function of overall heat loss coefficient and glazed ratio. Based on regression analysis necessary corrections in function of the above parameters are investigated, the consequences of neglected Mean Radiant Temperature are analysed. Operative temperature represents a control problem, too: disregarding the sensor itself its position in the room, the uneven distribution of radiant field in one room and in the rooms of a flat requires compromises. The possible solutions, their pros and cons are presented.

Section 8: Daylighting and Insolation

Modelling of Daylight Sources in the Artificial Sky

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Keywords: Daylighting, Daylight Sources, Artificial Sky, Calibration of Artificial Sky, CIE General Standard Sky.

Abstract. Daylight in nature is characterized by daily permanent changes of sunlight and skylight. Real measurements of daylight availability are showing that different daylight exterior illuminance for building interiors can be expected each minute. This brings some complications in the window design and the choice of criteria for daylight evaluations. There are several ways how to find basic conditions and typical relations combining sunlight beam with diffuse skylight from the whole sky vault. The older assumption considered that interiors have to be sufficiently illuminated under the worst overcast conditions. The newer approach is based on the utilization of daylight in specific localities and the determination of changes in sunlight and skylight occurrence probability. Therefore, both daylight sources are researched in detail specifying sky luminance distributions and sun influences to find conditions for their simulation in laboratory facilities. The most sophisticated equipment to study daylighting in exterior and interior architectural spaces are artificial skies with the artificial sun. These have to be precisely calibrated with a verified zenith luminance and horizontal illuminance levels by theoretical calculations and checked by experimental measurements. Reference daylight conditions defined in the ISO/CIE 15469:2004 standard have to be respected with trials to determine natural sun and sky as sources of daylight in the real environment and modelling these in the artificial sky in a certain intensity scale. This paper presents the method and results of modelling daylight applying electrical light sources in artificial sky which is installed in the Institute of Construction and Architecture, Slovak Academy of Sciences (ICA SAS) and discusses possibilities of their simulation in laboratory conditions.

Comparison between Dynamic and Static Metrics for Daylight Evaluation in the Case of Obstructed Buildings

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Keywords: Daylighting, Dynamic Daylight Performance Metrics, Static Daylight Performance Metrics, Useful Daylight Illuminance, UDI, Daylight Factor, Daysim, Climate-Based Daylight Modelling.

Abstract. Daylight in buildings can be evaluated using dynamic and static daylight metrics. The daylight factor is a static daylight metric which evaluates daylight conditions under the overcast sky model according to the International Commission on Illumination. However, the dynamic daylight metrics (e.g. daylight autonomy, spatial daylight autonomy, useful daylight illuminance) can be more complex evaluation criteria because they are based on annual daylight illuminance data for a building site. While the daylight factor value depends only on a room geometry, optical properties of surfaces and positioning of daylight obstructions, the dynamic daylight metrics also include an effect of a building location, window orientation or building occupancy pattern. The article deals with a comparison of a daylight evaluation using dynamic and static daylight metrics in the case of buildings whose daylight is obstructed by external barriers.

Impact of External Shading on Light Comfort and Energy Efficiency in Apartment Buildings

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Keywords: External Shading, Equivalent Shadow Angle, Legislative Limits, Light Comfort, Passive Solar Gain, Energy Efficiency.

Abstract The paper introduces an example of a superstructure volume solution designed within legislative limits and its impact on light comfort in shaded flats. It focuses on external shading as a factor affecting hygienic quality, insolation time, and passive solar gain in apartment buildings in Slovak conditions. It pays attention to the assessment of energy efficiency and heat loss during the heating period depending on the amount of external shading, building´s orientation and its thermal insulation in all model situations - current, legislatively allowable, and optimized. It also deals with compatibility of optimized shading in terms of hygienic quality and solar gain efficiency to cover heat loss by building envelope in contemporary and prospective low-energy buildings.

The Influence of Internal Coloured Surfaces on the Circadian Efficiency of Indoor Daylight

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Keywords: Spectral Characteristics of Daylight, Spectral Transmittance, Circadian System, Experiment in Situ.

Abstract. The discovery of circadian stimulation by daylight has changed our understanding of the important effect the daylight has on our health and wellbeing. The new medical facts that emerged during the last decade have proven that a long-term absence of circadian light stimulation may be associated with sleep disturbance, tiredness and increased incidence of chronic depression, bipolar disorder, and seasonal affective disorder. The reason is the difference between the visual and biological (circadian) response to light and how it is being perceived by human beings: while the visual perception represented by the luminous efficiency function peaks at the wavelength of 555 nm, the circadian photoreception curve peaks in the blue light spectrum at ~450 nm. The primary circadian stimulation by daylight depends on the properties of light impinging on the retina. An experimental study was designed to quantify the effect of internal coloured surfaces on our circadian stimulation by daylight. Four identical models of a standard office were manufactured, equipped by wallpapers of different colours, and exposed to daylight. Illuminance and spectral distribution of light were measured at different positions along the room and the potential circadian stimulation was evaluated by an established model. The measurements have proven that although the visual comfort may be satisfactory, circadian stimulation may be inhibited, especially when room´s surfaces are yellow. Thus, proper choice of internal surfaces´ colours is important to prevent the potential negative health consequences.

The Implications of Assumed Boundary Conditions for the Reliability of Indoor Illuminance Predictions: A Case Study

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Keywords: Sky Luminance Distribution Models, Indoor Illuminance.

Abstract. In order to model daylight availability and distribution in architectural spaces, simulation tools require reliable representations of boundary conditions – typically in terms of sky luminance distribution models. However, the impact of sky model errors on simulation-based indoor illuminance predictions is not well documented. There are different tools and methods to simulate indoor illuminance conditions and related daylight indicators. In the present study, we selected Radiance lighting simulation program. In order to generate sky scene description, Radiance contains two routines, namely, Gendaylit and Gensky. These routines require, as input, information on both direct and diffuse components of solar radiation. To explore the implications of the sky model selection on the fidelity of simulation results, we used Radiance to compute the indoor illuminance in an existing test space on the rooftop of a university building. Thereby, the aforementioned two sky models were considered. A third option (SC) was a sky model generated based on measured values obtained from a sky scanner. Simultaneously, the actual illuminance levels in this room were monitored under different outdoor conditions (clear, intermediate, overcast). The comparison of the measurement results with multiple model prediction results facilitates an empirically based evaluation of the reliability of indoor illuminance predictions in the face of different assumptions pertaining to the prevailing boundary conditions.

A Comparative Assessment of Diffuse Fraction Models

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Keywords: Solar Radiation, Diffuse Fraction Models, Performance Simulation.

Abstract. Many building performance applications (energy use, solar gains, thermal comfort, renewable energy systems, daylight, etc.) require information about both direct and diffuse components of the incident solar radiation. However, most meteorological stations only monitor global horizontal irradiance. Consequently, multiple methods have been proposed in the past to derive from measured global horizontal irradiance data the diffuse fraction. Thereby, additional data regarding other parameters such as clearness index, solar altitude, air mass, and turbidity are used. Given the importance of this procedure for the down the line tool, its reliability represents a critical issue. To address this point, we pursued an empirical approach. A number of existing methods for the computation of the diffuse fraction were selected. Actual measurements of global and diffuse irradiance were obtained for seven locations in USA and one location in Austria. The measured global irradiance data for these locations were fed to the aforementioned diffuse fraction models. The calculation results were then compared with the corresponding empirical data. The comparative assessment yielded a number of findings. The relative performance ("ranking") of the models was found to be more or less consistent across the different locations. However, none of the models can be said to be performing wholly satisfactory. For instance, the best performing model displayed only in 45 to 65% of the cases relative errors less than 20%. In case of the worst performing model, the percentage of the cases for which relative errors were less than 20% was even smaller, namely 30% to 60%.

Section 9: Acoustics and Noise Protection

Problems in the Designing of Acoustic Properties of Musical Rehearsals

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Keywords: Acoustic Microclimate, Musical Rehearsal, Musical Laboratory, Reverberation Time, Absorption Material Surface.

Abstract. Content of the post is to describe the creation of building structures, typology, internal environment, and internal wall coverings music rehearsal for optimal acoustic performance. One of the aspects of its internal environment is reverberation time. For this variable there are several methods of calculation. Article gives an indication of how the music was the laboratory building in the centre of the music created and what problems the authors in its proposal met. Article contents and solving spatial and building acoustics model music musical rehearsal building downtown. Calculation fully respects Slovak standards valid for the design of room acoustics, as well as hygiene regulations on noise pollution. Acoustically treated room should serve as a laboratory for musical performance. If the building is more proof is needed to solve the sound insulation (building acoustics) that these areas do not interfere with each other. In addressing acoustics of testing can't talk about bad or good acoustics, but rather on the season and out of corresponding with room acoustics, respectively, with activities in it.

Improving the Impact Sound Insulation of an Existing and Refurbished Wooden Beam Floor Construction

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Keywords: Impact Sound Insulation, Impact Sound Pressure Level, Renovation, Refurbished, Wooden Beam Floor, Building Acoustics, "Gründerzeit" Buildings.

Abstract. A common source of dissatisfaction in buildings pertains to acoustical issues. Specifically, in existing buildings, exposure to impact noise represents a frequent problem. In Central Europe generally, and in Vienna (Austria) specifically, there is a significant number of existing buildings with floor constructions involving wooden beams as structural elements. Given the steady rise in inhabitants' expectations regarding buildings' acoustical quality, such existing floor constructions do not sufficiently provide the sufficient impact noise insulation. In many instances, the replacement of these floor constructions with concrete slabs is not an option, given a number of structural, financial, and legal (conservation related) obstacles and constraints. The present contribution thus explores the acoustical improvement potential of floor constructions with wooden beams by using modern materials and techniques. Toward this end, a typical 19th century building in Vienna downtown was selected. Multiple improvement options were realized. These involved the deployment of a honey-comb acoustic system, installation of stiffeners bolted to the original wooden beams, as well as an additional structurally decoupled ceiling layer. The impact sound was measured at different stages of retrofit and compared with the performance of the original construction.

Double Skin Facades with Natural Ventilation Capability: A Case Study of Acoustical Enhancement via Passive and Active (Noise Cancelling) Methods

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Keywords: Double Skin Facades, Noise Control, Natural Ventilation, Sound Insulation, Active Noise Cancelling.

Abstract. Within an ongoing project, we explore the potential of double skin facades to provide both noise control and natural ventilation capability. Three strategies are investigated: i) Manipulation of sound paths via offset of the openings in the two shells of the façade; ii) Application of absorbing materials in the interstitial space of the façade; iii) Active noise cancelling methods utilizing wave-destructive interference. This contribution describes the overall project but focuses primarily on the active noise cancellation approach. Aside from a comprehensive background research on existing technology, we undertook the design of an actual setting for noise cancellation testing with suitable low-cost components as a proof-of-concept. Results of the experiments are expected to inform subsequent efforts to include noise-cancelling technology in double skin facades.

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