ABSTRACT

The design professions have seen a proliferation of new types of translucent glazing and cladding systems in the past decade. The design strategies, detailing, and choice of materials for the windows and building envelope are essential factors in creating a meaningful experience of architectural space and form. Yet, little attention has been given to the daylighting impacts of translucent versus clear glazing. This paper compares and contrasts the daylighting and envelope designs of the Naked House and the Shutter House by architect Shigeru Ban. Qualitative and quantitative analyses for each project illustrate the impacts on daylighting and human experience of translucent versus clear building envelopes.

1. INTRODUCTION

Do translucent building envelopes enhance the three-dimensional experience of daylighting in space or do they shift the focus of light to the two-dimensional skin, suggesting that the beauty of daylighting may be only skin deep? Japanese architect Shigeru Ban is internationally recognized for his innovative approaches to construction, the building envelope, and daylighting design. His minimalist attitude and experimental investigations of materials, space, and the construction combine design excellence and ecological-responsiveness. Two residential projects, the Naked House in Kawagoe, Japan and the Glass Shutter House in Tokyo, illustrate the daylighting design challenges and opportunities of translucent versus clear glass. The selected projects provide a useful cross-section of new design strategies for the building envelope and their broader daylighting design considerations. Each project will be considered in terms of the building context, program, users, and design strategies. Quantitative and qualitative daylighting analyses are compared and contrasted.

3. THE NAKED HOUSE, KAWAGOE, JAPAN

3.1 Project Background

The Naked House by Shigeru Ban is located in the city of Kawagoe, Japan at 35°NL. The temperate climate provides an opportunity for the architect to open the building to the site during many months of the year and to respond to the changing diurnal and seasonal environmental forces of sun and wind. The average temperatures in Kawagoe range from a low of 34-48°F in January and a high of 72-84°F in July, with a distinct sunny and overcast season (World Climate, www.worldclimate.com). The rainy season occurs from early June to mid-July, with the typhoon season in September. Clear skies dominate during the winter months.

Fig. 1: The Naked House, exterior during the day and night (© Shigeru Ban Architects)
Located in an agricultural area adjacent to rice fields, the house is exposed to the environmental forces from all orientations. The building massing is a simple rectilinear form, with the length of the southern façade oriented to the south west. A car port is located on the east side of the building adjacent to the bathroom and service spaces. The main living space in the residence is a two-story volume that contains four modular wooden rooms that can be easily repositioned within the space or moved outside to the west terrace. According to Shigeru Ban, the client requested openness and flexibility: *What he wanted was described as a house that “…provides the least privacy so that the family members are not secluded from one another, a house that gives everyone the freedom to have individual activities in a shared atmosphere, in the middle of a unified family”* (Shigeru Ban, www.shigeru-ban-architects.com). The north and south facades are translucent double-skin envelopes that admit abundant daylight. Small clear windows and one set of sliding translucent doors are provided for discrete views and air. In contrast, the west wall is fully glazed with clear operable doors to provide site views and connection to the terrace (which is enclosed on the south and north by translucent wing walls and an overhead plane). Although the east façade is glazed, the bathroom and service areas block the view from the living space to the site.

The extreme degree of transparency and openness is Shigeru Ban’s response to the client’s desire to optimize connections between the family and flexibility. The lack of opaque walls creates a degree of translucency that optimizes light transmission and a sense of spaciousness; however, as the name of the Naked House implies, the occupants are literally exposed throughout the house. One has to literally enter one the mobile rooms for retreat and privacy. In addition, since the space is illuminated from all four sides, there is little contrast, shadow, or relief from the light. During the day, one is constantly surrounded by diffuse daylight. As requested by the client, the house provides limited privacy on the inside and from without. Even at night one is able to see the movement of occupants from the exterior of the building (Figures 1 and 2).

### 3.2 Space, Program, and Activities

The house is designed for a family of five, including two parents, two children, and a Grandparent. Ban responded to the need for flexibility by providing a simple open plan with moveable rooms that can be configured in various relationships and locations within and outside the house, as Ban explains: *The house consists of one unique large space of two-story high in which four personal rooms on casters can be moved freely. To reduce weight and optimize mobility, these rooms are not very large and hold a minimum of belongings and fittings. They can be moved accordingly to the needs of their use. Placed against the walls of the house, in front of the heating or air-conditioning units, warm air or a cooling breeze can flow into it. They can also be put side by side and create a larger room, when their sliding doors are removed. They can be taken outside, on the terrace, for the full use of the space inside. They can also work as a supplementary floor for the children to play on top* (Shigeru Ban, www.shigerubanarchitects.com).

Shigeru Ban also provides a translucent adjustable curtain on the east edge of the living area, which enables the occupants to open or close off the service areas. A translucent wall separates the bathroom on the east from the living space. Figure 3 illustrates the floor plan with the mobile rooms in various configurations. The lighting needs for residential buildings are quite flexible. Most residential activities require a modest level of illumination, ranging from the Illumination Engineering Society’s (IES) *Illuminance Category B* (*5-7.5-10 fc*) for simple orientation to *Category D* (*20-30-50 fc*) for simple visual tasks. Residential programs also provide an opportunity to integrate daylighting with passive solar heating and natural ventilation. Although the building is well oriented for passive solar gain, the architect did not integrate passive solar strategies for winter heating. Of equal importance is the daylighting opportunity for connection to the site, nature, and views, which are limited on the translucent southern and northern walls and optimized on the west.

### 3.3 Daylighting Design and the Building Envelope

The thin rectilinear house is illuminated by multilateral sidelighting from the four cardinal directions. The south...
and western translucent walls are punctuated by a few small transparent windows. In contrast, the east and west walls are completely transparent, with glass doors on the west side of the living space and opaque operable shutter-doors covering the transparent glazing on the bathroom wall on the east façade. The view in the living room is directed to the transparent west façade due to the modest size of the clear south and north windows. The translucent interior wall of the bathroom blocks the view to the east from the living space. The east façade (oriented southeast) is deeply recessed under a two-story overhang, which doubles as a terrace and car port. The clear glazing is treated with horizontal louver to control the low south-eastern sun and the operable shutter-doors on the lower portion of the façade provide privacy and shading to the adjacent bathroom. The translucent envelopes on the north and south are comprised of a double skin system that diffuses direct sunlight. Shigeru Ban describes the construction of these two walls as a series of translucent layers: The external walls made of two sheets of corrugated fiber-reinforced plastics and the inner walls made of a nylon fabric are both mounted on wooden stud frames and sit in parallel. In between are attached clear plastic bags, carefully stuffed with strings of foamed polyethylene for insulation purpose. Through these bags a soft diffused light fills in the interior of the house (Shigeru Ban, www.shigerubanarchitects.com). Figure 4 illustrates the design features of the translucent walls.

The house is essentially a light-diffusing box with select transparent openings to permit minimal direct sun and controlled views to the site. The thin massing of the building provides excellent opportunities for diffuse daylight throughout the house. Interior spaces are thoughtfully considered to optimize diffuse and borrowed light. The mobile rooms are “space within a space” that provide privacy and a contrasting quality of indirect sidelight, which is borrowed from the living space by adjusted the size of the opening of the sliding wooden doors. With the exception of the wooden portable rooms with their tatami-mat floors, white surfaces are used throughout the space to optimize reflective light and to create the sense of spaciousness and openness desired by the client. The wood-frame structure and cross-bracing, which can be seen from both the interior and exterior, provide a welcome visual counterpoint to the uniform translucent walls. While the design strategies and building envelope provide abundant illumination throughout, the resulting uniformity, quantity, and quality of light are also the challenges of luminescent building envelopes.

3.4 Daylighting Assessment

The analysis of the Naked House considered both qualitative and quantitative daylighting issues. A photometric analysis was conducted using a scaled model, measured under overcast sky conditions in the artificial sky (a mirrored-sky box) at the School of Architecture at the University of Minnesota. Photographs were taken under clear-sky conditions at 9:00 a.m., noon, and 3:00 p.m. during the summer and winter solstices and the spring and fall equinoxes. The resulting data provide an approximation of the quantity and quality of light on a seasonal basis. The study found an average daylight factor of 17%. Corresponding footcandle (fc) values range from an average of 550 fc in July to 175 fc in December. Since the space is sidelite with translucent glazing on the north-south axis, the distribution of light on this axis is very even throughout the space. The highest levels of illumination and greatest contrast are found on the east-west axis immediately adjacent to the clear glazing at the west wall and shaded terrace (with a 42% daylight factor dropping quickly to the average 17% daylight factor). Shigeru Ban far exceed the recommended levels of illumination for residential activities (IES Illuminance Category B: 5-7.5-10 fc and Category D: 20-30-50 fc), which is acceptable if issues of heat gain and lighting quality are addressed. The study confirms that the translucent envelope provides high levels of illumination and a fairly uniform distribution of light throughout the space. The Naked House truly is a daylit space, with little need for electric lighting save during the evening hours. See Figures 5-7 for the daylighting analysis and time sequence photographs.

The time sequence photographs illustrate that direct sunlight is highly controlled throughout the year (see Figure 5). Only small patches of sunlight are allowed to enter the living space on clear days through the tiny south windows and from the clear glazing on the western façade (which is recessed under a deep overhang and surrounded by the translucent wing-walls that extend out to the terrace). The photographs do reveal the natural variations in the quality of light under direct sunlight on a diurnal and seasonal basis. This effect would be intensified under real site conditions and the varying diurnal and seasonal sky conditions.
As Ralph Knowles explains in his essay “For Those Who Spend Time in a Place,” the daylighting design is a primary factor in our experience of time, seasons, and geographic location: “Any space that is oriented from east to west strengthens our experience of the seasons. One main wall is nearly always dark; on the other side of the space, a shadow line moves gradually up the wall then down again. To experience the complete cycle takes one year (Knowles 1992:42).” The seasonal and diurnal photographs reveal the movement of direct sunlight across the southern façade from morning to mid-day and evening, as well as the changing patterns of direct sunlight admitted through the small southern windows. The south façade receives and contains the direct sunlight within the double-layer cavity of the translucent envelope.

On a clear day, the south façade is illuminated in a dramatically different way than the north façade, which only sees direct sunlight in the very early morning in the summer under clear sky conditions. Given the south-western orientation and deep translucent fin-walls, the west façade is well sheltered from the summer sun until early evening. Since the rainy season occurs from June to September, the typical daylighting challenges of the summer months (including direct sunlight, glare, and excessive heat-gain), are climatically mediated due to the predominantly overcast skies. Under direct sun, the south envelope becomes a diffuse lighting fixture. The photographs suggest that the uniform and even distribution of light under overcast skies is contrasted by more variable light qualities under clear-sky conditions. The dramatic movement of the sun and resulting patterns of light provide the occupants with a diverse quality of light as well as a visible connection to time, the cardinal directions, and a sense of place.

While abundant diffuse light is provided throughout, potential challenges of the luminescent walls include high levels of illumination, relentless and monotonous quality of diffuse light, glare, and the limited play of light and shadow. High levels of illumination are not inherently problematic if lighting quality and thermal considerations are addressed. In this case, the challenge of the project lies in the limited ability for users to adjust, vary, or modify the light levels and quality. Considering Shigeru Ban’s original design concept, which was to provide great flexibility for the occupants, little variation can be found in the lighting quality and quantity. As Shigeru Ban explains: *This house is, indeed, a result of my vision of enjoyable and flexible living, which evolved from the client’s own vision toward a living and a family life* (Shigeru Ban, www.shigerubanarchitects.com).

The design concept for the Naked House is coherent and formally compelling; however, as a luminous space in which people live, Shigeru Ban falls short of his stated design goal of flexibility and adaptability. Little relief is provided from the uniformly diffuse, even relentless, daylight within the space. It is only possible to adjust the daylight in the portable rooms by modifying the position of the sliding wood doors and thus the size of the opening and resulting light levels and quality. Although attention has been given to the distinct qualities of light and thermal considerations for each orientation (e.g. selectively positioning the diffuse versus direct light, transparent versus translucent envelopes, deep overhangs, louvers, sliding doors, shutter-doors, and interior translucent curtain), the occupants can do little to modify the quantity and quality of daylight within the house.
3.5 Daylighting Lessons

In contrast to a transparent or clear wall, a translucent envelope is much more difficult for designers and users to modify, control, and mediate in terms of the quality and quantity of light. If sufficiently large in size and oriented to receive direct sunlight, a translucent envelope becomes a light-source that contains and holds daylight. The translucent envelope can become a source of glare under high levels of illumination and direct sunlight. This daylighting challenge is found, not only in the Naked House by Shigeru Ban, but also throughout contemporary architecture. In addition, the Naked House reveals that designers need to consider how much light is appropriate. Good daylighting design includes far more than providing sufficient and even levels of illumination. In many cases, less is more; a small window may be more successful than large apertures and high levels of illumination. It is easy to over-illuminate a space with translucent (or even transparent) envelopes. Contrary to traditional Japanese architecture, Shigeru Ban works minimally with shadow and contrast. Relief from the high levels of illumination and its even distribution would provide a counterpoint to the daylight and welcome visual relief. In the second of Shigeru Ban’s houses, we see a much greater attention to the role of shadow and varying qualities and quantities of light.

4. THE GLASS SHUTTER HOUSE, TOKYO, JAPAN

4.1 Project Background

The Shutter House is located in a dense urban site in a mixed commercial and residential neighborhood of Tokyo, Japan at 35°NL. As neighboring cities, Tokyo has the same climatic conditions as Kawagoe. The average temperatures range from a low of 34-48°F in January and a high of 72-84°F in July (worldclimate.com). The rainy season is experienced from early June to mid-July, with the typhoon season in September. Predominantly clear skies occur during the winter months. The thin infill site is oriented on a north-south axis, with the street façade oriented to the north, which presents challenges for solar access, ventilation, and daylighting. The massing of the Shutter House responds to the site challenges by pulling back the building boundary on the west to create a courtyard that admits light and air and allows the first floor to extend outside. The three-story building contains a restaurant on the ground floor with residential living spaces on the second and third floors. Given the site constraints to the east and south, the three-story façade is completely glazed on the west and north. The envelope is comprised of a series of layers that include an adjustable glass shutter-wall, moveable glass doors, and interior translucent polyester curtains. Shigeru Ban discusses the intention of the envelope: The relationship between interior space and exterior space is controlled by completely closing all shutters, or opening just the shutters on the side of the building, or opening just halfway, and further still, when adjusted in combination with the curtains, it becomes possible to create situations to adapt to any occasion. Architecture which supposedly does not change aspects, has, in this project, become an architecture which can adjust to varying seasons and occasions just as we change clothing accordingly (Shigeru Ban, www.shigerubanarchitects.com). These simple strategies can be combined to provide great flexibility in response to varying seasonal and diurnal lighting, ventilation, and cooling needs (Figures 8 and 9).

4.2 Space, Program, and Activities

Similar to the Naked House, the clients of the Shutter House also desired a building that was flexible and adaptable to accommodate a variety of programmatic uses and needs, including a restaurant, an educational space, and the residence for a family of three. The building is zoned vertically, with the public restaurant and courtyard on the ground floor, an educational studio-kitchen on the second floor, and the private residential space on the third floor. As a combined restaurant and residential building, the lighting program is fairly flexible. For most activities, modest levels of illumination are needed, ranging from the IES’s Illuminance Category B (5-7.5-10 fc) for circulation to Category D (20-30-50 fc) for ambient illumination and most non-critical visual tasks.
4.3 Daylighting Design and the Building Envelope

Despite the site constraints, the thin building form and massing optimize daylight and ventilation. Bi-lateral sidelighting is provided on the north and west facades. The quantity and quality of light, air, and direct sunlight can be modified through the adjustable glazing, operable glass shutter-wall, and translucent curtains. The open plan, exterior courtyard, and adjustable envelope allow occupants to modify both the spatial configuration (to extend the interior space into the courtyard) and the lighting quality and quantity. The degree of privacy and openness of the building can be changed from a very private inward-focus when the shutter-wall is down and the translucent curtains are pulled to a completely transparent building that extends out to the courtyard and streetscape when the shutter-wall, curtains, and doors are open. By varying the layers of the envelope, the occupants have a spectrum of design options (e.g. they can combine different configurations of partially open shutters, doors, and curtains). Interior finishes are also considered to optimize light distribution. Reflective white surfaces are used on all interior walls and the ceiling. A contrasting black floor and furniture used on the restaurant level and light colored tatami-mat floor are found on the upper levels. The design of the building envelope includes layers inside and outside, including the interior reflective surfaces, the interior translucent curtain, the operable glass shutter-walls, as well as the bamboo wall on the western side of the courtyard. Although the temperate climate creates modest heating needs, passive solar heating could be used in the winter months; however, the site constraints severely limit this opportunity.

4.4 Daylighting Assessment

A physical model of the Shutter House was evaluated under overcast skies in the artificial sky at the School of Architecture at the University of Minnesota. The qualitative aspects of the model were evaluated using photographs under clear-sky conditions at 9:00 a.m., noon, and 3:00 p.m. during the summer and winter solstices and the spring/fall equinoxes. The study found an average daylight factor 16%. Corresponding footcandle values range from an average of 550 fc in July to 250 fc in December. The analysis illustrates the typical problems of sidelighting, where light drops off quickly away from the window wall. The Shutter House, with its bi-lateral sidelighting and opaque east and west walls, has a variation of light levels on both the east-west and north-south axes (ranging from a daylight factor of 32% to 1%). In contrast to the Naked House, the Shutter House needs supplemental electric lighting in the first floor along the east and south walls. Despite the dramatic change from east to west, in much of the building the daylight levels easily meet the IES recommendations for ambient daylighting for the restaurant and residential activities (IES Illuminance Category B: 5-7.5-10 fc and Category D: 20-30-50 fc). See Figures 10-11 for the quantitative analysis.

The quality of light on a seasonal and diurnal basis is revealed in the photographs of the daylighting model illustrated in Figure 12. With the exception of late afternoon in the summer, little direct sunlight enters the narrow infill site due to the north-south orientation and adjacent buildings. Although the site poses many challenges, Shigeru Ban uses simple daylighting and envelope strategies to provide the occupants with the ability to modify the character and quality of the relationship to the site, light, and environmental forces. Ban’s intention was to design a building that was easily adaptable to different programmatic needs. The open plan, vertical zoning, and adjustable skin enable the occupants to reconfigure the envelope and subsequent relationship to the street, courtyard, and light. As Ban explains, Architecture which supposedly does not change aspects, has, in this project, become an architecture which can adjust to varying seasons and occasions just as we change clothing accordingly (Ban website).

4.5 Daylighting Lessons

Despite the challenging site, the Shutter House illustrates successful daylighting design decisions at the scales of the site, building massing, envelope detailing, and interior finishes. The strength of the design lies in the layered and adjustable envelope, which can be modified to provide varying quantities and
qualities of light and site relationships. In contrast to the Naked House, the Shutter House represents a fundamentally different concept for the building envelope by combining the abundant transparent glazing of the shutter-wall with a diffuse translucent curtain. Views to the inside and outside are celebrated, yet users are able to modify light and control privacy. In addition, Shigeru Ban provides a greater variety of lighting levels and contrast in the Shutter House. High levels of illumination along the curtain wall are contrasted with the darker areas under the second and third floors. Although electric lighting is needed on the east and west, the thin building plan and section ensure a generally good ambient daylight distribution. Modest apertures on the east and south or borrowed top-lighting could have mitigated the need for electric lighting on the lower level while still providing variety in the quality and character of the daylight.

5. CONCLUSIONS

During the past decade, the design professions have witnessed a proliferation of new glazing types and approaches to the building envelope. In his essay on “Space, Light, and Transformation,” Brent Richards suggests that designers face new challenges and opportunities concerning glass architecture: Glass and translucent materials do not necessarily open up the architecture to reveal space. Instead they adopt an ambiguous stance and demonstrate the autonomy of the cladding to the whole. With increasing focus on surface, the nature of the materials becomes the key focus of the architectural enquiry... (Richards 2006:20).

Have translucent envelopes shifted the focus of daylighting from the space within to the surface without? Is the beauty of daylighting only skin deep in buildings with translucent envelopes? The increasingly popular use of translucent envelopes can be found throughout contemporary high-style architecture, as in the works of Steven Holl, Peter Zumthor, and Raphael Moneo, to name a few. Yet, in many cases, little attention has been paid to the resulting quantity and quality of daylighting, the potential for glare, the role of both light and shadow, and the ability to modify or change the envelope for view, connection to site, and varying seasonal and diurnal lighting, cooling, and heating needs. The Naked House and the Shutter House provide a variety of lessons related to the translucent envelope that can broadly inform daylighting design thinking:

1) **Quantity of Daylight:** Prior to the design of the envelope, the building siting, massing, and design of the plan and section must be considered to optimize daylight access and distribution. Translucent and clear glazing both provide excellent opportunities to admit daylight; however the resulting qualities of light are profoundly different for the two types of glazing.

2) **Quality of Daylight:** In most building programs, care must be taken to counteract the potentially high quantity and monotonous quality of diffuse light by providing visual relief and contrast. Translucent glazing provides continuous control of direct sunlight throughout the year independent of sky conditions (e.g. the resulting
daylight is always diffuse). The choice of translucent glazing should be weighed against the programmatic and luminous objectives: when is diffuse light needed, where, in what quantity? The play of sunlight should be considered to provide visual relief and contrast in all but the strictest luminous programs.

3) **Glare Potential:** When exposed to direct sunlight, the luminous envelope becomes a light-source that can create glare. Clear glazing combined with interior and/or exterior shading and solar control provide greater flexibility for occupants to modify the quantity and quality of daylight as well as the potential for glare.

4) **Light and Shadow:** Depending on the program, designers should consider the role of light and shadow. Both play an important role in creating a diverse and meaningful luminous environment.

5) **Ability to Modify Envelope for View and Connection to Site:** Translucent glazing limits access to view, the site, and seasonal variations. It is critical to provide some transparent view windows as a counterpoint to the diffuse envelope. The integration of adjustable layers, shading, and operable windows enables the occupants to interact with the light and environment.

6) **Seasonal and Diurnal Variations:** Translucent glazing should be combined with some clear glazing to celebrate the changing quality and quantity of light under different sky conditions, seasons, and times of day.

The work of Shigeru Ban provides many lessons concerning the translucent building envelope and its impact on daylighting design and the experience of light in space. The Naked House and Shutter House both provide excellent lessons concerning critical design considerations for the building siting, massing, and the design of the room plan and section. The different approaches to the building envelope found in the two houses represent two fundamentally divergent attitudes concerning daylighting quality and quantity. While the Naked House has many excellent daylighting attributes, the challenges of translucent envelope, uniform distribution of light, lack of luminous variety, static nature of the skin, and the problem of glare cannot be underestimated. In contrast, the simple layered and adjustable envelope in the Shutter House resolves many of the daylighting problems found in the Naked House. Unfortunately, neither project takes advantage of passive solar heating, despite the need for winter heating in this temperate climate.

As designers continue to explore new building envelope materials and construction techniques, it is critical that they continue to assess the role of the envelope in supporting the desired lighting quantity and quality, as well as the importance of views, connection to site, and the poetics of shadow. Few lighting programs require uniformly high and even distributions of light (save factories and production spaces).

For most building types, great care must be taken in the sizing, placement, and design of translucent envelopes to avoid over-illuminating space and to provide appropriate relief from potentially uniform light distribution. Jun’ichirō Tanizaki reminds us of the importance of light and darkness in his book “In Praise of Shadows”…we find beauty not in darkness... but in the patterns of shadows, the light and the darkness...A phosphorescent jewel gives off its glow and color in the dark and loses its beauty in the light of day. Were it not for shadows, there would be no beauty (Tanizaki 1977, 30). The poetic opportunities of shadow should not be underestimated. The translucent envelope should be used cautiously to create a meaningful and rich luminous environment and evaluated in terms of the resulting quality and quantity of daylight. While translucent building envelopes may positively enhance the three-dimensional experience of light in space, designers should take care that the focus of daylight is not shifted exclusively to the two-dimensional envelope, for the beauty of daylighting is more than skin deep.

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7. **REFERENCES**