SZENT ISTVÁN UNIVERSITY

EXTERNAL GLASS COVERINGS IN THE BUILDING ENERGETICS

Thesis of PhD work

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CONTENT

1. INTRODUCTION

1.1. The importance of the subject

The reducing amount of traditional energy sources, the uncertainty of their availability – the import-dependence of Hungary – the continuous increasing of their price make necessary the energy saving.
The energy consumption of the buildings (heating, cooling, to prepare domestic hot water, lighting, air conditioning, operation of the devices) is up to 40 % of the total energy consumption. If we take in consideration the buildings in the industry with similar function (e.g.: offices) this ratio achieves the 50 %.
Reducing these energy consumptions makes more effective the operation of the buildings. The energy demand of the heating and cooling we can influence by architectural – building constructional – tools, over the effective function of the engineering installations.
The formation of the external building covering changes the energy used for the indoor space climatization.
Nowadays increases the importance of this building construction subsystem, because this separates the indoor space from those external space, which is modified by the more and more extreme climate conditions.

The new forecasts, which were published in June, 2009 in the "Journal of Climate" of the American Meteorological Society, determines to 5,2 ^{o}C the average surface warming probability for the year 2100. The 90 % probability range is between 3,5 and 7,4 ^{o}C. It can be compared with the increase of 2,4 ^{o}C probability average forecasted in the examination in 2003.

Because the cars are durables for more years, the buildings are for more decades, therefore is important as soon as possible to began to introduce essential changes in the field of national and international energy-policy. " The cheapest variation of the risks-reducing is to began it now and reforming continuously the global energy system in the further decades onto low or zero greenhouse gas emission technologies." (ScienceDaily, May 20, 2009)
The building constructional function of the external coverings among others is, to save the indoor space from the extreme climate conditions in winter and in summer.
The structure, measurement, orientation, the situation in the building of the external coverings effects onto the indoor space energetic conditions.
The ratio of the opaque and transparent coverings is also a significant point of view in this subject.

Nowadays the architecture makes an effort to use large glass surfaces, in esthetical and visual point of view too.
But the traditional glass surfaces are considered as the weak points of the building in energetic point of view.
The energy conscious change of glass external covering construction became a priority.
The thesis deals with the analysis of these constructions, with special regards onto the problem, that their spectral characteristics how do influence the energetic and comfort condition of the building indoor space.
Supports the importance of the work the fact also, that the energetic examination of glass external coverings is inevitable and necessary in the architectural, building engineering and energetic design work.

It has to have a priority the design and reconstruction of the buildings with passive building technology and low energy technologies.
It is needed to base on this fact the product- and technology-development program and activity of the industry.
The 40 % of the dwelling stock will work without any greenhouse gas emission. The emission of the building not built with passive technology decreases in 75 %.

1.2. The appointed objectives

The convenient application of the glass external coverings influences significantly the effectiveness of the buildings energetically.

Therefore my objective with this thesis is,:
- to analyse the achieved results on the international and Hungarian research field,
- to explore our existing possibilities in the glass building material and construction, and
- to find out the relations in the glass-energy relation-system.

In order to elaborate the new scientific results, the appointed objectives are:

1. The **literary systematization of those special glass constructions**, which with their spectral optical characteristic-change allow improving the thermal balance of the indoor space.
To demonstrate that the effect of the thermo physical capacity onto the indoor space energetic circumstances is due to the spectral characteristics of the glass.

For the understanding my objective I consider necessary :
* to make known :
- the comfort-demand requirement system of the human,- depending on the human organism behaviour – during their material-change – depending on their activity, environmental effects, healthy estate and age;

- the conditions to meet the human-comfort requirements;
- the results of the related Hungarian and foreigner research;
- the effects onto the human built environment;
- the factors influencing the effects:

  the thermotechnial and energetical relation-system,
  the essential characteristics of the eco-architectural glass construction in energetical point of view;
  the examination methods of the Hungarian and international research.

* to present the human heat-convection playing role in forming the indoor space thermo physical condition, the importance of the metabolic heat, taking into consideration the high-number indoor space.

- to present the effects onto the human built environment, the **building physics** phenomena and relation-systems:
  the connection of the thermal-comfort equations and the building physics and energetic expressions, - considering the **heat-production of the living being** into the internal heat-load.

To prove, that the convenient choose and designed glass constructions result a significant energy saving, and providing the required thermal comfort in the same time.

Regarding to this, my objective is to demonstrate those glass constructions, with which is possible to modify according to the demands, - in the case of extreme weather conditions – the indoor space thermal condition, to present the attainable favourable behaviour with the different production technologies.

Furthermore my objective is:

- to analyse the thermal technical and energetic relation-system on the evidence of the standards and relevant technical bibliography,
- to explore the energetically significant characteristics of the eco-architectural glass constructions,
- to present the prepared measurements and results in the course of the relevant test methods survey used at the Hungarian and international research,
- to make known the use and methods of the simulation methods used in international field for the thermal physical problems of different required indoor space.

2.To prepare those measurements, which results prove the required spectral behaviour of the glass constructions.

The objective of my measurements is to demonstrate that which possibilities are in the installation of a single or multi layer coated glass construction in energy saving point of view.

3. To form those expressions from the data gained from the spectral measurements, which characteristics give a more precise picture from the energetic behaviour of the single or multi layer constructions.

4. To prove for Hungarian conditions also the energetic behaviour of the constructions – with the calculated characteristics of the glass constructions tested during the measurements – by a complex simulation model.

5. To elaborate a simulation model, which determines the energetic parameters and the characteristic value for the occupants' thermal comfort in the indoor space taking into consideration the characteristics of the examined covering constructions.

2. MATERIAL AND METHOD

In the course of the work, I examine and analyse the behaviour of the eco-architectural glass constructions and its' effects with attention in the energetic system of the building. I supposed, that these characteristics are based on the spectral characteristic-change of the glass.

From the different new glass external covering building construction I analysed:
- the low emissivity glass - with their special thermo-technical parameters - makes possible to choose and apply the one most convenient and economical for the given human thermal-comfort demand of the indoor space from the variety,
- the electrochromic and thermochromic glass due to their special controllable and automatic self-controlling characteristic makes possible to accomplish a given thermal-comfort demand in an indoor space.

With the developed glass constructions - due to the incoming heat radiation across the traditional glazed surfaces – the asymmetrical radiation reach to the human, as the primary problem of the thermal-sense discomfort, can be reduced.

The discussed external coverings with the new glass surfaces can become homogenous in thermo-technical point of view (the glazed surface can be equivalent with the conveniently insulated and formed solid walls in thermo-technical point of view)

The glass surface will be not the source of the radiating thermal-load, therefore does not cause any asymmetrical thermal-sense discomfort in the summer period; and this glass surface from these reasons does not play any more significant role in the thermal loss of the indoor space comparing with the conveniently built solid wall in winter or in transition periods.

Preparing the thesis the followed **methods** were :

1. The evaluating study of the Hungarian and emphasizing the foreign technical literature ,
- the evaluation of the laboratory models and analysing tests,
- analysis of the manufacturing technologies,
- the examination of the usability of glass products,
- the presentation of the simulation methods.

2. Laboratory tests in the Guardian Orosháza Glass Plant

3. Calculation of the characteristical spectral parameters of the glass using the results of the laboratory measurements.

4. Application of the simulation model for Hungarian conditions.

5. Praparation of a simulation model for comfort-analysis.

3. NEW SCIENTIFIC RESULTS

1. The systematizing evaluation of the special glass constructions

I systematized the manufacturing technologies and functions of the special architectural glass and glass constructions in energetically advantageous point of view.

I considered :

-the low emissivity glass with the coating technologies,

-the electrochromic and rhermochromic glass and their function-principles,

- the photochromic glass,
- the gaschromic glass,
- the most recent developments, e.g. : heated glass, “Heat Mirror” glass constructions, XIR foil glass,
- and all the method preparing construction from these.(the effects of the number of glass layers and gas filling).

I found by the analysis, that the development takes into consideration the energy-economy and the indoor space thermal-sense aspects.

The analysis demonstrated, that these **effects are based mostly on the spectral optical characteristic-changes of the glass.**

2. Determination of spectral characteristics of the float and IGU glass

I find - as result of my measurements made, that the energy consumption of a glassed indoor space (e.g. : greenhouses) is in relation with the transmitted infrared radiation difference-amount through the certain glass. The wave-lengths are considered between 300nm and 2500 nm.

The spectral values of the float and IGU glass transmission I summarized by the prepared measurement. According to this, I found, that the indoor space energy-economy and comfort depend from the spectral characteristic of the inbuilt glass and glass construction.

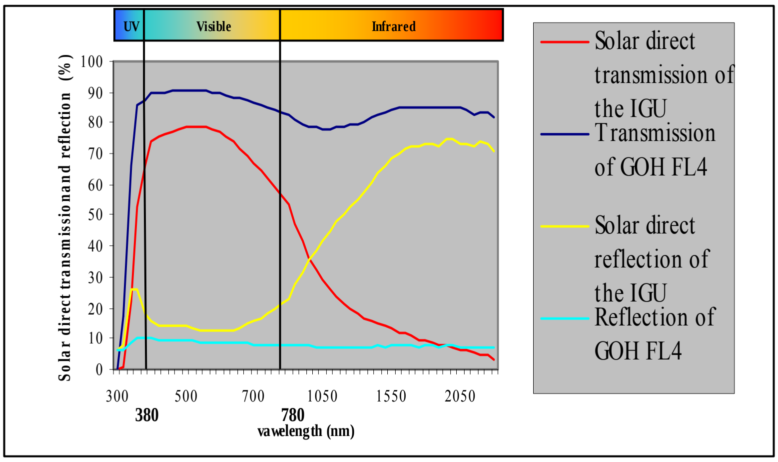


Figure 1. Solar direct transmission and reflection of the IGU and float glass

I prepared concrete examinations with the float glass without coating and with the coated glass in the 300-2500 nm range.

The examinations related to the glass presented, that the measured glass in the winter period reduce the heating energy consumption and in the summer period prevents the indoor space overheating, reducing the cooling energy consumption. My concrete measurements prove, that the better capacities of the coated IGU glass comparing to the float glass without coating, how it does effect the indoor space energy efficiency.

3. The determination of the optical characteristic-values in the infrared range.

The optical characteristics of the different glass by my measurements are the followings in the infrared range :

	Float glass	IGU double-layer coated glass
Transzmission	**80,90 %**	**29,86 %**
Reflexion	**7,47 %**	**45,04 %**
Absorbtion	11,63 %	25,10 %
	100,00 %	100,00 %

Thus, the percentage distributions present the significant optical characteristic variation of the two glass, which I verified by the values of the above table.

4. The energy-saving amount in the different periods

Based on my examinations the following energy savings happens in the different periods :

- **in the transition periods (spring and autumn)** the heat-loss through the IGU glass is less :
  29,86 / 80,90 = 0,37.
  Thus, the heat-loss through the IGU glass comparing to the float glass is reduced onto 37 %, and :
  the IGU glass reflects 45,04 / 7,47 = 6,03- times more back into the indoor space from the infrared radiation comparing with the float (FL4) glass.

It can be achieved an energy saving proportional with the above values with the double coated glass, when the other related conditions are the same in both cases.

- **In the warm periods (summer)** : the IGU glass reflects more infrared radiation back outwards:
  45,04/7,47 = 6,03-times more, so it need to use less energy for cooling the indoor space.
  This is supported by the fact, that the two type of glass transmit significantly different amount from the global radiation. The difference between the two value indicates the energy-amount, how less is needed to use for cooling e.g. in June.

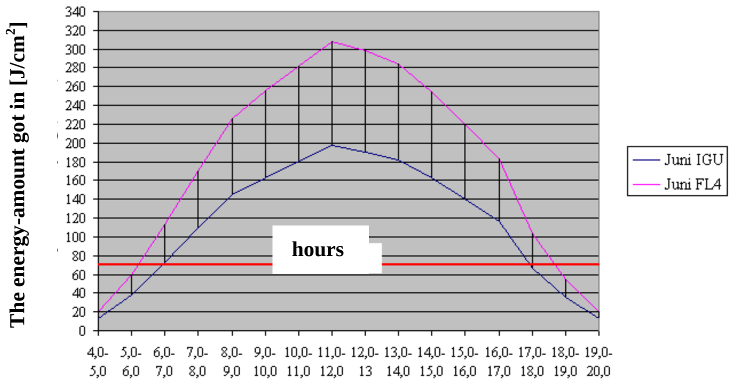


Figure 2. The energy amount got in through the FL4 and IGU glass from the global radiation in June

The spectral display of the parameters gained at my measurements gives a precise view from the building energetic capacity of the glass. Thus the consideration of these are essential in the design practice point of view.

5. Calculation model of the summing parameters for the glass constructions

I calculated the summing parameters of the glass and glass constructions taking into consideration the Hungarian and international standards.

Thus I determined from the spectral values :

– τ_v light transmission :

$$\tau_v = \frac{\sum_{\lambda=380nm}^{780nm} D_\lambda \tau(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda=380nm}^{780nm} D_\lambda V(\lambda) \Delta\lambda}$$

– ρ_v light-reflexion :

$$\rho_v = \frac{\sum_{\lambda=380nm}^{780nm} D_\lambda(\lambda) \rho(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda=380nm}^{780nm} D_\lambda(\lambda) V(\lambda) \Delta\lambda}$$

- τ_e Direct solar radiation transmission :

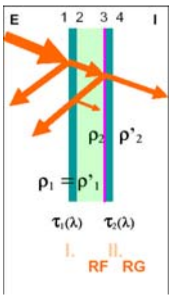
$$\tau_e = \frac{\sum_{\lambda=300nm}^{2500nm} S_\lambda \tau(\lambda) \Delta\lambda}{\sum_{\lambda=300nm}^{2500nm} S_\lambda \Delta\lambda}$$

- ρ_e direct solar radiation reflexion :

$$\rho_e = \frac{\sum_{\lambda=300nm}^{2500nm} S_\lambda \rho(\lambda) \Delta\lambda}{\sum_{\lambda=300nm}^{2500nm} S_\lambda \Delta\lambda}$$

- Similar in the case of double layer glass constructions :
While these coated glass are used only in insulating glass unit (IGU), I calculated the spectral parameters for these constructions.

In this case the following equations are needed to substitute into the above equations:



$$\tau(\lambda) = \frac{\tau_1(\lambda)\tau_2(\lambda)}{1-\rho'_1(\lambda)\rho_2(\lambda)}$$

$$\rho(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda)\rho_2(\lambda)}{1-\rho_1(\lambda)\rho_2(\lambda)}$$

The calculation method is suitable to get the required result with changing the spectral characteristic of the glass, using the convenient coating in the case of a certain transmission and reflexion.

6. ARCHIPAK-QBALANCE simulation model used for Hungarian conditions

I used the ARCHIPAK-QBALANCE simulation-model to Hungarian conditions, which importance is, that allows the real evaluation of the newest and most effective products and constructions in the market and under development in the glass industry in the indoor space thermal balance point of view.

The simulation model is a part of the ARCHIPAK program-package, which structure and data system for hot climate were elaborated by Dr. S. V. Szokolay, professor of the Queensland University (Australia)

The **essence of the** model is, that evaluates **the steady state thermal capacity of the buildings** , taking into consideration between others:
- the geographical location of the buildings,
- the related convenient climate data,
- the related convenient insolation, and
- the constructional elements of the building,
- the materials in these constructions – thus the glass construction types – with their related parameters.

The listed factors form the subject of the adapting task, that the program would be manageable for Hungarian conditions too. The necessary information and data needed for the adaptation are inbuilt into the model on the base of the previous chapters of the thesis.

The simulation model allows, **as result**:
- to determine the solar-radiation-load values reached the human living in the indoor-space, regarding the more frequently used glazing proportions depending from the orientation, in the case of different glass constructions in the heating period (winter);
- to select and to rank the glass constructions from this point of view in the heating period (winter);
- to determine the main parameters to the constructions for summer condition the necessary solar-radiation-control solutions;
- to prepare economical and comfort optimization, and under this to elaborate proposals for the application, development of the convenient glass constructions;

as I presented with the ARCHIPAK-QBALANCE model used for Hungary in an example for the cases of new glass external covering building constructions described in the thesis.

7. The determination of the PMV (Predicted Main Vote) by simulation model

I elaborated a simulation model to determine the PMV -predicted main vote – for the indoor space with glass external covering.

The essence of the prepared simulation model is that:
- allows to determine the comfort-sense of a human living in an indoor space, in given environmental conditions.;with the variability of the considered building construction components, and
  building physics parameters, and the changing number of persons in the indoor space, can give answer e.g.: for the constructional and thermo-technical appreciation of a crowded indoor space as a hospital, classroom, theatre etc.

The thermo-technical condition of an indoor space is influenced strongly by glazed constructions, which is described in details in the thesis. These constructional parameters are the part of the input data of the model, so one can visually follow the effects of their variation.
The input parameters are :
- the air-state characteristics of the external and indoor space,
- the characteristics of the solar radiation effect (solar gain factors)
- the data of the constructions (measures, layers),
- the thermo-technical data of the constructions,
- the human-comfort parameters (metabolic heat, clothing)

I determined by the model **as result** :
- the vapour pressure of the indoor space,
- the surface temperature of the clothing,
- the convective heat transfer factor,
- the average radiating temperature of the covering surfaces and
- the PMV predicted main vote value, which value can be defined by the ASHRAE thermal-sense scale.

4. CONCLUSIONS AND PROPOSALS

The found results with my research work are suitable for the followings:

1. Utilizing the knowledge, and making it known in the education also, the "weak points" of the built environment can be explored, improved, or eliminated.

2. Meeting the requirements of the relevant EU prescriptions, the energy efficiency of the buildings can be investigated having the knowledge collected in the thesis.
   These can be incorporated into the energy-auditor training. With this we can contribute very much to the economical operation of our built environment.

3. Utilizing the knowledge in the practice, we can use those in the energy conscious forming of our dwellings, public buildings.
   It means that it can be used to control the load of the built environment prepared for human, finally for forming the healthy, energy saving buildings, living spaces.

4. In the case of extreme climate conditions due to the climate change, the convenient human-comfort for the human who don't suffer the extreme climate, can form with the developed glass constructions of the external covering.

5. The building physics and energetic calculations and the Hungarian regulation don't take into consideration the glass with variable parameters. The changing and variable characteristics of the developed glass analyzed in the thesis, can be incorporated into these relations.

6. Using the experiences of the international research, I plan to investigate the thermal-balance of the indoor space without heating, using the "5000" simulation model, taking into consideration the human heat-withdrawal at analysing the building physics conditions of the passive-buildings.

5. SUMMARY

According to the above written subjects, that the Hungarian energetic and environmental problems justify those of my research, which :

- make more economical and environmental-friendly the energy-consumption of the buildings,
- focus onto satisfying the requirement-system of the human thermal comfort,
- analyse the relations of the related building physical thermo-technical connection system,
- promote the development of the products' and constructions' capacity in the glass industry and the utilization of it's products, and
- focuses onto the elaboration of the methods managing this comprehensive problem.

Therefore in my thesis, I have analysed for the solution of this composed demand the related effects, evaluated the most suitable theories and the simulation methods which allow the fast and precise results.

The domestic utilization :

- this research method is a continuously maintainable tool,

- at the education activity in comfort-design, building physics, building construction, and at the training of engineering, energetic, architectural and environment.
- for the research activity at the determination of the research directions,
- at the practical building-design,
- at the decision-preparation of building-reconstructions,
- for the manufacturers at the preliminary determination of production capacities on the field of building industry and building-material industry, and at the determination of the further product-development directions;

- with a complex, comprehensive approach by the analysis of thermal-comfort and building physics of the buildings to give precise and fast answers at the design-process of low-energy and passive buildings.

The experiences and results gained during my research work are suitable to allow favourable indoor comfort and energy-saving operation in the same time using architectural glass.

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