Building's imitation of a human body's thermal behavior

B. Todorovic
The Faculty of Mechanical Engineering, University of Belgrade

ABSTRACT

Human organism is probably the most perfect example of thermal behavior, adaptation to different climatic conditions, and a way of keeping it's temperature constant, which is existent in nature. Observing various buildings, their thermal characteristics, maintenance of interior thermal conditions, it could be concluded that many human body's characteristics and their helpful systems are reflected in buildings.

Aim of this paper is to present similarities, to define which human organism characteristics are expressed or used in buildings, which cannot be copied, and which can, but have not been used.

A man instinctively protects himself from extreme coldness, but also uses his mind and intelligence to help his natural protective characteristics in extreme cold or heat.

Special attention is paid to the use of the evaporative building cooling, achieved in humans by sweating. Also use of buildings' envelopes moistening and general use of water in buildings as an element of architectural expression in regard to their look, combining interiors with natural effects, realization of the "green buildings" concept, with special regard to potential energetic effects.

1. INTRODUCTION

In the light of our knowledge of nature, or at least of our planet, the Earth, a human body possesses the most perfect mechanism of adaptation to various thermal conditions, keeping the constant body temperature and control of thermal behavior. During the winter, the blood vessels tighten, blood circulation toward the skin surface is lowered, and so the heat transfer through the skin toward the outside environment. The heat is kept in a body, conserved, and in fact a process is going on which is desired in buildings, in low temperature environments. If all the mentioned is insufficient, muscles additionally contract producing shivering, the body in order to produce additional heat. During the summer and in regions of constantly high temperatures, a human organism still produces heat and needs to get rid of its surplus, so that body temperature may remain unchanged. In such conditions, an organism needs to lose extra heat, so blood vessels expand, and blood flow toward the skin is increased. When that is not enough, sweat glands secrete more intensively, and body gets moistened. Sweat evaporates from the skin surface, and so cools it.

Human functions, his protection from excessive heat loss or overheating are located in his brain center, hypothalamus. A brain center receives stimulations from skin sensors, inducing adequate body reactions (expansion or tightening of blood vessels, sweating, shivering). It is done instinctively, without a man's conscious efforts, since reactions are the result of an inbuilt reaction to a certain registration of a low or high temperature, or some other signal. If we use the modern IT terminology, it is a characteristic by default.

Using his mind and intellect, man adds to his protection facilitating to his instinctively reacting system. Besides all his automatic reactions, man has advantage being not static. He moves, turns, puts himself into a shadow, uses head covers, parasols, protections, so that besides his natural self-control of his thermal functioning, managed from hypothalamus, he also reacts consciously. As a mobile being, different from static constructions, he finds warm or cold "oasis", uses pullovers, coats, gloves, etc. In summer, in environments of high temperatures of 37°C, human organism may protect itself only by sweating, so that in tropic areas and during the hot summer seasons in the regions with continental climate, human conscious reactions are more prominent. In order to protect himself from solar radiation, a man uses light clothes, colours and materials which reflect radiation and don't accumulate heat, moisture-conductive, as heat loss is ensured through sweating. Of course, cooling mechanism by sweat evaporation is more efficient in less humid environments, as well as in conditions of more intensive air circulation, as in such conditions air saturated by evaporated sweat do not stick to human body.

2. BUILDING'S SIMILARITY TO HUMAN ORGANISM

A living organism breathes, and part of heat is eliminated from the body through air heating in lungs. A similar process occurs in buildings. Not so much because of a building itself as because of people in it. They all need oxygen, so fresh air is brought into a building, earlier by natural ventilation, and today in big buildings in mechanical ways. Though as well to eliminate unpleasant smells, evaporations…

Human body temperature is about 37°C. Constant temperature in buildings is also kept constant at some 22°C. In order to achieve it, a heating system must compensate for heat losses, so that in cold environments or cold periods of a year a building always produces heat in direct or indirect ways if connected to a district heating system. Naturally, the lesser needs that quantity, the more profitable the building heating system exploitation costs, and also cheaper regarding the initial investments costs.

How a man reduces his body heat loss? It had been mentioned the blood circulation lowering toward the skin surface, blood vessels tightening, but a man also dresses, adding thus an additional protective cover over his body, his skin, and acquiring thus better insulation. This human way of additional protection can be applied on buildings. Why they not to be covered by movable covers, in winter to protect them from wind and low outside temperature, and in summer from the sun, in order to reduce heat gains from the solar radiation, and so reduce the necessary energy for its air conditioning. Maybe a kind of automatic lowered shades? Or covering a building with a second façade?

3. DOUBLE-FAÇADE BUILDINGS

Man's instinctive functioning and what goes on in a building are more similar in conditions of low outside temperatures. Heat is produced in a man's body, like in buildings with a heating system. A man loses heat, but not more than a quantity ensuring his body temperature. A building also loses heat, not out of some need, but because of its incapacity to avoid it in conditions of the contemporary construction technology and availability of construction materials. Such losses should be reduced as much as possible. By better insulation, double facades, etc.

There are buildings today with such double protection, mostly static, like a "pullover" or a "winter coat" on a man. Those are the double-facade buildings – additional cover is added to the main façade, usually made of glass.

A double façade, which in a cold season presents an additional cover for a building, may in the summer be its protection from the sun. A winter coat or a pullover is changed by a light material blouse of the bigger size, roomy over the body, so that the air may circulate next to the body.

In the double façade is put in the inter-space for the sun-protection various forms of shades, curtains, or similar devices, though a passage must be provided for the outside air circulation, so that the inter-space temperatures may be as close as possible, if not identical, to the outside temperature.

From the construction point of view, a double-façade outer envelope may be continuously extended by covering the total height of a building, or discontinued with breaks at each floor level. Disregarding the height, the inter-space is opened both at the bottom and at the top, thus providing the outdoor air circulation in summer, when the temperature of inter-space should be as low as possible, in principle equal to the outside temperature. Or the openings may be closed, which is the case during the winter, in

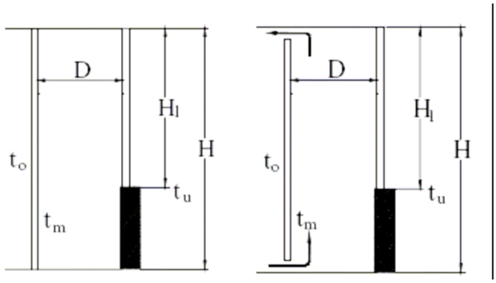

Figure 1: Double façade cross section in winter with closed openings for air circulation and in summer period when openings are closed.

order to trap the air in the inter-space, which will act as insulation layer with the temperature above the outside temperature, producing lower heat losses of a building (Fig. 1).

Figures 2 and 3 show the course of temperatures in the inter-space on an average sunny and cloudy day in January, for the South-turned double façade, in Belgrade (45NL). Figures 4 and 5 are presenting the temperatures during the sunny and cloudy days in June.

It is evident that during the heating period, a building with a double-façade will have lower needs for heating. In summer, during the cooling period, the temperature between the two facades could be equal to the outside temperature and additionally can have smaller heat gains from solar radiation depending of glass properties regarding solar transmittance.

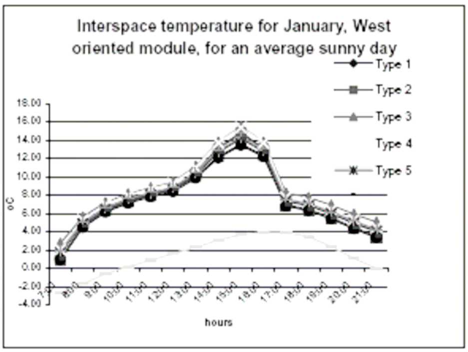

Figure 2: Inter-space temperatures, January, sunny day.

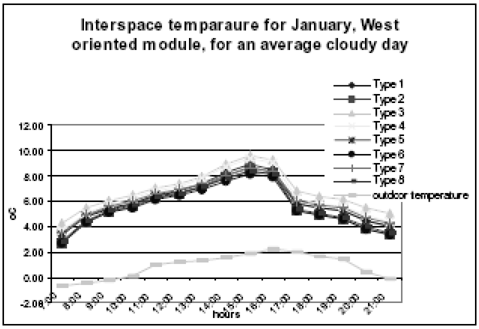

Figure 3: Inter-space temperatures, January, cloudy day.

4. BUILDING PROTECTION FROM THE SOLAR RADIATION

During the summer, a man uses his conscious reactions for the additional protection of his body. He may protect himself by hats, or make a shade using a parasol. Similar protection is used in buildings by various curtains, shades, and venetian blinds at windows, while today copies of caps and parasols are constructed, as immovable

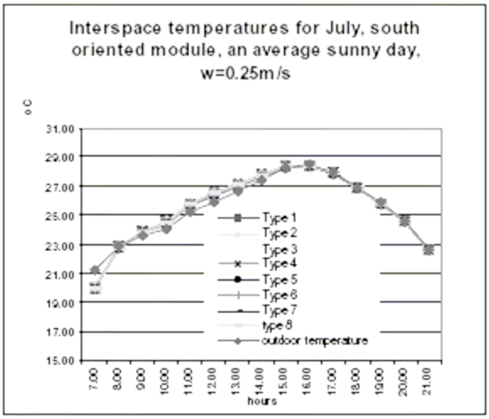

Figure 4: Temperatures in inter-space between two facades, July, South, sunny day, average air velocity o,25m/s.

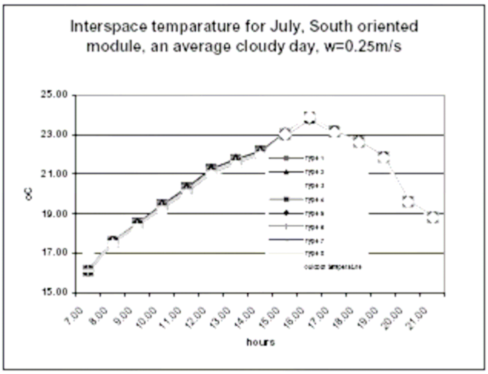

Figure 5: Temperatures between two facades, cloudy day, July, south exposed façade.

elements over roofs, or movable, depending on the sun temporary location. All those protections may be also used on facades.

Examples of building protection from the solar radiation are numerous, especially in the regions of tropical conditions. An illustrative example is a building designed by the English architect Grindshaw in Seville, built for the EXPO 1992 (Fig. 6). Movable protection on the roof is put according to the momentary sun location, controlled by "building's intelligence", by default.

5. BUILDING'S "SWEATING" - EVAPORATIVE COOLING

During the summer heat enters into buildings from the outside hot air, the solar radiation, but exists also of the inside heat gains (lighting, domestic hot water systems, people, electric appliances and devices). Such heat must be eliminated so that the inside temperature would not be increased above the planned one, for example 22°C. In conditions when the outside temperature is above human body temperature, the only way to a man to eliminates his inner heat is by sweating, through evaporation. A building cannot sweat, so that it has to be cooled mechanically by air conditioning system.

However, may we use the human body sweat evaporation effect on buildings? There are buildings for which it may be said that they use the effect of water evaporation for their cooling. As in man's sweating.

It is an old practice to put water sprinklers on the roofs of large surfaces, and use them at high outside temperatures, when the sun radiates intensively. The roof is so moistened, and because of the heat absorbed by the outer roof surface and the air layer next to it, water evaporation occurs, and the roof temperature is lowered. Pools are also installed on roofs of multi-story residential and business buildings.

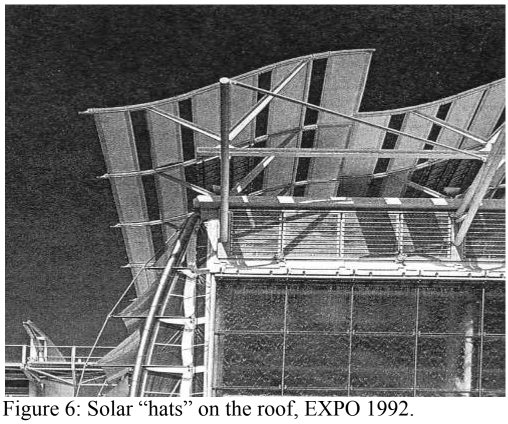

Figure 6: Solar "hats" on the roof, EXPO 1992.

The idea to let the water flow down a building façade, an imitation of human sweating, is an option in a modern architecture, in case of glass facades as frequently used elements in contemporary buildings, probably more for visual effects, but also as a way to get some kind of the close nature effects. Flowers, grass, but also water as an especially important element in some cultures becomes a repeatedly used element in the modern architectural expression. Most often inside the large halls, restaurants, atriums.

There are several buildings around the world with water flowing down the glass vertical or inclined facade. One of such examples is again the building of the British pavilion in Seville (Fig. 7). Such façade has smaller coefficient of the solar radiation admission and with the water layer, due to its evaporation, the temperature next to the façade is significantly lower than the outside one, reducing so the heat gain from the solar radiation, as well as from temperature difference between the outside and the inside.

The measurements approved that the uniform water flow above glass façade has a lower solar radiation transmittance for 10-15% then dry ordinary glass. And when the water flow is turbulent and disturbed, even 25-30% depending to water quantity.

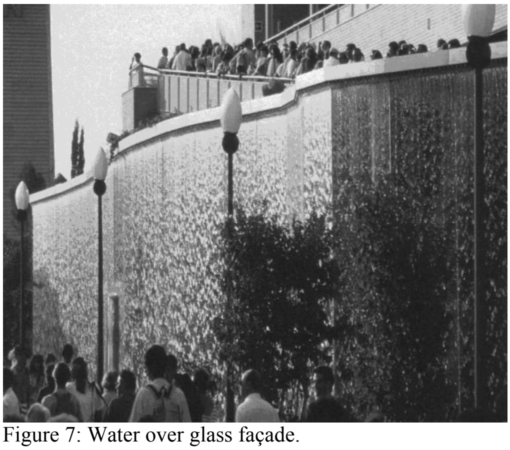

Figure 7: Water over glass façade.

6. CONCLUSION

Buildings mechanism of thermal behavior is in many details copy of human body reaction. By his unconscious, instinctive behavior, with the defaulted characteristics, a man reduces or increases heat loss into the outer environment, by his blood circulation regulation toward the skin as a body’s outer envelope. Besides, using his mind humans dress themselves into clothes with better insulation characteristics. Buildings are protected with insulation which remains unchanged during both the summer and the winter season. It is an advantage for a building, as, opposite to a man, a building uses cooling devices to reduce it’s temperature. But that needs energy, which should be avoided in the present situation regarding energy crisis. The task remains to expand it, but before an each such a building design should exact calculations, simulations, optimization be done, resulting with the total energy balance, taking into account water and energy balance.

Sweating, the only possible effect of a human body cooling in high temperature areas has not been used largely in buildings. A few buildings around the world show it is a possible option. Unfortunately, the impression is that building cooling was not the primary task of the water flow on facades, although it was one of the aims to design those buildings.

REFERENCES

Todorovic, B. and T. Cvjetkovic, 2001. Classical and double building facades-Energy needs for heating and cooling, CLIMA 2000, REHVA, Naples, 2001.

Todorovic, B., 2004. Post, present and future buildings envelopes-human body thermal behavior as final goal, Energy for buildings, Proceedings of 6th international Conference, Vilnius. Lithuania.

Todorovic, B., 2005. Can a building mimic the thermal behavior of human body? Presentation at ASHRAE Chapter in Singapore, Singapore.