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Innovative Façade Systems Of Japan

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Japanese architecture has traditionally provided for tight integration between the façades of buildings and their overall form, as well as their interiors. Through a combination of traditional vocabularies and sophisticated contemporary technology, new paradigms in façades are being established, with implications for use at much greater scales and heights than before.

Contemporary Japanese Architecture: External Characteristics

In the façade design of contemporary architecture, American, European, and many Asian architects commonly tend to emphasize symbolism in façades, sometimes to the point where it is independent of the overall building form.

Japanese architects have tended not to separate the façade from the overall building form, because the façade is recognized as something that cannot be given its shape independently from the entirety.

For Japanese architects, the façade is where the internal space of the architecture and the external environment intertwine. Furthermore, the façade is where the geographic, climatic, and cultural aspects – which cannot be separated from the structural and environmental systems – also intricately intertwine. A façade is recognized as something that should be "generated" by various conditions that make the architecture possible, rather than something that an architect gives its own independent form.

> "In contemporary Japan, *engawa, tategu,* and *arawashi* are extended to the fanatical level, beyond the framework of rationality that normally dictates the design of high-rise building façades."

Five Vocabularies

Five vocabularies are important in considering Japan's tradition-inspired façade design:

1. *Engawa* (internal and external continuity)
   As the weather is mild throughout the four seasons in Japan, the façade is considered as an interface that connects the internal and external space, rather than as a boundary that separates the internal from the external. *Engawa* (veranda) is one of the typical examples. Contemporary Japanese architects are trying to find a way to realize this internal and external continuity within large-scale buildings in contemporary architecture (see Figure 1).

2 *Engawa* (multi-purpose)
   A belief that architectural elements should serve multiple purposes is at the core of Japanese design culture. For example, the *engawa* (veranda) acts not only as an interface that physically connects the internal and external space, but also as a bench where people can sit. Furthermore, it forms a kind of transition space that connects to the back corridor. During winter, it becomes a double skin by closing both the fittings facing the exterior corridor and the fittings facing the rooms. It

Figure 1. *Engawa* (veranda) in traditional Japanese architecture.

Figure 2. Multi-purpose Japanese *engawa* (veranda). © Mizuho Watanabe

Figure 3. *Tategu* – façade in traditional Japanese architecture, which consists of exposed pillars, beams, and fittings.

Figure 4. *Kojo-moe* (factory infatuation) in action. © Takuro Watanabe

prevents heat in the room from escaping to the outside (see Figure 2). On the other hand, during summer, both fittings are opened to let the air in. Eaves that cover a large section above the corridor block high-angle sunlight. This is a Japanese aesthetic, in which the exterior has multiple purposes, not only as a boundary between the internal and external space, but also as a circulation path and furnished place of repose. Contemporary Japanese architects aim to imbue this aesthetic in large-scale architecture.

3 *Tategu* (variable adjustments to the environment)
Japanese architecture, which was nurtured through the tradition of wooden structure and earthquakes, is based largely on orthogonal framing that consists of linear pillars and beams. Therefore, exterior or internal partitions are considered as *tategu* (fittings), rather than walls. Fittings that form façades are freely opened and closed. They change and vary the relation of the internal to the external condition in accordance with the season and time. This variety in adjusting to the environment is what Japanese architects look for in the contemporary façade (see Figure 3).

4 *Arawashi* (exposure)
In traditional Japanese architecture, basic components, such as pillars, beams, and fittings are not hidden, but instead are exposed to compose a design element. This is called *arawashi*.

This ideology of *arawashi* still has a great influence on today's Japanese design culture. Japanese architects resist to the idea that a façade should be mere "cladding" – external finish material that hides the structure. It is the basic ideology of Japanese architects to compose architectural exteriors with minimum requirements by using only structures and fittings, such as pillars or beams, in exposed status, while the required insulation is provided from the environmental point of view.

5 *Suki* (refined taste)
Suki is a term that means "complex aesthetic sense," dating from the end of the 16th century to the beginning of the 17th century, when tea-ceremony houses were established. This is one of the concepts that forms the foundation of Japanese aesthetics. Taking some liberties, the author would advocate for strengthening its meaning to be "fanatical inclination in the material beauty or structural beauty that the Japanese people prefer." While the previously mentioned four vocabularies still have the most influence on Japanese architecture, they sometimes tend to be implemented to a fanatical level beyond the framework of rationality.

An analogue for this architectural condition can be found in *kojo-moe* (factory infatuation), in which the display of an industrialized aesthetic is implemented, exposing pipes and other equipment that is normally hidden away (see Figure 4).

In contemporary Japan, *engawa, tategu,* and *arawashi* are extended to the fanatical level, beyond the framework of rationality that normally dictates the design of high-rise building façades.

These characteristics are obviously seen in the design of Kenzo Tange and the Metabolists, the Modernist movement in Japan in the 1950s and 1960s, which translated International Style into a special kind of localism. For example, the façade of Kagawa Prefectural Government Office (1958) is considered one of Tange's masterpieces (see Figure 5).

In general, the pattern of joists used on the underside of the eaves, reflected in the reinforced-concrete (RC) structure, is often treated as an architectural aesthetic inspired by the joinery used in traditional wood architecture. Although it is polished to be extremely thin, the joist is actually not a cosmetic feature. It is in fact the *arawashi* of the physical structure, and also communicates the theme of "internal and external continuity." Moreover, the balcony surrounding the exterior of the joist bridges the exterior and interior of the building as a modern *engawa,*

Figure 5. Kagawa Prefectural Office, Kagawa.

while at the same time functioning as an eave, its apparent purpose.

Since the time of Metabolism, albeit with variations, these five vocabularies are repeatedly adopted by many architects across contemporary architecture in Japan.

Applying the Five Vocabularies In Contemporary Work

These five vocabularies have their roots in traditional Japanese architecture. In 20th century architecture, they have most often been practiced in relatively small-scale buildings. But in the 21st century, they began to be tested in large-scale buildings. One of the reason for this is the rise of computer-assisted architectural design.

The invention of design software, which solves design problems by way of algorithms and variables; the spread of Building Information Modeling (BIM), which affords a truly three-dimensional and multi-disciplinary approach to design; and improved visualization capabilities, have together pushed forward the strategic deployment of "traditional" design vocabularies on modern high-rises. These three software types working together have made it possible on a practical basis to design integrated structural forms and façades with intricate relationships.

What is interesting here is that computer-aided three-dimensional design is commonly used to design and produce complex and iconic forms in countries other than Japan. But in Japan, the same method leads to the search for simpler forms within complex conditions and for innovative façade systems that make them possible. In the view of the author, this is largely due to the persistent influence of the aesthetic vocabularies discussed earlier. Façade construction based on such aesthetics is beginning to be realized in large buildings by utilizing advanced computational methods.

Jinbocho Theater Building

This facility, composed of two theaters, was generated using a computational method, whose aim was to determine the external form that would maximize the gross floor area while meeting strict setback requirements. The structure is reinforced concrete, but the triangular steel sheets, stretched over the exterior, enhance safety by acting as dampers that absorb seismic energy (see Figure 6).

At the same time, the air in the space between the concrete frame and the façade is used as an insulation layer. Also, when the air temperature rises, an oil damper is activated, releasing warm air to the outside. In addition, during an earthquake, the steel plate of the façade functions as a vibration control member, absorbing some of the energy of the earthquake. Although the façade is oddly shaped, it has various meanings in its form. Three-dimensional BIM design and computational fluid dynamics (CFD) analysis made the design possible, but the long-lived "vocabularies" persist.

Here the steel plate composes the façade as *arawashi,* and simultaneously serves both an

Figure 6. Jinbocho Theater Building, Tokyo. © Nikken Sekkei

environmental and structural role. In Japan, a country with frequent earthquakes, both the structural framework and the ductile steel plates are used effectively for vibration control. It is reasonable to anticipate that such vibration control members will continue to emerge as façade elements in the *arawashi* of the near future.

Hoki Museum

In this design, the team fashioned the steel structure itself into the building's internal and external finish (see Figure 7). By deploying the costly steel structure as both interior and façade, further savings could be made beyond the elimination of the need for a frame structure.

Figure 7. Hoki Museum, Chiba. © Nikken Sekkei

Figure 8. Interior of Hoki Museum showing the computer generated lighting pattern. © Nikken Sekkei

Maximum potential was realized by using the steel frame structure as an air conditioner, smoke exhaust duct, and LED lighting fitting case. By deploying BIM computational simulations, the team was able to predict in advance that condensation from thermal bridging and heat loss were unlikely.

The holes for the ceiling lights needed to be placed so that they formed a particular pattern, while supporting optimal lighting distribution (see Figure 8) and avoiding conflict with the stiffening ribs of the steel sheets. This was made possible by computing the layout pattern. The artwork, stuck by magnets to the exposed steel sheeting, can be placed freely along the surface without set layouts.

Here, the structure of the steel plate performs as *awarashi* by continuing from interior to exterior, becoming a mechanical duct and façade simultaneously. Multi-purpose façades are aggressively pursued in Japan, based on the spirit of *suki*. But what pushed the concept into reality were BIM, computer simulation, and digital fabrication. It can be expected that these new methods will be deployed in the construction of skyscrapers, which will yield their own uniquely Japanese "fanatical façades."

Figure 9. Mokuzai Kaikan, Tokyo. © Gankosha

Mokuzai Kaikan

This office building uses non-fire-retardant-treated timber for the exterior, interior, and secondary structural members in various locations, including the structure of the top floor (see Figure 9). In order to provide safety that exceeds the requirements in the Building Standards Act, the architects placed balconies at each floor and external stairs that connect each balcony directly to the ground. By placing pillars at the balconies, the workplace could be column-free.

The combination of extending the slab, placing the pillars along the balconies, and extending the wooden eaves acts not only as a façade that has well-defined features, but also as a shade that blocks the strong western sun. In normal situations, this provides a place for office workers to relax, but in case of emergency, it also acts as an extremely safe evacuation route. BIM played a large part in designing and simulating a façade that has such a profound meaning. Furthermore, in construction, the team managed to deploy principles of traditional joinery in a contemporary application at a reduced cost.

In Japan, fabrication is the largest component of the cost of wood used in architecture. Even in a case of standard wood, the cost of the material itself is 30% with fabrication comprising 70% of the total. Thus, in order to effectively reduce the cost of using wood, a reduction of fabrication labor cost is essential.

In Mokuzai Kaikan, *Oikake Dasisen Tsugi,* a traditional wooden joinery method is used, which is effective for bending, compression, and tension. This type of joint has a soft angle for fabrication, and thus even an experienced carpenter requires 10 to 20 minutes to fabricate one joint. On the other hand, if a computer numerical control (CNC) fabrication machine is used with accurate digital data from the beginning, it fabricates 100 times faster, and sometimes more accurately than humans. In other words, the fabrication cost that dominates 70% of architectural wood's price is reduced to 7%, and as result, the cost of wood theoretically drops to about 33% of the original cost.

In reality, the author and colleagues successfully reduced the cost to 50% at Mokuzai Kaikan.

To do this, designers transferred the three-dimensional shape into the CNC fabrication machine tool during the design stage, in order to realize digital fabrication of joints that are as sophisticated as their traditional forbears, in terms of their compressive, tractive, and shear force resolution.

Currently, interest in the construction of high-rise buildings with wood as the primary structural material is on the rise over the world, and in Japan, without a doubt, structural wood will be part of the fanatical pursuit of the *arawashi* principle, not only for the interiors, but also the exteriors of tall buildings.

> "Here the steel plate composes the façade as *arawashi,* and simultaneously serves both an environmental and structural role… both the structural framework and the ductile steel plates are used effectively as vibration control members."

Figure 10. Lazona Kawasaki Toshiba Building, Kawasaki. © Gankosha

Lazona Kawasaki Toshiba Building

This is a large-scale office building in a shape of a cube, whose sides are 81 meters long (see Figure 10). A large space (16 to 25 meters' depth) is preferred for offices in Japan. Also, many of the offices use cooling systems throughout the year, due to the heat generated by PCs. Thus, the role of the façade here is to block the direct sunlight and to take in the ambient daylight necessary for the office periphery. As a result, it is possible and desirable to construct offices in such cubic shapes in Japan.

The pattern of the exterior is determined by multiple parameters, including the heat-

Figure 12. NBF Osaki Building, Tokyo. © Gankosha

Figure 11. Lazona Kawasaki Toshiba Building – façade system. © Gankosha

exhaust efficiency of the external air-conditioning unit, the shade of the buildings in the neighborhood, and the angle of the sun. The project also included a façade system that resists rapid heating in sunlight, easily cools down with minimal airflow, and suppresses the heat island effect of the building, by way of a third key element (see Figure 11). A heat sink is formed by the combination of extremely thin metal louvers, perforated with holes, and concrete panels with relatively high heat storage capacity placed behind the louvers.

To optimize air conditioning, the location of mechanical equipment is predetermined. The precise position of the louver is fixed because of the angle of the sun. Here, these critical elements of the building serve multiple purposes and compose the façade as it is. In addition, because of its cubical geometry, a maximum floor area, surrounded by a minimal, cost-conscious exterior is the result. The unique façade was realized by deploying BIM and computer simulation, resulting in a 50% construction cost reduction from a conventional office building.

BioSkin

In the search for computationally designed façades, BioSkin on the NBF (formerly Sony) Osaki Building represents the latest refinement of technological innovation at this point in time (see Figure 12).

The main function of this building was to facilitate research and innovation at Sony, one of the world's largest technology companies. As this facility was designed to gather together Sony's brain trust, it was important to offer safe evacuation routes by placing balconies all around the workplace, as well as to allow researchers to do their best work within a safe and pleasant environment.

The prototype of BioSkin was realized from an idea of using balcony handrails as additional environmental equipment. If handrails are comprised of ceramic pipes and Japan's plentiful summer rainwater is allowed to pass through them, the resulting evaporation could cool down the building and the surrounding environment. If reproduced at scale, could eventually cut down on the urban heat island effect significantly.

The design team first researched the gradual temperature rise in Tokyo over the past 100 years, determining that it has risen by 3°C. Temperature increase attributable to climate change contributes to 0.6–0.7°C of change within that figure, but the heat island phenomenon contributes to the rest of the figure – more than 2°C. The heat island phenomenon raises the temperature within the metropolitan region, as buildings holding the heat generated by the sun during the day release it at night.

If evaporated rainwater can cool down the building, it can reduce the heat island effect. An initial experiment consisted of pouring rainwater into ceramic pipes. It was discovered that the surface temperature decreased by 12°C in the sun, and 6°C in the shade. Furthermore, the ambient temperature around the ceramic pipes decreased by 2°C. In this localized instance, mere rainwater had decreased ambient temperature equivalent to the rise in temperature that had occurred over the past 100 years of urban heat island phenomena. It is easy to appreciate the implications of deploying this at a larger scale. Based on the test results, a computer simulation of the building using BIM data was conducted. The team also discovered that the temperature around the footings of the building decreased by 2°C. This provided sufficient grounds to move forward with implementing the façade system on the actual building. Without BIM and computer simulation technology, it would have been difficult to implement this project, and this plan would have remained an impractical idea.

In the final design, the whole structure is supported by tension, with minimal support members. This contributed to minimizing the CO_2 generated by the project, and was a determinant of the aesthetics of BioSkin.

After completion, the team measured the temperature inside and outside the building on the ground and from the air, by utilizing a thermal camera attached to a helicopter. The moment of confirmation that BioSkin was demonstrating the expected effect was an unforgettable one (see Figures 13 and 14).

The design team is currently pursuing two further projects using the BioSkin technology. Capitalizing on BioSkin's success, the team is also developing an environmental device that utilizes water vaporization energy.

Such a device, which applies primitive natural phenomena, is simple, durable, and highly reliable. The effect of individual devices acting in isolation is insignificant. But they will be extremely effective when deployed on high-rise buildings, which can use thousands of such devices simultaneously and abundantly.

In addition to the water vapor effects, environmental devices that apply latent heat from the material phase transitions fully utilize the primitive characteristics of those materials. To use such mechanisms in the façade as *arawashi* perfectly conforms to the taste of architects in Japan, and thus the author expects such research and development will continue to develop in the country.

Of course, the applications are not limited to Japan. In Asian countries with high temperature and rainfall, the concept of BioSkin is valid, and already has the keen interest of designers in those countries.

A Future of Mass Customization

Many suggestions have been made about the potential commercialization of BioSkin, but the designers politely refuse them. The team's feeling is that the "mass production" method – is a rather old-fashioned way of producing goods. It was popular back in the 20th century, but in light of the environmental concerns of the 21st century, a different line of thinking is needed.

Architecture in the 20th Century reflected engineering and aesthetic norms developed in the auto industry and highly valued the concept of mass production. In an era fixated on producing high-quality goods in mass quantity at lower cost, skyscrapers were the very incarnation of this trend. However, the essence of architecture is to produce a singular masterpiece with each project.

Furthermore, we have entered an era of environmental consciousness, wherein value is accorded to the careful production of high-quality architecture according to the conditions of each project and site. Digital fabrication, computer simulation, and computational technologies like BIM have been introduced to realize cost reductions while maintaining high quality. Three-dimensional printing technology is an intersection of mass production, high-performance computing, desktop publishing and electronic publication technology. Examining how printing technology has changed – where the essence of the business has gone from producing a large variety of publications in small quantities to one that produces high-quality publications with rapid digital distribution to the world – delivers a comparable analogue to architecture.

Contemporary Japanese architects are investigating the potential of generating innovative façade systems that unite the internal and external spaces of architecture, fusing together advanced computational technologies with traditional perceptions of interior and exterior that have informed Japanese architecture for centuries. ■

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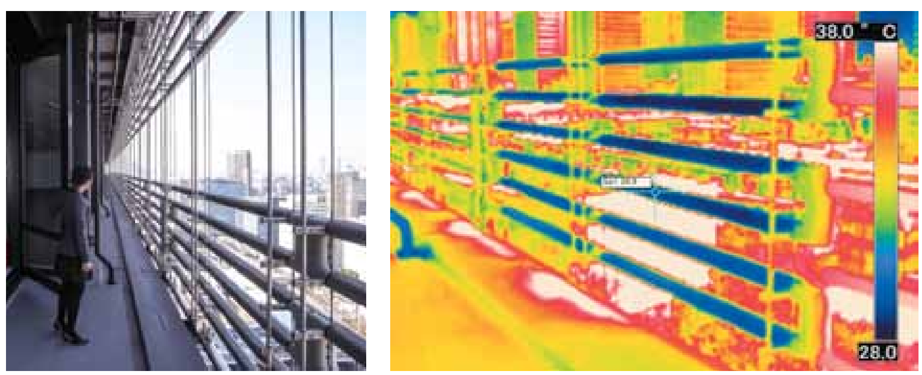

Figure 13. Thermographic photo of NBF Osaki Building's façade after the BioSkin was activated. © Gankosha

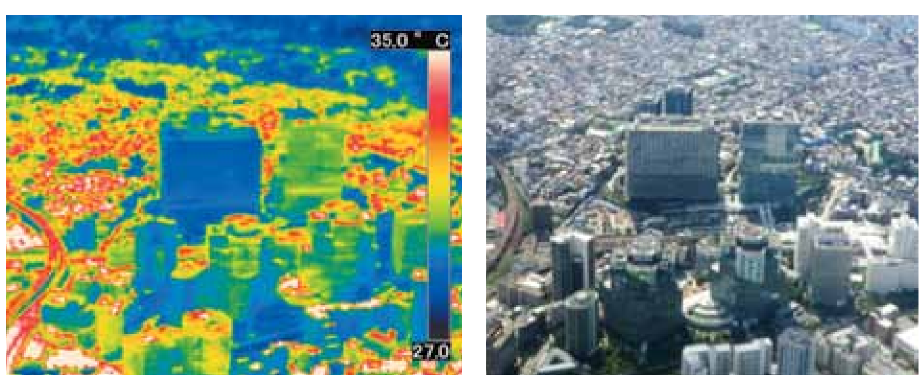

Figure 14. Aerial thermographic photo of the BioSkin-clad building. © Nikken Sekkei