The Tectonic Complexity of Minimalist Architecture

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Abstract
This study analyzed the tectonic development of minimalist architecture according to material and immaterial characteristics and the ontological versus representational aspects of tectonic form. Among the early minimalist architects, Ludwig Mies van der Rohe and Louis I. Kahn represent two different architectural fields of thought regarding simplicity: Mies employed immaterial constructions made of steel and glass to present ontological and representational tectonic features, whereas Kahn used material constructions composed of brick, stone, and concrete to present ontological tectonic features. Following the immaterial and material characteristics of structural elements derived from Mies and Kahn, contemporary minimalist architects have transferred the tectonic form from the ontological to the representational aspect by combining the two architects. In addition, they extended the expression of form from space to skin with multiple layers, which exhibits the tectonic complexity of minimalist architecture hidden behind the simplicity of its form.

Keywords: minimalist architecture; tectonic; simplicity; complexity

1. Introduction
Ludwig Mies van der Rohe, who used the immaterial and transparent characteristics of glass and steel, is considered as an important initiator of modern minimalist architecture. His immaterial architectural form implemented the "Bekleidung" Theory of Gottfried Semper, who was an architect, a scholar, and an aesthetic critic. In the Great Exhibition held in London in 1851, Semper noted the architectural trend that separated the enclosure and the structure, in which cast iron and gutta-perchas were employed for the simulation of stone and wood, respectively, through casting, stamping, and molding for symbolic conservation. Recognizing both the architectural symbolic value as well as its enclosure, Semper developed the subsequent "Bekleidung" Theory (Semper, 1989).

Since the "Bekleidung" Theory declared that the enclosure and the structure were separate, it provided an appropriate foundation for Mies' immaterial and transparent architectural form. Mies used light glass enclosures covering the structure to allow for the transparency of immaterialization and transferred the stone pillars and trabeated structure of Greek architecture into slender steel pillars and steel frames, which implemented simplicity in immaterial and transparent architectural form. However, the immaterial architectural form was not the only way to express simplicity. Some architects in the modernist period, such as Louis I. Kahn, were not influenced by Semper's "Bekleidung" Theory, but rather explored another aspect of minimalist architecture using concrete, stone, and brick, which transformed the materiality to traditional architectural structures made of stone.

The analysis in this paper begins with the discussion of the tectonic feature of Mies, which was presented in immaterial construction, and then moves on to discuss the tectonic features of Kahn, which were presented in material construction. What we mean by tectonic refers to Frampton's definition. In Studies in Tectonic Culture, Frampton defined it as the mutually interdependent relationship between the order of structure (the inner architectural thinking of a specific architect) and the method of construction (the outer architectural form) in the art form (Frampton, 1995, pp.19-21), and distinguished ontological tectonic features from representational ones. The first presents accordance in the materials and the construction of the enclosure and structure, while the latter presents discordance in the relation of the enclosure to the structure (Frampton, 1995, pp.16-19).

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(Received April 6, 2010; accepted October 7, 2010)
After categorizing and illustrating the immaterial and material characteristics and the tectonic features via Mies and Kahn, the analysis clarifies the tectonic features of contemporary architects who, following Mies and Kahn, manipulate simple form in their works.

2. The Implementation of Immaterial Tectonic Form
The early works of Mies, such as the Brick Country House in 1923, the Concrete Country House in 1924, and the Monument to Karl Liebknecht and Rosa Luxemburg and the Wolf House at Guben in 1926, were mainly constructed of brick, which presented materiality. However, the Glass Skyscraper on a Prismatic Plan in 1919 and the Glass Skyscraper on a Polygonal Plan in 1920 were mainly constructed of glass and steel, which innovatively presented the transparency and simplicity of space. Starting with the German Pavilion in 1929, Mies obviously made the transformation from mainly using bricks to present materiality, to the overt use of glass and steel to present immateriality. Using the architectural form of a glass enclosure outside with a steel structure inside became the foundation for the incorporation of transparency and simplicity in the later works of Mies, including the Farnsworth House at Plano in 1950, the 860 and 880 Lake Shore Drive Apartments in Chicago in 1951, and the Crown Hall at the Illinois Institute of Technology in 1956.

Mies began an architectural trend in his presentation of transparency and simplicity of form via glass enclosures and steel structures. In the German Pavilion of 1929, the work established the immaterial expression of Mies. He did not choose a structure made of stone, reminiscent of architectural tradition; instead, he opted to use steel and glass to represent modernism in an immaterial form. In the implementation of materials, Mies avoided the traditional decorative effect of carved stone, using instead the simplest form to present the materials’ characteristics. Mies used eight freestanding cruciform slender columns to support a 50 centimeter thick, huge, steel-structured hollow roof, and arranged transparent and semi-transparent glass walls in the interior in accordance with a free plan to create a labyrinth-like experience of space. He also used reflective glass and polished stone to create transparent and reflective visual effects between the glass and stone walls. These choices not only broke the definite space border created by stone in traditional architecture but also transferred the relation between inside and outside to an ambiguous and multi-defined condition, which resulted in the weightlessness and transparency of the immaterial tectonic form (Fig.1.). Since Mies did not attach non-metal materials to the steel structures he designed, visitors could comprehend the relationships of the structural system's articulation.

Regarding the structural design, Mies chose to use steel as the main material and designed eight freestanding cruciform columns to support the roof. Although the cruciform columns were composed of four L-shaped steel plates, he covered them with polished chromium-plated steel plate to create visual simplicity (Fig.2. left). In the vertical enclosure, Mies used glass to create transparency and delicate hardware to combine the glass, ceiling, and floor to present a clear visual articulation. In this way, Mies' works were mostly comprised of immaterial constructions made of steel and glass in order to present the ontological tectonic form. However, while striving to accomplish the greatest immaterial visual effect, Mies also endeavored to manipulate the representational tectonic form. The German Pavilion provides an excellent illustration of this. Although it mainly presents the ontological tectonic form, Mies manipulated representational tectonic form in the horizontal enclosure. The roof appears to be constructed of concrete; however, it is actually made of a steel frame structure and covered with non-load-bearing gypsum plates. By analyzing the roof, the authors found that Mies intended its steel-structure to produce a visual effect that was not unlike concrete in nature. In fact, a roof with a steel frame structure that follows the rules of structural mechanics should produce the same thickness in the roof plate; however, the roof of the German Pavilion appears to be an imitation of a reinforced concrete structure. Mies reduced the thickness of the edge of the roof plate, which caused visitors to misinterpret the steel structure roof as a reinforced concrete structure roof (Fig.2. right). In addition, since the vertical structures beneath the roof are composed of slender steel columns and the vertical enclosures are constructed of different types of glass, allowing for transparency, the imitation concrete roof structure appears immaterial in form, all of which give it the visual illusion of floating.

In the Crown Hall at the Illinois Institute of Technology, Mies also used a transparent architectural form constructed of steel and glass to produce immateriality. By exposing the articulations of the steel structure, he revealed the structural mechanics and the relations between the structure and the enclosure. The Crown Hall is a transparent square box with a steel structure, and the enclosure comprises glass and I-shaped steel. The main load-bearing structure is composed of eight I-shaped steel columns located in the enclosure which support four steel plate beams from which hangs the roof. In the hope of enhancing the immaterial tectonic form, Mies did not include in his design the placement of any columns in the interior. Accordingly, the roof of the Crown Hall at the Illinois Institute of Technology exhibits the same visual effect as that of the German Pavilion, giving the illusion of weightlessness (Fig.3.). Mies hung the roof from four high anti-tension steel plate beams to create an illusion of stretched space. The loading of the four plate beams, supported by the eight steel columns in the enclosure, creates a space without columns that is minimal in
nature. In the vertical enclosure, Mies used extensive glass walls to ensure that the mass of the building would not appear overly flat, and designed I-shaped steel columns for the enclosure. For the horizontal enclosure, the roof, Mies used steel plate beams to hang the steel-frame roof structure, which created an immaterial visual effect similar to that in the German Pavilion. The transparent walls included glass that was inlaid in metal frames welded to the steel columns and connected with the architrave via L-shaped hardware. As with the German Pavilion, the vertical enclosures were designed with delicate hardware that presented a clear articulation of the structure and the enclosure (Fig. 4.).

![Fig. 1. Ludwig Mies van der Rohe, the German Pavilion; Exterior (left) and Construction (right)](image1)

![Fig. 2. Ludwig Mies van der Rohe, the German Pavilion; Plan of Column (left) and Section of the Roof (right)](image2)

![Fig. 3. Ludwig Mies van der Rohe, the Crown Hall at the Illinois Institute of Technology; Façade (left) and Construction (right)](image3)

The works of the contemporary Japanese architects Kazuyo Sejima and Ryue Nishizawa appear at first glance to be similar to those of Mies in that they are made of steel structures with glass enclosures and present immaterial tectonic transparent forms. However, different from Mies, Sejima and Nishizawa chose another way to design their structures. The Toledo Museum of Art, designed by Sejima and Nishizawa, being a single-story construction and made of locally-produced glass, corresponds to its site. The museum appears to be a steel structure with slender steel columns installed inside, but in reality, the main load-bearing structure is made of concrete walls, which are located in its interior. The inner and outer forms of architectural design are discordant in nature (Fig. 5.). Within the structure, the building is a compound of slender steel columns and concrete load-bearing walls supporting the flat slab roof, which is constructed of steel covered with concrete and appears to be floating. Since the enclosure is constructed of glass walls that hide the main structure behind the glass façade, visitors might misunderstand the articulation of the structure and the enclosure. Since the architects wanted to allow for the visual penetration of the glass façade, they inlaid the unframed glass walls into the ceiling and the floor, which produced an ideal visual effect of transparency and an immaterial tectonic form (Fig. 6.). The architects used a considerable amount of glass to accomplish the design concept of transparency in the vertical enclosure, making the concrete slab-like roof appear to float on air to present an immaterial visual effect.

Sejima and Nishizawa hid the steel structure and its articulation inside the ceiling and the floor in an attempt to enhance the simplicity and the horizontal transparency of space. In addition, they employed a compound of steel structure and concrete load-bearing wall structures, rather than a purely steel structure. Since these two architects covered the relation of the structure and the enclosure along with the relation of the two types of structural systems, which manifested the representational tectonic form, visitors often misinterpret the composition of the structure. In contrast, the works of Mies are comprised mostly of purely steel structures with revealed articulations, which present the ontological tectonic form via the accordance of the structure and the enclosure.
3. The Implementation of Material Tectonic Form

In the 1950s, in contrast to Mies’ minimalist and immaterial architectural forms, Louis I. Kahn emphasized material forms and clearly displayed the relation of the structure to the enclosure in the exterior. In doing so, he clearly showed the characteristic of the materials used, along with the structural mechanics of the corresponding structural system. In the Kimbell Art Museum, Kahn used concrete and limestone to create a material form in accordance with the structure and the enclosure. The exterior of the Kimbell Art Museum was based on a specific module, which was then developed into a series of rectangular masses with an arched roof. The construction of the reinforced concrete structure and arched roofs were clearly visible in the façade. Since the main structure was constructed of reinforced concrete, and the walls and roofs were not load-bearing elements, Kahn attached limestone slabs to the exterior of the enclosure walls in an effort to suggest to visitors that the main structure was a series of reinforced concrete structures, rather than load-bearing walls. Additionally, to clearly present the structures’ relationships to the enclosure, Kahn used glass to separate the arched ceiling from the façade to emphasize the structural independence of the structure and the enclosure; hence, the façade did not consist of load-bearing walls. Moreover, inlaid in the peak of the arched roof was a linear glass groove for natural lighting and a distinct presentation of the arched roof, which was made of cantilever-reinforced concrete, rather than a traditional load-bearing arched roof, which would typically be made of stone or brick (Fig.7.).

Kahn exhibited the structural mechanics of brick in the enclosure of the Exeter Library, in which the widths of the brick piers of the brick façade decrease gradually from the ground floor to the roof, while each opening of the brick façade is constructed with a flat arch. With this approach, the grand brick façade could be said to demonstrate a material visual effect. The structure and the enclosure were two independent structural systems that supported their own loads. The main structure behind the brick enclosure was formed of reinforced concrete, which was different from the material and the corresponding structural system of the enclosure. Kahn also used anchors and a waterproof layer to connect the two (Fig.8.).

Tadao Ando is a contemporary minimalist architect whose work manifests the material tectonic form of architectural reinforced concrete. In contrast to Kahn, Ando does not focus on presenting the structural mechanics of different materials. His architectural reinforced concrete structures appear to be massive stone-like images at first glance; however, most of the flat concrete pieces, each comprised of a concrete wall and a concrete ceiling, have glass linear openings for individual subjective reinforcement. Meanwhile, natural light flows onto flat concrete slabs and shines throughout the interior, creating a unique atmosphere. The Place of Meditation was designed as a seven-meter high architectural reinforced concrete tube. This tube is covered with an architectural reinforced concrete circular roof surrounded with a glass circle, which allows natural light to shine down into the interior, creating a tranquil space. For the sake of creating
a peaceful atmosphere with natural lighting, the articulation of the circular roof and tube is irrational in terms of the mechanics of reinforced concrete structures (Fig.9.).

The Church of Light also demonstrates the principle of irrational structural mechanics. The glass cruciform slices the wall behind the altar into four architectural reinforced concrete flat pieces, resulting in a short beam at the top of the glass cruciform and two short columns at its left and right corners (Fig.10.). Since these irrational mechanics of a reinforced concrete wall, such as a short beam and two short columns, could cause structural weaknesses, the Church of Light was not designed to present the principles of structural mechanics, but rather the architect's own thoughts on design. Although the works of Kahn and Ando could all be said to represent the material tectonic form, their ideas concerning design were different. Kahn followed the objective characteristics of material, which were clearly portrayed in the relationships between the structure and the enclosure; in contrast, Ando pursues a personal interpretation of the materials used and conceals the relationships of structure and enclosure. Hence, Kahn produced ontological tectonic form, while Ando produces representational tectonic form.

**Fig.9. Tadao Ando, the Place of Meditation; Interior (left) and Section (right)**

**Fig.10. Tadao Ando, the Church of Light; Interior (left) and Section (right)**

**Fig.11. Peter Zumthor, the Thermal Bath Vals; Exterior (left) and the Construction of the Gneiss Enclosure of the Façade (right)**

Kimbell Art Museum displays noticeable differences between the structure and the enclosure. Kahn attached limestone only in the enclosure, and the façade, rather than the structure, visually enhancing the articulation and relation of structure and enclosure. In addition, he separated the reinforced concrete structure and the non-load bearing enclosure wall by inlaying in the façade a circular linear glass opening around the arched roof to emphasize the differences between the structure and its enclosure. Zumthor's style was different in that he did not emphasize the presentation of the principle of structural mechanics, as did Kahn. Except for the roof, the reinforced concrete structure of Thermal Bath Vals was covered with gneiss. Additionally, although the gneiss enclosure is non-load bearing in nature, it was constructed with the principles of the structural mechanics of stone or brick. This presents an ontological tectonic form, rather than simply attaching a reinforced concrete structure without referring to the rules of structural mechanics (Fig.11.). Visitors cannot clearly comprehend the relation between the structure and the enclosure from the exterior. In the category of tectonic form, the Thermal Bath Vals combines both ontological and representational tectonic forms.

**4. The Combination of Material and Immaterial Tectonic Form**

The greatest difference in structural tectonic form between early and contemporary minimalist architectural works is that in the former, the structure and the enclosure are constructed for the most part of steel and glass, or concrete, brick, and stone, as in works by Mies and Kahn. However, in the latter, the works adopt a multi-material and compounded multi-structural system. The result is complexity in the relationship between the structure and the enclosure, which are made of different materials and with different structural systems. Meanwhile, contemporary minimalist architects have presented their personal interpretations of specific materials with corresponding designs of the structural system in the tectonic form of the enclosure. This form incorporates a combination of the immaterial and material characteristics of the material and the ontological versus representational aspects of the tectonic form. For instance, the Art
the double façade (stone façade outside and concrete makes for an unstable interior climate; meanwhile, snakes from inhabiting the cages. The natural lighting floor uses smaller stones in steel cages to prevent the space; the façade of the wine cellar on the ground floors in response to the functional requirements of Meuron used two different sizes of stone in the two façade and filled with stones. Herzog and de Meuron constructed of steel cages fixed on the steel columns in the façade, but simply welded them together, for the stone wall constructed of steel cages could bear its own loading without the aid of other supporting structural elements (Fig.15.). The architects interpreted a regular material, stone, in a revolutionary tectonic manner between the material and the immaterial multi-layer tectonic forms, producing a material tectonic form in the wine cellar on the ground floor. In relation to the immaterial tectonic form, the design allows natural light to shine throughout the space, between the stones and into the interior.

Peter Zumthor's Art Museum Bregenz is constructed of reinforced concrete, in the material tectonic form, but the enclosure is constructed of a steel structure and ground glass, in the immaterial tectonic form. The structure and enclosure are different in that the materials used in the structural systems and the enclosure are semi-transparent immaterial tectonic forms in nature, while the concrete structure inside blocks the visual penetration of the building. The building itself is composed of a semi-transparent, material, ontological tectonic form; however, included in the enclosure is a semi-transparent, immaterial, representational tectonic form, enabling visitors to view the articulation of the steel elements, the ground glass, and the steel structure behind the ground glass façade. The main structure of the Art Museum Bregenz is three reinforced concrete load-bearing walls and beamless reinforced concrete flats behind the ground glass façade. The enclosure is a double-skin façade made of two ground glass skins and a steel structure in between them (Fig.12.). Zumthor designed delicate and specialized hardware, rather than a steel frame, to fix each piece of square ground glass of the outer ground glass skin to display the subjectivity and the characteristics of each piece of ground glass. Since the ground glass façade was installed without a steel frame, it seems naturally fused into the gray-blue sky and the lake of the site, which presents the visual effect of multi-layer semi-transparency between the immaterial and material tectonic forms (Fig.13.).

The Dominus Winery in Napa Valley by Herzog and de Meuron appears to be formed of a solid stone box at first glance; actually, however, the enclosure is a light filter skin presenting the tectonic form between a semi-transparent material and the immaterial. The main structure of the Dominus Winery is comprised of two ground glass skins and a steel structure. The articulation of the two structural systems is unrevealed in the exterior. The structure and the enclosure are made of two different materials and structural systems, utilizing the combination of material and immaterial with representational tectonic form. The enclosure is constructed of steel cages fixed on the steel columns of the façade and filled with stones. Herzog and de Meuron used two different sizes of stone in the two floors in response to the functional requirements of the space; the façade of the wine cellar on the ground floor uses smaller stones in steel cages to prevent snakes from inhabiting the cages. The natural lighting makes for an unstable interior climate; meanwhile, the double façade (stone façade outside and concrete wall inside) enhances the stability of the climate, as the higher density of stone absorbs heat and releases it at night. The façade of the first floor, where the office is located, is covered with larger stones, which responds to the requirements of natural lighting and vitalization (Fig.14.). Herzog and de Meuron did not design specialized hardware to combine the steel cages with the steel columns in the façade, but simply welded them together, for the stone wall constructed of steel cages could bear its own loading without the aid of other supporting structural elements (Fig.15.). The architects interpreted a regular material, stone, in a revolutionary tectonic manner between the material and the immaterial multi-layer tectonic forms, producing a material tectonic form in the wine cellar on the ground floor. In relation to the immaterial tectonic form, the design allows natural light to shine throughout the space, between the stones and into the interior.

Kengo Kuma's the Nakagawa-machi Bato Hiroshige Museum of Art also reveals a combination of the immaterial and material of the multi-layer tectonic form. The structure of the museum is comprised of combined reinforced concrete load-bearing walls, and a steel structure. The relation and articulation of the structure with the enclosure are hidden, which represents the material representative tectonic form. The vertical and horizontal enclosures of the museum are constructed of wide timber palings to create a skin of semi-transparency, but the main structure of the museum is a compounded reinforced concrete and steel structure. The roof consists of multiple layers: the timber palings on the top, ground corrugated sheets, the steel structure supporting and connecting different layers, and another layer of timber palings at the bottom, which creates a specialized natural lighting effect that produces a tectonic form between the immaterial and material of semi-transparency in space (Figs.16., 17.).

Fig.12. Peter Zumthor, the Art Museum Bregenz; the Façade (left) and the Enclosure and Structure (right)

Kengo Kuma's Stone Museum presents an anti-tectonic feature that subverts the principles of the
structural mechanics of a load-bearing stone wall. The museum has two types of stone building, designed with different structural systems. The first is made of a steel frame structure, and the enclosure is constructed of non load-bearing stone columns. The columns include chiseled grooves, allowing for the installation of stone palings horizontally between the stone columns. The stone façade presents an immaterial tectonic form and semi-transparency that is similar to timber buildings, which challenges the tradition that stone can only be used to present material tectonic form. Accordingly, the first building type presents innovative tectonic aspects. The museum’s second building type is constructed of a load-bearing wall structure made of stone slabs, with...
the structure also functioning as the enclosure. The architect inlaid sliced stones into the square openings between stone slabs to allow natural light to shine through, into the space. This presents a multi-layer, semi-transparent space that is totally different from the solid and closed atmosphere of the material tectonic form of a traditional stone building. Furthermore, Kuma drew out stone slabs forming the corner of the stone load-bearing wall, which subverted the principles of the structural mechanics of stone (Fig.18.-24).

5. Conclusion

The two representative architects of early minimalist architecture, Mies and Kahn, used purely geometrical forms to present simplicity and emphasized the characteristics of materials and the corresponding structural systems. The difference between Mies and Kahn is that the former used steel and glass to present immaterial tectonics and lightness of form, whereas the latter used concrete, brick, and stone to present material tectonics and massiveness of form. The similarity between them is the accordance between the structures and the enclosures of their works with the material and the corresponding structural systems, and the use of ontological tectonic forms to produce simplicity. Contemporary minimalist architects, while following the immaterial and material tectonic forms of Mies and Kahn to produce simplicity, developed different tectonic forms that contrast with Mies and Kahn. Kazuyo Sejima and Ryue Nishizawa have followed Mies’ immaterial tectonic form, but the structures and the enclosures of their works demonstrate discordance, which is presented via representational tectonic form. Tadao Ando chose to follow Kahn’s material tectonic form, but did not pursue the principles of structural mechanics or use the ontological tectonic form to present materiality, as did Kahn. Ando has presented a representational tectonic form. Besides following Mies’ and Kahn’s immaterial and material tectonic forms, some contemporary minimalist architects such as Peter Zumthor, Herzog and de Meuron and Kengo Kuma choose to combine immaterial, material, ontological, and representational tectonic forms, and personally interpret the material within the corresponding structural system and combine immaterial, material, ontological, and representational tectonic forms, that present multiple tectonic expressions.

Through an analysis of the immaterial and material characteristics and ontological versus representational aspects of tectonic form, we uncover the development of minimalist architecture. The early minimalist architects used ontological tectonic form to emphasize either the immaterial or material characteristics of materials to the stage of combining ontological and representational tectonic form to reveal the characteristics of a specific material. Contemporary minimalist architects prefer to use multiple materials and combine immaterial, material, ontological, and representational tectonic forms, which reveal the complexity behind the form of minimalist architecture's simplicity.

Acknowledgments

This research is supported in part by The National Science Council, Taiwan (NSC 94-2211-E-011-029).

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