PROCEEDINGS OF INTERNATIONAL CONFERENCE ON ADVANCED TECHNOLOGIES

11th International Conference on Advanced Technologies, ICAT'23
Istanbul, TURKIYE, August 17-19, 2023

Editor
Omer Faruk BAY

International Conference on Advanced Technologies, **ICAT'23**
Istanbul, TURKIYE, August 17-19, 2023

PREFACE

11th International Conference on Advanced Technologies (ICAT'23) has been organized with success in Istanbul, TURKIYE on August 17-19, 2023.

The main objective of this conference is to provide a platform for researchers and academicians from all over the world to present their researches and professional development activities. This conference provides opportunities for the delegates from the electrical and computer engineering areas to exchange new ideas and to establish business or research relations and to find global partners for future collaboration.

All paper submissions have been double blind and peer reviewed and evaluated based on originality, technical and/or research content/depth, correctness, relevance to conference, contributions, and readability. Selected papers presented in the conference that match with the topics of the journals will be published in the following journals:

• International Journal of Applied Mathematics, Electronics and Computers (IJAMEC)

• International Journal of Automotive Engineering and Technologies (IJAET)

• International Journal of Energy Applications and Technology (IJEAT)

• Intelligent Methods in Engineering Sciences (IMIENS)

• Tribology and Materials

At this conference, there were 187 paper submissions. Each paper proposal was evaluated by two reviewers, and 122 papers were accepted. 18 of the participants (%23) have attended from Turkiye. Totally 76 papers were presented at the conference from 28 different countries (Algeria, Australia, Brazil, Bulgaria, Canada, Finland, Germany, Greece, Hungary, India, Italy, Japan, Korea Republic of, Latvia, Macedonia, Mexico, Myanmar, Namibia, Palestinian Territory, Poland, Romania, Russian Federation, Saudi Arabia, South Africa, Spain, Taiwan, Turkiye, United States).

We thank to Plusbase Ltd. Sti, and colleagues in our conference office. They have made a crucial contribution towards the success of this conference.

Looking forward to see you in next ICAT.

Omer Faruk BAY
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Double Skin Façade Mechanical Systems as Advanced Building Technologies

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Abstract— **The double-wall façades (or "double skin façades") are determined as building mechanical and engineered systems realized by the cavity between the inner curtain and the outer screen, for thermal and acoustic insulation, for ventilation and for the insertion of functional devices (such as sunscreens) and, also, plant ducts. The cavity between the two enclosures constitutes a ventilated cavity that can be used according to certain modes of functioning (passive or active type) aimed at controlling external climatic and environmental stresses in order to regulate the conditions of the interior spaces. The double envelope system is realized as an apparatus of mediation and reaction towards environmental loads, according to the needs of well-being and reduction of energy consumption. In general, the system offers the functioning in the form of a passive solar system, assuming the use and accumulation of solar radiation for the regulation of indoor thermal comfort conditions, and the functioning for the capture and input of air flows. The calibration of solar radiation is integrated with the use of shading devices in order to achieve diffuse lighting conditions in interior spaces. In addition, the application of the double glass surface reduces thermal losses from the interior spaces by reducing the speed of the airflow in contact with the inner curtain, increasing thermal insulation. The system foresees that the ventilated cavity performs various integrated functions (for the definition of complex mechanisms of dynamic interaction with the external climatic conditions), both permanent (e.g. for the increase of thermal inertia and acoustic insulation relative to the internal curtain) and temporary (e.g. for the cooling of the same spaces during periods of high temperature).**

Keywords— **Double skin façades, Environmental and energy sustainability, Interaction and perceptive mediation, Technical skins**

I. INTRODUCTION

The double wall façade system (or "double skin façade") is determined in the transition from the continuous curtain wall to the multilayer type, articulating the specific performance of the levels and the relative technical elements: this with the possibility of realizing the interspace between the two walls for thermal and acoustic insulation, for ventilation and to apply functional devices (such as, for example, sunshades) and also plant ducts. The double envelope constitution provides the use of a screen (or "second skin", in general, made of glass) outside the vertical enclosure, with the aim of optimizing the functions allowed in the cavity: this is through the additional application of a glass enclosure in front of the curtain wall or the external building curtain (in general, equipped with openable frames), in the form of a ventilated cavity that can be used according to certain modes of operation (passive or active type) aimed at controlling external climatic and environmental stresses to regulate the conditions of the internal spaces [1] [2].

The examination detects the prospects of "dynamic interaction" between the double envelope system and the external environment, observing the criteria aimed at realizing built spaces in a stable and balanced manner, with the possibility of transmitting, modifying or rejecting climatic stresses. The double-envelope system typology is understood as an "interchange" tool for the ability to respond to external loads through the development of different functional levels and the use of means of regulation to manipulate interactions with the environment. Furthermore, this typology is applied as:

- the mediating and reacting apparatus, specifying the "sensitive" type of functioning that acts with adaptive and control capacities, according to the needs of well-being and reduction of energy consumption [3];
- the "programmable" surface apparatus, capable of interpreting the functions and needs of users in an *eco-efficient*, selective and multi-purpose form, with respect to the control of temperature, humidity and ventilation levels, perception towards the outside and lighting levels [4].

The technical and typological definition of this system can be calibrated with respect to the activities inside the built spaces, referring to the main external environmental and micro-climatic parameters (such as, for example, the intensity of solar radiation and its distribution) and internal ones (such as the temperature of the air and the perimeter vertical curtains, relative humidity, air speed and its quality) [5] [6]. The composition of the double envelope system considers:

- the functioning in the form of a passive solar system (in general, through the capture of radiant energy, the reduction of heat dispersion, the possibility of heat accumulation in the form of a thermo-insulating air chamber and, therefore, of heating the air section by the "greenhouse effect", the increase in lighting performance), based above all on the thermo-building principles inherent in the control of air flows in the cavity (by means of parietodynamic transfer processes). In this regard, the system assumes the use and accumulation of solar radiation for the regulation of indoor thermal comfort conditions, together with the possibility of a reduction in the use of heating systems [7];

- the functioning in the form of a system for capturing and injecting air flows (whereby the amount of air exchanged between the external environment and the cavity depends on the temperature gradient, wind pressure and the size of the ventilation slots), in general:
  - the passive type, by capturing convective flows close to the façade plane (by means of profiles and devices with aerodynamic geometry and openings), their introduction into the cavity between the internal and external closures and the conduction of convective flows by the "chimney effect" (due to the rise in temperature due above all to solar radiation) in an upward direction until they reach the internal spaces (considering the possibility of reducing the use of air-conditioning systems for cooling);
  - of the active type, with the use of electro-commanded equipment to generate the aeration of convective flows in the cavity between the internal and external enclosures (such as, the fans for the conduction of air flows) (Fig. 1);

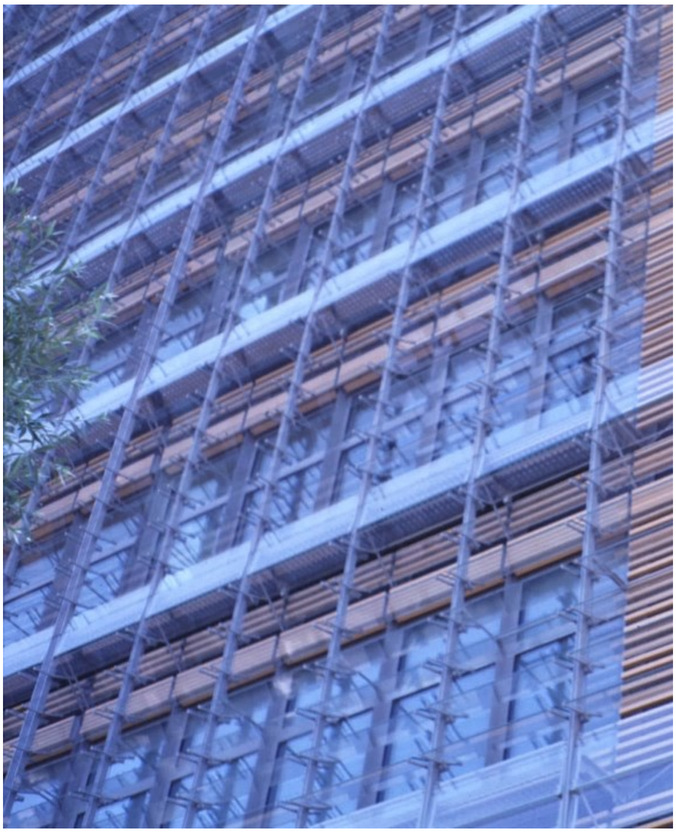

Fig. 1 Renzo Piano Building Workshop, *Debis-C1* Building, Potsdamer Platz sector, Berlin. Functional and environmental expression of the façade components: the outer membranes made of glass sheets create, when closed, a thermal and sound-absorbing storage cavity and, when open and regulated, a filtering function with respect to incident wind loads © by the Author

- the calibration of solar radiation, in an integrated manner with the use of shading or diffusing devices, in order to obtain diffused lighting conditions in interior spaces (capable of limiting the use of artificial light, achieving energy savings of 60-70%). These devices, placed in the cavity (protected from atmospheric pollution and bad weather), keep the heat absorbed by solar radiation outside the built spaces and determine:
  - the accumulation of heat aimed at increasing the temperature of the air in the cavity, the flow of which is directed upwards, until it is expelled (through the ventilation devices);
  - the accumulation of heat outside the built space, limiting air conditioning loads and reducing the need for cooling.

The calibration of solar radiation can be specified through the use of devices capable of transmitting, reflecting and diffusing natural lighting in interior spaces [8] [9] [10] (Fig. 2).

Fig. 2 Norman Foster and Partners, *Swiss Re* Tower, London. Type of enclosure enveloping the cylindrical tower, streamlined and tapered according to a progressive double-curved conical winding. The enclosure, warped by the diagonal lattice construction, is composed of the double envelope system that generates an upward air flow (stimulated by the "chimney effect" and increased by the thermal gradient between the temperature in the cavity and the temperature of the incoming air) © by the Author

II. The Functional, Executive and Mechanical Configuration of the Double Skin Façade

A. *Technical Functioning and Environmental Interaction*

The application of the double-glazed surface makes it possible to reduce thermal losses from internal spaces, by reducing the speed of the air flow in contact with the internal curtain, increasing thermal insulation: therefore, the reduction in thermal transmission makes it possible to maintain the glass surfaces at a temperature close to the values of the average internal ambient temperature, so as to make the adjoining spaces more comfortable [11]. The change of air inside the cavity increases in direct proportion to solar radiation, since the airflows that lap the façade are heated by the elements that make it up: therefore, convective circulation and the amount of evacuated heat increase according to the intensity of solar radiation, so that the interior spaces are ventilated even in difficult climatic conditions [12]. During the winter season, the cavity inside the double envelope systems acts as a passive heating device through the accumulation of heat (due to solar radiation), sheltering the internal surface from the effects of low temperatures and improving the thermal insulation of the curtain wall (Figs. 3, 4).

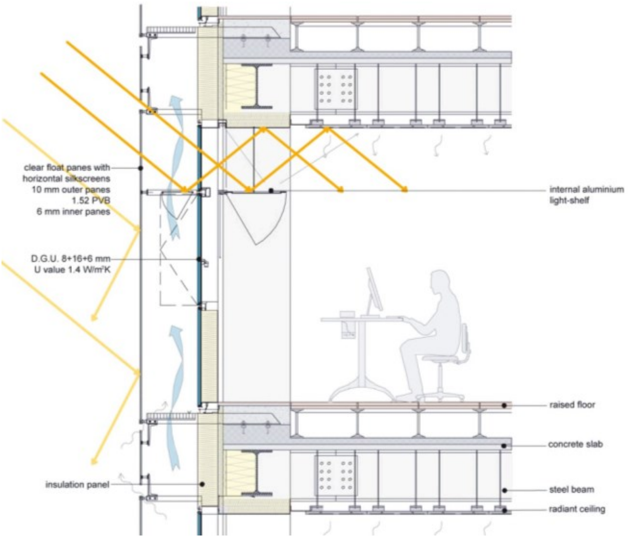

Fig. 3 Mario Cucinella Architects, *SIEEB*, Beijing. Application of the "double wall" envelope supplemented by horizontal reflective elements in the form of light shelves, for the calibration and diffusion of natural light into the interior spaces © Courtesy of Mario Cucinella Architects

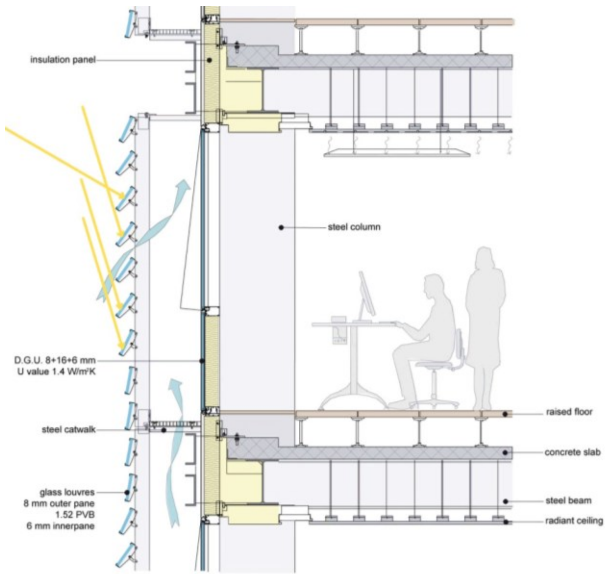

Fig. 4 Mario Cucinella Architects, *SIEEB*, Beijing. Application of the envelope with reflective glass louvres, in addition to the glazing curtain, based on the angle of inclination to the control of solar radiation © Courtesy of Mario Cucinella Architects

The double envelope façade system is defined, principally, through the use of prefabricated cellular façade components, equipped with adjustable operating modes according to the external micro-climatic conditions and the heating or cooling requirements of the internal spaces. The system foresees that the ventilated cavity (wide = 20÷120 cm) performs various integrated functions (for the definition of complex mechanisms of dynamic interaction with the external climatic conditions) as:

- the permanent typology, for example, for the increase of thermal inertia and acoustic insulation relative to the internal curtain;
- the temporary typology, for example, for the disposal of water vapour accumulated in the internal spaces during periods of reduced environmental temperature or for the cooling of the same spaces during periods of high environmental temperature [13].

B. *Composition of the Double Skin Façade System*

Specifically, the double skin façade system is composed of:

- the frame and connective apparatuses with the main load-bearing structures;
- the internal curtain wall system consisting, in general, of double-glazed sheets (with low-emissivity film insertion), in order to avoid the phenomena of both surface condensation of water vapour (on the internal sheet, since, in this situation, the temperature is in any case higher than the external temperature), and overheating (especially during the summer). In this case, it is not possible to foresee direct openings towards the ventilated cavity (also for the placement of the shielding devices), foreseeing the use of sliding or vasistas type openings (towards the inside);
- the cavity interposed between the two closing walls, aimed at the accumulation of thermal energy related to solar radiation and/or aimed at determining the upward motion of the air flow (which also performs the function of an insulating layer), according to the operation referred to:
  - the periods of reduced environmental temperature, for which the air contained in the cavity creates a *buffer zone* (functioning by "greenhouse effect", providing for the enclosure of the ventilation slots) characterized by the intermediate temperature between the external and internal climatic conditions;
  - the periods of high environmental temperature, whereby the air contained in the cavity is set in upward motion (by the "chimney effect") through the absorption of solar radiation by the glass walls, by the shading devices and by the additional connective elements, usually metallic (which re-radiate the radiation itself): in this way, the flow transports and evacuates the accumulated heat towards the outside (for an amount equal to 25% of the heat resulting from the radiation directed into the cavity);
- the air flow regulation devices and the ventilation louvers, located near the deck sections that are connected to both the external screen (for the entry and exit of air flows from the environment to the cavity), and to the internal curtain (for the entry and exit of air flows from the cavity to the internal

spaces): these louvers can be constantly open (for the realization of a passive system) or they can be controlled by means of a centralized management system (for the realization of an active system) with the aim of also regulating the temperature and air speed [14] (Figs. 5, 6);

Fig. 5 Maurizio Varratta, *iGuzzini Lab*, Recanati. Assembly of air flow regulation devices and ventilation louvers, located near the deck sections that are connected to both the external screen and to the internal curtain © Courtesy of Pichler Projects

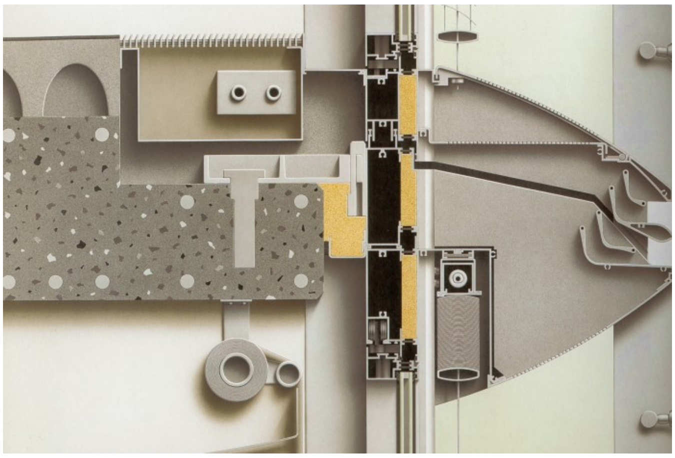

Fig. 6 *Ingenhoven Overdiek und Partner*, *RWE* Building, Essen. Application of the louvers that can be constantly open (for the realization of a passive system) or they can be controlled by means of a centralized management system (for the realization of an active system) © Courtesy of Ingenhoven Overdiek und Partner

- the transversal baffles, placed horizontally or vertically to the façade plane, which typologically and functionally delimit the contiguous components of the system, necessary for:
- the aerodynamic control for the inflow, conduction and outflow of air flows;
- the separation between component units, in order to prevent the outflow of air from one unit being reintroduced into the ventilation duct of the contiguous unit, guaranteeing the inflow of air from the outside without the risk of it being affected by the air expelled (Fig. 7);

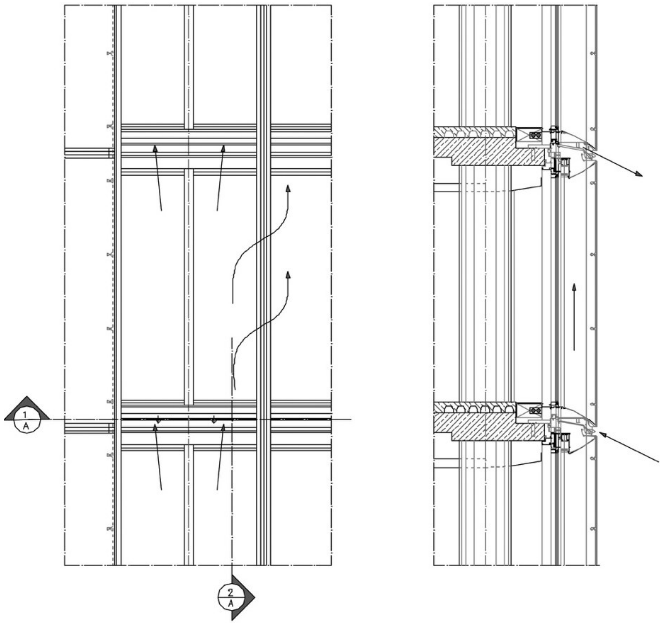

Fig. 7 *Ingenhoven Overdiek und Partner*, *RWE* Building, Essen. Assembly of transversal baffles, placed horizontally or vertically to the façade plane, which functionally delimit the contiguous components of the system © Courtesy of *Ingenhoven Overdiek und Partner*

- the solar shading devices (in an adjustable form), placed inside the cavity and, therefore, protected from atmospheric agents and external pollutants: these devices reduce the heat input according to the external temperature and solar radiation conditions, being particularly effective when the external temperature is lower than the temperature of the internal spaces and for low values of total radiation;
- the external screen, in the form of a totally or partially transparent façade, made up of monolithic tempered or double-glazed glass panes: this screen, in addition to allowing the creation of a ventilated cavity or as a *buffer strip* for thermal accumulation and insulation, reduces wind pressure and allows the opening of windows relative to the internal curtain (allowing the exchange of air by natural ventilation) [15] (Figs. 8, 9).

The functioning of the double envelope system, for example, provides that:

- during the summer season, by the day, the vertical passive ventilation conducts upwards the heat generated in the external cavity, recalling (through the opening of the window relative to the external curtain) the flow of air consequent to the opening of the window in the opposite and parallel curtain wall section;

- during the summer season, by the night, the vertical passive ventilation recalls the flow of air resulting from the opening of the window in the opposite and parallel curtain and conducts it (inside the internal false ceiling) up to the cavity, cooling the internal spaces;
- during the winter season, with the closure of the windows and the covering of the open horizontal grid, the thermal accumulation chamber creates (due to the "greenhouse effect") a heated air section (directed to the heating of the internal spaces) and thermal insulation (Fig. 10).

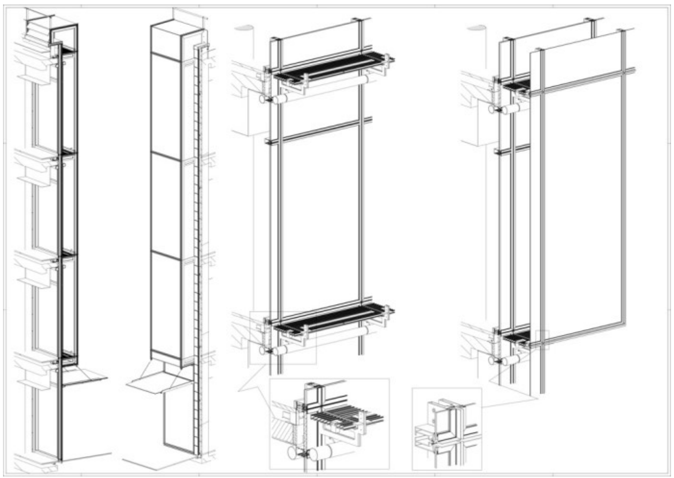

Fig. 8 Maurizio Varratta, *iGuzzini Lab*, Recanati. Assembly of solar shading devices inside the cavity, reducing the heat input according to the external temperature and solar radiation conditions © Courtesy of Pichler Projects

Fig. 9 Maurizio Varratta, *iGuzzini Lab*, Recanati. Application of the external skin to the main cutain wall, reducing wind pressure and allowing the opening of windows relative to the internal section (even at high levels of the building) © Courtesy of Pichler Projects

Fig. 10 Maurizio Varratta, *iGuzzini Lab*, Recanati. Assembly of the external screen, in the form of a totally or partially transparent façade, made up of monolithic tempered or double-glazed glass panes: this skin allows a ventilated cavity or as a *buffer strip* for thermal accumulation and insulation © Courtesy of Pichler Projects

III. THE FUNCTIONAL AND TYPOLOGICAL CONSTITUTION OF THE CONTINUOUS AND DISCONTINUOUS DOUBLE SKIN FAÇADE

C. *Double Skin Façade System with Continuous Cavity (Multistorey Façade)*

The double envelope façade system with continuous cavity (or *multistorey façade*) is composed according to the homogeneous and progressive development of the cavity interposed between the internal enclosure and the external skin, considering, with respect to the traditional "ventilated wall" configuration, the possibility of segmenting and articulating the façade by means of adjustable openings: this for the introduction and for the expulsion, even partial, of the convective flows contained during the upward flow (in any case generated by the "chimney effect"), on the basis of appropriate geometric adjustments aimed at confirming the dynamic continuity and avoiding the occurrence of intermediate turbulence. The application of the double envelope system, in the case of the continuous cavity façade, is determined with respect to the development of functional and adjustable equipment by means of the activation of mechanical devices, aimed at regulating the transmission of heat, light and natural ventilation, together with the attenuation of external wind and acoustic loads [16] (Fig. 11).

The double envelope systems operate with respect to two functioning models:

- the winter functioning, with the aim of exploiting the heating of the air mass present in the cavity to transfer the heat to the interior spaces; that is, with the objective of directly

distributing the accumulated heat, through the natural thermo-circulation established by vertical convective flows;
- the summer functioning, with the aim of avoiding overheating of indoor air by removing the heat and transferring it outside (Figs. 12, 13).

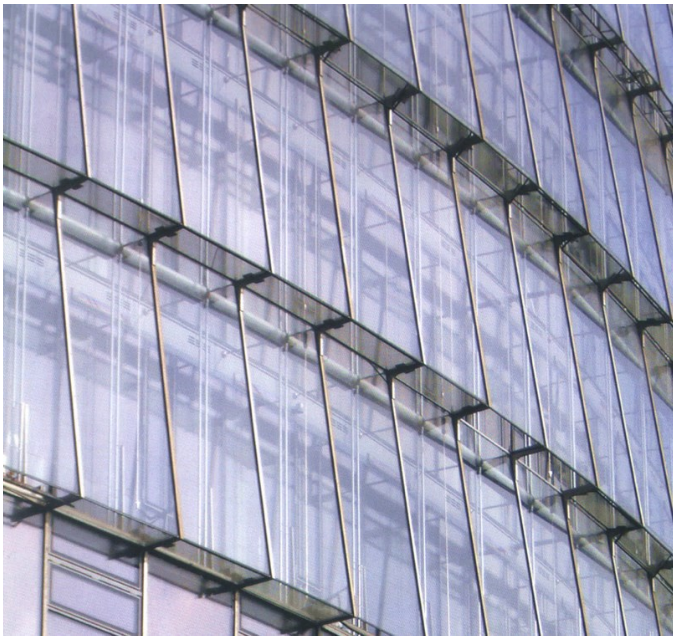

Fig. 11 Helmut Jahn, *Post Tower*, Bonn. Segmented external shading skin (south elevation), framed by linear vertical and horizontal aluminium profiles, that creates a visual and functional membrane to the internal curtain wall © Courtesy of Helmut Jahn

Fig. 12 Helmut Jahn, *Post Tower*, Bonn. Connection of the shading to the building curtain made either through the assembly, with shaped profiles, to the brackets integrated by the ventilation grilles © Courtesy of Helmut Jahn

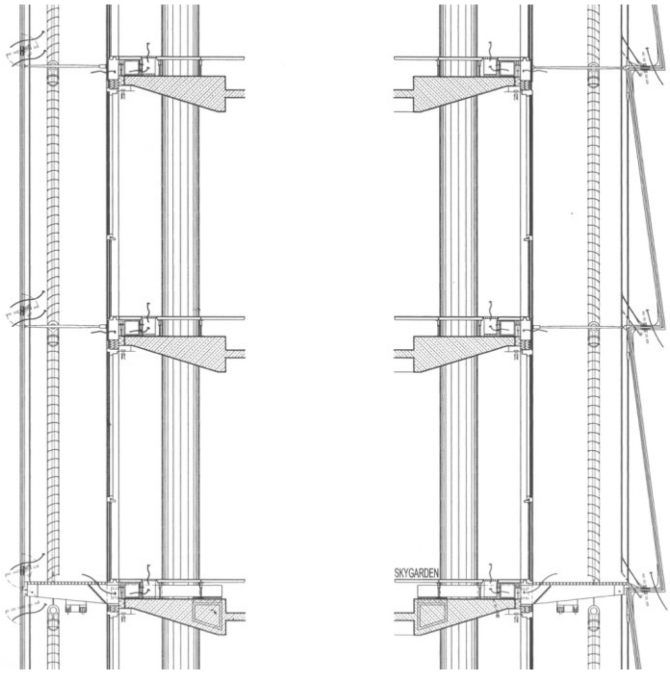

Fig. 13 Helmut Jahn, *Post Tower*, Bonn. Double envelope systems, consisting of the inner curtain wall with linear external shading for the north elevation and segmented for the south elevation, that involve the natural ventilation of the cavity by capturing air flows through adjustable louvers applied to the lower sections of the outer screens © Courtesy of Helmut Jahn

The cavity of the double envelope (as a ventilated duct) reduces the need for heating and mechanical cooling. This equipment generates an upward air flow, which is also increased by the thermal gradient between the temperature in the cavity, the temperature of the incoming air and the "chimney effect" produced by the transparent curtain at the perimeter: this with respect to the objective of reducing heat during hot periods and controlling energy losses, water vapour flows and frost formations on the façade plane during cold periods. In the case of the external shading configuration, the functioning of the system provides that:
- during the winter period, the glass blades are closed: the solar radiation, heating the air in the cavity, generates a heat-insulating layer (due to the "greenhouse effect") which contributes to maintaining heat in the interior spaces and reducing energy consumption for heating;
- during the summer period, and depending on the outside temperature level, the glass blades are open, allowing ventilation of the cavity and night cooling of the buildings, acting in combination with the opening of the windows. Even in the open position, the blades assume a filtering function with respect to incident wind loads, the speed of which is high at the highest levels of the towers, allowing the windows of the internal façade to open.

The double envelope system with a continuous cavity determines the control of air exchange and the thermal compensation effect of the façade since, by placing ventilation openings at the base and at the top, it is possible to vary the air inlet and outlet section [17] (Fig. 14).

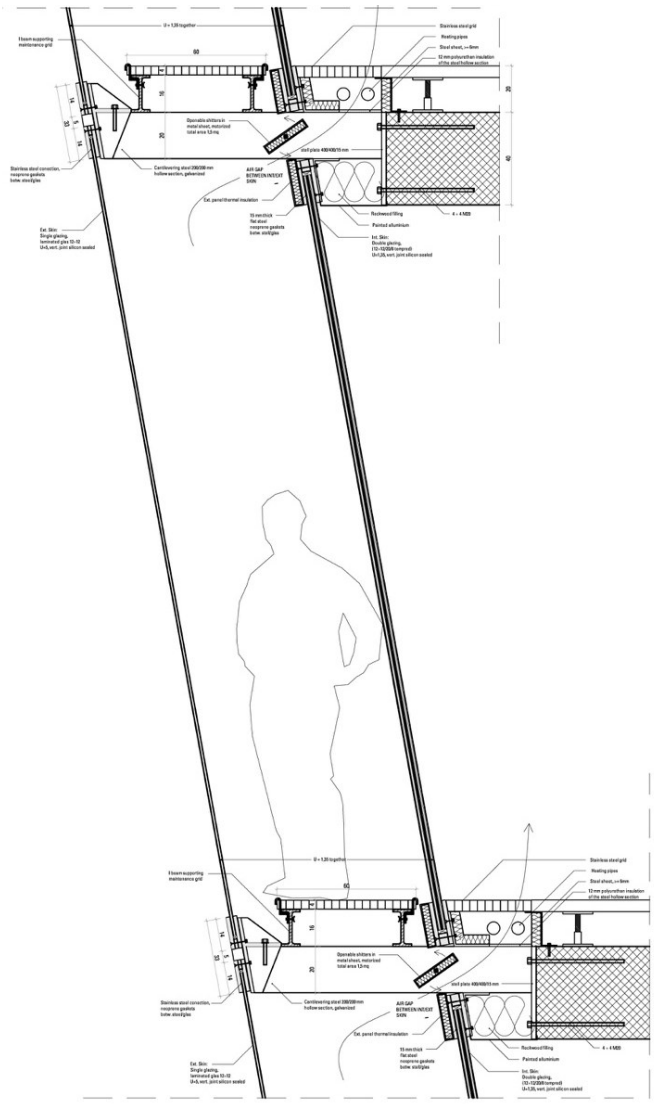

Fig. 14 Mario Cucinella Architects, *CSET* (*Centre for Sustainable Energy Technologies*), Ningbo (China). Functional and executive closing apparatus realized by the external screen and by the internal curtain, assembled to the external truss © Courtesy of Mario Cucinella Architects

D. *Double Skin Façade System with Discontinuous Cavity*

The double envelope façade system with discontinuous cavity is composed:

- with a horizontal-type division, which results in *corridor façades*;
- with a horizontal-vertical division.

The *corridor façade* type has the cavity segmented by horizontal connective elements (in reticular and practicable form) placed in correspondence with the extrados of the structures. The outside air is introduced in the lower strip of each inter-floor curtain module, while inside exhaust air is expelled from the "corridor" in the upper strip.

The application of the double envelope system, in the case of the *corridor façade*, provides for passive ventilation by the "chimney effect" (triggered by the heat radiated by the glazed panels) in the cavity and the capture of external convective flows: this by means of a device articulated through a series of aerodynamic elements aimed at the input of air flows close to the façade plane.

Therefore, the functioning of the double envelope system is realized through the regulation of the ventilation devices, which creates passive ventilation for cooling or heating of the interior spaces (in this case, in combination with the reduction of heat loss by transmission): the calibration of these devices allows the adaptation of the overall operating conditions with respect to the temperatures of the air outside and inside the built environment, to solar radiation and wind stress, limiting the energy consumption necessary for air conditioning and heating of the interior spaces. The double envelope system consists of components defined by two main sections:

- the internal enclosure realized by a double-glazed frame at floor height, with sections that can be opened outwards;
- the external enclosure realized by a single tempered glass panel, connected, at each inter-floor level, to the apparatus including the external ventilation devices [18] (Fig. 15).

The double envelope units composed in this way provide for the lateral approach between two components (and, therefore, ventilation devices) of which:

- the left component provides for the inflow of convective flows, by lowering the regulating element, and the flow, first vertical and then diagonal, towards the cavity; the lower and upper sections of the ventilation device are open;
- the right component provides for the outflow of air from the cavity to the outside, by lifting the regulation element; the lower section is open and has deflecting wings that guide the air in the cavity to the outside, and the upper section is closed (Fig. 16).

The ventilation devices of the *corridor façades* consist of:

- a series of deflecting wings, facing outside the façade, which guide the external convective flows towards the regulating equipment;
- the regulation apparatus, electrically operated with centralized control;
- a series of deflecting wings inside the device, located in the lower section, necessary to direct the flow, in a vertical direction, inside the cavity (Fig. 17).

The type of envelope with horizontal-vertical division determines the construction of the *shaft-box façade*, in which the cavity is divided by vertical separating elements, which alternate the internal sections in closed wall modules and in wall modules equipped with ventilation openings: this type combines the functioning of the continuous cavity façade, in the area of vertical separations, and the *shaft-box façade*, in the area of ventilation openings [19].

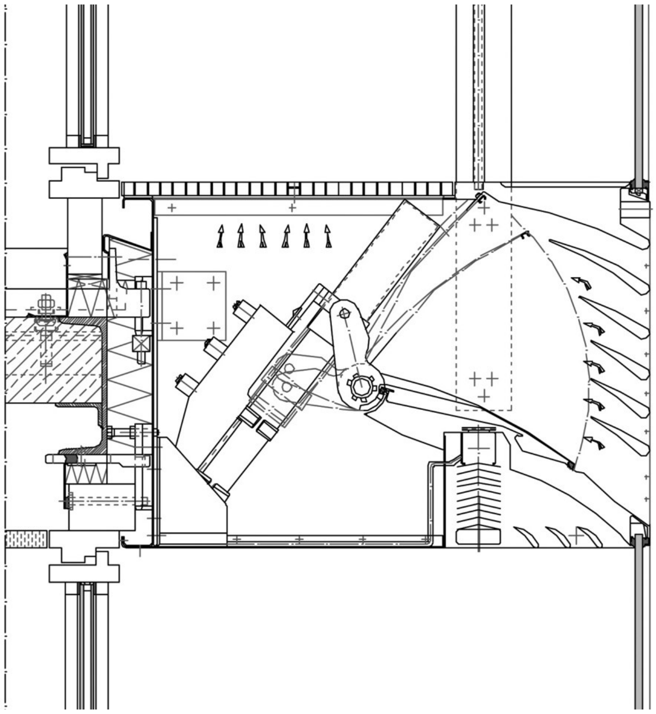

Fig. 15 Karl-Heinz Petzinka and Partners, *Düsseldorfer Stadttor*, Düsseldorf. Double envelope system that provides for passive ventilation by the "chimney effect" in the cavity and the capture of external convective flows through a series of aerodynamic elements aimed at the input of air flows close to the façade plane © Courtesy of Karl-Heinz Petzinka and Partners

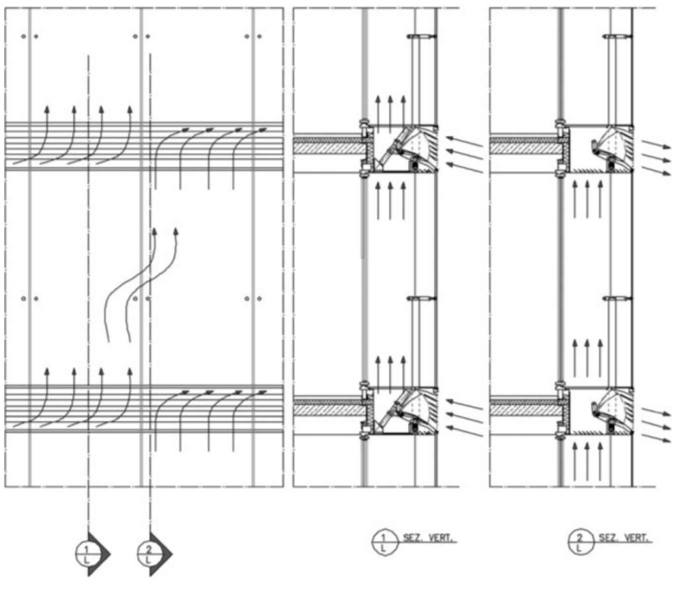

Fig. 16 Karl-Heinz Petzinka and Partners, *Düsseldorfer Stadttor*, Düsseldorf. Functioning of passive ventilation that takes place by means of the "chimney effect", activated by the heat radiated by the internal glass panels in the cavity, and involves the capture of external convective flows by means of a slot and by means of the aerodynamic action of the deflectors that leads them towards the ventilation devices: the left component provides for the inflow of convective flows, by lowering the regulating element, and the flow, first vertical and then diagonal, towards the cavity; the right component provides for the outflow of air © Courtesy of Karl-Heinz Petzinka and Partners

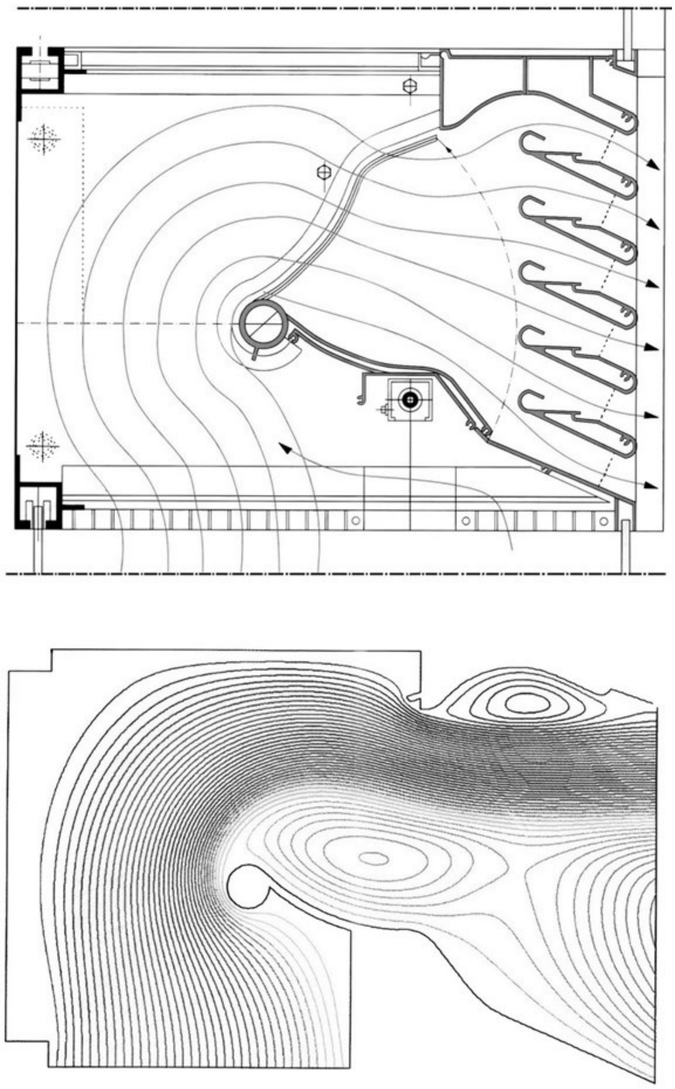

Fig. 17 Karl-Heinz Petzinka and Partners, *Düsseldorfer Stadttor*, Düsseldorf. Ventilation devices of the *corridor façades* characterized by a series of deflecting wings, facing outside the façade, necessary to direct the flow, in a vertical direction, inside the cavity of the double envelope © Courtesy of Karl-Heinz Petzinka and Partners

The temperature difference generated in the areas of the vertical partitions and the resulting convective flows are used to increase the air exchange between the cavity and the interior spaces. The supply of outside air takes place at the curtain modules equipped with ventilation openings: the expulsion devices are located at the top of the side modules dividing the cavity. In this way, a depression is created that draws the exhaust air and allows the entry of outside air. The device that encloses the modules behaves in the form of an *environmentally responsive wall*, capable of "responding" actively and "organically" to climatic loads: it operates differently during the winter period, distributing the heat accumulated by the mass of air in the cavity, and during the summer period, with the aim of preventing overheating in the rooms by removing the heat and transferring it outside (Fig. 18).

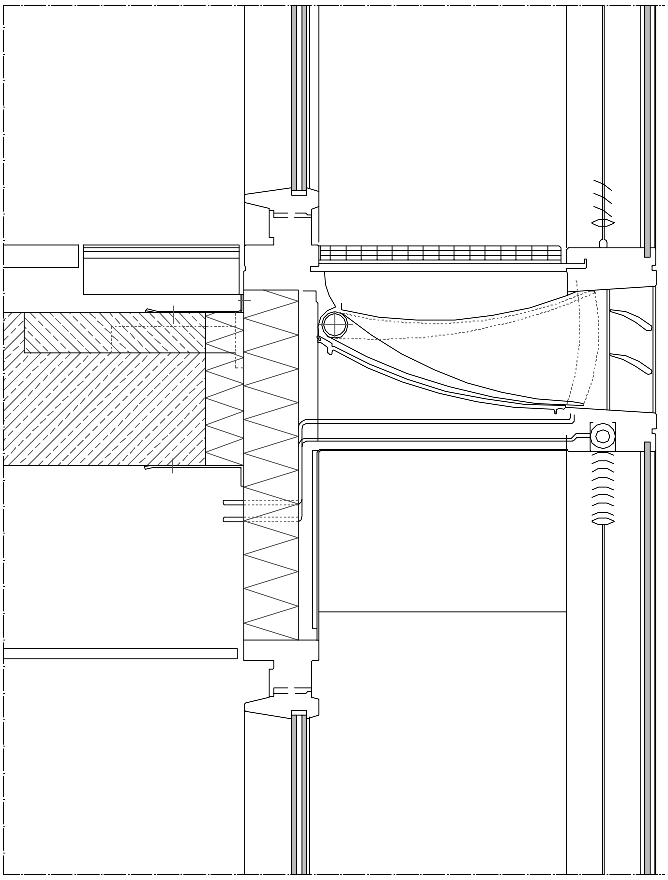

Fig. 18 Norman Foster and Partners with RKW (Rhode, Kellermann, Wawrowsky), *Arag* Tower, Düsseldorf. Louvers at the base of the two side components (as box-windows) introduce the outside air, which is drawn in convectively (for natural ventilation) through the motion generated by the central ventilated module: the opening and closing of these louvers regulates the ventilation flow with respect to the differences in air temperature (outside and inside) and solar radiation © Courtesy of RKW

The passive ventilation is of the vertical-diagonal type, through the integrated and functional constitution of three contiguous components, laterally enclosed by the transverse tempered glass partitions in order to conduct the air upwards and to prevent the internal flow from being reintroduced into the interspace. The double envelope units composed in this manner provide for side-to-side joining between the components and, therefore, between the ventilation devices:

- the first and third box-window components (integrated, laterally, by the vertical separation panel) provide for the ventilation devices to be in the open condition towards the outside, by means of the downward rotation of the concave wing element;
- the intermediate component is open to the reception of air flows extracted from the interior spaces (by means of the opening of the windows related to the two lateral components), by diagonal conduction and through the bypass openings arranged at the top of the vertical separation panels. It provides for the ventilation devices to be in the closed condition, by means of the upward rotation of the concave wing element, so that the inflow of external air is prevented and the outflow of internal air into the cavity (coming from the diagonal conduction from the two side components) is prevented (Fig. 19).

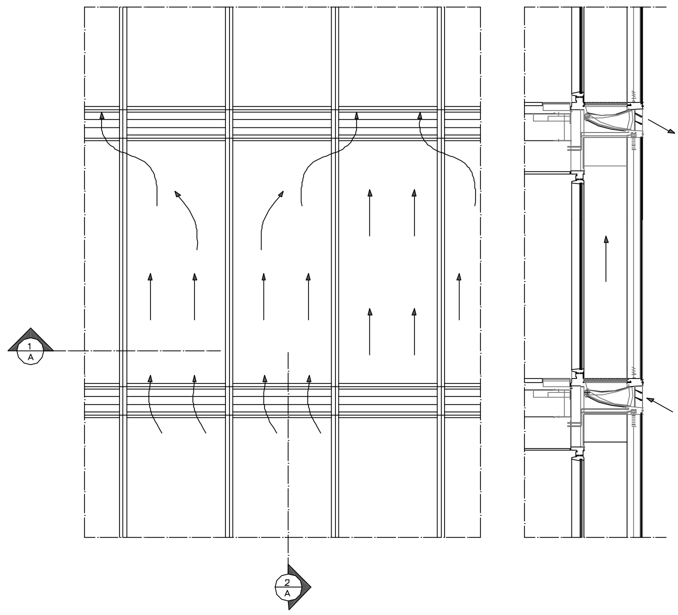

Fig. 19 Norman Foster and Partners with RKW (Rhode, Kellermann, Wawrowsky), *Arag* Tower, Düsseldorf. Double envelope units providing for side-to-side joining between the components and the ventilation devices, where the first and third box-windows provide for the ventilation devices to be in the open condition towards the outside and the intermediate component is open to the reception of air flows extracted from the interior spaces © Courtesy of RKW

The double envelope system consists of unit components, defined by two main sections:

- the internal enclosure, realized by an opening frame at floor height, with an aluminium frame and double-glazing. The frames relating to the central band (equipped with the components in which the air flow intake takes place) can only be opened for maintenance operations;
- the external screen, assembled to mullions and transom framing of the unit, made of a single sheet of laminated glass at floor height.

Moreover, the type of envelope with a horizontal-vertical division is articulated through the "cell" façade typology, defined by units that are independent of each other both on a functional level (as far as the ventilation of the cavity is concerned) and on a production and construction level. The units are equipped with air inflow and outlet openings, in which the ventilation louvers (also of the adjustable type) are displaced laterally, so as to prevent incoming and outgoing air currents from mixing. The application of the "cell" façade is defined according to the objective of regulating thermal, lighting and internal ventilation conditions, balancing environmental comfort in office spaces and controlling energy consumption (Fig. 20).

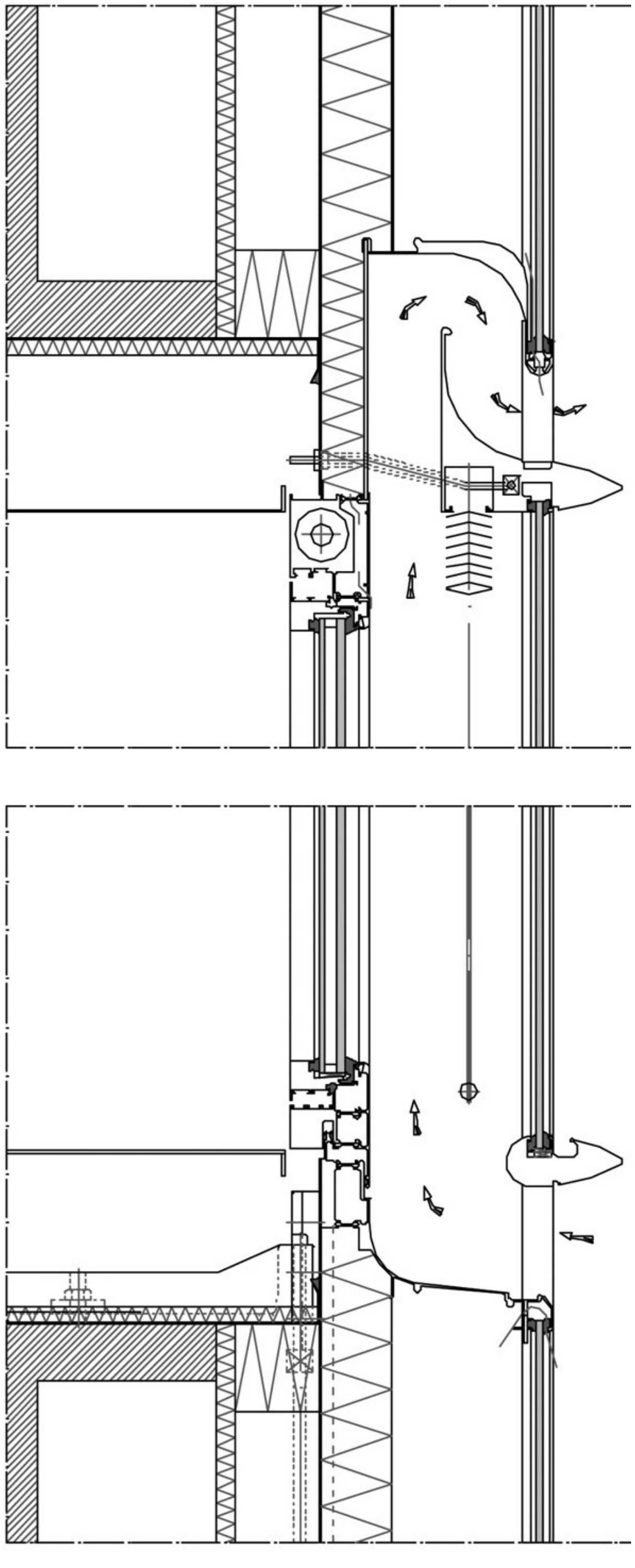

Fig. 20 Norman Foster and Partners, *Commerzbank* Tower, Frankfurt. Functioning of the system through the opening of the internal window frame with double-glazing, the regulation of air inflow and outflow, by the aerodynamic action performed by the two extruded aluminium wing profiles, for the capture of convective flows © Courtesy of Norman Foster and Partners

Specifically, the system provides, through the opening of the internal window frame, for the regulation of air inflow and outflow, according to the aerodynamic action performed by the wing profiles (in extruded aluminium), for the capture of convective flow (in the lower position) from outside the façade towards the inside of the ventilated cavity and, subsequently, for outflow (in the upper position) towards the outside. The cavity between the internal window frame and the external cladding incorporates a sunscreen, which filters and reflects daylight, protecting the interior spaces from direct solar radiation and glare phenomena: during the winter season, this device can be closed, depending on the lowering of the temperature, so that the cavity can be configured as a thermal storage air cavity, sheltering the internal surface from the effects of low temperatures (Fig. 21).

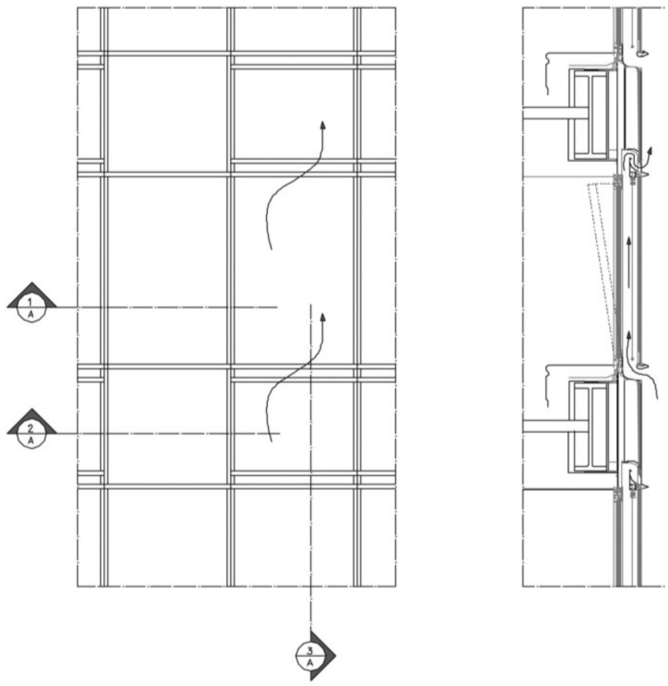

Fig. 21 Norman Foster and Partners, *Commerzbank* Tower, Frankfurt. Natural ventilation inside the cavity activated by the air induced from the outside which is deflected into a convective motion by the solar radiation transmitted inside © Courtesy of Norman Foster and Partners

The process by which natural ventilation occurs involves the air induced from outside being diverted and forced into a circular convective motion by the flow generated by the solar radiation transmitted inside. In this way:

- part of the radiation is reflected and diverted by the sunshade foils;
- the upward rotational flow, heated mainly by computer equipment and operators in the office, is sucked in and conveyed outside through the opening at the top of the window frame.

In addition, the application of the shading device inside the ventilated cavity allows the thermal load to be conveyed towards the outside, preventing it from affecting the cooling and air exchange processes of the internal spaces.

IV. The Functional and Typological Constitution of the Active Double Skin Façade

The "active" double façade system determines that ventilation in the cavity generally takes place by means of heated air from the interior spaces, which flows along the envelope and is then conducted to the treatment plant. The application of the system is delineated towards an architectural organism defined by a procedure of "climatic regulation" of the interior spaces, involving the generation of energy inputs that can be accumulated, transmitted (by conduction and thermal convection) and radiated into the interior spaces (Fig. 22).

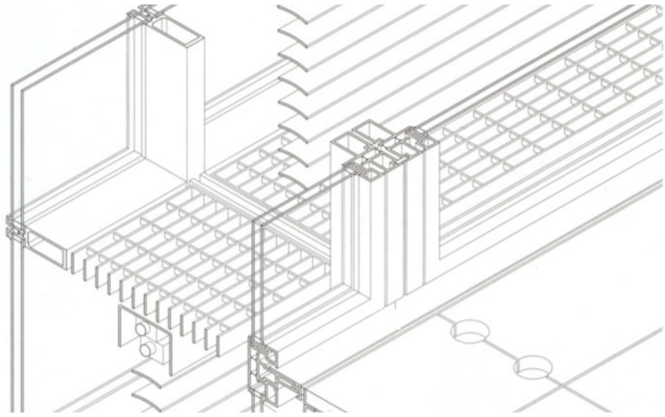

Fig. 22 Martin Webler and Garnet Geissler, *Götz* Headquarters, Würzburg. Perimeter curtains formed by the aluminium frame supporting the double-glazing envelope with the sun shading in the cavity over the horizontal continuous grid © Courtesy of Götz

Inside the cavity, convection flows generate a "chimney effect", which involves:

- the conduction of external air, entering from the lower level, and its expulsion through the passage in the upper ventilation opening;
- the increase in the horizontal or vertical circulation of preheated air by means of the ventilation fans, which balance the conditions inside the cavity when there are considerable temperature differences between the illuminated parts and those shaded by the interposed solar shading: in this way, the air chamber enclosed in the double envelope system is configured both as a thermal storage cavity (due to the "greenhouse effect"), and as a device for the dissipation of heat due to the internal air heated by solar radiation.

During the summer period, when the foils of the sunshade devices are inclined in the shielding position and the ventilation openings are open, the architectural organism is cooled by the convective flows. When the outside temperature is low, the ventilation openings are closed, so that the air heated inside the cavity envelops the perimeter curtain: only the façade facing solar radiation allows air to enter the cavity, which is absorbed by the sunshade devices and then conducted into the interiors through the ventilation fans.

The development of the "active" double skin façade components is configured in the unit type with a discontinuous horizontal corridor cavity. The functioning of the system is divided with respect to:

- the winter period, which provides for the prevalent enclosure, so as to reduce heat dispersion, generating the performance of the "greenhouse effect" that takes advantage of solar radiation in order to allow the formation of a *buffer zone* capable of containing a mass of air at a higher temperature: this produces an increase in the average radiant temperature of the curtain wall (in double-glazing) and, consequently, an increase in the temperature of the internal spaces, as well as reducing heat transmission from the inside to the outside;
- the summer period, which provides for the inflow and ascension of convective air movements inside the cavity, with the aim of partially dissipating the heat (Fig. 23).

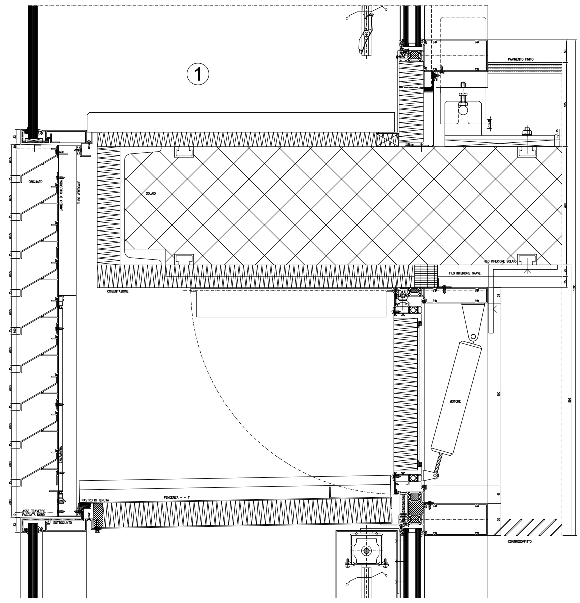

Fig. 23 Open Project, *Unipol* Tower, Bologna. Fanlight section which can be opened (by means of mechanical actuation) to the outside, in order to provide for the outflow of airflows from the interior spaces, with the contribution of the finned type of ceiling © Courtesy of Schüco

V. Conclusions

This paper on the types and constitution, both functional and mechanical, of the double envelope façade systems is intended to form the basis for a field of in-depth study aimed at:

- the identification and analysis of design principles, also through further researches into the applications in the contemporary experimental scenario;
- the formulation of a guiding tool for the executive design and technological transfer of these typologies (aimed at researchers and operators in the façade sector);

- the generation of an abacus of solutions, components and materials for the construction of these systems with respect to different climatic and environmental conditions.

ACKNOWLEDGMENT

The study is developed inside the experimental laboratory *Material Balance Research* within the Architecture, Built Environment and Construction Engineering-ABC Department at the Politecnico di Milano, where the advanced façade systems are examined according to the constitutive and typological characters, as well as the functional and applicative requirements such as the expressive, constructive and interactive criteria towards the environmental, perceptive and energy conditions.

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