COURTYARD ENVIRONMENTAL PERFORMANCE ANALYSIS OF YUNG HO CHANG’S SPLIT HOUSE

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Abstract: Yung Ho Chang is an influential contemporary Chinese architect. He is the founder of the Graduate Centre of Architecture at Peking University and was the Head of the Department of Architecture at Massachusetts Institute of Technology. One of his most famous works is the Split House built in Beijing whose V-shaped layout aims to embrace an open courtyard. During the conceptual stage, Chang produced a series of diagrams to explore different geometrical configurations. This study aims to compare the performance of these different alternatives in order to assess whether environmental factors were addressed in their full potential. Accordingly, air-flow and shading analysis were conducted and contrasted against the performance of the final configuration. The importance of visualisation of such performance measures during early stages of the design process is also discussed.

Keywords: Contemporary Chinese architecture, Yung Ho Chang, air flow analysis, shading analysis, Split House
1 Introduction

Chinese architects acted as public servants in state-owned design institutes in the Mao era (1940-1976) and the post-Mao era in the 1980s, fulfilling national tasks and enforcing government policies. Since the implementation of the architect registration system in the 1990s, Chinese architects can now work independently, enjoying more freedom and individual expression. After the economic reform of Deng Xiaoping, the expanding middle class and emerging design-oriented developers encourage architects to carry out design experimentation. Some architects have responded to this shift through a demonstration of self-conscious practice and reflective thinking. Among them, Yung Ho Chang (b. 1956) is a prominent figure, who set up his private architectural practice in Beijing as early as 1993. His design strategies are shaped primarily by his cross-cultural exposure.

Chang’s cross-cultural exposure correlates with his family background and architectural education. He was brought up in a liberal family environment in Beijing, which allowed him to develop individual interests. Both his parents were good at English, and his father, Zhang Kaiji (1912-2006) was a famous architect responsible for the design of many landmark buildings in China, including the National Museum of Chinese History, Beijing (1959) and the National Art Museum, Beijing (1962). Since his childhood, Chang was frequently taken to see exhibitions and exposed to foreign pictorials and journals, which aroused his interest in drawing and fine art. Since his father did not have the opportunity to study abroad, he insisted that his two sons were well prepared for overseas study (Chang 2012: 11). Following his father’s advice, he studied architecture, enrolling at the Nanjing Institute of Technology (NIT), the same school as his father, in 1977, and went to the US for further study in 1981. Compared with his Chinese counterparts, Chang is a pioneer in many respects. He belonged to the first cohort of students who received local university education and overseas study opportunities after the ten-year Cultural Revolution (1966-76). He was the founding professor of the Graduate Centre of Architecture at Peking University, Beijing (1999), the first Chinese professor to be the Head of the Department of Architecture, Massachusetts Institute of Technology (MIT, 2005-10), and has been appointed as a jury member of the prestigious Pritzker Architecture Prize since 2012.

Chang lived in a traditional courtyard house in Beijing during his childhood until thirteen years old (He 2008: 62-63), which has a profound influence on his architectural design. Due to his obsession with Chinese courtyard houses (Ruan 2006: 118), the courtyard becomes one of the most recurrent themes in his work as exemplified in the Qingxi Hillside Housing Project (1995), the Morningside Centre for Mathematics (1998), and the Southwest China Bio-Tech Base (2001). The earliest study was his Courtyard House Projects (1991) demonstrating a strong preference for rational guiding principles of spatial and formal subdivision. Both Courtyard Houses 3 and 4 show a meticulous attention to proportion and are rigorously based on the symmetrical principle (Figs. 1 & 2), in which these two houses can be equally bisected and the Courtyard House 4 has a pair of building blocks on both sides of a linear courtyard.
Courtyard Houses 3 and 4 are theoretical projects without being realized. Both of them did not have any actual site location and, apparently, the architectural design of these two houses only involve pure aesthetic spatial subdivision and formal manipulation without considering its relationship with surrounding contexts and its orientation in response to climatic conditions.

The bisected form of the schematic Courtyard House 4 has been further elaborated in the subsequent Split House built in Beijing in 2002. The Split House is one of the residences at the Commune by the Great Wall in Beijing developed by SOHO China. Conceived as a generic modular concept, the Split House is designed to cope with various site conditions by adjusting the angle between the two blocks (Chan 2005: 130). The design concept behind is the adjustment of a flexible prototype, which can be adapted to other locations.
A total of eight different configurations were developed during the conceptual stage (Fig. 3). In Scenario A, the two building blocks are combined to form a single house. In Scenario E, they are joined together to form a long linear structure. Scenarios B and H show parallel arrangement with a linear in-between courtyard in resemblance to the previous Courtyard House 4 project. In Scenarios C and G, the two blocks are in V-shaped relationship, whereas in Scenarios D and F, they are perpendicular to each other. Depending on various site conditions and the actual needs of the client, the Split House can become a single house, a parallel house, a right-angle house or even a back-to-back house (Pearson 2004).
Among the eight configurations, Scenario C is adopted as the final disposition of the Split House. The two building blocks are connected together by the vestibule embracing the courtyard in the middle with living area on one side and dining area on the other side. (Fig. 4). According to Chang, the original idea was to “transplant the traditional courtyard house in Beijing from its dense urban context into the pristine landscape” (Pearson 2004: 95). Instead of fully enclosing the courtyard on four sides, one side of the courtyard directly opens to the landscape. This conveys a clear gesture to embrace the natural landscape by drawing the magnificent scenery into internal spaces and preserving the existing trees within the triangular courtyard.

By splitting the house into two wings at a forty-five degree angle, functions inside each wing can be effectively demarcated. An internal staircase is provided in each wing for accessing to the bedrooms above (Fig. 4). Staircases are strategically located on the inner side of each wing to act as a semi-private transitional circulation space. Spatial hierarchy is demonstrated with an open plan for living and dining areas on the ground floor, servant rooms behind the kitchen, semi-private staircases connecting the two floors, and more private bedrooms on the upper level.

When the former Courtyard House 4 and the subsequent Split House are compared, the arrangement for the upper floor plans are quite similar. Both designs have significant setback on both ends of the upper levels. In the Courtyard House 4, the first floor plan of each building block has a tripartite division with enclosed rooms in the middle portion. In the Split House, the tripartite proportion is no longer maintained but the indoor-outdoor relationship on the upper level is more clearly defined with direct access to roof garden from each bedroom.

During the conceptual stage, a total of eight configurations have been developed as mentioned before (Fig. 3), so the question is whether the current design can provide a comfortable courtyard environment for users. In this paper, the relationship between
different geometrical configurations of the building form and their air flow and shading performances are analysed. In order to facilitate the comparison, air flow diagrams and shading diagrams for different configurations are prepared to see whether these factors have been well addressed.

![Image of the courtyard of the Split House]

**Figure 5: The courtyard of the Split House**

## 2 Air Flow Performance

The courtyard is a traditional building form used by many civilisations all over the world (Muhai sen 2006: 245) and has been widely recognised as an environmentally responsive form (Ratti 2003: 54). People living in hot regions have attempted to deal with the issue of thermal comfort over the centuries through their vernacular architecture with the courtyard form. The relationship between the proportions of the physical parameters of the courtyard form and its associated air flow pattern has been investigated by many researchers such as Ok (2008) and Moosavi (2015). The major concerns are how to influence the wind speed through building geometry and to improve the comfort level of the living environment through natural ventilation, especially in hot and arid climates, which is quite different from the context of the Split House.

The Split House is located in Badaling, which is 65km to the north of Beijing CBD. The mean of maximum air temperature per month ranges from 31°C in July to -2°C in January and the mean of minimum air temperature per month ranges from 19°C in July to -15°C in January. According to the Wind Rose of Badaling, the mean wind speed per year is 14 km/h and the highest wind speed can reach 61km/h. The prevailing wind mainly comes from the north-west direction (Meteoblue 2016). Figure 6 compares air flow diagrams of different configurations of the Split House. Since Scenario H and Scenario B are quite similar, so only seven configurations from Scenarios A to G are compared.
Figure 6: Air Flow Diagrams of Different Configurations of the Split House
Taking the specific climate of Badaling into consideration with only a maximum of 31°C highest temperature in summer, it is important to orientate the Split House in a manner that can reduce the speed of airflows within the courtyard, especially during the cold winter time. Both Scenarios D and E are very effective in reducing the wind speed in the courtyard against the strong wind coming from the north-west direction. This is in line with the findings of Sharples & Bensalem (2001) as both scenarios have a main façade to be positioned perpendicular to the wind direction.

From the air flow perspective, the adopted configuration of Scenario C may not be the optimum arrangement. In fact, the air flow at the junction of the V-shaped building blocks reach a higher speed. The wind speed in the courtyard cannot be effectively reduced through the building configuration. If the V-shaped relationship of the two building blocks has to be maintained, an alternative disposition can be considered by having a façade facing in perpendicular to the wind direction (Fig. 7). This can achieve a lower wind speed in the courtyard compared with Scenario C.

![Figure 7: Air Flow Diagrams of an Alternative Scenario of the Split House](image)

## 3 Shading Performance

Similar to the air flow analysis, shading performance of the courtyard has attracted the attention of many researchers, such as Mohsen (1979), Muhasilen (2006) and Yasa (2014). Most of these studies examined the geometrical parameters of courtyard forms in hot climate and discussed how the courtyard could be shaded from intense solar heat gain to achieve the thermal comfort of the environment as the absorbed solar radiation can increase the surface temperature of the courtyard. As mentioned by Mohsen (1979: 90), the building orientation is an important factor in controlling heat gain. Muhasilen (2006: 1050) also states that whether the courtyard is shaded or exposed to the sun depends on the position of the sun and the geometry of the form. A proper configuration of the courtyard can ensure adequate solar heat gain in winter for warming up the space and providing sufficient shading in summer to reduce the need for cooling.

In the case of the Split House, the situation is different from those courtyard forms in hot climate. In Badaling, the winter can be as low as -15°C and the highest temperature in the summer is 31°C, so it is crucial to maximise the solar heat gain during the winter in addition to provide shading during the summer. As the winter solstice is on 21 December and the summer solstice is on 21 June, Figures 8 and 9 compare shading diagrams of different configurations of the Split House on winter solstice and summer solstice respectively.
Scenario A

Scenario B

Scenario C

Scenario D

Scenario E

Scenario F

Scenario G

Figure 8: Shading Diagrams of Different Configurations of the Split House on Winter Solstice (21 December)
Figure 9: Shading Diagrams of Different Configurations of the Split House on Summer Solstice (21 June)
As shown in Figure 8, both Scenarios B and G have the longest shading period during the winter, which is not desirable under cold weather. Comparatively, the adopted configuration of Scenario C has the least shading period for the courtyard among the seven configurations, which is a favourable option during the cold winter. If the V-shaped relationship of the two building blocks has to be maintained, an alternative disposition can be considered by orienting the courtyard directly facing the south direction. This can maximise the solar heat gain as shown in Figure 10.

Figure 10: Shading Diagrams of an Alternative Scenario of the Split House on Winter Solstice (21 December)

Since the summer time of Badaling can still reach up to 31°C, it is still desirable for the building form to have some shading performance for the courtyard. As shown in Figure 9, the adopted configuration of Scenario C provides some shading for the courtyard, but is not as good as Scenarios B and G, which have longer shading period.

4 Conclusions

This paper aims not to identify the optimum arrangement for the Split House nor to thoroughly quantify the impact of air flow and shading performance on the interior spaces of the house. Instead, through the use of the Split House as a case study, the importance of visualising the relationship between the building form and different environmental parameters, such as the air flow and shading factors, is illustrated. Since the courtyard geometry and house massing have a significant impact on the air flow and shading performances, visualisation since early stages of the design process can be a useful approach to identify the possibilities and limitations of different layout and site planning alternatives towards making informed design decisions. Although only two factors (i.e. air flow and shading) are discussed in this paper, more comprehensive approaches to environmental performance analysis and visualisation focused on further environmental parameters may provide critical information to pursue desirable and comfortable living ambiances for dwellers.

References


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