

■ 2.1 Smart skins

Brian Cody

Skygarden concept for residential tower in Manhattan, Coop Himmelb(l)au architects

A building facade can act as an adaptable filter between the external and internal environments. The physical properties of facades are, however, at the present time unable to adapt to changing conditions in a significant manner. This applies to the ever-changing external conditions such as climate, noise, air quality and light, as well as to the fluctuating demands and needs of building occupants on the internal side of the facade interface. The specific properties of facades in terms of thermal conductivity, solar heat gain transmission, light transmittance, porosity, etc. are static and remain essentially constant with time, although the requirements for an energy-efficient building skin differ significantly under the widely varying climatic conditions and patterns of use at different times of the day and year. The building skin, as interface between the internal and external environments, has an important role to play in the task of achieving desirable internal conditions. The external conditions vary during the course of the day and more so over the course of a year. Internal conditions considered comfortable for human occupation are more or less constant and vary little throughout the world. However, due to the fact that we occupy and use buildings in a dynamic way, coming and going, changing our activity, etc., the internal side of the interface also includes a highly dynamic component. We would expect, therefore, that for a building skin to be effective in energy design terms, the skin as interface should reflect the dynamic worlds on both sides of the interface. If we look around us, however, whether in Manhattan, Moscow, Berlin or Hong

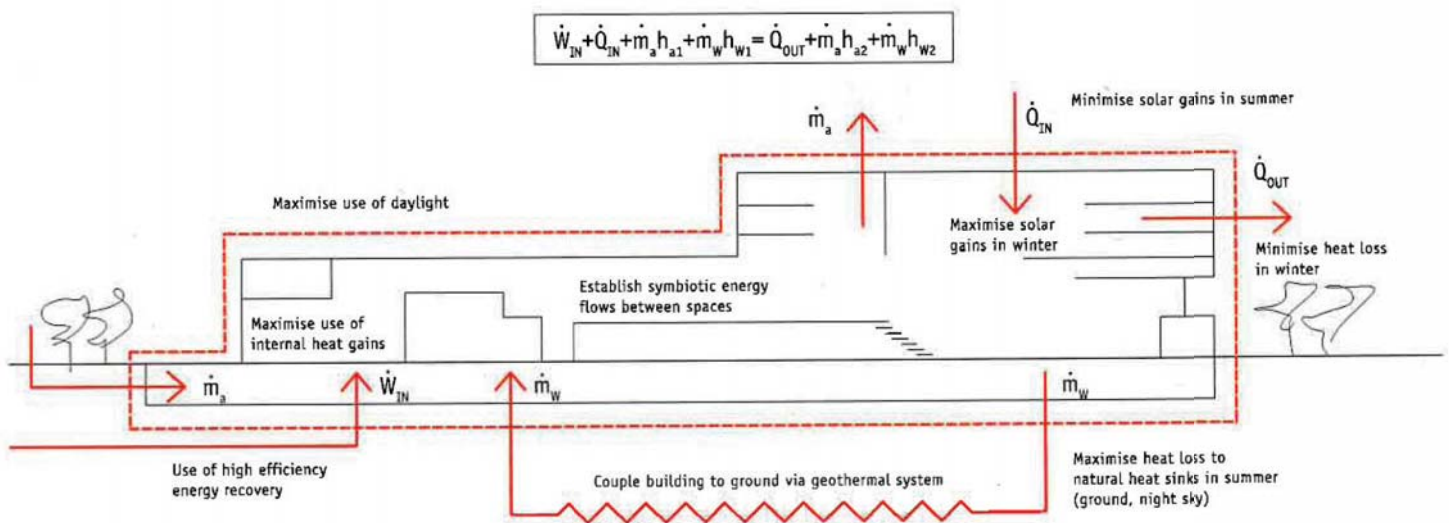
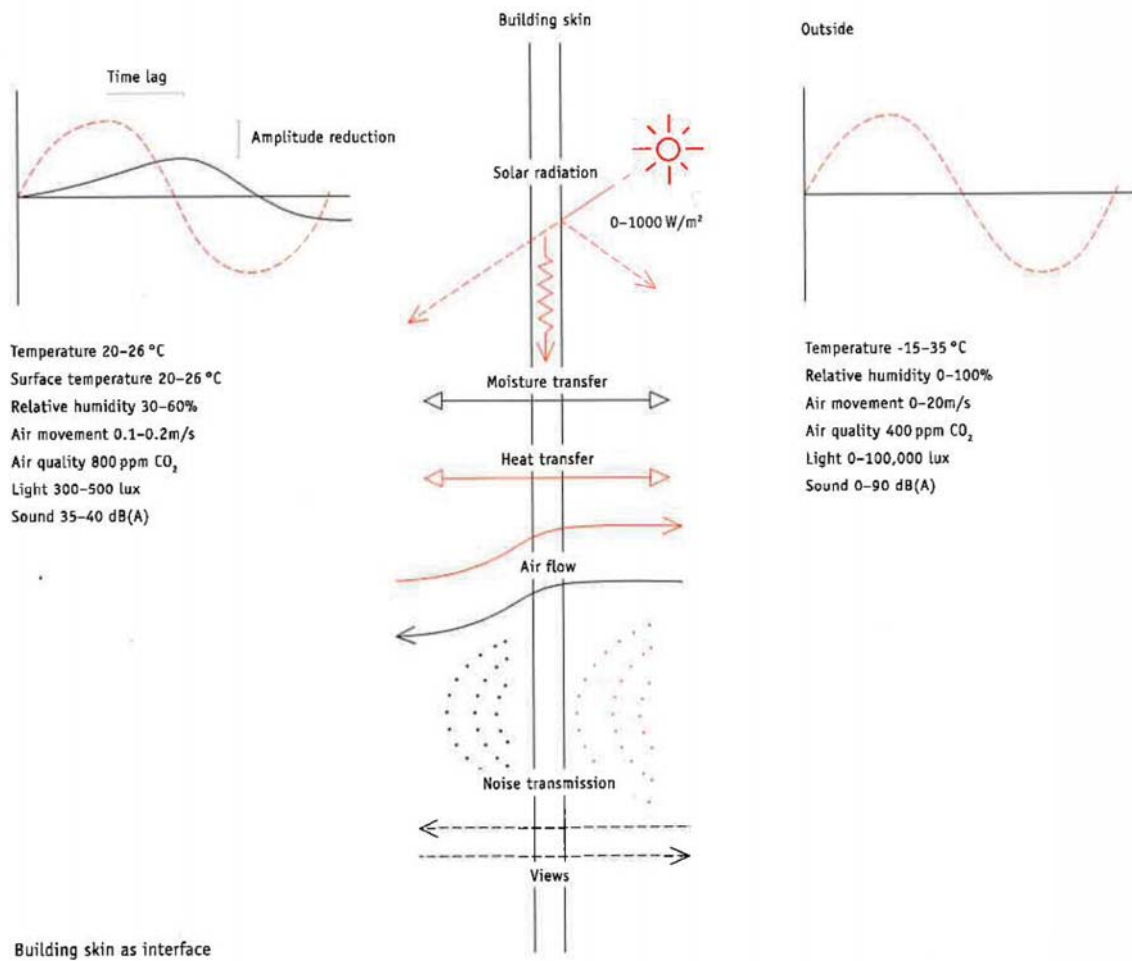
Kong, we see static surfaces of stone, concrete and glass – building envelopes which remain unresponsive to and unchanging, totally oblivious of whether it is -20°C and dark or 35°C and sunny outside: with the result that the buildings HVAC systems have to work hard to achieve comfort within. Building skins should be dynamic. They should not only provide protection against the elements but act as a filter, selecting, mediating and modulating between inside and outside. The fact that they do not, for the most part, has of course to do with cost and complexity but also perhaps with certain architectural dreams we are still chasing. The famous unbuilt glass skyscrapers Mies van der Rohe designed in the 1920s come to mind. Sometimes, buildings which were not built are more important than those which were. If we look at contemporary architecture, the static unchanging envelopes make this apparent. On the other hand, if we look back to buildings from past centuries, we see building envelopes which evolved to include many elements that react to sun, light, temperature and the need for privacy.

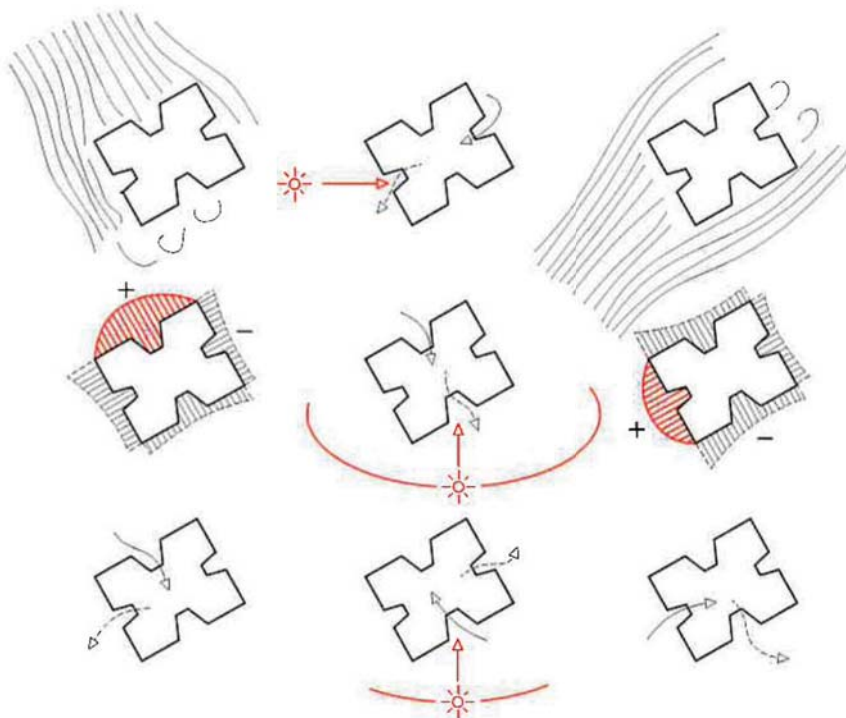
In a research project at the Institute of Buildings and Energy, Graz University of Technology, we are studying the possibility of reinterpreting this type of adaptability using the technology available today. This research forms the scientific basis for the development of entirely novel facade constructions. The emerging "Smart Skins" are facades that maximise energy performance by varying their properties to adapt to changing external and internal conditions. An adaptable and variable building skin

can react and adapt to both internal and external conditions, effectively creating "Space on Demand." One simple example is movable, highly insulated elements, which in a closed position form an airtight connection with the primary building facade, allowing the transparent portion of the building skin to vary down to 0%, provided that the spaces behind are not in use or their use, at a given time does not require daylight.

Energy and climate concepts developed for recent projects by the consulting firm Energy Design Cody show some interpretations of how smart skins can be used to achieve high energy performance. For a residential tower structure on 101 Murray Street, Manhattan, New York City designed by Coop Himmelb(l)au architects, we developed an adaptive facade which enables an innovative system of natural ventilation, while providing a new type of winter garden space. The outer layer can be modulated to react to different conditions relating to wind, noise, security, etc. Sliding doors in the inner facade layer, positioned roughly 2m back from the outer layer, allow the living space to be extended for a large portion of the year. The "Sky Garden" acts as a buffer zone in cold weather, reducing heat loss and providing solar shading for the living spaces in the hot season. Natural ventilation and nighttime cooling in summer can be controlled by modulated opening of the two facade layers.

The void contained in this facade system offers inhabitable space and, at the same time, incorporates strategies to provide energy-efficient ventilation and maximise energy performance. It fulfils the





Amorepacific tower design concept, Delugan Meissl Associated Architects



European Central Bank HQ, Coop Himmelb(l)au architects

functions provided by typical present-day complex multilayered external wall constructions – with all their associated problems relating to embodied energy, disposal, etc. – and by mechanical ventilation systems with heat recovery systems. In a sense, this facade concept replaces the traditional wall construction with inhabitable space.

At the new campus of the Medical University of Graz, designed by Riegler Riewe Architekten, the buildings are orientated with the long axis running north-south on account of wind considerations related to the local microclimate. The external shading devices were designed as vertically aligned perforated metal elements which are automatically controlled and allow daylight and views while blocking solar radiation. In this way, the movement of the shading elements expresses the reaction of the building to its external environment.

The facade developed for the European Central Bank headquarters building in Frankfurt (Coop Himmelb(l)au architects) incorporates an array of devices which offer a high degree of selectivity and adaptability, including highly selective glass coatings, automati-

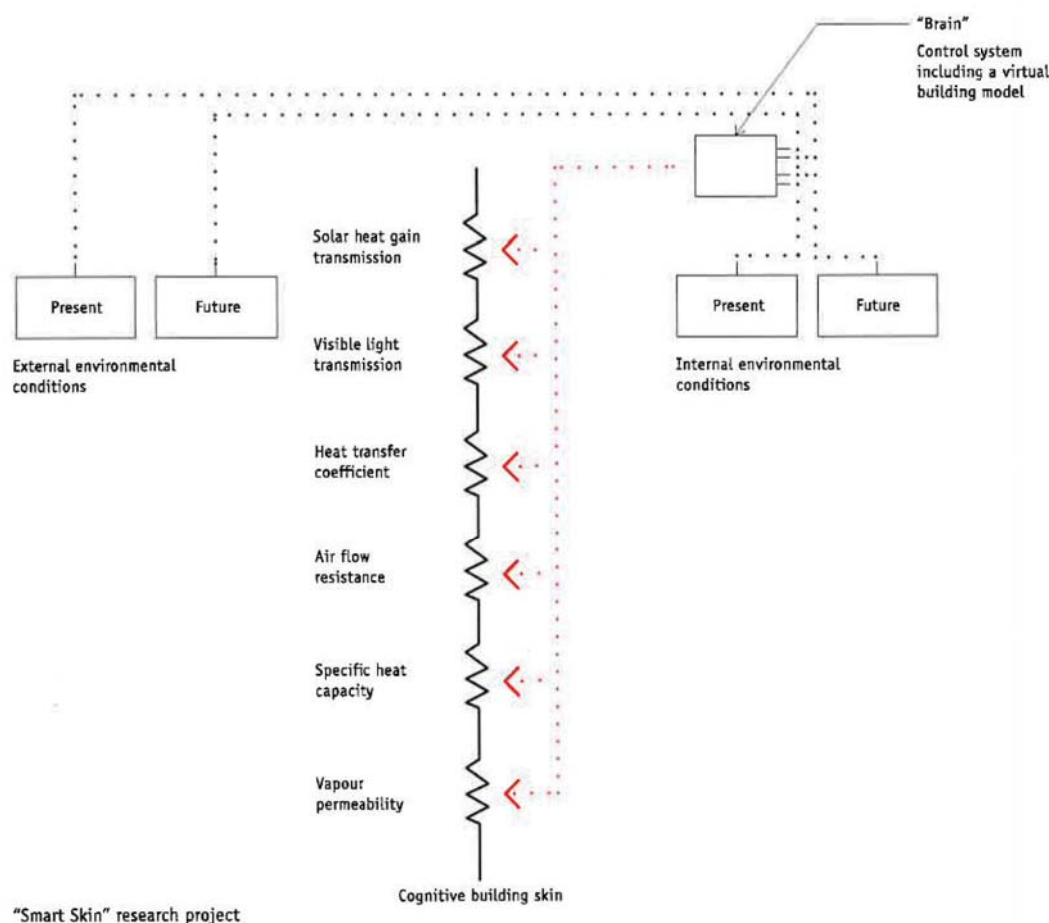
cally controlled movable solar shading and elements specially developed to provide natural ventilation for this high-rise building in a windy environment. The building facade presents a monolithic homogeneous exterior appearance, demonstrating that similar energy design approaches can lead to very different architectural expressions and concepts.

The proposal for the new headquarters building for Amorepacific in Seoul, designed by DMAA Delugan Meissl Associated Architects, includes vertical sky gardens on all sides of the building. The sky gardens act as transitional spaces, mediating between inside and outside and also providing the office spaces with filtered and tempered fresh air. Ground water is used to temper the incoming air and dehumidify it in summer. The resulting condensate in summer is used directly for irrigation of the planting and vegetation, in a symbiotic relationship between humans and nature, where humans receive the dried cooled air and the vegetation receives the condensed water.

The Amorepacific building itself is, as are most buildings, a static object in a sea of ever-changing

conditions. However, the building skin and systems react to these conditions in a dynamic manner. The fresh air intakes of the decentralised air-handling units installed on the office floors draw air from the sky gardens. These are interconnected so that the orientation of the fresh air intake is dynamically adapted to suit the prevailing conditions: in winter, outdoor air is taken from the sky garden with the highest temperature, in summer, from the area with the lowest temperature. The sky gardens are also utilised to support the driving pressure required to distribute air to the occupied spaces, by employing the stack effect on the hotter side of the building (sky gardens connected vertically) in combination with the static pressure of the prevailing wind.

The École Centrale Paris (CentraleSupélec) engineering school building on the campus of the Université Paris-Saclay, designed by OMA architects, demonstrates a new university campus building typology. It achieves high energy performance by utilising synergetic interactions between the various uses, creating a new form of campus space under a “climate envelope” composed of a PTFE foil roof and



glass facades. The building encloses teaching spaces, laboratories and offices within a climate envelope, so that the in-between spaces form an indoor campus. Compared with traditional typologies, the design offers major advantages in terms of communication among research staff and students as well as flexibility and adaptability regarding future changes in use and the configuration of offices and laboratories. Placing the climate envelope around the entire building volume instead of individual office and laboratory cells increases building compactness, reduces the amount of heat transfer area, and creates unique spaces between the office and lab cells.

Within the climate envelope, a macroclimate is created, largely by passive means, which is not as closely controlled as the internal environments inside the laboratories and offices. The hall is conceived as a transitional space between the internal and external environments, supporting and enhancing the campus atmosphere and informal communication. The potential for enhanced communication offered by the macroclimate in the climate envelope

is significantly increased in the climate of Paris. This building typology enhances both communication between people and synergetic energy flows between the many diversified uses under its roof, transferring surplus heat from the laboratories to spaces which require heat, such as the offices.

The proposed "Smart Skin" concept goes far beyond the strategies we have been able to implement in practice to date. It also incorporates and uses forecast data relating to future weather and likely user behaviour (based on data of past experience and using an embedded artificial intelligence approach) as well as present-time data to select the optimal configuration of physical properties and thereby optimise performance. A novel dynamic simulation model, specially developed for the project, provides meaningful insight into the potential and possibilities. This type of model could also serve as a virtual model incorporated into the building's automatic control system to provide part of the intelligence necessary for the optimal performance of the smart skin. Further research will look at how the intended degree of adaptability can be physically accom-

plished: mechanical devices, fluid-filled cavities or smart materials which can change their physical and/or chemical characteristics.

The final goal is the development of adaptive facades, which automatically change their thermal and optical properties, constantly adapting to changing requirements by manipulation of variable parameters for thermal insulation, solar energy transmittance, light transmission, thermal energy storage, airtightness and moisture diffusion, in order to achieve the desired internal conditions with the least amount of energy expenditure. Investigations carried out in the first stage of this project show potential energy savings of up to 90% compared to conventional energy efficient facade systems today.

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