The implementation of building envelopes with controlled thermal resistance

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SUMMARY
Two building's components – the envelope and the air-conditioning system - have the major impact on building's energy efficiency. As a rule, the building's envelope is a passive element and the air-conditioning system is an active element regarding the possibility of regulation in order to ensure optimal indoor air parameters. The paper analyses values of building's envelope's thermal resistance factor depending on outdoor air parameters. Currently different technical decisions exist for regulation of thermal performance of building's envelope: double skin facades, multiple films on windows, ventilated curtain walls, automated venetian blinds. The paper is devoted to the analysis of possibilities to integrate building's envelope with controlled thermal resistance into air-conditioning system working regimes. The combination of working parameters of air-conditioning system and building's envelope's thermal resistance in summer, when the electricity demand for cooling is maximal, could provide the way for significant energy save in public buildings.

KEYWORDS: *IAQ*

1 INTRODUCTION

Traditionally low energy buildings are supposed to have maximally big thermal resistance of building envelope. In reality, big thermal resistance is justified only in coldest winter days in countries with cold climate or in hot summer days with intensive solar radiation. In other periods buildings with full air conditioning would have to have different properties of building envelope that could allow heat flow in one or another direction. There are also periods when minimal resistance to vapour transfer is required. Sometimes the building envelope is needed only to prevent from rain, insects or to give the intimacy and it is not needed from the point of energy efficiency, as it does not have to form the shield against the heat or vapour flow [1]. The fact is known to the scientists who use simulation of building energy performance during the whole year. Building energy performance simulation models allow choosing optimal characteristics of building envelope on the basis of annual heat consumption. The model described in this paper would help to optimise building energy performance even more on the condition that we can change the properties of building envelope.

Two building's components – the envelope and the air-conditioning system - have the major impact on building's energy efficiency. As a rule, the building's envelope is a passive element and the air-conditioning system is an active element regarding the possibility of regulation in order to ensure optimal indoor air parameters.

In case if it would be possible during the building exploitation to change building envelope thermal resistance R_0, solar radiation resistance R_s and vapour resistance R_v the building envelope became by the active element. At the moment there are constructive decisions which have changeable thermal characteristics the double skin facades, multiple films on windows, ventilated curtain walls, automated Venetian blinds. Nevertheless not all of them are efficiently integrated into the air-conditioning system's working regimes. Also the vapour barriers with variable diffusion resistance are well known nowadays.

In order to improve energy performance of air-conditioning systems it is necessary to create algorithm for controlled building envelopes. The combination of working parameters of air-conditioning system and building envelope's thermal and solar resistance in summer, when the electricity demand for cooling is maximal, could provide the way for significant energy save in public buildings.

2 THERMAL AND RADIATION RESISTANCE REGULATION

Suppose that in the room where the building envelope constructions have controlled thermal resistance R_0, solar radiation resistance R_s and vapour resistance R_v and there is air-conditioning system, it is necessary to keep constant temperature and moisture content in the work area. Also suppose that room has the heat and moisture production ($\Delta Q > 0$, $\Delta G > 0$), i.e., the direction of process:

$$\varepsilon = \frac{\Delta Q}{\Delta G} > 0 \quad (1) \quad \text{air exchange rate } 0 < m < 1.$$

$$m = \frac{t_p - t_s}{t_e - t_s} = \frac{I_p - I_s}{I_e - I_s} = \frac{d_p - d_s}{d_e - d_s} \quad (2)$$

t_I, I_I, d_I – temperature, enthalpy and moisture content in the work area;

t_s, I_s, d_s - temperature, enthalpy and moisture content in supplying air;

t_e, I_e, d_e - temperature, enthalpy and moisture content in exhaust air.

In the calculation of air-conditioning system assumes that the air passing through the working area assimilate all heat and moisture in the room. If the solar radiation resistance of building envelope would be minimized, the amounts of the heat gains will increase. As the result the temperature in the work area rises to t_{p1}. Supplying air passing through the work zone assimilates also additional amount of heat and the exhaust air temperature rises to t_{e1}, but the direction of process ε will increase to ε_1. In order to ensure fixed temperature in working area it is necessary to reduce the incoming air temperature to t_{s1}.

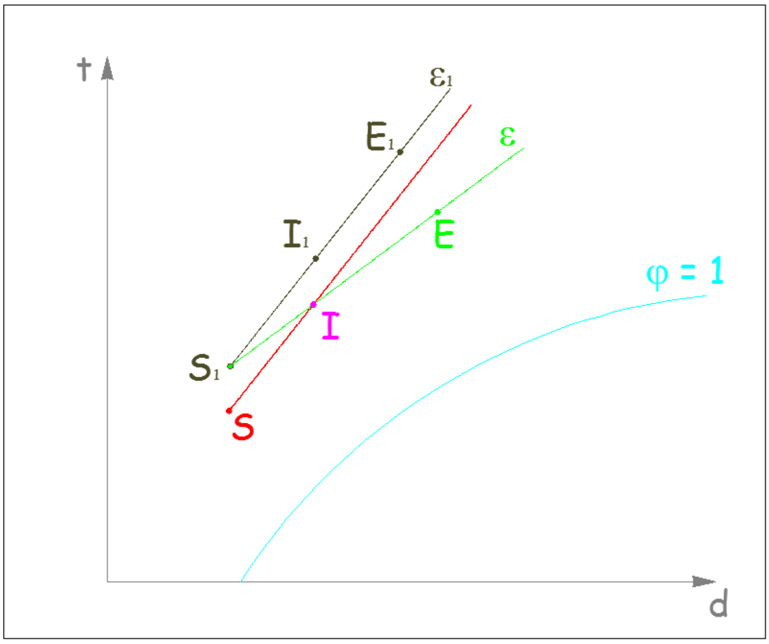

Figure 1 Process in room with normal solar radiation resistance (ε) and with minimized solar radiation resistance (ε_1) (S – parameters of supplying air; I – air parameters in working area, E – parameters of exhaust air).

In case if solar radiation resistance of building envelope can be increased, then point "E" in I-x diagram moves down, but in order to ensure I point constant, working regime of air-conditioning systems should be recast so that the point S moves up towards. The changes of location of point "E" when R_s is changing are independent of outside air parameters, as well as the amount of indoor heat and moisture production. In case when $t_o < t_s$ (t_o – outdoor air temperature) the thermal resistance can be increased consequently point E moves up towards but in case if $t_o > t_p$ – moves down. Reducing the thermal resistance of building envelope the point E moves up towards at $t_o > t_p$, and down at $t_o < t_p$. Changing vapour resistance of building envelope point E moves to the right or left, depending on the amount of moisture in the outside air (d_o)and the moisture quantity in work area d_I. Accordingly, R_0, R_s, and R_v changes may change the parameters of exhaust air and the point "E" may change its location along a limited area of the diagram which is a square shape $E_1E_2E_3E_4$ (Figure 2).

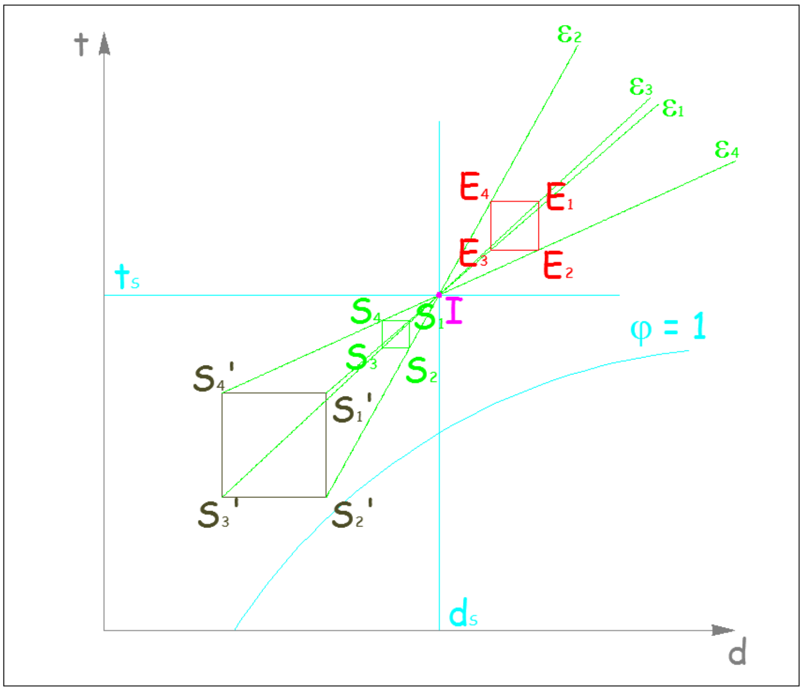

Figure 2 Dependence between parameters of supplying air and air exchange rate in case of building envelope with regulated thermodynamic parameters.

In order to keep constant t_i and d_i, it is necessary to change the location of the point S. Border area of location depends on air exchange rate. For example, if m = 0.5, S varies on figure $S_1S_2S_3S_4$, when m = 0.75, then $S_1'S_2'S_3'S_4'$.

3 ENERGY CONSUMPTION FOR AIR-CONDITIONING SYSTEMS WITH CONTROLLED THERMODYNAMIC PROPERTIES OF BOUNDARY CONSTRUCTIONS

In order to evaluate heat and cold consumption by air-conditioning systems the theoretical comparison of two rooms was done. One room has external elements with constant thermal resistance, solar radiation resistance and vapour resistance (R_0 = const., R_s =const. and R_v = const). The second room has external elements with changeable thermal resistance, solar radiation resistance and vapour resistance.

Point "S" characterizes the parameters of supplying air in rooms with constant R_0, R_s, and R_v. Area of the outside air changes in this case can be separated into 4 parts according to the working regimes of the air-conditioning system. The limits of this process are shown in pull-line in I-x diagram (Figure 3).

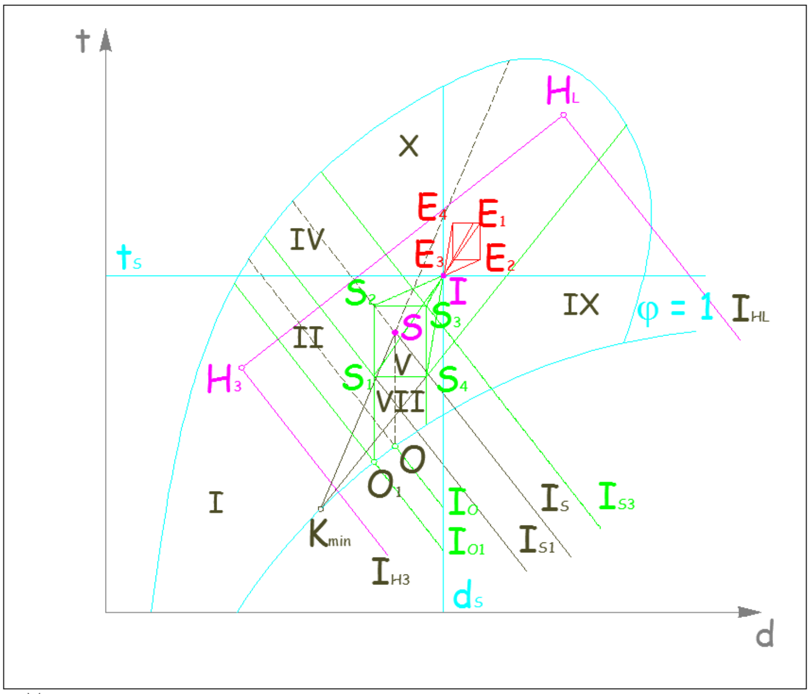

Figure 3 Possible outdoor air parameters for evaluation of working regimes of air-condition systems

In the second case, when room has changeable R_0, R_s, and R_v values, in order to keep fixed t_i and d_i the point "S" should move in area limited by $S_1S_2S_3S_4$ and area of the outside air changes in this case can be separated into 7 parts according to the working regime of the air-conditioning system - I, II, III, IV, VI, IX and X. The limits of this process are marked by a bold line in I-x diagram (Figure 3).

During the year outside air parameters are changing constantly. Consequently, the heating and cooling capacity will be changeable. We can assume that the parameters of the outside air vary along a straight line that connects point-to-point H_3 and H_L in I-x diagram. Figure 4 shows the heat consumption will be changed in first and second preheating process Q_I and Q_{II} and cooling Q_X depending on outside air enthalpy for the building envelope with constant R_0, R_s, and R_v (pull line) and for the building envelope with variable R_0, R_s, and R_v (full line).

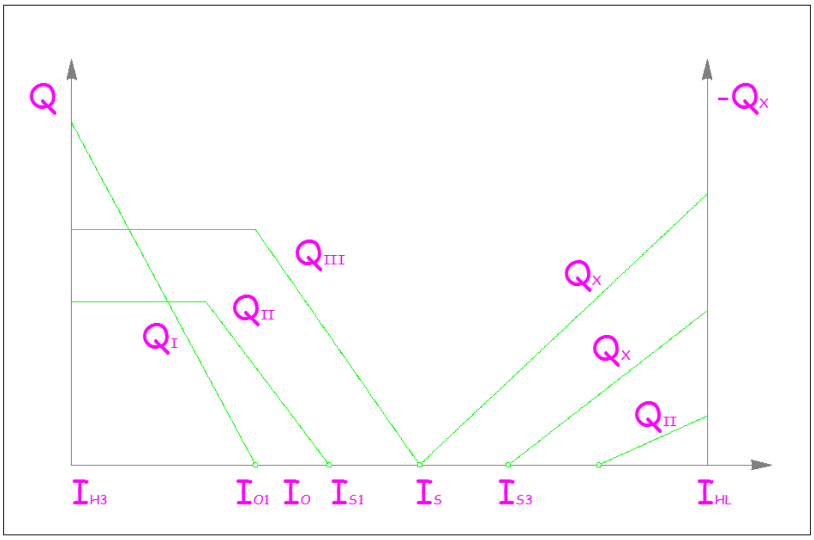

Figure 4 Dependences between heating/cooling capacity of air-conditioning system and properties of building envelope

Figure 4 demonstrates that use of the building envelope with changeable R_0, R_s, and R_v, gives the possibility to reduce energy consumption by second heater and to reduce cooling loads.

Efficient use of building envelope with changeable parameters R_0, R_s, and R_v is dependent on air exchange rate in room - it will increase if the exchange rate is increased.

4 IMPROVING OF AIR CONDITIONING SYSTEM USING BPUNDARY CONSTRUCTIONS WITH CONTROLLED THERMAL RESISTANCE

There are four main temperatures that are usually distinguished in air conditioning. Two of them are widely used in all other calculations: the temperature of outside air t_e, and the temperature of inside air t_i. Two others are connected to the thermodynamic processes in the air of inside space and may be higher or lower than inside and outside air temperatures (Kreslins 1984). These temperatures are: the temperature of supply air and temperature of exhaust air (Figure 5).

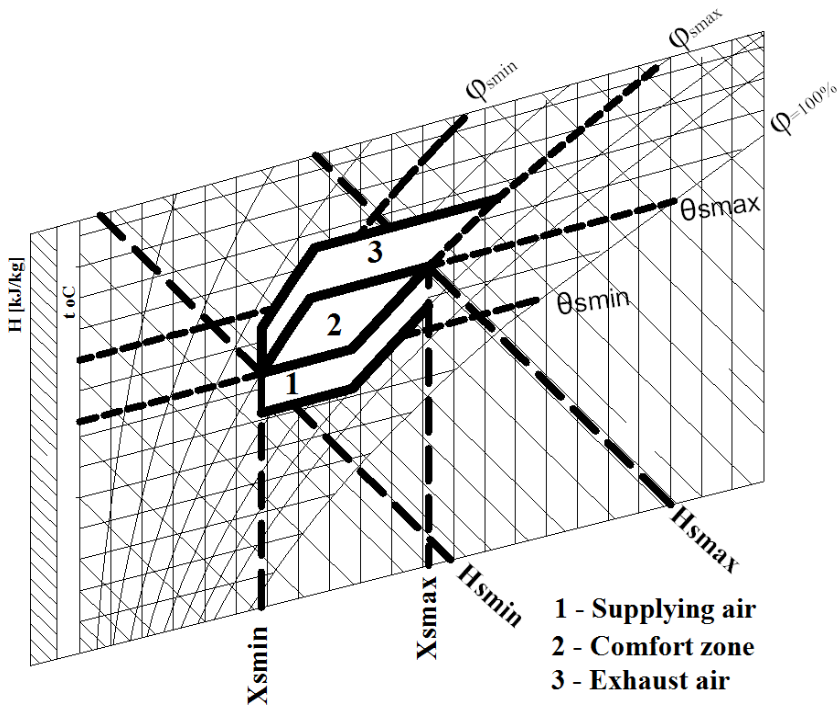

Figure 5 Air parameters in air conditioning system

Building envelopes with controlled thermal resistance can be efficiently used in hot summer periods, when the outside air temperature is much higher than inside air temperature. In working regime after the outdoor air cooling the heating device heats up supply air till minimal required temperature and internal heat gains further heat air till comfort zone. Although it is possible to reduce heating loads using solar radiation and heat transfer from outside air to inside thought the building envelope in order to heat up outdoor air till minimal required supplying air temperature. For that purpose it is necessary to reduce thermal performance of building envelope and resistance of glazing surface to heat radiation.

5 DISCUSSION

In practice the choice of the regulation mode depends on the level of technical development and economic considerations.

Some of the regulation decisions, such as shutters or solar reflectors, are known for generations. They are in compliance with the model described in the paper but they were known long before and without it. On the other hand the given algorithm shows all possible directions of technical development in order to minimize annual heat consumption of buildings.

At the present stage of scientific and technical development it is naturally to expect fast progress of technology toward the building structures with changeable characteristics. For example, even now it is possible to imagine inflatable buildings with changeable thickness' insulation air layers, or regulation of structures' vapor permeability by perforation with changeable dimensions.

Building envelope with changeable thermal resistance, solar radiation resistance and vapour resistance gives the possibility to reduce energy consumption by second heater and to reduce cooling loads.

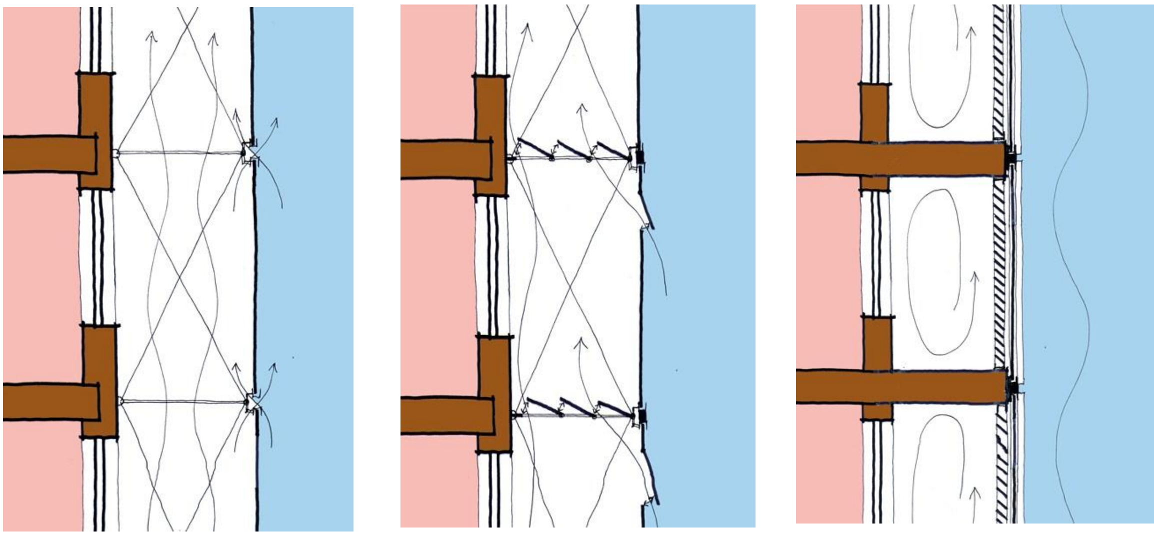

Figure 6 Possible decisions of envelopes with controlled thermal resistance

6 REFERENCES

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