

The Environmental Performance of Traditional Courtyard Housing in China - Case Study: Zhang's House, Zhouzhuang, Jiangsu Province

Brian Ford¹, Benson Lau² and Zhang Hongru³

¹ University of Nottingham, Nottingham, UK

² University of Nottingham, Nottingham, UK

³ Shanghai Research Institute of Building Sciences

ABSTRACT: In existing studies of the Chinese vernacular architecture, pictorial and romanticised literature dominates. Research into the design philosophy, history of development, architectural built forms are the common topics, but meaningful investigation on the environmental performance of the vernacular architecture is rarely touched upon. This study is a contribution to filling this gap. The main focus of this paper is the vernacular dwellings in Zhou Zhuang Village, which is located on the edge of Shanghai. This paper describes preliminary results from a study of the environmental performance of a Ming dynasty courtyard house, located in the heart of the village.

The spatial poetry and drama of these courtyard houses is evident to the visitor, while the environmental performance is being investigated through a programme of on-site measurements which started in February 2006. This study hopes to reveal how these buildings respond to the local climate and provide comfort throughout the year by passive means. It also shows how a clever manipulation of spatial and building elements helps to promote thermal and visual comfort, while also providing a tranquil and visually stimulating sequence of spaces.

Keywords: Chinese Vernacular, environmental performance

1. INTRODUCTION

The fishing village of Zhouzhuang, is in south-east China, about 30KM south-east of Suzhou, and west of Shanghai, located at the junction of the lakes of Baixian and Beibai. Zhouzhuang has remained an island of tranquility for many centuries, and has survived remarkably intact.



Figure 1: Aerial view of Zhouzhuang

In Zhouzhuang, nearly 1,000 households are distributed along the streets and lanes. Most of the original architecture is preserved, including almost 100 ancient houses with courtyards and 60 carved

brick archways. [1] With white walls and lattice windows, the residential houses are located close to the rivers and lakes, manifesting a tranquil and picturesque atmosphere (Fig 1).

Founded initially as a Buddhist monastery in the 11th Century, its economy was based initially on the abundant aquatic life of the lakes, and later became a centre of grain, silk and craft manufacture. The settlement grew around a network of natural and man-made waterways, in a similar way (but on a smaller scale) to Suzhou, which has a worldwide reputation for its exquisite 'Scholar Gardens'.



Figure 2: Zhang's House view of ceremonial hall

Within Zhouzhuang, many of the buildings date back to the Ming and Qiang Dynasties. This paper focuses on one particular house, and the subtlety of the ways in which it was designed to respond to seasonal changes in climate, to achieve not just visual and thermal comfort throughout the year, but also a calm and dignified interior which delights all the senses (Fig 2).

2. CLIMATIC CONDITIONS

Zhouzhuang has a subtropical monsoon climate with four distinct seasons. The summer months are hot and humid with an average temperature of 26 degree C, while the winter months are cold and humid with an average temperature of 6 degree C. The annual average temperature is about 16 degree C and the relative humidity varies from 30% to 80%.

South easterly winds characterize the warm season thus bringing warmth and high humidity from the ocean, as well as monsoon rain for part of the season. North westerly polar winds bringing cold and damp characterize the cold season.

3. ZHANG'S HOUSE

The entrance to Zhang's house faces almost due west, adjacent to a landing stage from the canal (Fig 3). It is the house of a wealthy merchant, and follows the traditional layout of public reception and ceremonial halls in the front with more private living spaces for the family behind (this layout is also found in the Forbidden City in Beijing, although the orientation there is on a strict north/south axis).

Frontage to the river/canal would have been very

valuable, so the houses have a relatively narrow frontage and are stretched out as a series of pavilions and courts, the geometry of which is manipulated to provide light, and air while maintaining privacy and security

From the first low reception hall, the contemporary visitor is allowed to proceed directly on axis via a very narrow (2m wide) court into a second reception hall, from where one looks through a very imposing doorway within a blank masonry wall, towards a slightly raised and much bigger ceremonial hall which is reached across a larger courtyard (Fig 4).



Figure 4: Roof of the ceremonial hall screens the sky to reduce glare in the eyes of the visitor



Figure 3: Zhang's House ground floor plan and section

In the past the central screen doors between the reception pavilions may have generally been closed (except in summer to allow air movement) and the visitor forced to go either side of the first narrow court, not gaining a glimpse of the ceremonial hall until arriving at the imposing central doorway.

The door here is heavy and solid and sits within a completely opaque masonry wall, not allowing light or air to pass through, and providing a line of security and privacy. Standing just inside this doorway one has a clear view of the imposing ceremonial hall opposite, and looking up one sees the roof of the hall which completely screens the sky. This relationship is carefully designed so that the visitor does not suffer glare from the sky, but rather the eye takes in the beauty of the main pavilion and its forecourt.

The main ceremonial hall is reached up three steps to a platform under a magnificent roof of dark beams and tiles. This is where the family will have received and entertained their guests, in a space diffusely lit via paper covered screens which fill both the longer sides of the space.

Gable walls are rendered brick incorporating columns to support the roof trusses. The central screen wall opposite the entrance into this Hall will normally have been closed, so that members of the family passing through to the more private domain beyond go via the doors either side of the screen (Fig 5)

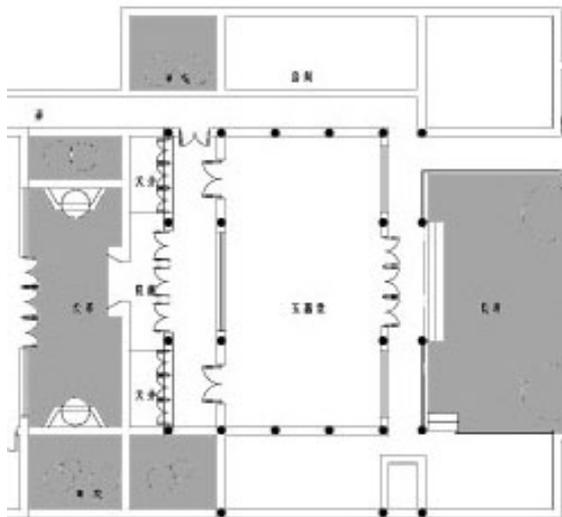


Figure 5: plan of ceremonial hall and related courts

One is then within a corridor space. But it is more than a corridor space. Two 'crab eye' light-wells provide reflected light to this space, while also providing the backdrop for a bamboo plant which appears in silhouette like a traditional painting, delighting the eye and softening the space. The geometry of this light well prevents direct sunlight penetration, while providing reflected light off the white rendered masonry wall. This diffuse light will have had a psychological as well as physical effect in

achieving 'light without heat', compared with the harsh bright light of the outside world (Fig 6).



Figure 6: 'Crab Eye' light well to the left of ceremonial hall

Entering the first private court, the axis slightly changes and one faces another (smaller) hall, which would have been a family room, with stairs via an adjacent space up to bedrooms at first floor level. This pavilion has similar screens in the walls facing west, and an opaque masonry wall facing east, like the main ceremonial Hall, but this time without the 'crab eye' light wells.

A further two narrow courts and single storey pavilions, lead to the back of the house and another narrow canal. Adjacent to the last pavilion, and on the other side of the long service corridor which runs the full length of the house, is a kitchen and tea room, overlooking the narrow canal (Fig 7). Land on the other side of this narrow canal has been used to provide a private study (consisting of two pavilions which both address a very private and quiet court) (Fig 8), a garden of rocks and cherry trees, and the family temple or shrine (turned to align with the obligatory north/south axis).



Figure 7: The canal at the back of Zhang's house



Figure 8: The private study with the court in front

4. NATURAL VENTILATION THROUGH CRAB EYE LIGHT-WELLS

Closer observation reveals a further function for the 'crab-eye' light wells. Openable screens rise from about 500mm from the floor to the ceiling, and they would have been opened in the summer to promote air movement. The screens sit above a low bench, the so called 'beauty seat' (Fig 9), where the ladies of the house apparently sat in the summer. Why sit here in this 'corridor'? The answer involves one of the most subtle aspects of this design.

Air from the front of the Hall (which has a very large open area) passes through the doors (a much smaller area) and accelerates as it moves across the bench seat and up the 'lightwell' (spot measurements on a recent visit revealed air velocities of 0.1 to 0.3m/s through the screens at the front of the Hall compared with 0.7 to 1.2m/s through the doors adjacent to the 'beauty seats') (Fig 10)

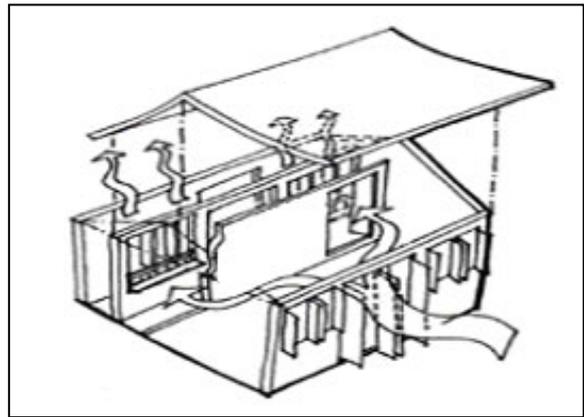


Figure 10: Axonometric view showing ventilation schematic through the hall to crab eye light wells



Figure 9: 'Crab Eye' light well with the beauty seat in front

On a hot and humid summer day this would therefore have been an ideal place to sit; a calm and tranquil place, promoting not just thermal comfort but an experience which combines air movement, the rustle of bamboo leaves, diffuse light from above, and oblique views through the Hall and into the reception courtyard from where guests would approach.

One can imagine the pleasure and excitement of the ladies of the house on formal occasions, when the house would have provided an exquisite setting for ceremony and entertainment.

The masonry wall to the 'crab eye' light wells provides a second layer of security, as well as protection from the cold easterly and north-easterly winter winds, and acoustic privacy between the public areas and the private rooms of the house behind. Also this wall acts like a blank canvas to receive the beautiful plants in the light well (Fig 11).

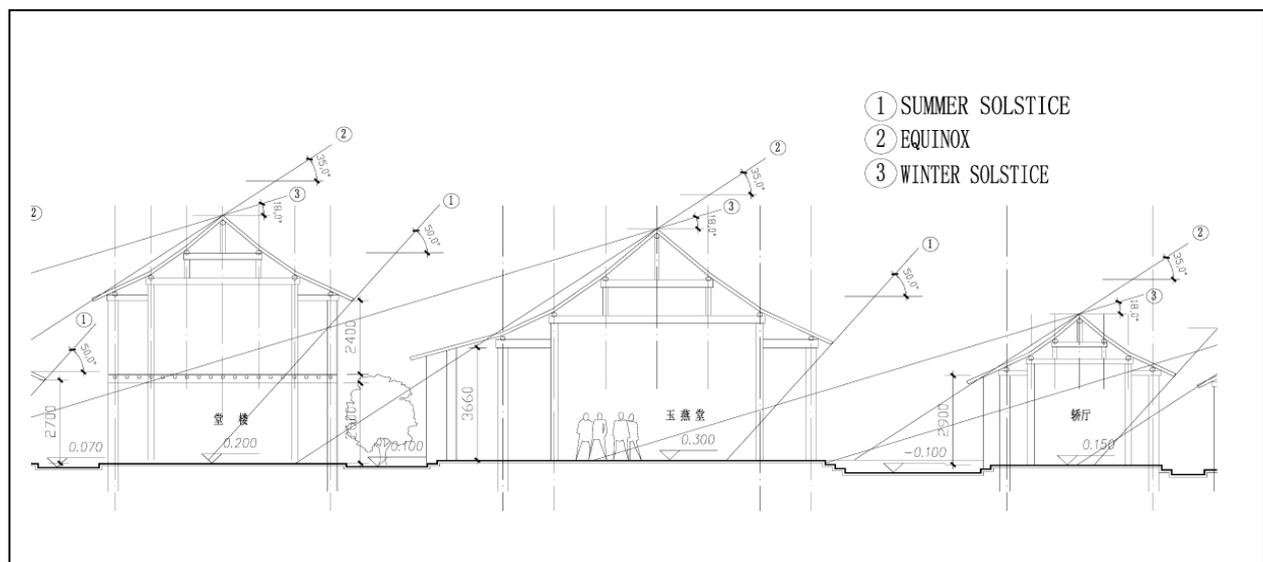


Figure 12: Section showing the sun angles at 3pm on Summer Solstice, Equinox and Winter Solstice.

5. GLARE CONTROL AND ADAPTATION

In the eastern part of China, the intense heat and glare from the sun, especially in the summer months can easily cause overheating and discomfort glare if the building envelope is not designed properly. Colonnades, roof overhangs, lattice work screens and trees had been carefully designed in Zhang's house to reduce excessive solar radiation and glare.

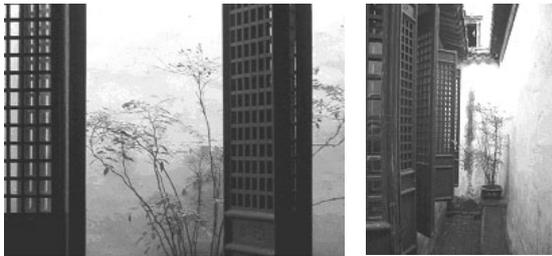


Figure 11: 'Crab Eye' light well acts as wind barrier, picture wall and ventilation shaft.



Figure 13: Low angle winter sun penetrates into the pavilions and the roof overhangs, while lattice screen windows and trees reduce glare.

Since Zhang's House has its main entrance facing west, the west facing facades in the pavilions will be vulnerable to low angle sun in the afternoon. By plotting the sun angles at 3pm on the building section, one can see that the summer sun is blocked out by the colonnades and roof overhangs, while the spring

and winter sun can penetrate into the ceremonial pavilion to warm the interior spaces (Fig 12). The glare associated with the low angle sun is dealt with by the lattice screen windows, doors and trees (Fig 13).

In order to reduce the abrupt change of illuminance level between the courts and the pavilions, colonnades and a thick stone architrave were used as light 'shields' to reduce the brightness contrast between inside and outside (Fig 14).



Figure 14: Colonnades and stone architrave as light shields to reduce brightness contrast.

Spot measurements on site made on an overcast day in winter indicate that there is a relatively gentle illuminance fluctuation along the central axis of the Zhang's House. The illuminance distribution graph indicates that the transitional spaces between the pavilions and the courts, either in the form of colonnades or stone architraves, allow an adaptation period for the eyes to adjust to the change of light intensity when one walks through the house (Fig 15).

Overall the well tempered luminous environment here is achieved by allowing restricted view to the sky, providing light buffer zones and making use of colonnades, roof overhangs and lattice windows and doors. Also careful positioning of trees provides a natural sun screen that is responsive to seasonal changes.

5. CONCLUSION

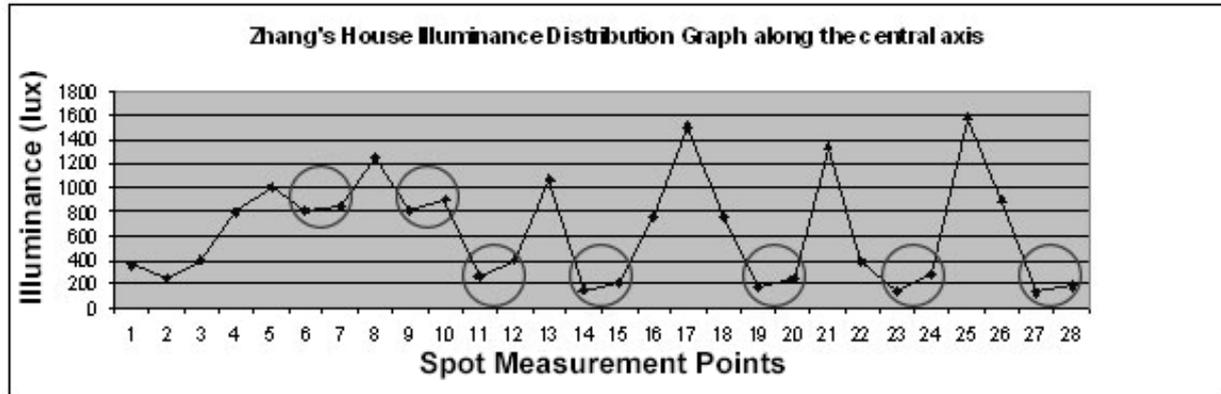


Figure 15: Zhang's House illuminance distribution graph with light shields highlighted in circles.

The multiple functions and the subtle interactions of the different elements, promote admiration for the designers of this house. But this is not the work of a single designer (and certainly not a single period). The different forms and elements of this house are representative of the traditional house found in many parts of China, which has developed over millennia.

It is interesting to speculate about the process of gradual empirically based improvement to achieve such a synthesis. However, the purpose of this paper is not to trace this pedigree, but rather to explore how the numerous and subtle ways in which visual and thermal comfort and delight are achieved.

This paper is the start of this process. Measurements of light, air temperature and air movement are ongoing, to establish whether our claims that such a house really would have been comfortable without air conditioning are valid. Whether this is the case or not, this exquisite house was certainly designed to delight all the senses, and it is exemplary in the way that it moderates the impact of the external climate on the internal environment.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance of the Township Government of Zhouzhuang, and of the Shanghai Research Institute of Building Science.

REFERENCES

- [1] Chen Yi, Zhuang Chundi, Zhang Jihan and Liu Ji, 2000, Nine Hundred Years Old Town of Zhouzhuang, Xi'an Map Press, Xi'an, China.