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Research on Order Aesthetics of Traditional Chinese Architecture from the Perspective of Design Geometry

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Abstract: *Design geometry is a discipline that studies the scale division standards of ratio and composition, which reveals the aesthetic laws based on human aesthetic preferences. The construction of traditional Chinese architecture combines "circular heaven and square earth", "harmony between human and nature", "golden mean" and other philosophical thoughts to form √2 and √3 ratio relationships and the expression form of central axis symmetry, which also combines mathematical relationship with cultural and aesthetic preferences. Taking core architecture complex of Beijing Ancestral Temple as an example, this paper analyzes its spatial construction method and mathematical ratio relationship, and order aesthetics of traditional architecture based on the design geometry theory, in order to provide references for the combination of traditional Chinese culture and modern design theory, and to provide more bases for practicability of design geometry.*

Keywords: *Design geometry, traditional architecture, order aesthetics, harmony between human and nature, Ancestral Temple*

1. Introduction

Squares and Circles, The Sum of Heaven and Earth - A Research on Composition Ratio of China's Ancient Capitals, Architecture Complexes and Individual Architectures written by Dr. Wang Nan from School of Architecture, Tsinghua University researched 459 Chinese ancient architecture cases, found the extensive application of √2 and √3 composition ratios based on the square-circle drawing method, and summarized the aesthetic principle of traditional Chinese architecture gardens and the emphasis on harmony and order of composition ratio. The design geometry is also a research on the ratio and composition. Exploring the aesthetic laws of harmony and unity in form is a general rule in the field of design, which is widely applied in the architectural design. This paper researches the order aesthetics of traditional Chinese architectures, further demonstrates the formal aesthetics law of traditional Chinese architecture design, and explores new ideas that combine traditional Chinese culture with modern design theories.

2. Overview of design geometry

2.1. Concept of design geometry

The design geometry is not geometry in the purely mathematical sense, but the deep integration of design and geometry. Dividing space by using the geometric drawing techniques to pursue visually coordinated and balanced order aesthetics [1] is the design principle of two-dimensional and three-dimensional space aesthetics. The design geometry is a research on ratio and composition. The ratio refers to the relationship between the parts and the parts, the parts and the whole; moreover, the ratio is constant in vision, and is determined by the spatial structure framework. The composition is a means of analyzing the relationship between shapes and obtaining visual balance, as well as a systematic method [2] of assembling various elements into an overall structure. The purpose of the design geometry is not to quantify aesthetics by using mathematical laws, but to combine the mathematical laws with human cognitive ratio preferences to find visually coordinated and balanced formal aesthetics, and to reveal the visual relationship that meets aesthetic standard; therefore, the design geometry has the dual characteristics of rationality and sensibility. Le Corbusier argued that the design geometry is a scale division standard that conforms to human beings and form of nature. The design products that conform to this law can produce harmonious aesthetics" [3]. The design geometry is an aesthetic law that people

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accumulate visual experience and summarize in design and production activities, which has an important guiding significance for the design work.

2.2. Research content of design geometry

2.2.1. Order that exists in nature

The ratio relationship of the design geometry exists in many natural forms. Observation found that the ratio relationship between some natural objects has a certain order. The order of biological behaviors is mostly related to efficiency, for example, the included angles of spirally-arranged leaves are mostly about 137°30′28″, that is 0.382 (1-0.618) times of 360°,at which the adjacent leaves can overlap at the lowest angle to improve the efficiency of photosynthesis to the highest. The order of non-biological behaviors is due to the physical law that works in an isolated system without interference [4], for example, a stone thrown into still water creates circular ripples, which become irregular due to wind or water current. The simple geometric shapes are in sharp contrast with the disordered shapes in nature. Human perception for the order begins with simple geometric forms, and the contrast between order and disorder awakens human perceptual system.

2.2.2. Sense of order and human cognitive ratio preferences

The sense of order is a predictive function, which refers to the form of the visual object to predict its regular movement and changes. Human perception for form order is subjective, transcendental and innate. The ratio and composition are the starting points of form. Pythagorean School's "all is number" principle argues that the derivation process of number is the evolution process of all things, and the golden section ratio is the absolute symmetry of the mathematical relationship, so the ratio coordination is pleasant to look at.

The main content of human perceptual activities is the expressiveness of things, and the application of ratio relationship in the design geometry is based on mining a high degree of expressiveness. In the 19th century, German aesthetician Gustav Fechner researched human cross-cultural aesthetic preferences for the golden section rectangle. In the early 20th century, Lalo repeated Fechner's experiments that proved human cognitive preferences for the golden section ratio.

2.2.3. Research method

2.2.3.1. Golden section method

The golden section ratio is one of the most coordinated ratios. The golden ratio is defined as dividing a line segment into two segments of different sizes, so that the ratio of the small line segment to the large line segment is equal to the ratio of the large line segment to the entire line segment, and its mathematical relationship is 1:1.618. The golden section sequence has generated properties, that is, a new golden section sequence is generated by accumulating numbers or similar figures. Its concept was first discovered by the Pythagorean School in pentagon and five-pointed star. The ratio of the large and small pentagons is exactly 1:1.618, which can be extended indefinitely(Fig. 1). In addition to the golden ratio rectangle, which is currently the most widely applied, there are golden ratio triangle and golden ratio ellipse.

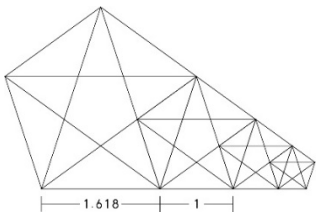

Figure 1: The golden ratio of a pentagram

The integer of the golden section ratio is expressed as the Fibonacci sequence, which was discovered by the Italian mathematician Leonardo Fibonacci in the 13th century. Its mathematical relationship is as follows: 0,1,1,2,3,5,8,13,21,34,55,89,144……starting from the third number, each number is the sum of the first two numbers, and the larger the numerical value is, the closer to the golden section ratio the ratio of the adjacent numbers is.

2.2.3.2. Radical rectangle section method

The radical rectangle, like the golden section rectangle, is a dynamic rectangle that can produce varied

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and harmonious subdivisions and combinations. The ratio of side of square to its diagonal is √2, and the extended side of the √2 rectangle is vertically divided into two smaller √2 rectangles.

The ratio of the short side of the √2 rectangle to its diagonal is √3, and the √3 rectangle can be obtained on the basis of the √2 rectangle by using compass drawing method. The √3 rectangle can be equally divided into three smaller √3 rectangles.

By analogy, a new radical rectangle can be derived infinitely.

2.3. Application of design geometry

The design geometry is not only a drawing method, but also has the application value of ratio and composition in the two-dimensional and three-dimensional space design. By impleme/?nting method and principle of the spatial section, the design geometry plays a guiding role in various fields of design practice. Architecture can be regarded as the combination of multiple geometries in space. The essence of architectural design is to research the relationship between various geometries. The ratio and composition of the façade of Notre Dame de Paris tally with the design geometry. The front of the church is within a golden rectangle, and the square part of the golden rectangle is exactly the main part of the church; the two diagonal lines intersect above the circular ventilation window, and the diameter of the ventilation window is 1/4 the diameter of the inscribed circle of the square; the main entrance also conforms to the ratio of the golden rectangle(Fig. 2). In addition, most of the excellent design works in other design industries also flexibly use the golden ratio and other design geometry principles.

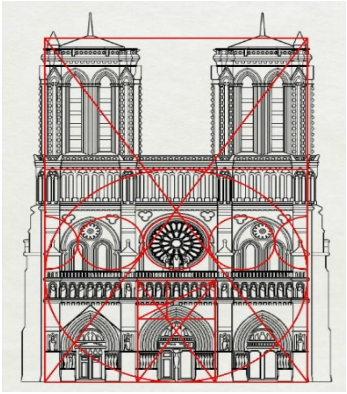

Figure 2: The main entrance of Notre Dame de Paris

3. Order aesthetics of traditional Chinese architecture

3.1. Aesthetic thought of "harmony between human and nature"

The concept of "harmony between human and nature" is core of traditional Chinese philosophical thoughts. Both Confucianism and Taoism advocate the thought of "harmony between human and nature". The difference is that the Confucianism argues that way of human are consistent with way of nature in ethics and morality, while the Taoism pays more attention to the consistency of natural life between human and nature [5]. Therefore, the construction of traditional Chinese architecture not only pays attention to the concept of hierarchy, but also emphasizes coordination and harmony with nature. For example, the construction of palaces and other architecture complexes follows a strict hierarchy. *The Book of Rites* records that "the heights of the stylobate are 9 *chi* (1 *chi* is approximately equal to 33.33cm) for emperor, 7 *chi* for feudatory king, 5 *chi* for *dafu* official, and 3 *chi* for *shi* official", which clearly stipulates the architecture sizes of different classes; the construction of classic garden focuses on the integration with nature, breaks through the boundaries of space, and pursues the objective of "although the garden is artificial, its landscape seems to be naturally generated".

3.2. Ratio relationship implied by concept of "circular heaven and square earth"

The "circular heaven and square earth" is a traditional Chinese cosmology. The circle-square and square-circle drawings drawn in *Yingzao Fashi* expresses the order of the spatial relationship between the square and the circle as "outer square and inner circle" and "outer circle and inner square". The space modeling of traditional Chinese architecture combining squares and circles contributes to formal

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aesthetics in space, and artistic aesthetics of "harmony between human and nature".

In the traditional construction process, the concept of "circular heaven and square earth" is gradually evolved into √2 and √3/2 geometric and mathematical relationships: the ratio of diameter of circle to side length of square in the circle-square drawing is √2, the ratio of diagonal of square to circumference of circle in the square-circle drawing is also √2; the ratio of height of isosceles triangle to side length of square is √3:2, which is generated by connecting the intersection points of the arc drawn with the vertex of the square as the center and the side length as the radius. The mathematical research of "circular heaven and square earth" first appeared in *Jiu Zhang Suan Jing*: ratio of the circumference of a circle to its diameter (π) is approximately 3.143, ratio of diagonal of a square to its side length is 1.41, and the ratio of the side length of an equilateral triangle to its height is 1.74. Regardless of the error from today's numerical value, these numerical values are adequate for application in the construction process.

The √2 ratio and the √3/2 ratio are widely applied in traditional Chinese architecture, for example, the ratio of eaves height to column height in the Tang and Song Dynasties was √2, and many bays, facades, and sections also followed the ratio; the planning of Chang'an City in the Sui and Tang Dynasties made extensive use of the √3/2 ratio [6].

3.3. Symmetrical and balanced order contained in "golden mean"

Traditional Confucianism advocates "golden mean". The original meaning of the "golden mean" is to be impartial, and the core of its thought is to "attain a state of harmony". The "golden mean" in the architecture is reflected in the use of central axis symmetry, being one of the traditional concepts of Chinese ancient architecture culture. The courtyards in Zhou Dynasty had already adopted the layout of the central axis symmetry form, which gradually evolved into the main mode of traditional architectural layout. The architectures are symmetrical on the left and right with the north-south central axis as the main line, presenting a harmonious and unified order. In addition, the architectures after the Zhou Dynasty gradually had adopted odd-numbered bays, complete symmetry of architecture facade compositions and even-numbered arrangement of annexes on both sides, which strengthened the symmetry of the plane space [7]. The symmetry of plane and facade combination tends to create a sense of stability and seriousness.

In the traditional Chinese architecture aesthetics, in addition to symmetry, the formal aesthetics law with the effect of "attaining a state of harmony" also includes balance. The balance is equivalent and non-equiform symmetry, that is, dynamic balance. Both have a logical ratio relationship, which can achieve a sense of stability in aesthetics. Absolute symmetry can produce a sense of solemnity, which is not suitable for all architecture forms. A balanced composition technique can add a relaxed and ethereal feeling to the space while maintaining a sense of balance. Most of Chinese classical gardens adopt the balanced technique for the space construction.

4. Case analysis - Beijing Ancestral Temple

Beijing Ancestral Temple is a three-storied enclosed courtyard. Inside its outer wall is basically vegetation. Inside the second wall is the main architecture complex. The inner wall surrounds the core architectures of Beijing Ancestral Temple. Along the central axis are Ji doors, Xiang hall, Qin hall and Tiao tampie. The order aesthetics is analyzed based on scales and ratios of Beijing Ancestral Temple recorded in *Squares and Circles, A Sum of Heaven and Earth*.

4.1. The overall proportion analysis of Beijing Ancestral Temple

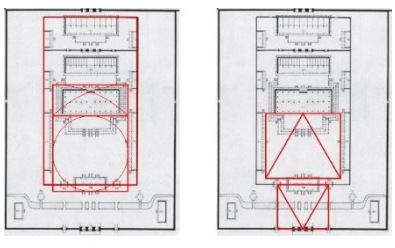

Figure 3: The overall proportion analysis of Beijing Ancestral Temple

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a. The ratio of depth (207.45 meters) to width (114.42 meters) of the overall layout of the core building complex is 9/5, symbolizing the "Ninth Five Year Plan supremacy" of imperial power(Fig.3a);

b. The length width ratio between the distance from the south edge of Ji doors pedestal to the north edge of the pedestal on the third floor of Xiang hall Hall (128.835 meters) and the surface width of the main courtyard (91.05 meters) is √ 2 (Fig. 3a);

c. The ratio of the distance (78.765 meters) from the north edge of the Ji doors pedestal to the south edge of the small pedestal of the hall of enjoyment to the surface width of the main courtyard (91.05 meters) is √ 3/2 (Fig. 3b);

d. The ratio of the distance from the East-West Center line of the front door to the East-West Center line of the Ji doors (54.94 meters) to the distance from the East-West Center line of the Ji doors (62.89 meters) is √ 3/2 (Fig. 3b);

e. The ratio of the total height of the Xiang hall (30.123 meters) to the total width of the foundation (82.64 meters) is about 2 √ 2 (Fig. 4a);

f. The ratio of the height above the foundation of the Xiang hall (26.645 meters) to the width of the open space (9.59 meters) is about 2 √ 2 (Fig. 4a);

g. The ratio of the width of the open space (9.59m) to the height of the eave column (6.865m) is √ 2 (Fig. 4b);

h. The ratio of the width of the open space (9.59m) to the width of the secondary space (6.43m) is √ 2 (Fig. 4b).

(Data source: *Squares and Circles, A Sum of Heaven and Earth*)

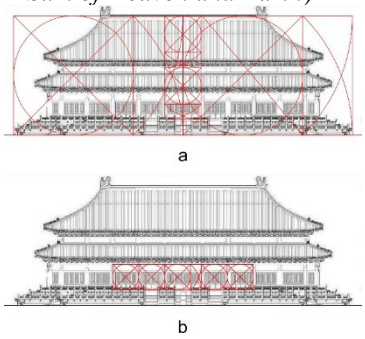

Figure 4: Analysis of the proportion of enjoying the temple

4.2. Analysis on order aesthetics of Beijing Ancestral Temple

The construction of Beijing Ancestral Temple organically combines the √2 and √3 ratios, with visually coordinated and balanced order aesthetics. The overall layout also reflects the artistic aesthetics of “harmony between man and nature”. The internal and external environments of the overall space are coordinated with each other. Between the outer wall and the second wall is a large area of vegetation. The area of vegetation exceeds total area of the architecture complexes. There is an obvious contrast of scale between the vegetation and the architecture. Its function is to foil a solemn atmosphere, and separate this space from secular activity space to strengthen the divinity of sacrificial space, which pursues “harmony between human and nature” in ethics and morality, and takes into account “harmony between human and nature” in nature.

As the imperial sacrificial space of the Ming and Qing Dynasties, Beijing Ancestral Temple pays special attention to the feudal hierarchy relationship. Its layout adopts the central axis symmetry method. Its main architectures are arranged on the longitudinal central axis. The most important architecture is located in the center. The wing rooms and the side halls symmetrically arranged on both sides are also based on the central axis. The three-storied courtyard structure in the longitudinal direction forms a layered and deep architecture space. The distinction between primary and secondary parts of the entire architecture highlights dignity of royal family and solemnity of sacrificial site.

5. Conclusions

Simple geometric forms in nature give rise to a perception for order, which evolve into the design

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geometry. The design geometry is to reveal the visual relationship between ratio and composition and pursue visually coordinated and balanced aesthetics. The design geometry is widely applied in various design fields to achieve method and principle of spatial section, which has important guiding significance for artistic design creation. Especially in the field of architecture, the shape and structure of architectures follow the laws of design geometry. Although there is no clear concept of the design geometry in ancient China, the relationship between ratio, scale and composition has been systematically summarized in the construction process of architecture. *Yingzao Fashi* evolved the √2 and √3 ratio relationships based on the cosmology of "circular heaven and square earth", which is widely applied in the construction process of traditional architecture. Moreover, the symmetrical and balanced order is extracted from the philosophical thoughts of Confucianism and Taoism, such as "harmony between human and nature", "golden mean". Therefore, traditional architectures mostly adopt the layout of the central axis symmetry, with formal aesthetics and artistic aesthetics, to form the unique order aesthetics with Chinese characteristics.

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