Revitalization of Environmental Sustainability Hidden in Yeongyeongdang

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Abstract

In this paper, a traditional Korean residence, Yeongyeongdang in Seoul, is selected to demonstrate the achievement of environmental sustainability in the formal composition of traditional Korean architecture. Using the computational analysis features of Ecotect, as performed on geometric models of the Yeongyeongdang complex, the paper highlights the method of articulating environmental factors in the design of its spatial systems, which were heavily influenced by social hierarchy during the Joseon dynasty (1392-1910).

Keywords: environmental sustainability; simulation; spatial system; Korean residential building; social hierarchy

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1. Introduction

Vernacular architecture employs locally available resources to address the inhabitants' needs and evolves to reflect the environmental, social, and cultural setting in which the architecture exists (Roodman and Lenssen, 1995). This paper begins with the hypothesis that traditional Korean architecture developed its own method for meeting the given requirements in the best possible manner, utilizing natural resources and with limited technological advantages. Traditional Korean architecture made use of locally available materials such as wood, red soil, straw, and porcelain. Environmental conditions arising from different geographical characteristics also influenced the layout of dwellings. A Korean vernacular dwelling and its layout developed under the historical and social conditions of Korea.

During the Joseon dynasty (1392-1910) of Korea, the basic design and layout of a traditional Korean residence was influenced by the social hierarchy and the cultural environment. At the time Yeongyeongdang was being built in the 19th century, social status played a more important role in determining the composition of typical living quarters. The Confucian principles underpinning the hierarchical social system had a tremendous influence on the basic design and layout of a traditional Korean residence. Accordingly, the separation of men from women, separation of superior from inferior classes, and the need for an ancestral shrine became fundamental elements in the composition of the residence (Inaji and Virgilio, 1998). Then, the question that arises is this: how could Yeongyeongdang also accommodate various environmental needs within its building design, which was governed by the social and cultural structure of the time? Yeongyeongdang comprises four distinctive areas: those reserved for the man of the house, areas for women and children, servants' areas, and service areas. The spatial composition of Yeongyeongdang was prioritized according to social mores, as follows:

- The men's areas: Sarangbang (master's room), Sarangchae (men's quarter), Sarangmadang (courtyard of the men's quarter), Middle Room, Numaru (master's summer reception room), Seonhyangjae (library), Nongsujung (pavilion)
- Women and children's areas: Anbang (matron's room), Anchae (women's quarter), Anmadang (courtyard of Anchae), Arangbang (children's room), Arangchae (children' quarter), Konnobang (women and children's room)
- Servants' areas: Haengnangbang (servants' room), Haengnangchae (servants' quarter)
- Service areas: Puok (kitchen) & dining area

This paper mainly tests and demonstrates the environmental sustainability of a selected building complex, Yeongyeongdang, using the analytical software, Ecotect. Ecotect is easily formulated to work in three dimensions for evaluating energy efficiency and thermal performances. First, the apparently vague and non-systematic features in the expression of the traditional spatial concepts that appear in the building

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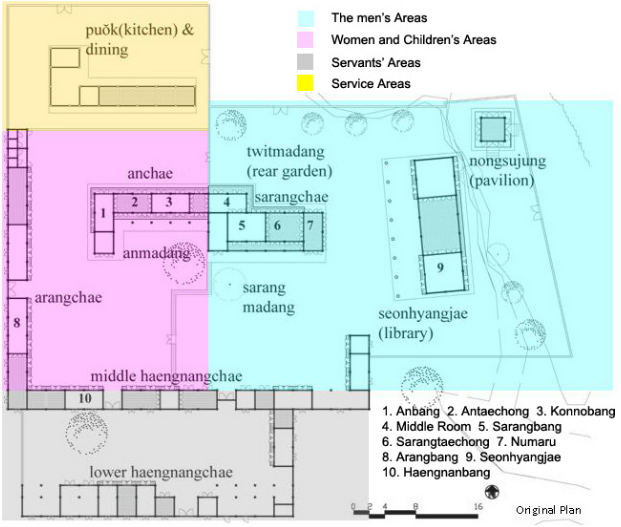


Fig.1. Site Plan of Yeongyeongdang

are analyzed and rearranged. Then, the environmental expressive characteristics of Yeongyeongdang are extracted based on the tendencies of a contemporary paradigm using the energy simulation software. Lastly, the relationships between social hierarchy and environmental design considerations in the context of Yeongyeongdang, an upper class residence in Korea's Joseon dynasty, are analyzed. Ecotect shows that environmental design elements such as shading and solar analysis, analysis of wind and air flow, and thermal performance analysis were incorporated into the design of Yeongyeongdang.

2. Methodology – Modeling & Simulation

The analysis starts with constructing geometric models of the Yeongyeongdang complex using AutoCAD, which allows precise detail in any scale. Based on the models, the design strategies and environmental factors of Yeongyeongdang are redefined. Design strategies include layout of the buildings, position and size of windows, landscape, roof overhangs, distance between buildings, their orientation, and material selection. Environmental factors include water and rain, wind and airflow, sunlight, micro and macro climate, temperature, energy, consumer goods, human comfort, thermal performance, and onsite natural resources (Kim, 2000). The environmental factors embedded in the buildings are compared to the design strategies. On the basis of these comparisons, architectural principles that sustain the environmental advantages in Yeongyeongdang are analyzed. Furthermore, the influence of social status on the design strategies is reviewed.

Ecotect is a highly visual and interactive building design and analysis tool, covering a wide range of analysis features including solar, thermal, energy, lighting, acoustics, and regulations. It is used for analyzing shadows, shading and solar influence, thermal performance, heat gain and loss, spatial comfort, ventilation, and daylight and sunlight (Marsh and Raines, 2007).

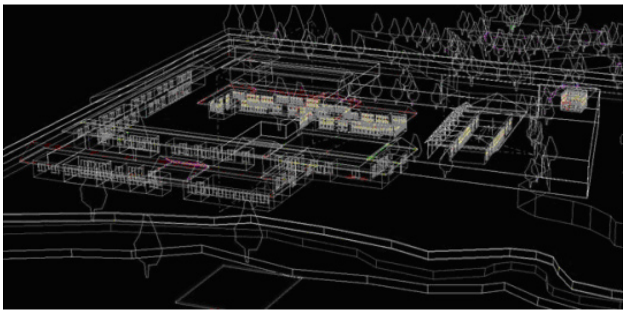


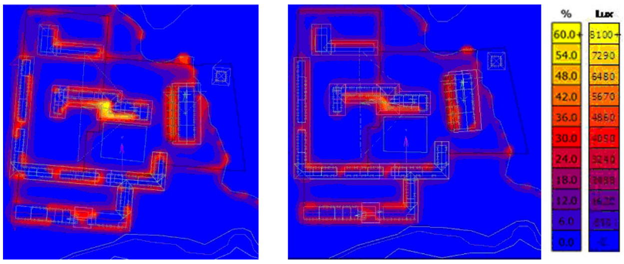
Fig.2. The Use of Ecotect

The experiments are focused on the Korean summer and winter seasons, during which additional efforts are required for maintaining a comfortable environment indoors. January 13 is considered the coldest day; May 6, the start of summer; June 21, the summer solstice; July 23, the hottest day; August 23, the end of summer; and December 23, the winter solstice.

3. Analysis

This paper analyzes a traditional Korean residence, Yeongyeongdang, in order to discover its design features and strategies for controlling various environmental factors during the four seasons of the year. Yeongyeongdang is analyzed by simulating the following rooms: Anbang (matron's room), Antaechong (matron's living room), Konnobang (women and children's room), Middle Room, Sarangbang (master's room), Sarangtaechong (master's living room), Numaru (master's summer reception room), Haengnangbang (servants' room), Arangbang (children's room), and Seonhyangjae (library).

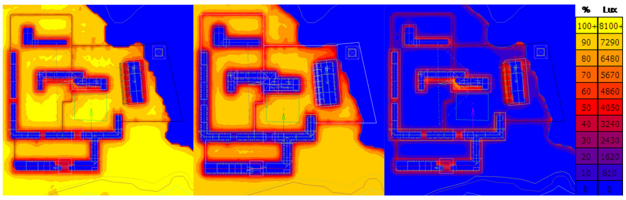
Unlike most traditional Korean Architecture, the building orientation of the existing Yeongyeongdang is tilted fifteen degrees towards the west from due south. Following several reconstructions after many wars and rebellions, the current Yeongyeongdang is different from the original plan (Choi, 2005; Zu, 2003). The existence of these different layouts of Yeongyeongdang presents a difficulty in performing the analysis, as it leads the authors to question which layout will be a research model in this paper. To assist with the selection of the preferred building plan, the authors used Ecotect. Daylight factor analysis was performed on both the original layout and the existing building layout, in order to compare the fundamental environmental values embedded in both the existing building layout and the original layout. The analysis reveals that the original layout is environmentally superior to the current layout. The authors therefore selected the original layout of Yeongyeongdang as the research model rather than the existing building. Fig.3. shows that the daylight distribution in the original layout is more consistent than that in the existing one.



(a) Existing (b) Original

Fig.3. Daylight Analysis, August 23 Noon

The daylight factor (DF) is related to three principle components. The sky component (SC) is light received directly from the sky. The externally reflected (ER) light is that received directly by reflection from the buildings and landscape outside a room. The internally reflected component (IRC) is that received from surfaces inside a room (McMullan and Seeley, 2007). Daylight usually enters a building through oilpaper windows or doors, but these windows or doors also transmit heat, which affects the thermal performance. The amount of daylight, as well as the cooling energy, is a deciding factor as far as choice of lighting is concerned. The provision of natural lighting in a residence must be considered together with factors such as artificial lighting, heating, ventilation, and sound control. The outcomes of daylight analysis become the sources of shadows, shading, and solar analysis. In Yeongyeongdang, the ER light spreads out evenly in most of the rooms, as seen below.

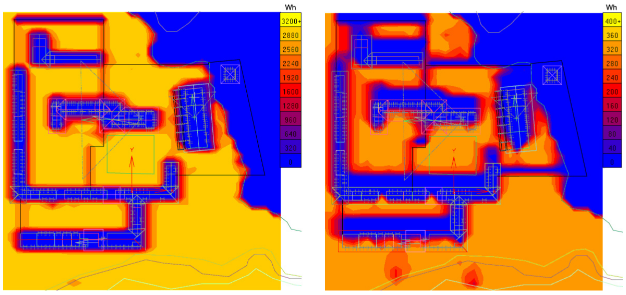


(a) Daylight Level (b) Sky Component (c) Externally Reflected Light

Fig.4. Daylight Analysis

3.1 Shadows, Shading, and Solar Analysis

Solar analysis shows how the roof eaves offer protection from sunlight during summer and allow for sunlight during winter. Solar analysis also provides data concerning space heating, cooling load avoidance, natural ventilation, and natural light. Ecotect enables three major functions for solar analysis: shadows and reflections analysis, shading design, and incident solar radiation. The measured value eliminates ambiguity regarding when and how the length of the roof eaves was decided. The summer season extends from May 6 to August 23, with the sun at its highest altitude on June 21, and at its lowest on August 23. In summer, with the sun at high altitudes, sunlight affects the roof more than it does the wall. Solar analysis shows that the eaves provide perfect protection during summer and ample light during spring, autumn, and winter. In the summer, Yeongyeongdang's roof eaves offer excellent protection from the strong sunlight. All rooms receive an equal amount of sunlight during the winter and summer. The summer sky component is stronger than the winter sky one, which leads to more heat gain in the summer. The thick roof of a traditional Korean residence offers protection from the strong sunlight during summer. Then, in winter, it preserves the heat absorbed from the sunlight during the day and releases it at night.



(a) Summer Solstice (b) Winter Solstice

Fig.5. Sky Component

Sunlight is an important factor in the supply of heat inside rooms during winter. The roof absorbs and transmits solar radiation into the rooms by means of conduction. The walls and windows absorb and transmit heat energy as well. Excessive solar exposure is one of the main causes of summer overheating, but it is also one of the most important sources of natural energy in winter. In summer, Yeongyeongdang's design offers excellent protection from the strong sunlight, while ensuring that during both winter and summer, all rooms receive equal amounts of sunlight, as shown in Fig.5.

3.1.1 Protection from Sunlight in Summer

Summer in Korea extends from May 6 to August 23. The sun's altitude is at its highest at noon on June 21. On the last day of summer (August 23), the sun reaches its lowest altitude at 10 am. The sun's rays then hit the lower edge of the roof at an angle of 56.6°. At this angle, it creates shading that encloses the whole house, cooling the atmosphere inside. The design of Yeongyeongdang incorporates this 56.6° angle. Fig.6. shows the sunlight conditions for Sarangbang (master's room).

On the summer solstice (June 21), the Anbang (matron's room) has a high heat gain, which increases the discomfort level of the occupants. The highest increase in heat gain occurs after 2 pm on June 21, because the room's windows open toward the west.

The Anbang's roof eaves are not long enough to protect from the evening sunlight, because the solar altitude is lower than the roof eaves. The solar altitude on June 21 is up to 43.3° after 2 pm. Anbang gains heat incrementally because the angle of the roof eaves is greater than 58.8°, which does not offer protection

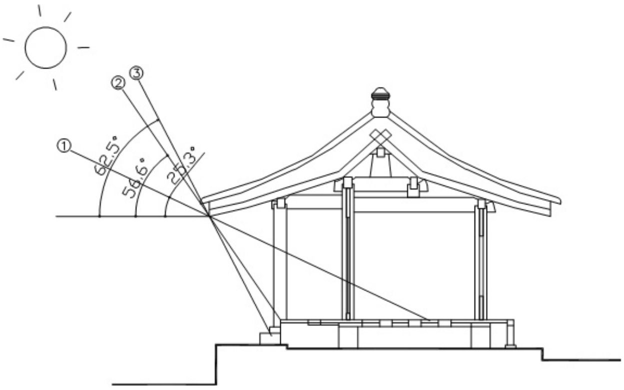


Fig.6. Sun Path Analysis and Sunlight Angle Section for the Master's Living Room: (1) Winter Solstice, December 23; (2) Sunlight Angle, August 23; (3) Summer Solstice, June 21.

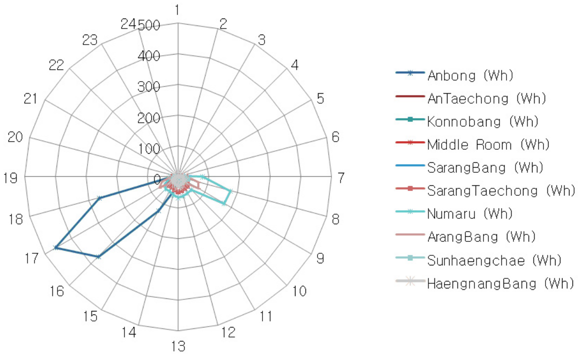


Fig.7. Solar Hourly Gains, Summer Solstice (June 21)

from the strong afternoon sunlight after 1 pm.

The results of the summer heat gain analysis show how the size and area of the windows affect the amount of solar heat gain. The hourly heat gain of the Ecotect Thermal Calculation, as shown in Fig.7., indicates that the Anbang (matron's room) has the highest heat gain, while the Sarangbang (master's room) has the smallest. The second highest heat gain occurs in the Numaru (master's summer reception room). It is located in the eastern part of the master's building, with some heat gains in the morning. The Antaechong (matron's living room) and Sarangtaechong (master's living room) have the next highest heat gain. The other rooms, used for sleeping during nighttime, have an almost equal value of heat gain. However, the heat gains of the Anbang are mitigated by the design of its floor layout, which allows the strong southwest prevailing winds to flow through the room in summer. All these heat gain issues are resolved with wind flow through the flexible openings. All the windows and openings of Yeongyeongdang are treated with translucent oilpaper, which minimizes unwanted heat gains in summer and which can be moved, creating a wide (100%) opening. The window area as a percentage of the floor area in the Anbang is 52%, while those in Sarangtaechong and Antaechong are 82% and 123%, respectively.

Fig.8. Sarangchae (Men's Quarters) Showing Traditional Sliding Door Openings

3.1.2 Accommodating Sunlight in Winter

The basic natural processes used in winter utilize solar energy and thermal energy flows associated with radiation, conduction, and convection. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. The heat produced by the sun causes air movement that can be predictable in designed spaces. These basic responses to solar heat lead to layout elements, material choices, and placements that can provide heating and cooling effects in a residence. Excessive solar exposure is one of the main overheating causes in summer, but it becomes one of the most effective natural energy sources in winter.

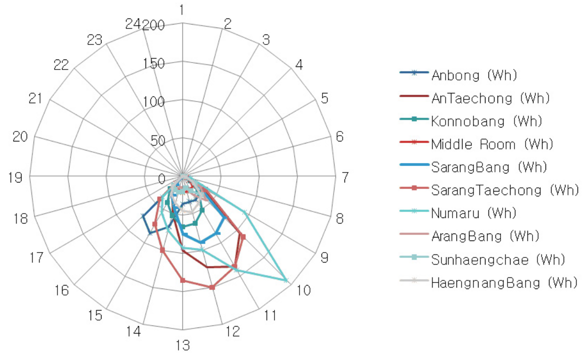


Fig.9. Solar Hourly Gains, Winter solstice (December 23)

In winter, the sunlight is strongest between 9 am and 11 am. Therefore, if the room has its windows facing southeast, or if it is located in the eastern part of the building, the solar heat gain will be higher there than in any other area of the building, such as the southwest or north. On June 21, the summer solstice, the daily heat gain in the Numaru (master's summer reception room) is 973 Watt, while on December 23, the winter solstice, it is 1256 Watt.

The sunlight analysis shows that in the case of south-facing windows, the winter sunlight, from the lower altitude of the sun as it enters the rooms, covers more than half of the floor, which is a much larger area than the zero penetration during summer when the sun is higher in the sky. However, the Numaru has many windows, which can lose the heat easily in winter. A comparison between the Numaru and Sarangbang shows that the Numaru has higher heat gain values than the Sarangbang. The differences are even greater during winter. The lower heat gain values in summer support the Numaru's function as a summer reception room. The Anbang, which is located in the western part of the building, has the third highest heat gain among all the rooms. In winter, most of the heat gain in the Anbang occurs in the afternoon, and can be released during the night.

3.2 Cooling Strategies: Wind and Air Flow

Two cooling strategies are used in Yeongyeongdang. The first strategy is natural ventilation, which provides cross ventilation driven by wind and is accomplished with windows. It relies on the long and narrow plan style of Yeongyeongdang with large ventilation openings on either side. The second strategy is high-mass cooling, which is ideal for warm, dry summers, when the extremes of hot days and cool nights are tempered by cool thermal mass and a thicker roof. Cool nights then slowly drain away the heat that such mass accumulates during the day. The roof has the advantage of preventing quick radiation to the cold night sky.

3.2.1 Flow in Summer

The average wind flow for Seoul is 2.4m/s with a minimum airflow of 0.7m/s that might occur for a few days, according to the Korea Meteorological Administration records from 1961 to 1980. If this 2.4m/s airflow consistently affects Yeongyeongdang in summer, there is enough cooling for human comfort. The traditional sliding doors of Yeongyeongdang can be opened to 100% of the window-installed space, unlike the modern glass doors (D. K. Kim, 2000).

The building layout of Yeongyeongdang is important for gathering the wind flow from the southwest and northeast in the summer as shown in Fig.10. Ecotect displays the prevailing winds in the 3D model of Yeongyeongdang, showing wind speed, frequency and direction. In this prevailing winds simulation, 35% of the total wind from the northeast is directed to the building in the morning (6:00~10:00 am), and 40% of the total wind from the southwest flows through the building during the day (10:00~6:00 pm). Diurnal airflow in the valley also cools down the temperature during the summer. Mountain breezes and valley breezes result from a combination of differential heating and geometry. During the day, sun first heats the tops of the mountains, creating high pressure. The temperature inequity causes the warm air to rise off the slopes, and cool air then moves up the valleys, creating what is called the valley breeze. The mountain breeze is the opposite effect that takes place in the afternoon. This mountain wind flows from the peaks both gravitationally and convectively.

The layout of Yeongyeongdang channels the southwest wind to the women's quarter, situated on the west side of the compound and back, out of the line of the men's quarter, which is on the east and frontward. Therefore, the women's quarter does not interrupt the flow of wind to the men's quarter. The layout is admirably suitable to take advantage of the summer prevailing winds, as shown below.

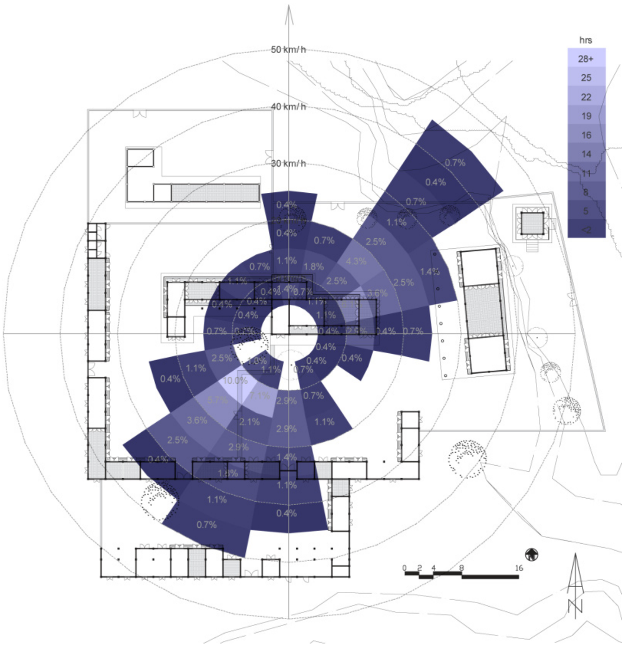


Fig.10. Prevailing Winds during Summer

In addition to the wind consideration, the Seonhyangjae, is angled toward the southwest and the lower floor of Numaru (Fig.1.). Recall that Numaru is a summer reception room in the Sarangchae (men's quarters). The Sarangbang is raised about 70 centimeters higher than the other rooms. The gap between the raised Numaru floor and the ground level allows wind flow towards the Seonhyangjae without interruption, as shown below.

Fig.11. Numaru and Seonhyangjae

Because it faces southwest, the Seonhyangjae has abundant light at sunset in the summer. An additional roof structure was installed outside the building to prevent strong sunshine from penetrating into the room, and an oil-papered blind is added below the roof eaves in the room. At sunset on August 23, from 2:00 pm to 5:30 pm, the additional roof structure does not perfectly block the strong sunlight, but upon adding the oil-papered blind on the Ecotect model, the blind blocks the sunlight completely.

3.2.2 Flow in Winter

During winter, the mountains wrap around a traditional Korean residence to protect against the strong cold northerly wind. Yeongyeongdang is surrounded by mountains from the high eastern hills through the north to the lower western hills.

The windows on the north-facing or windward side in winter are smaller than the south-facing windows. The size of the east-facing windows is about 790 mm × 790 mm, whereas the south-facing windows are more than twice as large, about 2235 mm × 1770 mm. The size of the north-facing windows in the living rooms (maru or taechong) is 1118 mm × 1465 mm for maru and 1118 mm × 1225 mm for the other rooms. The following figures show the prevailing winds in Yeongyeondang during winter. Compared to the summer winds (Fig.10.), the wind flow in winter, as shown in Fig.12., is remarkably reduced.

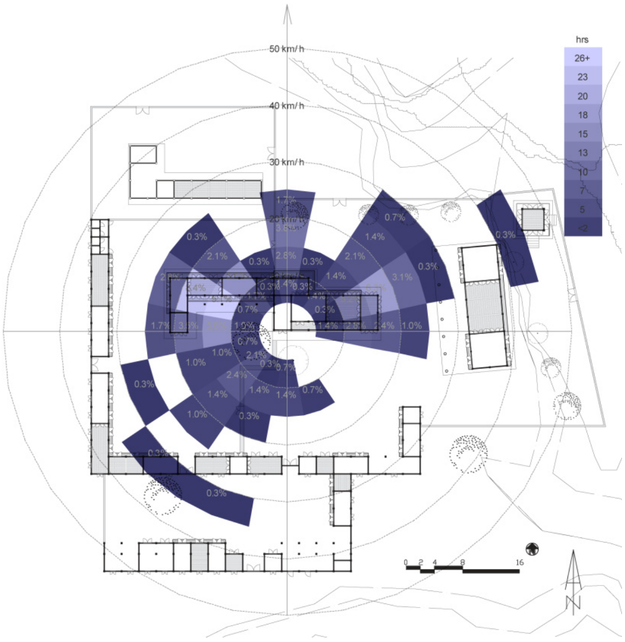


Fig.12. Prevailing Winds during Winter

3.3 Thermal Performance

Thermal performance is related to materials, window and door sizes, height, length, temperature, orientation, and many other factors. In Ecotect, the internal temperatures and heat loads are determined according to the Chartered Institute of Building Services Engineers (CIBSE) admittance method. The Ecotect Thermal Performance evaluates the thermal comfort of human beings, which is governed by many physiological mechanisms of the body and varies from person to person. In any particular thermal environment, it is difficult to get more than 50% of the people affected to agree on which conditions are comfortable (McMullan and Seeley 2007). The principal factors affecting thermal comfort can be conveniently considered in terms of personal variables such as activity, age, clothing, and gender, and physical variables such as air temperature, air movement, surface temperatures, and humidity.

3.3.1 Thermal Performance in Summer

The average outside temperature on the hottest day in summer, July 23, is 27.5°C, and the temperature ranges from 23.5 to 31.8°C during the day. Ecotect analysis shows that the Sarangbang, Anbang, Arangbang, Sarangtaechong, and the Seonhyangjae have relatively high temperature in summer. Among them, Seonhyangjae has the highest temperature, 29°C, at 1 pm. However, the thermal performance satisfaction increases to 70.3% when an air velocity of 1.9 m/s is included. Without any wind flow, the satisfaction level still increases to 45.6%. This implies that all the rooms in Yeongyeongdang provide more than 45.6% thermal performance satisfaction. Having sufficient window area for cooling, Yeongyeongdang satisfies the inhabitants' thermal comfort requirements in summer. This shows that air velocity is also an important factor for cooling. The ratio of the total window area to the total floor area in Yeongyeongdang is over 50%; it is 123% in Antaechong, and 92% in Sarangtaechong and Numaru.

3.3.2 Thermal Performance in Winter

For ideal indoor thermal comfort in winter, a warm temperature should be present and be retained inside. The Ecotect thermal performance simulation for January 13, the coldest day of the year, shows that Sarangbang has the best conditions, although it has a higher total admittance (AY) (W/m^2 K), which represents its ability to absorb and release heat energy and defines its dynamic response to cyclic fluctuations in temperature conditions. Sarangbang is the largest room, approximately 18.13 m^2, with the biggest exposed area, 21.63 m^2; but the exposed window area, at 8 m^2 , is only 45% of the total floor area, which is the smallest ratio compared to the other rooms.

4. Yeongyeondang: Environmental & Social factors

The outcomes of the environmental simulations performed on Yeongyeongdang using the Ecotect software show how its design takes into account environmental factors like daylight, wind and air flow, and thermal performance in combination with the hierarchical structure of the social system in traditional Korean residences during the Joseon dynasty. This social group consists of the men, women and children of the house, and the servants. These environmental factors are satisfied with its combined design strategies of floor layout, roof design, openings, sections and material selection in Yeongyeongdang.

4.1 Men's Quarters

The men's quarters include the Sarangbang (master's room), Sarangtaechong (living room), Seonhyangjae (library), Sarangmadang (courtyard) and Numaru (summer reception room). Based upon Confucian principles, the man's activities within the residence are highly respected. They are limited to reading, eating, sleeping and light exercise like walking, or directing his servants. The activities require good lighting, ventilation, and high thermal performance satisfaction. In summer, winds come mostly from the east and south, and the southerly windows are bigger, offering enough air circulation and daylight. The roof eaves perfectly protect from direct sunlight during summer. The roof length and angle were designed to block out the summer sun when it is at the solar altitude of 56.6°. Fig.13. shows the roof angle stopping direct sunlight from a solar altitude of 56.6°. The shaded interior of the residential area provides a desirable thermal performance in combination with ample sunlight reflected from the light-colored garden, the Sarangmadang. The light reflects smoothly inside, over 50 lux.

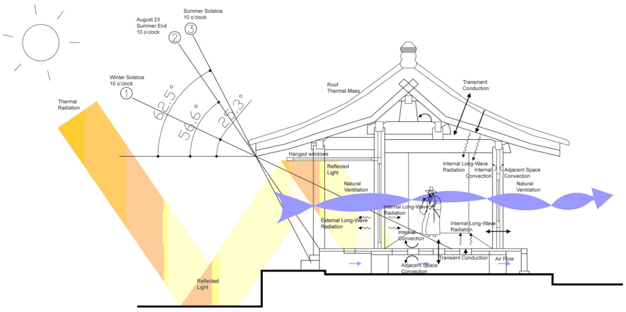


Fig.13. Summer

Furthermore, all the rooms in the men's quarters and other rooms in Yeongyeongdang have at least 46% thermal performance satisfaction without any wind at all, and 70% satisfaction with 1.9 m/s winds in summer. In summer, the average wind in Seoul will be about 2.4 m/s with a minimum of 0.7m/s for only a few days. Therefore, a consistent 2.4 m/s airflow affecting Yeongyeongdang during summer provides ample cooling for human comfort. Considering the difficulty of maintaining a level of 50% thermal performance satisfaction in summer, the 70% level of thermal performance satisfaction achieved at Yeongyeongdang is remarkable. This is made possible using 100% movable opening systems, a high ratio of window to floor area, translucent oilpaper for the openings, and the floor and window layout of the rooms in the men's quarters.

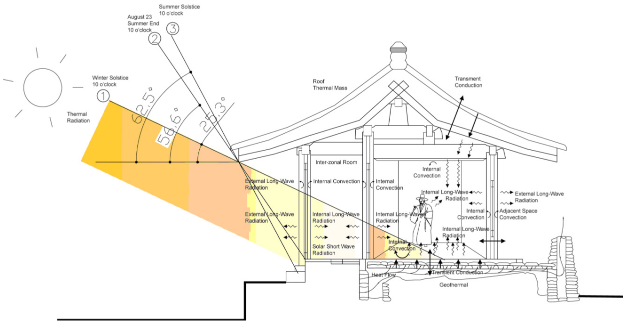


Fig.14. Winter

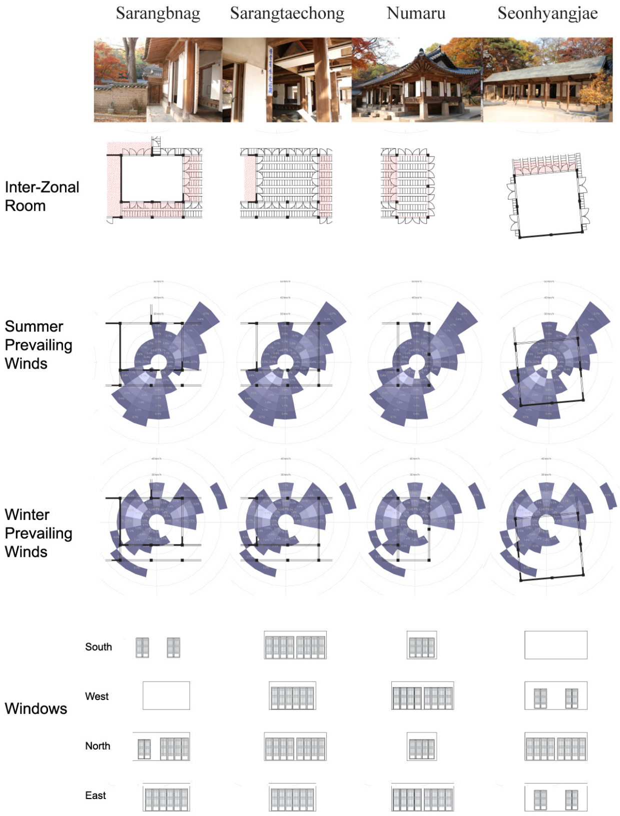


Fig.15. Men's Quarters

In winter, the most important factors in environmental design are maximizing the amount of solar heat gain and retaining the solar heat energy or the energy from the Ondol (central heating) system. Maximizing the amount of solar heat gain determines the length of the roof overhang (keeping a balance between the cold and hot seasons). The above figure shows that the sunlight reaches two thirds of the room in winter. In order to keep the solar heat energy, inter-zonal loads are applied in the design of Yeongyeongdang. Inter-zonal loads allow the residences to retain the heat energy by creating internal zones like closets, taechong, maru, and other storage spaces in the living quarters. The internal zones reduce the cold wind temperature and preserve the heat in the bang (room). The heat energy is maintained by thermal masses like the Ondol. In the Sarangbang the heat gain is retained and insulation from the cold air outside is achieved with the help of (1) the maru in front of the Sarangbang, which is enclosed by oilpaper windows, and (2) the Middle Room at the back of the Sarangbang. It is clear that the social hierarchy in the Joseon dynasty dictates that the most comfortable environmental conditions are reserved for the man of the house.

The Seonhyangjae has the second best conditions, even though it has the highest total admittance, 392 W/m^2 K, and no south-facing windows. The smallest total exposed area, which is 35.158 m^2 (98% of the total floor area), prevents heat loss. The Sarangtaechong has a higher temperature because it is an inter-zonal area between the Sarangbang and Numaru.

4.2 Women's Quarters and Children's Area

The Anbang (matron's room) represents the second largest room after the Sarangbang, and ranks as the second most important quarter; however, the thermal performance of the Anbang is worse than that of the Arangbang (children's room) and Konnobang (women and children's room). The Anbang window area is only 52% of the floor area, which is good for energy saving during winter, but it does not have any south-facing windows for solar heat gain. Social tradition according to Confucian principles, as well as privacy issues, dictated the lack of south-facing windows in the Anbang. Yeongyeongdang has the largest chimney after the Anbang, and the chimney position of the furnace, near the Anbang, provides further heat to the room. The Arangbang has limited openings toward the north and west, since the cultural preference of openings for children is toward the east and south, avoiding the strong winds as in the men's area during the summer. However, its comfort level in summer is achieved by the use of 100% movable openings as explained in Section 3.3.1.

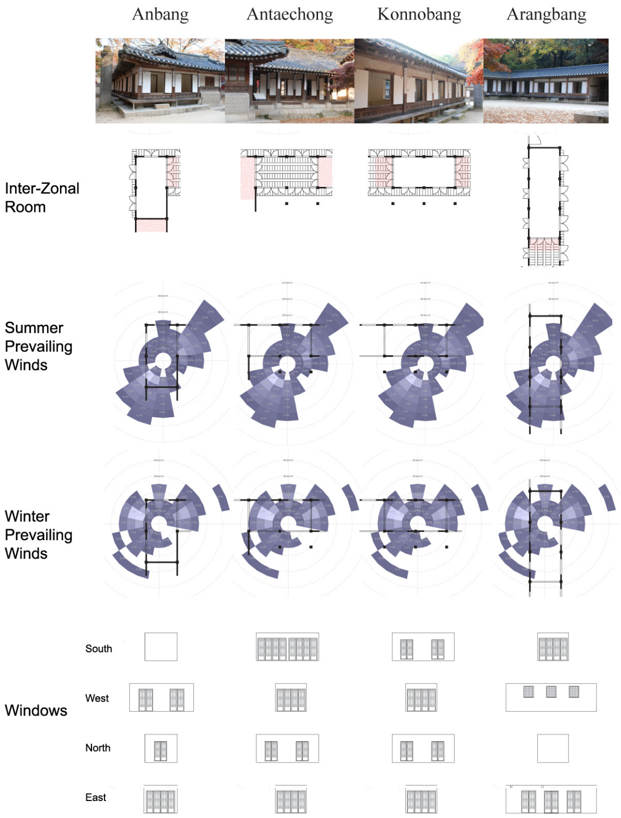


Fig.16. Women's Quarters and Children's Area

4.3 Servants' Area

Social status factors, which are influenced by the traditional hierarchical class system, decide the room function. The servants' area is employed mostly as an architectural feature serving as protection from the outside. The ratio of exposed area to floor area is 241% so that it receives strong sunlight from the south, where the main entrance of Yeongyeongdang is located. There are no windows on the east and west sides. However, its location is in the crossroads of wind flows around Yeongyeongdang. The servants usually work outside during the day time and occupy the rooms at night. At night, the prevailing winds from the northeast flow toward the Haengnangbang (servants' room), cooling it down considerably.

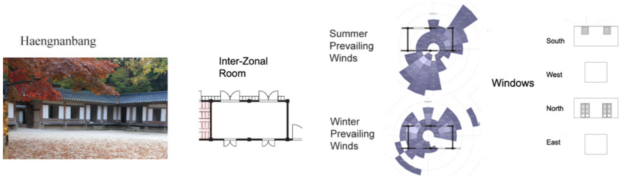


Fig.17. Servants' Area

5. Conclusion

In this research, Ecotect, the environmental analysis tool, sheds some light for a present-day understanding of the environmental principles embedded in the original design of Yeongyeongdang, a traditional Korean residence. Ecotect was employed to create Yeongyeongdang using a broad range of simulation, and analyzing the functions required for maximizing environmental values by data. The outcomes of the analysis demonstrate that Yeongyeongdang was built incorporating various ecological factors into its basic design and layout, which are heavily influenced by social hierarchy. It confirms that as a model of a traditional Korean residence, Yeongyeongdang satisfies the environmental and social requirements of the historical setting in which the architecture exists (Shin, 2000).

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