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DOUBLE-SKIN FAÇADE OFFICE BUILDINGS IN EUROPE

G. NĂSTASE[1] A. ȘERBAN[2]

Abstract: *Occupants and investors in office buildings ask increasingly these days building designer professionals, be they architects, structural engineers or building services engineers about confortable, healthy, energy efficient buildings that use at maximum free resources, renewable energy sources, performant materials or systems. The multitude of office buildings built with double-skin façade across Europe is a good example in respect these goals, even if is still too little experience of their behavior globally and more so in Romania. This paper aims to provide some examples of double-skin façade from Europe, with the ultimate goal to take into account all its benefits and apply them into our country.*

Key words: *office buildings, glass envelope, double skin façade, energy.*

1. Introduction

Double-skin façades have been developed as a response to provision of fully glazed curtain walls and as an effective way to control light, heat, cold air and noise through the building envelope and also to contribute on reducing energy consumption.

In Europe this system has been installed on several corporate office buildings, innovative, as an appropriate method to save energy and to receive as much sunlight during the day [1]. Installation of these façades is a complex process which requires combining several fields of engineering area and therefore according to the goal of the system is required very close cooperation between those involved in the project, architects, builders, building services engineers, energy auditors etc.

2. Double Skin Façades in Europe

As a basis for further research in this paper was made use of all available literature in our country, on the internet and over time were made visits to several European Union countries, such as Czech Republic, Slovakia, Spain, Belgium, The Nederlands, Austria, Germany and of course in our country, in Bucharest, Timișoara, Iași and Brasov where have been realized real and experimental models.

2.1. Czech Republic

In Czech Republic have been seen many double skin façade buildings but one of the most representative and known is *Fred and*

[1]Building Services Department, Faculty of Civil Engineering, *Transilvania* University of Braşov.
[2]Building Services Department, Faculty of Civil Engineering, *Transilvania* University of Braşov.

Ginger Building (after Fred Astair and Ginger Rogers famous dancers), also known as "*The Dancing House*", because it represents the mentioned couple dancing together. The building (Figure 1) was designed in 1992 and finished in 1996.

Fig. 1. *Exterior façade of Dancing Building, Prague*

The site was originally occupied by a Neo-renaissance house from the end of the 19th century, destroyed during bombing in 1945, its remains finally removed in 1960. The neighboring house (with a small globe on the roof) was co-owned by Czech ex-president Vaclav Havel, who lived there from his childhood until the mid-1990s. He ordered Vlado Milunic to make the first architectural study. Afterwards the Dutch bank ING agreed to build a house there, and asked Milunic to invite a world-renowned architect. Milunic first asked Jean Nouvel, he rejected the invitation because of the small size of the site (491 square meters); he then asked Frank Gehry, and he accepted the challenge. Gehry had an almost unlimited budget, because ING wanted to create an icon in Prague [2].

2.2. Spain

In Spain were visited in November 2011 two buildings in the city of Barcelona, *Torre Agbar* (Figure 2) and *Interface building* (Figure 3) both located in the Glories part of town.

Torre Agbar building was designed by French architect Jean Nouvel in association with the firm B720 Arquitectos, headed by Fermin Vásquez, is the headquarter of **Ag**ua de **Bar**ceona, has 35 floors and an overall height of 142 meters. The building is located in Barcelona, next to Plaça de les Glòries, between Avingua Diagonal and Carrer Badajos. This building's double skin façade consist of an inner concrete façade, upon were mounted boards painted in red, blue, green and grey, with integrated windows in the wall's structure and an exterior façade made of laminated glass modules, anchored by a steel structure on the interior concrete façade.

Fig. 2. *Exterior façade, the inner cavity and overview of Torre Agbar, Barcelona, Spain*

The tower has 4500 windows to maximize natural ventilation and reduce energy costs by optimizing the use of sunlight. Energy consumption for air conditioning is reduced by using external temperature sensors, which controls the

opening and closing tabs on the outer façade, adjusting the flow of fresh air in cavity, which enters then in the building, thus making natural ventilation.

Interface Building was designed by the design studio Battle i Roig Arquitectes, led by architects Enriq Battle and Joan Roig, and is the headquarter of several companies in the field of Information Technology and Telecommunications, has 14 floors and an overall height of 52 meters. At this building, the double-skin façade is more like a curtain wall with a fixed glass exterior façade opened on all sides [3].

Fig. 3. *Side view, front view and under the cavity, Interface Building, Barcelona, Spain*

The outside glasses on this façade are disposed upward, as can be seen in Figure 2, to create a beautiful architectural effect, and at every level in the cavity is a metallic platform to pass by.

2.3. Belgium

In Belgium were visited in March 2012 four buildings in the city of Brussels, *Berlaymont* (Building of European Commission), *Brussimo* building, *DVV office building* on the street Joseph II no. 96 and *North Galaxy* building.

Berlaymont hosted since its construction (1963-1969) European Commission and has become a symbol for the Commission and for the Europeans by its presence in Brussels. The Commission itself is divided into about 60 "strange" buildings but Berlaymont is the headquarter of the institution, the seat of the European Commission President and its Board of Commissioners.

The building has a cruciform design, with four wings and different sizes that start from a central core, and this design is intended to convey a sense of light and transparency. The design includes and other decorative design details such as carvings and frescoes, to prevent it from becoming monotonous.

The building now has 240,000 m^2 of floor, 18 floors, connected by 42 lifts and 12 escalators. Offices for the 3000 officials and meeting rooms are in the tower. And restaurant services, cafeteria with 900 seats, TV studio, conference rooms, storage rooms, sauna, parking for over 1,100 cars occupy the basement and other various services.

The architects Pierre Lallemand, Steven Beckers and Wilfried Van Campenhout conducted renovation during 1991-2004.

The façade was replaced with a double-skin façade with movable screens that adapt to weather conditions and reduces glare, while still allowing light to penetrate inside. It also acts as a sound barrier, reducing noise came from the Rue de la Loi. Windows cancels air conditioning, when open, to prevent energy waste. Offices, which are currently bigger, have a heating system that can adjust automatically or manually, and automatically turns off when they are unoccupied.

The exterior façade on *Berlaymont* building (Figure 4) is a blinds type, as in *Torre Agbar* building, in Barcelona, Spain. Inner envelope is composed of double glazed windows. The outer envelope is

made of a series of suspended frames, which are glass plates (200 cm by 50 cm), not all with the same thickness (8 mm at the bottom and 12 mm at the top of the facade) because of their sizing against the wind [4].

Fig. 4. *Front view, side view and overall view, Berlaymont Building, Brussels, Belgium*

Glass slides that form outer envelope are composed of two layers of glass separated by a perforated multilayer film showing a white face to the outside for better light reflection. On the inside blinds have a dark side, to allow visibility through them. The lighting contrast being positive, visibility is possible from the inside out, but it is impossible to reverse.

Brussimmo office building (Figure 5), the headquarter of the European Commission for Freedom of Movement. The site reveals a notable building, placed in the heart of Leopold district, the centre of business activities in Brussels and close to the main European institutions. Because of its location, the site is exposed to noise, dust and other pollution. The building had to be suitable for any kind of organization offices, from individual offices to a fully open plan arrangement, including concepts such as the Scandinavian "combi offices," which proved so effective and easy to use. Particular attention was paid to the architectural quality of underground parking area, as it is often the first contact of visitors with the building.

The concept was so designed to:

- Easy installation electrical of mechanical equipment, independent of partitioning;
- Simple change partitions without damaging the ceiling and soundproofing enough in enclosed spaces;
- Installation of equipment compatible with the current needs of large international companies;
- A quiet and pleasant working environment;
- Competitive performance of the project from a financial standpoint.

The building comprises a ground floor with reception area, a first floor with meeting offices and waiting areas, five floors with standard offices and level seven, which is half semi-cylindrical shape, which serves as a technical space [5].

Fig. 5. *Double-skin façade on Brussimo building, Brussels, Belgium*

The building is equipped with double glass façade, with the following

advantages:

- Sound insulation is very good;
- A glass exterior facade, easy to maintain;
- Using transparent windows, which practically do not affect the comfort or the temperature inside the building;
- A large influx of natural light, through facades that are completely build with glass, from bottom to top;
- Easy distribution of mechanical and electrical parts.

Ex-*DVV* office building (Figure 7), placed on Joseph II building on the street, at no. 96 is a double-skin façade building, type "box" with mechanical ventilation and inside curtain airflow.

The building was started in 1993 and was completed in 1995, in april, and is a five-storey extension office of DVV insurance company, which since 1990 has increased the number of operations and thus the necessity of an extension appeared due to overcrowding the headquarter. Choosing "box" type windows was motivated by considerations of energy conservation, and good thermal and acoustic insulation. Windows are an integral part of the HVAC system with forced air circulation. In this building air conditioning is discharged into the room at floor level through discharge holes with variable flow control, which incorporate also an electric resistance for heating shortfall. In Figure 6 can be seen the box type double façade system box coupled with the building's HVAC system.

Warm air is taken from the top, through a system of pipes and sent to the window cavity, which runs through and returns to the bottom of the HVAC system. Air can be recirculated or can be exhausted.

Design airflow to be circulated through the cavity varies between 100 and 140 m^3/h m window width.

Exterior glass is a double glass type window with thermal break aluminium joinery and the interior glass is a single safety glass panel simple. In the cavity, the shading device like roll is placed about 8 cm from the inside window.

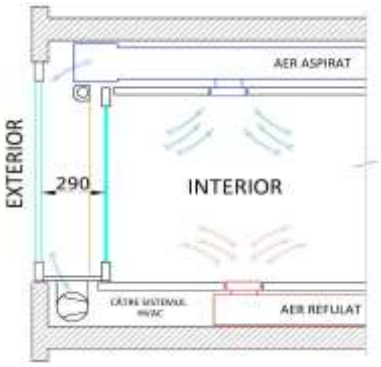

Fig. 6. *Air flow through DVV building's façade, Brussels, Belgium. Drawing not at scale.*

Fig. 7. *Double-skin façade, "box" type (southwest cardinal direction), DVV extension building, Brussels, Belgium*

North Galaxy complex was designed by the architectural offices group M. & JM Jaspers - Eyers & Partners, Art & Build and Montois & Partners, the buildings were built mostly of prefabricated and currently, Galaxy North offices complex is one of the largest real estate projects in Brussels.

North Galaxy Towers (Figure 8), located on the Boulevard Roi Albert II, Brussels,

Belgium have 28 levels each with two technical levels on top of each. The building is accessible through a majestic entrance, which is elliptical, with a double glass façade as a key feature. The windows are 13 m in height and hangs by tensioned cables using a steel structure from the roof to below ground floor [6].

Fig. 8. *Detail and overall double-skin façade from North Galaxy Towers entrance, Brussels, Belgium*

2.4. The Nederlands

In the Netherlands, at Amsterdam has been viewed *ABN-AMRO Bank Headquarters* building (Figure 9) located in the south of the city.
The building is one of the top 10 tallest buildings in Amsterdam, with a height of 105 m and 24 floors.

The façade of this building includes cavity ventilation, automatic blinds, heat recovery system in the building and lighting adjusts automatically depending on the occupancy and the level of brightness, thereby reducing energy consumption.

Fig. 9. *Views of double-skin façade, headquarters of ABN AMRO Bank, Amsterdam, Netherlands*

2.5. Austria

In Austria, Vienna has been viewed *IBM building* (Figure 10), located at Obere Donnaustraße 95, near the Danube Canal, which was built in 1969 and restored by architect Rudolf Prohazka in 1999-2001. Renovation of existing front consisted of mounting of a double glass façade, covering an area of 1000 m^2, to reduce energy consumption for cooling and heating. Outer envelope is slightly curved outward, as can be seen in the picture below.

Fig. 10. *Front view of IBM building's double skin façade, Vienna, Austria*

In the same area, just near IBM is building a *Raiffeisen Bank* with double glass façade (Figure 11) that allows good natural ventilation of the building. Construction is almost complete and is

intended to be a reference building in resource conservation, energy efficiency and environmental protection. Flagship office building was designed by architects Dieter Hayde, Ernst Maurer and Radovan Tajder and is modeled after the concept of "Raiffeisen Klimaschutz-Initiative" (Raiffeisen climate protection initiative) [7-8].

Fig. 11. *Double-skin façade of Raiffeisen Bank in Viena, Austria*

Also, has been viewed the *UNIQA Tower* (Figure 12), headquarters of insurance company UNIQA Group Austria, completed in 2004 and designed by the Austrian architect Heinz Neumann.

Fig. 12. *UNIQA tower's double skin façade, Vienna, Austria*

This building is the first building in Austria, which has been awarded with a "Green Building" certificate. UNIQA tower's double-skin façade allows the natural ventilation inside through windows. At the same time provide sound and thermal insulation, provide natural light inside the building throughout the year, and use the sun's heat during the winter, through the greenhouse effect achieved within the cavity. In order to maximize natural light without too much heat building, building management system adjusts the blinds, light according to need.

2.6. Germany

In Germany, at Nuremberg have been visited two double glass façade buildings: Business Tower and NCC Nuremberg building (Nürnberg Convention Center) from Nürnberg Messe.

Nuremberg Convention Center (NCC) is one of the most modern facilities for conducting conferences and one of the 20 largest sites in the world, to support international exhibitions. This building is complemented by 160,000 m^2 of exhibition space adjacent and offers seating capacity for 11,000 participants.

NCC building from Nürnberg Messe (Figure 13) is built with double-skin façade that allows natural light into a very high proportion, thus providing an open and communicative atmosphere, thus achieving optimal conditions for events for which it was made construction, but is also energy saving.

In the pictures above you can see some details of the double façade, such as inside the cavity, air intake valves from the bottom of the cavity, indoor unit for heating, embedded in the floor, right next to the inner glass of double facade.

To monitor double glass facade NCC has its own weather station, so regardless of the weather outside, inside the climate is pleasant and comfortable one.

The building was designed by S + P Gesellschaft von Architekten mbH, led by architect Heinz Seipel and was completed in 2005 [9].

Fig. 13. *Photo from inside the double glass facade of NCC building from Nürnberg Messe complex and view of floor heating unit.*

The next building viewed from Nuremberg, Germany, was the tower of 135 meters and 34 floors Nürnberg Business Tower (Figure 14), designed by architects Friedrich Biefang, Dürschinger and Jörg Peter Spengler and was built in June 1996 - October 2000 [10].

The tower is equipped with double glass façade, allowing its natural ventilation, at every level, despite its height and it was no longer necessary to install an air conditioning system, thereby achieving maximum economic and environmental efficiency.

The building has one of the largest and most powerful type network LON (Local Operating Network) in Europe, whereby Building Management System (BMS) process the data coming from the 120,000 points of the network hardware and software. This system allows individual control, each room lighting levels, heating system, air exchange, etc.

Fig. 14. *Overview of Business Tower Nuremberg, Germany (left) and double-skin facade detail (right).*

2.7. Romania

In our country until now have been realized 3 experiments with double skin façade, two in Iasi city, one conducted by Mr. Nelu-Cristian Chereches at Building Services Faculty from Gh. Asachi University of Iași and the other conducted by Mrs. Chereches Monica at INCERC Iași. The third is in Brasov, on Civil Engineering Faculty, on Transilvania University.

Fig. 15. *All three experiment of double-skin façade in Romania*

It can be seen in Figure 15 above those three experiments, which are all focused to determine the heat transfer through such system in our climatic conditions.

Also in our country, in Bucharest, in 2008 it began construction of the first building with double glass facade in Romania, namely tower *Crystal Tower*, Figure 16, on Boulevard Iancu de Hunedoara 48 and was completed in 2011. The tower has a height of 72 meters and offers a modern and stylish design that is placed in the area, was designed by the team leader Prof. dr. Arch. Adrian SPIRESCU.

Fig. 16. *General view of Cristal Tower in Bucharest, Romania*

With high architectural standards and technology, efficient office space, and with a focus on environmental sustainability and energy savings, the project is the perfect combination of functionality, flexibility and friendly atmosphere.

Double skin facade mounted on the building is saving both in terms of energy consumption of the ventilation system but also on heating and cooling, all leading to reduced maintenance costs for the building.

The energy needs of the building is 99.7 kWh / m^2 / year, while the primary energy needs of a building in the same category is standard 153.94 kWh / m^2 / year overall coefficient of heat transfer is K = 0.73 W / m^2K, the total thermal resistance in this case is R = 1.369 m^2K / W.

As standard, the building has a system of central heating with gas, hot water is produced by electric boilers, cooling is produced using a reversible heat pump VRV system, the ventilation system is in double flux with heat recovery and do not exist renewable energy conversion systems.

The building have a next-generation BMS, which controls, monitors and optimizes building facilities, shading system, mechanical and electrical equipment for comfort, safety and efficiency [11].

Another double skin façade building is in *City Business Center Complex Buildings* (Figure 17) which includes a series of 5 buildings. The buildings are placed downtown Timisoara in the vicinity of the historical Union Square and Victoriei Square.

Fig. 17. *General view of City Business Center, Timișoara, Romania*

3. Conclusions

Since the concept of double-skin facade is complicated, and the use and operation of such a system affects internal parameters of the building (which often interact with each other, such as energy use, natural ventilation, lighting, indoor air quality, acoustics, environmental, visual and thermal comfort, etc.) literature studies it from various directions. It was considered important to overview a few important buildings in Europe, which have installed this type of system, to see similarities and differences between them so they to be analyzed from several points of view.

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