Analysis of Façade Engineering in Japan

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Abstract
Japan is currently leading the world in many aspects of facade design and cladding technology development. Many buildings feature the latest technological and environmentally friendly concepts that provide Japanese architects with new possibilities to create impressive and innovative schemes. However, despite such advances and designs, facade engineering in Japan is still problematic. The reasons generally stem from the fact that this field is still evolving, and the function of the facade changes from project to project. In addition, the exact role of the engineer in facade design has yet to be clearly established. In this paper, three models will be presented and discussed: 1) facade engineering managed by general contractors; 2) facade engineering supported by specialized subcontractors; 3) facade engineering through collaboration between architects and engineers. We put Japanese facade engineering into better perspective by analyzing the status of the current field of facade engineering. As this is a developing field, new models must be established. Until that is accomplished, Japanese design and engineering of facades will remain divided and inconsistent. This paper highlights the causes of the problems and hopes of proposing a possible alternative for the future.

Keywords: general contractor; research and development institute; specialized subcontractor; environmental design

Introduction
When considered in terms of architecture, exterior walls are important not only in determining the impressions of the architecture but also in defining the interior environment. Exterior walls currently being designed and built function to adjust the relationship between outside and inside in terms of air ventilation and natural lighting, and the control of other elements, as opposed to conventional exterior walls that are simply designed to function as divisions to control and limit the interior and exterior relationship. New types of exterior walls with advanced control mechanisms that fulfill these opposing functions clearly are the key to sustainable architectural innovation. Unfortunately, except for a few advanced examples, such innovation is as yet diffused and its possibilities are not fully exploited.

Significant changes are sure to occur in engineering methods that will allow for such new types of exterior walls and in organizations responsible for their engineering. Through the few Japanese projects that currently feature innovative exterior wall designs, we can understand the nature of their change to some extent, but it appears necessary to gain a clearer comprehension of the process of the change.

Up to now, we will introduce the notion of ‘building skin’ and review how they have been engineered in Japan. Until this time, there has been no critical study of façade engineering in Japan. This paper will be the first to address issues regarding façade engineering, particularly from the viewpoints of environmental concerns and the construction process. Using various recent projects completed in Japan as examples, the three models will be presented and the state of Japanese façade engineering explored and clarified.

Wall to Building Skin
Ever since the appearance of double-skin walls or whole surface glass façades, exterior walling has become complicated in design, construction, and function. Exterior walls have traditionally been developed under the view that they shield the comfortable internal environment from changing external conditions and climates. Windows inserted in exterior walls have been perceived to play a role in moderating this relationship. Then considering recent glass buildings from this point of view, an evolution has occurred where windows have emerged to become exterior walls. The main cause of this change has been the advent and use of artificial climate control, such as air conditioning, which compensates for the function previously served by windows.
However, the examples of double-skin walls and glass façades that are discussed in this paper are clearly following a different process of evolution from windows transformed in exterior walls. This different process arises from the notion that a middle layer has changed. A new notion that encompasses opposing functions has emerged. In this paper, the term ‘building skin’ refers to such a notion, and thus building skin can be defined as that which effectively and efficiently adjusts exchange between the internal and external environment - light, heat, air and humidity - like the skin of an animal.

The Situation in Japan

In Europe, buildings employing building skins have been increasing in number with the current growth of environmental consciousness. In general, European façade-engineered buildings are owner-occupied buildings, and because these buildings serve as facilities for the owners, the general trend is to hire façade engineers and to supervise façade design and construction.

In Japan, the situation is essentially the same, except for the lack of façade engineering. However, changes have recently occurred. Some façade-engineered tenant-occupied buildings are appearing. These buildings are designed not by typical and conventional methods, which aim at maximizing floor space, but by very different methods. It is said that it is difficult to comprehend the difference in the functions of buildings without locational conditions. This is why buildings, which have the characteristics of good design and environmental consciousness, stand high in the opinion of tenants. Thus façade-engineered buildings would be welcomed among tenants in Japan.

Factors concerning environmental consciousness, such as initial and running costs, strongly influence design schemes in Europe and it has recently become a major factor for many owners in Japan as well.

The occupational description of façade engineer is not yet established in Japan. So far, the know-how of exterior wall design and construction has accumulated among subcontractors working on exterior walls. Thus engineers who work for such subcontractors have played roles under architects in the design stage and under general contractors in the construction stage (shown as Fig. 1). Their recompense is included in the material and construction costs that are paid by the general contractor, not by the owner or the architect. This means that architects do not have the authority to choose their subcontractors and there is also the possibility of subcontractors having to assist architects free of charge.

In spite of all that, such buildings require engineering in the early period of the design stage. This is the origin of façade design and construction problems in Japan.

In Europe, there are two types of façade engineering. One is façade engineering supported by specialized subcontractors, and the other is façade engineering by collaboration between architects and façade engineers. Regarding the former, know-how of building-skin design and construction has accumulated among subcontractors in Japan, it has a potential for evolving in the Japanese façade industry. Regarding the second case, there are no façade engineers in Japan yet. However, there are many architects and engineers with skills related to building skin. There is a strong possibility that façade engineers will emerge from among them. In Japan, therefore, the two types will develop similarly to Europe. In addition, façade engineering managed by general contractors has great potential. Japanese general contractors have their own design teams and technical research and development institutes. For this reason, they have the capability to carry out façade engineering independently from beginning to end. Therefore, in Japan, it is reasonable that three types of Japanese façade engineering will evolve.

![Fig. 1. The Feature of Organizations Dealing with Exterior Walls](image)
Facade Engineering in Japan

Our analysis begins by considering the groups that control Japanese façade engineering. General features of each case study are compared in Table 1. We can classify façade engineering in Japan into the following three types.

1. Façade engineering managed by general contractors
2. Façade engineering supported by specialized subcontractors
3. Façade engineering through collaboration between architects and engineers

In Japan, there had been few façade-engineered buildings with building skins until now. For this reason, we analyze façade engineering in Japan through case studies. In this study, to standardize the attributions of case examples, the targets of study are limited to middle-sized office buildings with building skins completed in the past three years. Case B is an additional example to support the case study of collaboration between architects and engineers. In general, a curtain wall committee is organized in the design and construction phase of a large-sized office building. This kind of committee comprises architects, structural engineers, fire engineers and engineers from specialized subcontractors dealing with curtain walls. Various issues are considered in this committee. It can be presumed that some people in the committee might be façade engineers. However, because there are no building services engineers in the committee and it is organized only for large-sized buildings, it cannot be universally applicable. This is why our examples are confined to middle-sized office buildings.

Through five case studies, we will be able to more clearly understand the current situation of façade engineering in Japan.

-Managed by general contractors

A consistent feature of large Japanese general contractors is that they have their own design teams and technical research and development institutes. These teams are composed of architects, structural engineers and building services engineers. Therefore, they can perform consistent and effective design and construction. In this section, we focus on two case studies, identified as S and M; we use RD as an abbreviation for a technical research and development institute.

In each of these case studies, the building skins were designed through cooperation among an architectural design team, a structural engineering team, building services engineering team, RD and subcontractors specializing in exterior walls. Currently, many significant technologies and practices have been developed among subcontractors dealing with exterior walls in Japan. If construction is carried out using conventional technologies, the input

| Feature of building skins | S                     | M                     | Y                     | G                     | B                     |
|---------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| -double skin              | -ventilation of fresh air | -Low-E double glazing | -double skin with exterior roll screen | -breathing double skin with jalousie |
| -ventilation of fresh air | -air flow window      | -point-fixed glass with double glazing | -louver eaves         | -louver eaves         | -louver eaves         |
| -Low-E double glazing     | insulating metal sash  |                       |                       |                       |                       |

| Building use              | office for rent       | office for rent       | office owner-occupied | office owner-occupied | cultural-arts complex |
|---------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Total floor area sq.meters| 9,135                 | 8,812                 | 4,938                 | 2,470                 | 4,875                 |
| Number of stories         | 11                    | 13                    | 10                    | 9                     | 3                     |
| Architect                 | general contractor    | general contractor    | architectural firm    | architects studio     | architects studio     |
| Timetable design construction | 2000.12-2002.6     | 1997.5-1999.9         | 1997.9-1999.2         | 1998.4-2000.6         | 1994.12-1997.12       |
of the RD is not needed. However, in these two particular cases, S and M, since ventilation of fresh air into the interior space was required, engineering by the RD was necessary. As a result, the RD played a role in the development of ventilation systems rather than in the design of exterior walls.

In case S, a European engineering consultancy took charge of the engineering from the beginning of the design scheme. Later, the RD of the Japanese general contractor took charge of engineering from the subsequent simulations of thermal and airflow environments. In the same way, in case M, the RD was in charge of engineering for such tasks as simulations of thermal and airflow environments inside the atrium, from the initial stage of the design scheme. It is common for the RD provide engineering expertise. It is important to note that companies without a RD may not accept a project that requires façade engineering because they would have to outsource thermal and airflow simulations which often require supercomputer calculations.

It is difficult to expect the cooperation of the RD if the general contractor has no part in the building design and construction. It is generally restricted to the buildings designed and constructed or the buildings constructed by the general contractor.

When we consider that façade engineering requires the cooperation of the RD, there is little possibility of outsourcing analyses such as simulations to the RD of other organizations. Such analyses are required in the early period of the design scheme, at which time the general contractor has not yet been decided. Therefore, the possibility of façade engineering through cooperation with the RD is limited to only two cases.

(1) Contract for design and construction
(2) Contract only for construction

The RD can be involved from the initial stage of design in case (1). On the other hand, in case (2), cooperative contribution is limited to evaluating the possibility of change at a production design level, such as value engineering proposal setting.

In cases S and M, remuneration was paid to the RD. However, there is the possibility of being included in material and construction costs. For this reason, appropriate methods of paying engineering fees to RDs must be established.

Supported by specialized sub-contractors

Specialized subcontractors are defined as organizations that construct specific parts of buildings under a general contractor. It is a general feature of Japanese specialized subcontractors that not only construction but also fabrication of specific components of buildings is carried out. Here we discuss two case studies, Y and G.

Façade engineering supported by subcontractors differs from the above projects managed by general contractors in that in each case, the building is owner-occupied. This is common in Europe.

The buildings in both cases Y and G have glass façades. In case Y, it is characterized by Low-e double-glazed glass, and in case G, there are sunshade roll screens as an environmentally friendly method. Neither of these designs requires a fresh air ventilation system. In these designs, there was no requirement for thermal environment simulations involving supercomputers, as was the case in façade engineering by general contractors, where the interior environment is controlled by sunlight and air-conditioning. The architectural firms that designed buildings Y and G attempted to use this manner of sunlight control in earlier projects. Because the façade engineer employed established and familiar methods, the façade did not need to be newly engineered, as is often the case in Europe.
Because the architectural firm that designed Y worked with the specialized subcontractor on earlier projects, the façade was also engineered using established technology. This example of a project featuring an established working relationship is common in Japanese design projects. As a result, the chief architect had little trouble in designing and constructing the façade.

In case G, in which a system of double-skins with external roll screens was chosen, the cooperation of a domestic specialized subcontractor that manufactures such screens was required. However, imported roll screens were chosen for this project because Japanese screens could not guarantee the same performance for rolls placed at high positions. Despite the screens being produced outside of Japan, the subcontractor took responsibility for the regulating system, its installation and maintenance. In Japan, it is generally believed to be difficult to find a contractor when imported products are used. The reason for this is that Japanese subcontractors are reluctant to have a contract for only installation since both the installation fee and the cost of materials are included in the contract fee in typical Japanese construction projects. Consequently, the nature of the construction industry will change greatly, if an increasing number of Japanese contractors would adopt imported products. In such a case, architects require collaboration with engineers who belong to other firms or organizations.

Case Y and case G provide an interesting comparison. Case Y is an example of a building engineered with the technology accumulated among architects and subcontractors from previous projects. In case Y, the key is how the architects worked and maximized their relationship with the subcontractor. When specialized subcontractors are involved in the engineering of the façade, the architect, who usually belongs to a large architectural firm, has the opportunity to develop a close and lasting relationship with that specific subcontractor. This relationship continues to develop particularly if the number of shared projects increases. However, architects belonging to small architectural firms will not have many opportunities to work with a specific subcontractor and to develop a similar close working relationship. As a result, they cannot benefit from the experience of shared teamwork.

-Collaboration between architects and engineers

This section concerns façade engineering through the collaboration of the architect and engineer components. This situation is similar to that of façade engineering in Europe but, in this particular case, architects who belong to small architectural firms that do not have in-house engineers will be discussed. In such a case, architects require collaboration with engineers who belong to other firms or organizations.

At this time, in Japan, the contribution of specialist structural and environmental engineers in façade engineering is becoming increasingly necessary. Usually, structural engineers and environmental engineers work independently. In addition, Japanese engineers in façade design tend to work only within the confines of a parent manufacturing company or subcontractor, resulting in a limited opportunity for further design or technological development. Although architects now have the important responsibility to break down boundaries that have limited engineering development, it is necessary to consider environmental and structural issues at the same time. As a result, it is certain that the building industry will require the emergence of engineers with specialized expertise in both fields.

In the structural engineers community in Japan, there are structural engineering designers who design spaces in collaboration with architects and there are also mere engineers who only carry out structural calculation. Similarly, among environmental engineers, there are environmental engineering designers who are proactive in the design process in collaboration with architects and there are also mere engineers who simply calculate such parameters as the required capability of air-conditioning.
In Japan, the roles of the environmental engineering designers are not yet established. However, it is clear that such people will play catalyzing roles in many projects in the future.

The last case, B, is characterized by the use of breathing double-skins that was engineered through collaboration among architects, an environmental engineering designer, specialized subcontractors and a building automation system company. Even if each organization is capable in its own field, the overall success of the façade design depends greatly on the capability of the lead engineer and not simply on the state of technology or simple involvement of a particular division or company. From this viewpoint, it is likely that architects and the changing nature of the building industry will greatly affect the roles and responsibilities of the engineers in Japan.

Conclusion
We analyzed three types of façade engineering prevalent in Japan at this time.

(1) Managed by general contractors
(2) Supported by specialized subcontractors
(3) Collaboration between architects and engineers

Of these categories, it can be said that the first is the most Japanized form of façade engineering. It has the greatest effect on a building which designed and constructed by same general contractor. For this reason, it offers little versatility with respect to a building designed by other company. Therefore, it is hard to expect on collective strength of general contractors in the establishment of façade engineering in Japan.

In the second type, façade engineering is undertaken using the practical experience of an architectural firm and subcontractors. However, not every architect can establish such a specialized relationship. In Europe, subcontractors often take responsibility for the engineering of the façade, and in Japan also, there are many opportunities for subcontractors to shape the façade-engineering field. Success depends, however, on how the building-skin industry develops. Currently, engineering fees are usually included in the material and construction costs. As a result, it is necessary to clarify and perhaps even restructure contractual agreements.

Cooperation between the domestic subcontractor and the overseas manufacturer is another possibility in façade engineering in Japan. If the domestic subcontractor assumes only the risk of installing imported products, there will be no expansion of such cooperation. It is preferable for collaboration to be one that expands into new forms of engineering and building possibilities.

The study of the third type revealed that there is a possibility for impressive projects if motivated engineers can work directly with an architect. Even in small projects, we can clearly see the possibilities for innovative façades. However, the key element in any effective façade design and engineering depends entirely on the capability of the engineers in charge and on the nature of the collaboration.

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