Analysis on the integrated design of architecture and furniture: Taking the Farnsworth House as an example

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Abstract. There has always been a connection between architecture and furniture in the construction of Chinese and Western architectural space throughout history. It reflects the inherent relationship between architecture and furniture in Farnsworth House which is designed by Mies Van Der Rohe who is one of the masters of modernism architecture, and it also conveys the design philosophy of "truth is the meaning of fact". This article tries to analyse the correlation between architecture and furniture from the angles of design idea, space modulus, structure system, material and the texture and node processing in Farnsworth House, and research the philosophy of design of Mies and his related works. The method which is based on integrated design has a positive meaning to deepen the space expression, strengthen the spatial perception, improve the whole space quality, and it also has the important inspiration and the reference value for the contemporary cooperative design between furniture and architectural space.

1. Introduction
There has always been a close connection between architecture and furniture in the construction of Chinese and Western architectural space. “Shuowen Jiezi” is a masterpiece of ancient Chinese linguistics and it records:“Home means the living. Furniture means the provisioning.”The architecture provides a living space that satisfies the need for rest of human, while the furniture focuses on the microscopic space of various practical functions. The Chinese ancient architecture and furniture originated from the same material and production process, and they have mutual influence in their development process. The concept of space, structure and construction of the architecture will logically be applied to the furniture at the same time. The changes on the furniture will also be reflected in the architecture - and vice versa. There is also an inseparable relationship between modern Western architecture and furniture. It stems from the holistic art concept in modern sense which is proposed by Josef Hoffmann and Otto Wagner: the furniture cannot be separated from specific places, and it should be combined with the comprehensive factors of architectural space to design. The Stoclet House in Brussels reached the pinnacle of overall art which is designed by Hoffman for the banker Adolf Stockerett in 1905-1911. The integrated design concept of architecture and furniture is reflected in the residential designs of many Western architectural masters. For example, the Schröder House which is designed by Rietveld (1925), the Aubette house which is designed by Van Doesburg(1926), and the Müller house which is designed by Adolf Loos(1930), etc. Similarly, Mies planted a uniform grid of tile paving with furniture as an important basis from the beginning in Farnsworth House, and used this homogeneous grid to synthesize the furniture and architecture into an organic whole. It reflects the echoes of furniture and architecture and the guiding role of architecture, in terms of space modulus, shape, structure, material, etc.
2. The philosophy of design related to Mies Van Der Rohe
Most works of architecture and furniture which is designed by Mies Van Der Rohe are presented as concise squares, rectangles, and other geometric shapes, and it reflects the rational space order and delicate material aesthetics.

2.1 The origin of design philosophy about Mies Van Der Rohe
Mies Van Der Rohe was born in a Mason family, and the medieval scholasticism of Europe had a profound influence on his design thought. The philosophical ideas of Saint Augustinus and Saint-Thomas Aquinas directly impacted his design philosophy. This is the basis of his emphasis on the integrity of the body, order and values. Saint-Thomas Aquinas's philosophical ideas are deeply influenced by Aristotle. He thought that the existence state of things is only a kind of appearance, and the truth is the essential meaning which is being obscured. Form is an advanced form that overrides material and the "form" of things is a kind of existence value with universality in Aristotle's philosophical ideas. Mies apparently accepted this form of apriorism. In fact, he interpreted Aquinas's philosophy of "truth is the meaning of truth" as form is the meaning or value of things. Conversely, Saint-Thomas Aquinas is greatly influenced by Plato's philosophy. Plato divides reality into the visible world and the intelligible world, and it corresponds to the physical world of reality and the abstract world of ideas respectively. Similar to Aristotle's view of "Truth", Plato thinks that "idea" is the essence of things. Under the inspiration and influence of the above two philosophical viewpoints, Mies began to realize that there is a transcendental "prototype" of architecture in metaphysics. He learned more deeply that the essence of architectural form is a two-dimensional square, and three-dimensional squares (including cubes and boxes) can evolve from two-dimensional squares. Mies tried to use rectangular geometric elements in the process of architectural design practice due to the influence of the later Cubism and other design movements.

2.2 The integrated design strategy of architecture and furniture
The two-dimensional square and three-dimensional squares of the work which is designed by Mies Van Der Rohe reflects the close connection between architecture and furniture. This method is particularly evident in the series of residential buildings which is designed in the 30-40 years of 20th century. It can be roughly divided into two stages. The first stage is from 1923 to 1930: Mies designed the "Village Concrete House" and used the cubism expression method by emphasizing on vertical and horizontal overlapping space in 1923, and this case has already manifested the early rational geometrical spatial form; the "Wolf House" was designed in 1925-1927, which is an important design work in the transition period; the important stage in the development of his design philosophy is from 1928 to 1930, in the meantime, he designed the "Barcelona Pavilion" and "Tugendhat House". The second stage is from 1931 to 1938: Mies designed the "Joint-row Courtyard Residence" in 1931; he successively designed the "Three-courtyard Residence", "Hubbe House", "Courtyard Housing Group" and other different types of residence after a few years. The planes of architecture and furniture are mostly enclosed by two-dimensional geometrical rectangular elements during the second stage of his design conception, and the spatial location of architecture and furniture is strictly limited by the homogeneous meshes formed by the surface paving. The architecture and furniture are enclosed together to create a "flowing space" in the interior space. Mies has incorporated the furniture into the...
collaborative conception at the initial stage of architectural design (Fig. 1). Mies has used the two-dimensional square geometric elements very skilfully when he designing the "Farnsworth House" until 1945 and the relationship between architecture and furniture is also clearer and tighter.

3. Homogeneous spatial modulus of architecture and furniture

The existence of architecture and furniture needs to occupy a certain space. The architecture creates space through the enclosure of the spatial interface, while the furniture embodies practicality through the expression of space. The space becomes the link between furniture and architecture, and the furniture becomes the medium which connects the architecture and the space, and it contacts the user directly. The homogeneous rectangular spatial modulus becomes the link between architecture and furniture in Farnsworth Housing. The homogeneous grid scale formed by lime-marble paving is not only influenced by the mechanical properties of the architectural structure, in addition, the size of the furniture also has a decisive effect on it.

3.1 The correlation between architecture and homogeneous grid

The flat of Farnsworth House consists of two simple rectangles. The main part of the space is supported by 8 I-shaped steel columns, and the other entrance platform is supported by 6 I-shaped steel columns (2 of these are shared with the body part). The residential main plane is about 77*28 feet and both ends of the house are overhanging 5 feet 6 inches. At the beginning of the design of Farnsworth House, Mies implanted the core of the concept of spatial construction—“homogeneous mesh”: the space modulus is 2-foot-9-inch-length and 2-foot-width formed by the ground marble paving blocks, and it is also associated with the structure of the building and the enclosure system, and exact alignment with it. The distance of the load-bearing columns is 22 feet in Farnsworth House. The basic spacing of the I-shaped steel girders on the roof is 1/4 of the load-bearing column spacing, which is 5 feet 6 inches. The size is exactly twice the length of the ground marble tile. 5 feet 6 inches is the length of the overhang at both ends of the dwelling, but also the distance between the entrance glass epidermis and the nearest east I-shaped load-bearing column. In order to maintain the pure geometric order of the homogeneous mesh, Mies changed the glass epidermis that he had tried before in the Barcelona Pavilion and took its position to the perimeter of the building. At this point, he had deeply realized that it does not allow any component with thickness, which interferes with the rational geometrical space order in the precise homogeneous grid system that he has built. As a result, he almost threw all the glass skins to the perimeter of the grid. The glass epidermis has not been able to achieve precise positioning with the homogeneous mesh in many places in the east-west depth direction of the building. In this regard, he devised an improved version of a square with a side length of 50 feet, with a ground-paved grid of 3-foot-1.5-inch squares (Fig. 2). In this scheme, the plane position of the furniture is strictly limited by the ground homogeneous grid, and its alignment relationship with homogeneous mesh is more accurate than the previous scheme. For example, the two sofa beds on the west side are confined to the 2 grid, and the right-hand closet is strictly confined to a vertically arrangement of 8 grid.

3.2 The Geometric correlation between furniture and homogeneous grids and architecture

The core-tube of I-shaped furniture is the core of its living space in the middle part of Farnsworth House, and it contains a lot of practical functions of furniture and facilities. It is similar to the shape of the section of I-shaped steel column, and it is also closely related to the paving homogeneous grid and the structural components in the space modulus (Fig. 3): the half of the core-tube of the furniture and the section of I-shaped steel column have the same length-width ratio; the two chairs in the reception area are arranged according to the symmetrical axis of I-shaped core-tube of the furniture; the rectangular space of the core-tube furniture has the same length-width ratio as the main residential space; the symmetrical axis of the core-tube of the furniture is the same as the two I-shaped beams above it in the façade. The other furniture also has a similar connection to the paving homogeneous mesh and building components (Fig. 4): the symmetrical axis of sofa bed at the entrance overlaps with
the centre line of the I-shaped steel column at the upper and lower ends, and the entire rest platform (along the axis of symmetry to the left side as mentioned above) and the section of I-shaped steel column also has the same aspect ratio; the wardrobe on the east side has the same length-to-width ratio as the main space along the 1/2 axis of the middle symmetry; the length-to-width ratio of the sofa bed at the entrance (approximately 2.11) is used to define the horizontal and vertical position of the main bed and wardrobe in the east; the lower axis of the bed in the east of the building limits the location of the south edge of the toilet in the core-tube of furniture, with the help of the length-to-width ratio of the dining table at the entrance. The furniture in the house is required to be fixed in place and should be involved in the construction of the whole architectural space. Once the overall space order is determined, the location of the furniture and its function are also accurately determined, which makes the furniture's mobility become an illusion. The furniture is fixed and turns into architecture.  

4. The structural system and material texture related to architecture and furniture
The architecture and furniture in Farnsworth House use the same frame structure. It reflects the integrated design characteristics in terms of colour, texture, fabrication process, and light and shadow performance of materials and components.

4.1 The frame structure system and material characteristics

Farnsworth House uses the transparent glass enclosure system and steel structure of the frame load-bearing system. The main space used 8 I-shaped load-bearing steel pillars, and the top and bottom plates are connected with 13 I-shaped steel girders. The rest platform uses 6 I-shaped steel pillars and connects with 9 one-way I-shaped beams. The load-bearing steel pillars use the "de-decorating" design technique, which is intentionally omitted from the stigma and column base. The structure is completely exposed in order to highlight its concise and crisp geometry. The side of I-shaped load-bearing steel column is connected with the roof and the bottom plate respectively which makes architectural space creates a sense of buoyancy. The overhang of the east and west ends of the house reinforces the sense of lightness. The internal joints of the building elements are connected by bolts and the nodes are deliberately wrapped and hidden by the steel on the surface, and it presents a concise and complete spatial interface effect. The entire architectural steel structure is covered with a layer of elegant white lacquer in order to make the interior and exterior of the building more complete and pure and it also makes the architecture and the environment harmonious and unified.

The "Tugendha Chair" in the Farnsworth House is an improved version and the whole structure uses the prestressed spring steel of 37*12mm. The seat surface and backrest are integrated into a streamlined cantilever structure with chrome-plated finish on the steel surface. The backrest and seat surface are connected by 4 transverse load-bearing pimps that can support the upper lattice modular leather mat. The composition of “Tugendha Chair" also uses the method of hiding the node that is similar to structural components: the integral structure is seamlessly connected and riveted with extremely small countersunk studs. The other furniture in the original design of Farnsworth House also used a framework structure which is similar to the architecture. For example: the table near the entrance uses a steel frame structure; the sofa beds with leather also use the similar steel frame structures and a combination of weight-bearing pimps; the glass coffee table uses the X-shaped stainless steel frame structure and the transparent glass which is fixed by 5 pivots on 2 sets of stainless steel brackets; the "Bnro Chair" uses the seamless cantilever structure made from steel rods and polished metal and leather.

4.2 The unification of architecture and furniture

Mies thinks that the structure is a whole that everything from the top to the bottom is subordinate to the same concept even the tiniest details. The frame structure of the architecture and furniture in Farnsworth House embodies the unification of the above-mentioned structure. Not only that, the consistency of the structural concept is also reflected in many common practices used in architecture and furniture: maintaining the independence of different structural components to highlight the clarity of construction; hiding nodes to maintain complete continuity of the overall interface; removing the decoration to show the geometrical purity of the component form; using the cantilever structure in accordance with the mechanical properties of steel; modulating the visual surface to enhance the echo of homogeneous paving grids, etc. The structural components and roofs of Farnsworth House are painted in a uniform white. The colour of the furniture is similar to the decorative panel which used in the I-shaped core-tube, and it creates a kind of elegant amid space atmosphere. Mies argues that the inner space must be carefully applied in neutral tones due to the colours that exist outside. These colours are continuously and completely changing, and I'd say it's a simple brilliant. He also has a strong interest in the reflective effects of materials, and the materials of construction and furniture are made of transparent glass, polished marble, lacquered panels, chrome-plated metal, polished leather and other reflective materials. The asymmetry of the material creates the symmetry of vision, and the natural light reflects on the ceiling, and it seems to have an artistic conception like the sky, and the space appears to be expanding in a slow and boundless way.
5. Conclusion
The furniture and architecture depend on each other, and they have their greatest value as an organic whole. There are different degrees of interaction between furniture and architecture in every era, the kind of influence cannot be separated completely, and the technology and style of architecture influence the development direction of furniture. The transformation of Chinese ancient furniture that vary from box-type to beam-column frame structure reflects the influence of architecture structure form on furniture. The phenomenon of the interaction between architecture and furniture is also very common in the development of modern Western architecture. For example, the architecture and furniture have a high degree of organic unity in terms of the form, colour, material, design method and so on in the Schröder House which is designed by Rietveld. The ground-paved homogeneous mesh is used to integrate the architecture and furniture into a unified whole in Farnsworth House. There are close correlations in space modulus, structure system, material texture, node structure and appearance form, which together embody Mies's construction logic and space design philosophy. The integrated design method based on the correlation between architecture and furniture has an important inspiration and reference value for the integration of furniture and architectural space in the collaborative design.

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