BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LVIII (LXII), Fasc. 4, 2012
Secţia
CONSTRUCŢII. ARHITECTURĂ

PHYSICAL MODELING OF A NEW COMPLEX SYSTEM FOR SUSTAINABLE BUILDINGS

BY

CODRINA PURCARU*, ADRIAN RADU and ANDREI PURCARU

“Gheorghe Asachi” Technical University of Iaşi
Faculty of Civil Engineering and Building Services

Received: September 5, 2012
Accepted for publication: September 28, 2012

Abstract. After an extensive study concerning the problem of ventilation buildings and building elements, in terms of comfort and air quality, but also in terms of energy efficiency, was born the idea of independent specific combination of passive buildings in a new concept – *permanent garden-façade*. This complex system with many advantages in the mentioned above directions, consists in a double glazed façade with an integrated vertical garden and a well coil Canadian/Provençal coupled to inside of the ventilated façade, which in turn can be continued with a roof channel ventilated roof structure. This system could be tested experimentally by constructing a physical model that simulates the natural circulation of air through a Canadian/Provençal tube well connected to a ventilated façade and roof channel. Results of measurements on the physical model shows that air only flows through the system due to temperature differences between inside and outside of ventilation duct..

Key words: scale physical model; Canadian/Provençal well; ventilated façade; energy efficiency; indoor air quality; vertical gardens.

---

*Corresponding author: *e-mail*: codrina.purcaru@ gmail.com

1. Introduction

To fulfill the European and world wide directive for the energy economy, an esential part belong to the construction sector stakeholders. Constructive solutions to reduce energy consumption in some cases, adversely affect indoor environmental quality, creating imbalances in the way of achieving natural ventilation. Thus, the introduction of central heating instead stoves and replaceing the traditional air permeable wooden joinery, with PVC tight joinery or laminated wood with double glazed windows, have generated a serious problem in natural ventilation of buildings. By removing chimneys and sealing the windows and doors joinery is not achieved that existed *prior* disorganized ventilation in buildings. This, added to the climatic conditions of our country comes to stimulate thinking of architects and engineers to find new solutions to maintain optimal conditions for life in buildings.

During an extensive research several areas of ventilation buildings and building components were studied in order to reach all these areas reunited in form of a complex system that actively participate in efficient natural ventilation and energy saving in buildings . It is the combination of the Canadian well, double glazed ventilated façades with a channel framework of a ventilated roof and also coupled with so-called "vertical gardens" inside the double glased façade, which together form an ensemble which could have better results and better performance than each subsystem. The following sections are allocated to motivation of the new concept, describing the principle of operation of the complex system, and composition scale physical model and to the results of measurements made in this simplified model of façade and roof ventilation, coupled to a coil of Canadian well.

2. Proposal for Improving Energy Savings and Indoor Environmental Quality of Buildings

Systems that are designed to improve hygrothermal comfort and energy-saving in buildings have some technological problems which can be corrected through careful design and execution but also by proposing and implementing a new construction concept called "permanent garden-façade" described below.

2.1. Canadian/Provencal Well, Ventilated Façades and Roofs

Sometimes, the Canadian shaft tubes can seep into buildings toxic gases (radon) or fungal spores and microorganisms (Purcaru C., 2011). Therefore, to facilitate the Canadian well generally function are used fans or heat pump that can increase the amount of heat but with electrical energy consumption, the production of which spents a double amount of primary energy. In addition, these machines generate noise and heat pump representing a very costly investment and maintenance, requiring a dedicated space in the basement or semi-basement building. All these inconveniences can be avoided by coupling Canadian / Provençal well in ventilated façade.

The challenge for an office building with single or double glass façade represents a solution of optimizing energy use, solar light, visual and thermal comfort for a reasonable initial investment. Office buildings with glass façades risk simply to consume more energy for cooling or heating than traditional masonry façades offices. A ventilated double glass façade designed accordingly, decreases the risk of thermal discomfort in proximity of inner façade. Office buildings are required to be carefully designed because they have a lower tolerance to errors in design or execution.

Compared to traditional roofing solutions, it is possible to benefit from the effects of ventilated air layer and a termo-reflectant sandwich material, both embedded between covering and insulation. In this regard, a team of Department of Civil and Industrial Constructions from the "Gheorghe Asachi" Technical University of Iaşi proposed prefabricated roof elements patent pending. Also a German patent shows possible roof frame ventilation with intake air underwent a Canadian well and heat pump system (Fig. 1) (Hake, 2005).

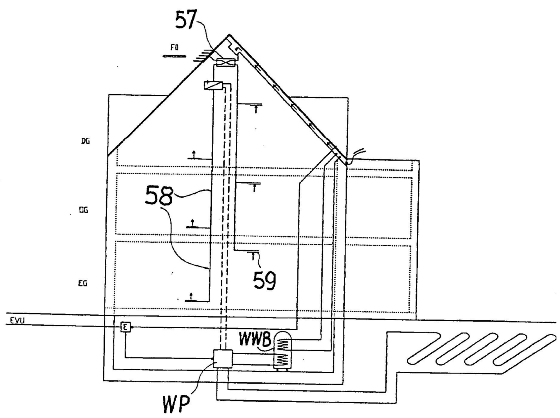

Fig. 1 –Diagram of a house whose roof ventilation system with air passed through a Canadian shaft and heat pump system (German patent: DE October, 2004, 001 875 A1 2005.08.04)

From the information presented so far, result the advantages and disadvantages of each of the systems: Canadian/Provençal well, ventilated façades, ventilated roof. It is understood that the proposed new coupling system of Canadian pit with ventilated front and ventilated roof is designed to optimize both hygiene and comfort, energy efficiency of the building and operation of each system.

2.2. Indoor Gardens

The idea of integrated double glazed façade gardens was presented by Zak Adams, along with other authors, in a symposium dedicated to the theme of building integrated agriculture (Fig. 2) (www.mediaderive.blogspot.ro/2010/07/terraform-1-workshop-part-2-building.html).

Cultivation of agricultural products above or inside buildings can help reduce the negative effects of human activity on the environment, reduce transport costs, improve food security, energy savings in the building envelope, and increase physical and mental comfort of the occupants.

Fig. 2 – Image of vegetable garden integrated in a vertically double glazed façade structure of an office building (www.mediaderive.blogspot.ro/2010/07/terraform-1-workshop-part-2-building.html).

What is not stated in the previous example, or other types of gardens mentioned in a previous paper (Purcaru C. & Purcaru A., 2012) is that these vertical gardens, plants wall kind or in the inside of a double glazed façade, although are a blessing in summer by shading effect, purifying and moistening air (Purcaru C., 2010), can not withstand the winter in the temperate continental zone, where the temperatures often drop below –10 ° C. Even if there are inside of a double glazed façade, without a triple glazed curtain walls with 2…3 insulating layers and even additional heating, otherwise agricultural cultivation can not be realized in negative extreme temperature conditions.

2.3. Proposal of Concept "Permanent Garden-Façade"

In consequence, the authors proposal, the concept of "permanent garden façade", involves connecting a Canadian well system to a double glazed façade with integrated vertical garden connected with an air layer of ventilated roof structure (Fig. 3) and makes possible existence of the plants in the winter, inside the ventilated façade with at least 5°C pre-heated air, as it is the winter underground temperature, at 1.5…3 m depth. Thus a significant amount of energy is saved through eliminating the necessity of heating façade for the winter. Pit benefit is felt equally in summer when the underground pre-cooled air will cool ventilated façade air layer, bend to overheating during hot summer days.

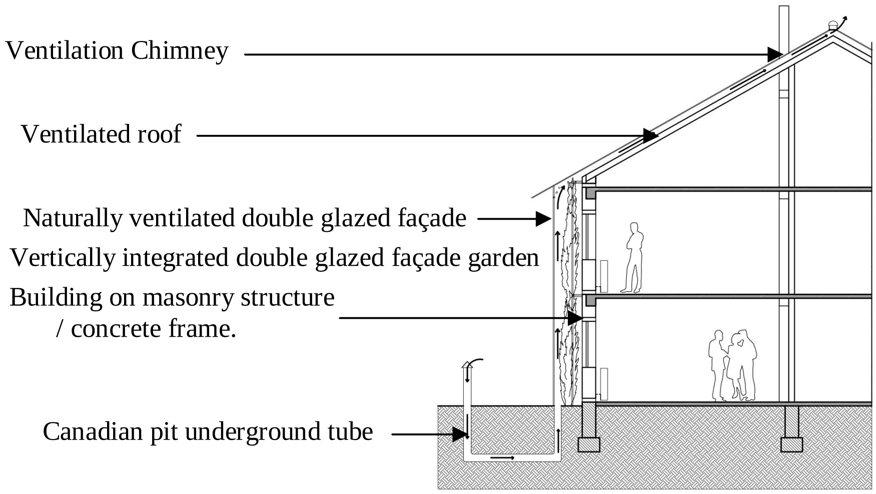

Fig. 3 – Ventilation scheme of a building through Canadian shaft connected to double glazed façade that includes a vertical garden and to a ventilated roof layer of air.

In conclusion, the clear advantage of this system is designed to achieve a indoor environment proper to the daily human activity and the cultivation of plants for ornamental purposes, shading and air purification, alimentar use, without extra energy consumption. Moreover, it saves a significant proportion of energy that would be consumed for heating, cooling and air humidification in building.

3. Scale Physical Model: Canadian/Provençal Well + Ventilated Double Façade + Ventilated Roof

3.1. The Description Scheme and the Driving Operation

The proposed experimental model simulates at physical scale (sc. = 1/5) air circulation through a complex system consisting of a Canadian/Provençal shaft coil coupled to a ventilated façade channel, continued with another ventilated roof channel. Simplified diagram of this system is illustrated in Fig. 4, both variant for winter and summer. In order to reconstruct reality laboratory conditions, the criterion of similarity Grashof ($Gr = \beta g l^2 \Delta t / v^2$) should use temperatures aprox. 1,000°C in the laboratory, which is not possible. At the Professor Radu suggestion, reverse procedure was performed by applying small temperature differences in the physical model and inferring natural-scale temperature differences, resulting much smaller. This has found a way to use small-scale physical models. On this basis we can create prerequisites tests Canadian shaft functionality without input of fan or heat pump.

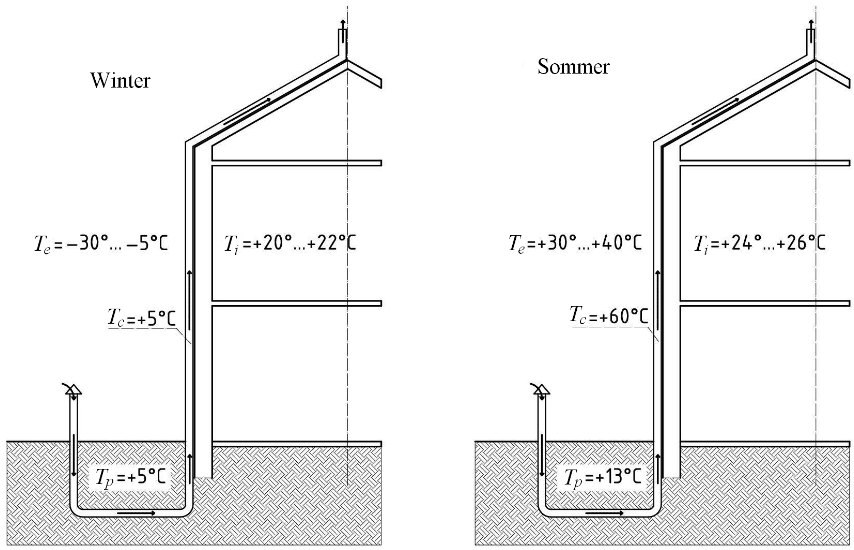

Fig. 4 – Simplified diagram of the system Canadian / Provençal well+ ventilated façade + ventilated roof, in winter variant (left) and summer version (right).

In winter case, the air with negative temperature is preheated in the tube of the Canadian well to temperature of +5°C and then enters in the ventilated façade, where will still accumulate the heat coming from inside of the house. Thus, the air moves through natural circulation generated by the the pressure and temperature difference between absorbed air into Canadian shaft tube and ventilated façade and roof air. Similarly, in summer, the temperature difference between the outside air and the façade and roof channel strongly heated by solar radiation causes thermal circulation necessary to cold air absorption in underground pit tube.

3.2. Physical Model Construction

In the proposed experiment is performed a pre-cooling/preheating air ventilation process on laboratory physical modeling at small scale (Sc. = 1/5), through a Canadian/Provençal pit (approx. 40 m coil) coupled with one ventilated façade section channel (10 cm depth) and sloping roof on a groundfloor building. Outdoor air absorbed in modeled system goes through a PVC pipe immersed in water (simulating the underground) after it is placed in a vertical rectangular channel continued with oblique one, they simulate a ventilated façade and roof, as is outlined in Fig. 5.

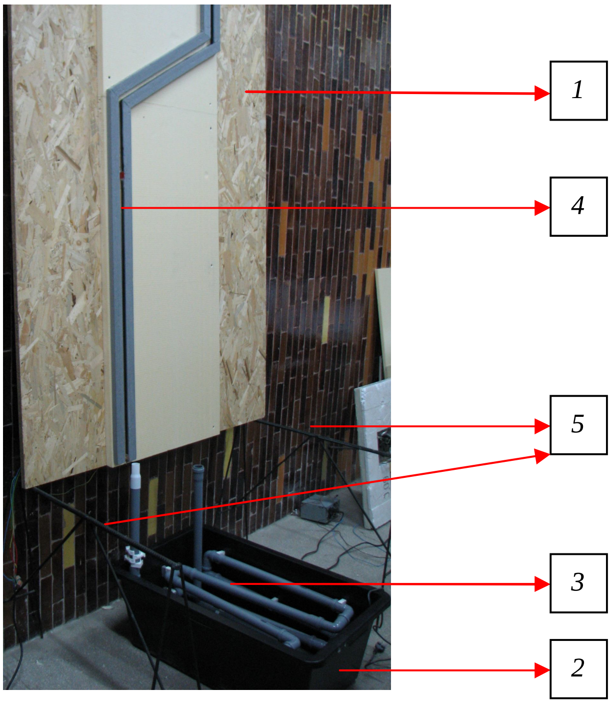

Fig. 5 – Physical model composition: *1* – OSB base plate, *2* – water tank, *3* – PVC pipe in coil, *4* – ventilated façade and roof channel in section, *5* – the metal stand.

The stand is designed and equipped so that it can simulate airflow both summer and winter. Thus, on OSB backing plate with dimensions of 1.00 m × × 2.45 m, are mounted two sets of extruded polystyrene bars, 2 cm width and height of 2 cm, with a cap of extruded polystyrene for isolating perfectly the vertically channel of the ventilated façade model, and the oblique part which simulate roof channel model (Fig. 5).

At the bottom, following vertical channel polystyrene PVC pipe, there assembled shaped coil, with total length of approx. 8 m and diameter of 3.2 cm (sc. 1/5), immersed in an isollated container with water at relatively homogeneous and constant temperature. Opposite end of the pipe, coming out of the water about 30 cm, is situated the absorption mouth of outdoor air. The pipe is sealed to allow air to circulate properly. The entire inner surface of the channel strips are mounted thermocouples connected to an autotransformer, providing temperature conditions required by the experiment scenario. Temperature sensors (thermocouples) are mounted in the key areas of the channel (into and out of PVC pipe in the middle of the polystyrene channel at both heated and cold face, also at the output polystyrene channel and in the water container. Air velocity is measured above the air absorption mouth of PVC pipe. Accordingly, there are two simulated cases: where winter and summer.

3.3. Working Scenarios

Acording to the proposal to use the Grashof criterion of similarity, are considered two different scenarios for the two extreme temperature regimes (winter and summer). Such data are considered as defaults temperatures, described in Table 1.

Winter simulation situation was conducted in the spring season, so laboratory temperature was about 16°C, corresponding to the physical model of outdoor temperature; in reality outdoor temperature is predetermined at –10°C. The temperature difference between these two values (26°C), is necessary to keep unchanged both between interior temperatures in the prototype and the model and also between real underground temperature and water temperature in the model.

Table 1
Limit Temperatures for the Two Cases Simulated by Physical Model

Winter		Summer	
Prototype	Model	Prototype	Model
T_i = 20°C	T_i = 46°C (temp. heated channel)	T_i = 60°C	T_i =53°C (temp. heated channel)
T_e = –10°C	T_e = 16 °C (temp. lab.)	T_e = 33°C	T_e =26°C (temp. lab.)
T_{earth} = 5°C	T_{water} = 31°C	T_{earth} = 13°C	T_{water} = 6°C

Thus, the indoor temperature on warm surface of the prototype “ventilated façade” channel (*i.e.* the outer wall of the house ventilated façade) is assumed to be 20°C, and the interior temperature of the model corresponds to 46°C. Just as winter soil temperature at a depth of 1.5 to 3 m, is relatively constant around 5°C, the model simulated underground environment temperature, *i.e.* tank water temperature, is raised at the 31°C with an immersion, respecting the difference of 26°C.

Similarly, to simulate the situation of summer executed in hot season, it starts from existing laboratory temperature at that time, *i.e.* 26°...27°C, which corresponds to the outdoor temperature in the model. Since summer soil temperature at the same depth of 1.5...3 m is about 13°C, and the temperature on the outside surface of the vented front exceed 60°C, it results a temperature difference of 7°C between the possible temperatures recorded in the model and in the prototipe, as shown in Table 1, right side. Water temperature is brought up to value of 5°...6°C by means of a ice quantity, being kept due to extruded polystyrene insulation on all sides of the tank.

In both cases, the cause of the thermal circulation is the temperature difference between outside air duct (the laboratory temperature) and that of the inside channel, every of attempts is increased gradually with the autotransformer coupled at the electric band heaters.

3.4. Case Study 1: Determination for Winter

Accordingly with the previous data, initially the heating water process in the tank was at 30°C and then starts gradually heating the electrical strips heaters in polystyrene duct. Thus began the temperature measurements of the six areas covered and the air speed that is absorbed into the "Canadian well + ventilated façade", obtaining significant amounts of air velocity (4 cm/s) only after the air ventilated channel temperature exceeded 28°C , *i.e.* a difference of at least 13°C between the inner and outer temperature of the ventilation channel model.

Given the rather slow and late movement of air, it was proceeded to decrease the absorption mouth diameter of PVC tube with a perforated plastic disc at its central hole diameter of 1.5 cm. Thus we obtained an increase of the air velocity in a shorter time and lower temperature differences.

It results that, unlike the first attempt, the same air speed of 4 cm/s is obtained from a difference of only 3°C between the temperatures inside and outside the ventilation duct layout, and get speeds almost three times larger (15 cm/s), approximately the same temperature conditions. If the temperature difference model that starts circulation is around 3°C, thermal circulation means that in reality will begin at much lower temperature difference of approx. $\sqrt[3]{3}$ °C.

To make a qualitative assessment of the "Canadian well" contribution in the air circulation system of "Canadian well + ventilated façade", was performed a set of measurements of air velocity and temperature in the channel, removing "Canadian well" from service, namely the failure temperature condition in the PVC tube, the water remains at room temperature. We obtained similar values of speed (12 cm/s), but start circulation was recorded at 7°C difference between the temperatures inside and outside the channel of the physical model. Hence, there is an improvement of the thermal circulation in the complex system of "Canadian well + ventilated façade", meaning that air circulation is starting at lower temperature difference and air speed is significantly higher.

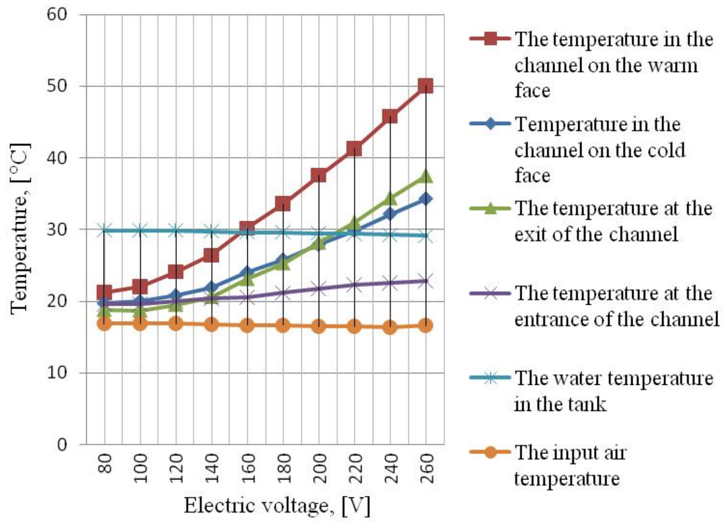

Fig. 7 – Graphic variation of air temperature in the six areas of the ventilation duct with input of Canadian shaft; winter case.

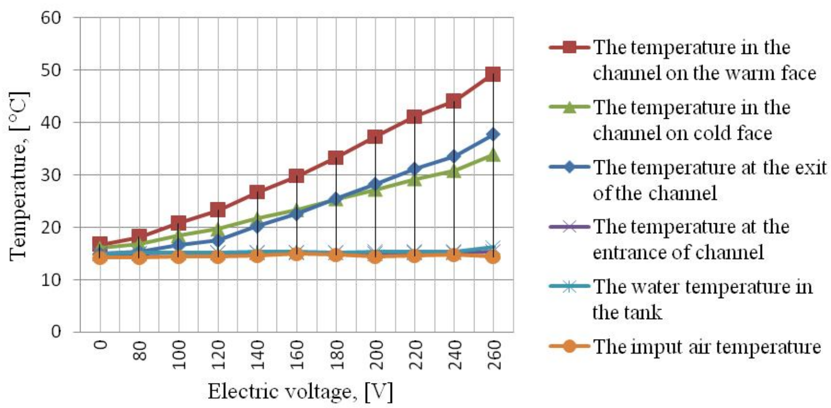

Fig. 8 – Graphic variation of air temperature in the six areas of the ventilation channel without input of Canadian shaft; winter case.

Comparing the graphs from Figs. 7 and 8 it is observed a temperature difference between the curves of temperature at entrance of the “ventilated façade” channel. If the Canadian shaft is activated by heating water, by placing a thermocouple at the end of the PVC coil just before its junction with polystyrene channel, there is a slight temperature increase corresponding to increase in the temperature difference inside – outside.

In this way we can say that the Canadian shaft helps to increase thermal air circulation, given the steady increase in air velocity in the system, compared to its variability in test situation without “Canadian pit”.

3.5. Case Study 2: Determination for Summer

To simulate summer situation have been provided in Table 1 (right side), proportional temperatures, in reality the model also asking heating duct polystyrene air to a temperature of 53°C and more, along with water cooling tank at a temperature of 5°…6°C.

In the previous section was showed the difference between an air circulation simulation model of “ventilated façade” coupled with a “Canadian pit” and the air circulation only in “ventilated façade”. Main parameters showed a positive input shaft of Canadian natural ventilation operation in air speed ventilated façade system and allowed the junction temperature measured before

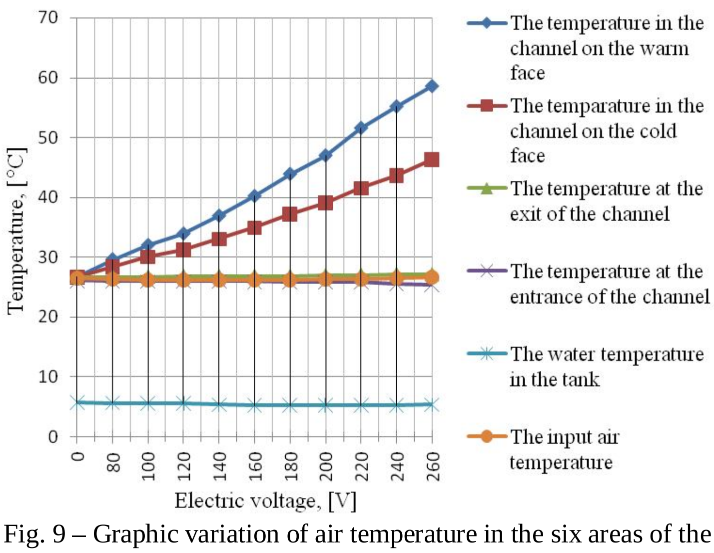

Fig. 9 – Graphic variation of air temperature in the six areas of the ventilation channel with input of Canadian shaft; summer case.

coil “Canadian pit” to channel “ventilated façade”. If in winter the second parameter indicates an increase in air temperature high enough trained through coil immersed in warm water (approx. 30°C), for summer (Fig. 9) the same parameter shows a slight contrast decrease of air temperature passing through the coil immersed in cold water (approx. 6°C).

4. Conclusions

A lot of conclusions can be drawn from measurements on the physical model described above namely

a) Canadian/Provençal shaft, whose implementation and functioning involves a number of advantages and disadvantages, can be optimized both in terms of energy efficiency and its operation.

b) Canadian shaft helps to increase thermal air circulation, meaning that the temperature difference at which starts the air circulation is smaller and with slightly higher air speed and suffer an increasing, unlike the case of non-active Canadian well.

c) Operation of natural air circulation in the "Canadian well+ventilated façade", although it is still possible at a temperature difference of 3°C in the model (much less in prototype), is more effective the more this temperature difference between inside and outside its ventilation channel increases, and this is favoured by the largest possible high and differential pressure between air suction and exhaust levels.

d) Canadian pit participate in the whole building energy savings due to preheated air intake with heat insulating role, but can also improve air quality provided by coupling coil at a ventilated façade system which can include filters technology or system of vertical garden integrated inside the ventilated façade which is itself a filter plant.

REFERENCES

Hake Th., *Offenlegungsschrift.* Deutsches Patent- und Markenamt, DE 10 2004 001 875 A1 2005.08.04, Bundesrepublik Deutschland, 2005.

Purcaru C., *Sick Building Syndrome Treatement Plant Using*. Proc. of Internat. Symp. ”Horticultură – Ştiință, Calitate, Diversitate şi Armonie”, USAMV, Iaşi, May 27-28, 2010, **53**/**1**, 2010.

Purcaru C., Purcaru A., *New Systems for Building Confort*. Proc. of Internat. Symp. ”Horticultură – Ştiință, Calitate, Diversitate şi Armonie”, USAMV, Iaşi, May 24-26, 2012, **55**/**1**, 667-672, 2012.

Purcaru C., *An Overwieu to Energy Savings Solutions for Confort in Buildings – Canadian Well*. Proc. of Internat. Conf. DEDUCON Sustainable Development in Civil Engineering, Iaşi, Nov.11, 2011, **2**, MR 54 –MR 66, 2011.

* * * www.mediaderive.blogspot.ro/2010/07/terraform-1-workshop-part-2-building.htm

CALITATEA AERULUI INTERIOR ŞI VENTILAREA NATURALĂ ÎN CLĂDIRILE DE ÎNVĂȚĂMÂNT

(Rezumat)

În urma unui studiu extins asupra problematicii ventilării clădirilor şi elementelor de construcție, din punctul de vedere al confortului şi al calității aerului, dar şi din punctul de vedere al eficienței energetice, s-a născut şi ideea combinării unor sisteme independente specifice clădirilor pasive într-un concept nou – „fațada-grădină permanentă”. Acest sistem complex, cu avantaje multiple în direcțiile amintite anterior, este alcătuit dintr-o fațadă dublă vitrată având o grădină verticală integrată şi serpentina unui puț canadian/provensal cuplată cu interiorul acestei fațade ventilate, care poate fi la rândul ei continuată cu canalul unui acoperiş şarpantă ventilat. Funcționarea acestui sistem a putut fi testată prin construirea unui model fizic experimental, care să simuleze circulația naturală a aerului prin tubul unui puț canadian/provensal cuplat la canalul unei fațade şi acoperiş ventilate. Rezultatele măsurătorilor pe modelul fizic demonstrează că aerul circulă prin sistem doar datorită diferențelor de temperatură dintre interiorul şi exteriorul canalului ventilat.