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**Ingrid Paoletti · Massimiliano Nastri**

# **Construction of the Façade Systems** Production and Assembly Procedures of the Advanced Building Envelopes



**POLITECNICO**  
MILANO 1863



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# Preface

The study, developed inside the experimental laboratory *Material Balance Research* within the Architecture, Built Environment and Construction Engineering-ABC Department at the Politecnico di Milano, examines the advanced façade systems according to the productive and constructive contents. The work is determined in the form of a knowledge and design concept tool for the construction of advanced façade systems, used for the realization of multiple types of envelopes. The book is configured in a cognitive and operative form, with the aim of providing researchers, technicians and professionals with the contents to proceed with the analysis, design and constitution of façade systems with the aid of the components, materials and assembly methods typical of the advanced and experimental contemporary scenario.

The purpose of the book is to provide operational guidance for the technological design, production planning and site executive coordination for the realization of façade systems. Moreover, the work goes into detail on how to form, connect and plan for the construction of the advanced façade systems, specifying itself as a manual text to provide guidelines for professionals in charge of design, production and construction.

The work involves the building characters of the envelopes with respect to both the range series (determined by the basic profiles) and the customized or “outside system” components. The scenario under consideration accommodates, in the range series, the types of envelopes transferred by complex, large-scale interventions, with the inclusion of appropriate tools and accessories aimed at widespread use: therefore, the components are proposed in the form of “integrated” elements, characterized by “specialization” processes. Then, the contemporary experimental production observes the application of the archetypal and tectonic properties of envelope systems and the hybridization of established façade typologies through the use of profiles and frames of different material, mechanical and connective invoices.

The study deals with the main building elements and technical interfaces, explaining the anchoring structures and their connections to the load-bearing structures, examining the criteria for the assembly between the mullion and transom profiles. The study of the façade systems focuses on the methods of collecting and draining rainwater, considering the execution of the sealing and the criteria of vapour pressure compensation and drainage for glass enclosures. The analysis of framing is completed with an explanation of the methods of mechanical and structural fastening of the enclosures, noting the criteria for pressure and structural silicone assembly. In particular, the text examines the technical interfaces of the main advanced envelope systems with respect to the functional, constructive and applicative coordination procedures of the mullions and transoms framing, of the structural sealant glazing façade system, of the unit façade system, of the suspended façade system and of the double skin façade system.

The technical and manual character of the book is also expressed through the analysis of the functional and application procedures of the gaskets with respect to the façade systems in order to prevent the transmission of air and water loads: the analysis focuses on the connections between the framing and the enclosure elements of the envelope, in accordance with the compensation of height differences in order to guarantee impermeability, airtightness and insulation. The study observes and investigates the types of framing elements in which the gaskets are inserted, emphasizing the specific function with respect to the connection interfaces.

Then, the study examines the assembly and interface conditions between elements of different composition and production within the façade systems: in particular, the examination of the technical interfaces involves the development and application of sealants, based on the loads exerted on the jointing devices, in order to fulfil the requirements of sealing and tightness with respect to mechanical, thermal and hygrometric, water, air and wind stresses. Moreover, the study of the envelope systems examines the methodologies directed towards fulfilling the requirements with respect to the actions caused by fire loads, considering the contents related to both components and connections and fixing surfaces. The design study involves the

specific sections of separation with respect to the fire compartments: this is to limit the propagation of a fire originating inside the building, the fire of a façade and its propagation, the fall of the façade elements.

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# Chapter 1

## The Productive, Constructive and Expressive Articulation of the Advanced Envelope Systems



**Abstract** The study examines the context of the façade systems characterized both by the confirmation and progression of the range series, and by the possibilities of performance increase based on the basic profiles, according to the paradigms of versatility and relational flexibility. Moreover, the context of envelope components is expressed according to the acquisition in its own production of technical solutions “outside system”: this considering the current component design strategies focused on production and combinatory procedures, or on criteria of integrated aggregation between elements and semi-finished products arranged “in catalogue”. The scenario under consideration accommodates, in the range series, the types of envelopes transferred by complex, large-scale interventions, with the inclusion of appropriate tools and accessories aimed at widespread use: therefore, the components are proposed in the form of “integrated” elements, characterized by “specialization” processes, as finished products, dimensionally coordinated, capable of providing mechanical assembly possibilities and applicable to different building types. Then, the contemporary experimental production observes the application of the archetypal and tectonic properties of envelope systems, through both the elaboration of external enclosures defined by the use of products belonging to the construction “tradition”, and the hybridization of established façade typologies through the use of profiles and frames of different material, mechanical and connective invoice. The alternative typologies are arranged with respect to the tendency towards rationalization and “reinvention” of the components and of the canonical application and interface methods, in an integrated manner with the multiplicity and variety of expressive possibilities: this is in order to legitimize the maintenance of the “solid” and “massive” presence within the growing “virtuality” and ephemeral, dynamic and “metamorphic” configuration of the envelope.

## 1.1 The Contemporary Characters and Paradigms in Advanced Envelope Systems

The study of the design and production sector of envelope systems is realized, in the current scenario, according to the confirmation and progression of the range series, with respect to the constant in-depth studies, refinement and improvement. The context offers situations of punctual analysis directed to reconfigure certain interfaces, to make explicit the possibilities of performance increase within systems and frames “hybridized” on the basis of the basic profiles. Or else, the context manifests the capacity to support, within its own research and development lines, the elaboration of “sub-components” that are themselves endowed with functional and applicative complexity, characterized by versatility and relational flexibility with respect to the basic frames. Furthermore, in some cases, there is a willingness to take on, channel and acquire in its own production the “out-of-system” technical solutions, increasingly present in the field of façade applications and ready to present themselves in the form of “system proposals”. This, ensuring the expression of consolidated and updated paradigms according to the building’s energy management and range expansion needs [5, 12].

The evolved expression defined by the productive sphere is characterized by innovative solutions at system or component level, affirming the correlation with the energy needs and the combined association with the entire architectural, plant engineering and functional set-up of the building, in the case of new construction as well as in the case of interventions on the building. In this regard, the evolution of production finally demonstrates the potential to go beyond the development of façade systems as an apparatus directed exclusively at new buildings, involving the technological transfer of functional procedures (above all in the field of bioclimatics and new materials, also studied for some time by techno-science) and experiments (for the most part already adopted and supported at a regulatory level in the Central European field) towards the use on vertical enclosures to be upgraded (Fig. 1.1).

The study of the building envelope made up of prefabricated components is specified as an actualization of the principles of functional architecture, of ergonomic performance combined with the morpho-typological conception of the building, through the use of technical solutions and contemporary materials of an evolved character: the current *component design* strategies focus essentially on the production and combinatory procedures, serial and modular, of enclosure and cladding materials belonging to the building tradition according to “hybrid” and “allusive” forms, or on criteria of mechanical, “tectonic” and integrated aggregation between elements and semi-finished products arranged “in catalogue”. At the same time, the *component design* of envelope systems examines ways of environmental, functional and adaptive design with respect to climatic stresses, as well as proposing new scenarios in the “interactive” and “communicative” constitution of building surfaces. The envelope, disengaged from the load-bearing function and in the form of a “curtain”, assumes the role of “transition” between interior and exterior space, questioning both the rigorous paradigms, sanctioned during the Modern Movement, of “formal purity”



**Fig. 1.1** Christoph Mayr Fingerle, *Cascade* Swimming Centre, Campo Tures (Bozen). Role of “transition” between internal and external spatiality of the envelope, understood as a modular apparatus warped from the load-bearing framework towards the glazed surfaces, inserted in the horizontal perspective composition. © Courtesy of Schüco

and “material functionalism”, and the formulation that the external expression of architecture should reflect the internal uses, as a “harmonic” relationship between form and function [1].

The correlation between the envelope and architecture specifies a specific and multidisciplinary field in design and construction, in which converge and relate:

- the notions and the practices relating to structural mechanical engineering, physics-technology, *component* and *industrial design*;
- the fine-tuning of support, interface and specialized “micro-systems”;
- the production logic (now enunciated by “light” industrialization, characterized by versatile manufacturing processes for small series and special requirements);
- the “component” processing of enclosure systems that requires skills in “strategic invention” and the “art of connection”, as a procedure of establishing connections for assembly sequences [2] (Figs. 1.2, 1.3).

The scenario appears mature and willing to welcome, in the range series, the types of envelopes previously the prerogative only of complex, large-scale interventions, with the inclusion of appropriate tools and accessories aimed at widespread use and also for contained interventions: these are façade systems conceived in flexible form, or systems in *multilayer* combination, in some cases investigated and offered with significant design features on the technical object. The systemic evolution, consolidated in the combination with environmental emergencies, sustainability and climatic balance, is determined decisively through the diffusion of domotics and the typological, functional and executive analysis of façade openings, solar capture and shading devices [10].

In this scenario, the complexity of the technical solutions is “hidden” in the apparent simplicity and immateriality of the envelope, for which specialized skills, at the same time scientific and craftsmanship, are involved. The field in question is proposed in a sophisticated way, the contents and knowledge to be made available require responsibility and figures with high technical preparation: this is so that the applications to the architecture correctly express the expected performance, connect to the other technological sub-systems in respect of the structural, thermo-hygrometric, acoustic and lighting functions, and correlate to the executive instances according to coordinated and studied procedural modalities in relation to the appropriate type of façade. Through the contribution of designers and technical experts, now protagonists in the experimental and evolved scenario, the thematic, operational and exemplary contributions are arranged for the understanding of the main methodological, functional and constructive aspects that define the correlations between the envelope and architecture [9, 11].

The components are concretized in the form of “integrated” elements, characterized by “specialization” processes that intervene to define the overall quality at different levels (e.g. through the configuration of material layers, which become composite or result from the assembly of multiple elements). These components, then, are understood as finished products, dimensionally coordinated, capable of providing mechanical assembly possibilities and applicable to different building types: they are simple or elementary components, complex or composite, i.e. formed