THE STUDY OF ENVIRONMENTAL SUSTAINABILITY IN THE 19TH CENTURY TRADITIONAL KOREAN RESIDENCE, YEONGYEONGDANG

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Abstract. In this paper, one of traditional Korean residential buildings in the 19th century, Yeongyeondang, is selected as a model to demonstrate the achievement of the environmental sustainability in the formal composition of traditional Korean architecture. With a computational analysis on the geometric model of Yeongyeondang using Ecotect, this paper investigates the ecological characteristics employed in the design of the traditional Korean residence and the applications of the sustainable principles for its spatial system.

Keywords. Environmental factors; Simulation; Yeongyeondang

1. Introduction;

With the rapid development of building technologies, architects have made remarkable contributions to our built environment since Industrial Revolution. In return, the serious consumption of natural resources, the pollution from the use of the technologies and the loss of vernacular architecture has been the hidden cost of our current environment. They inflict grievous harm to the environment, threatening to degrade our future habitability with current global warming and the lack of architectural identity. Vernacular architecture employs locally available resources to address the needs according to geographical characteristics and evolves to satisfy the environmental, cultural and historical requirements in which the architecture exists (Roodman and Lenssen, 1995).

During the Chosun dynasty (1392 ~ 1910) of Korea, the basic design and the layout of the Korean vernacular dwelling had been developed in the strong consideration of the historical circumstances and social environment of the Korean. Especially when Yeongyeondang was built in the 19th century, social status was getting more important factor in the composition of every traditional Korean dwelling, and the Confucian principles underpinning the hierarchical social system also had a tremendous influence on the design of the traditional Korean dwelling. The neo-Confucianism, with its emphasis on moral duties, was established as the dominant philosophy where ancestor worshipping became the core practice of people’s spiritual life. Several generations of an extended family lived together under the charge of the family patriarch. Social hierarchy was maintained within the extended family, as within the broader community, by Confucian principles. Accordingly, the separation of men from women and of superior from inferior, and the need for an ancestral shrine became fundamental elements in the composition of the traditional Korean residence (Inaji and Virgilio, 1998). It shows that the traditional Korean architecture, Yeongyeondang, was built on a very strict layout and formal composition in order to represent a rigid hierarchical social system required in the 19th century. It leads us to question that how Yeongyeondang would accommodate various environmental needs within its building design governed by the given social and cultural structure. With the help of a computation application, Ecotect, the paper provides the evidence
that Yeongyeongdang incorporated the ecological factors into its design with administering
the shadows, shading and solar analysis; wind flow and air flow; and thermal performance.

2. Yeongyeongdang

In his book “The Garden as Architecture,” Inaji (1998) introduces five basic factors that
influence the form of the residential environment: location, social status, social mores, function,
and locality. The location factor is based on the geomantic principles of pungsu, social status
factor is influenced by the traditional hierarchical class system, social mores factor comes
from Confucian principles, function factor includes the ondol system of heating, and locality
factor is related to the dwelling’s locale. The selective composition, Yeongyeongdang is also
represented those five factors, and is preserved well for analyzing the data (Inaji and Virgilio,
1998).

Yeongyeongdang was built in the Changdeokgung Palace after the model of Korean
gentry’s houses in 1828. It is made of 99 kan, the width of the span between columns, and
Yeongyeongdang was built inside the palace to show the King how typical master’s resident
looked like (Zu, 2003). In this respect, all the buildings are important artefacts that relate
ancient Korean housing, architecture and life history. Yeongyeongdang comprises of four
distinctive places: men’s quarters, women and children’s quarters, servants and service quarters.
Men’s quarters has public space and business space. According to the social mores,
Yeongyeongdang’s spatial composition can be prioritized as below.

1. Men’s quarters: sarangch’ae (master quarter), sarangmadang (garden in front of master
quarter), Seonhyangjae (library), nongsujung (pavilion)
2. Women and children’s quarters: anch’ae(family’s living quarter), anmadang(garden
in front of anch’ae), arangch’ae(children and lesser women’s quarter)
3. Servant’s quarters: middle and lower hangnangch’ae(long, narrow building used to
accommodate lesser family and servants)
4. Service quarters: puOk(kitchen) and dining area

Figure 1. Yeongyeongdang Site Plan
3. Methodology – Modeling & Visualization

The analysis starts from building geometric models of Yeongyeongdang with AutoCAD which allows precise detail in size. Based upon the models, the design factors and the environmental factors of Yeongyeongdang are redefined. The design factors include building layout, windows position and size, landscape, overhang, building distance, orientation, material selection, and thermal performance. The environmental factors include water and rain, wind and airflow, sunlight, micro and macro climate, temperature, energy, consumer goods, and on-site natural resources (Kim, J.J., 2000). The environmental factors embedded in Yeongyeongdang are compared to the design factors. With this comparison, architectural principles that sustain the environmental advantages in Yeongyeongdang are reviewed.

In Ecotect, the model of Yeongyeongdang is formatted on the grid that allows size changes. Because of the difference between the original plan and existing building plan, the drawings are made according to existing building size and position, and then the layout angle is changed to simulate the original building plan. After each space of buildings, called zone, are perfectly enclosed and assigned with correct materials, the analysis of the lighting, thermal, and acoustic is performed based upon the geographic and meteorological data regarding the site of Yeongyeongdang.

Ecotect is a highly visual and interactive building design and analysis tool, covering the widest range of analysis features including solar, thermal, energy, lighting, acoustics, regulations and so on (Marsh and Raines, 2007). It is employed for analyzing shadows, shading & solar influence, thermal performance, heat gain & loss, spatial comfort, ventilation and daylight & sunlight. Ecotect uses a system of inter-object relationships to assist with this. Based upon the plan of a zone, Ecotect automatically extrudes the corresponding walls and a ceiling. This is useful for modifying the nodes in the plan object. It keeps track of all related walls, ceilings and any added windows (Marsh and Raines, 2007).

Experiments are focused on summer and winter of Korea, which require secondary needs to maintain environmental comfort in a building: January 13 - the coldest date, May 6 - the start of summer, June 21 the summer solstice, June 23 - the Hottest date, August 23 - the end of summer, and December 23 - the winter solstice. (http://www.heritage.go.kr/tra/tra_pop_01.jsp: Nov 2007).

4. Yeongyeongdang Analysis

Unlike most traditional Korean Architecture, existing building orientation of Yeongyeongdang is tilted fifteen degrees towards the west from exact south. Korean Architectures follow a strict theory, “mountain behind and river in front” and the architecture face south based on the principles of p’ungsu. Due to several reconstructions resulted from many rebellions and conflagration, current Yeongyeongdang is different from its original plan (Choi, 2005; Zu, 2003). The existence of these different layouts of Yeongyeongdang provides a difficulty to
perform the analysis on Yeongyeongdang. In order to decide a research object between the original layout and the current layout, the original layout is compared to the current layout using Ecotect according to various environmental factors. The outcome from Daylight Analysis (figure 4) shows that in the original layout facing exact south, the externally reflected light spreads out evenly.

![Daylight Analysis](image)

*Figure 4. Daylight Analysis, August 23 Noon*

In the tilted fifteen-degree layout, the light spreads out irregularly and reflects strongly to the Sarangbang, master room and reception room. In the current layout, it is difficult to plan the overhang length that protects strong light during the hot summer. It shows that the original layout is environmentally superior to the current one. It leads us to take the original layout of Yeongyeongdang as our research object rather than the current building.

4.1 SHADOWS, SHADING AND SOLAR ANALYSIS

Solar analysis tests how the roof eaves protect the sunlight during the summer, and provides sunlight during the winter. The measured value takes off the ambiguous when and how the eaves’ length was decided. The summer starts from May 6th to August 23rd. The sun’s altitude is at its highest on July 21, and at its lowest on August 23rd. The Solar analysis shows that the eaves perfectly protect during the summer, and provides the light during the spring, autumn, and winter. The eaves length is decided on August 23rd, the last day of summer. As an example, the sun’s altitude on August 23rd and the eaves angle of the main building is at same angel 56.6 degree at 10 AM, azimuth 45.7° and at 2 PM, azimuth 134.3°.

During the summer, the eaves perfectly enclose the strong sunlight. Otherwise, the inside must darken because there is no light penetration (Sin, 2000). When it was built, there was no electrical light source, but the inside building is not very dark according to the simulation from Ecotect and Radiance software. The assumption is that the Madang, garden, collar. Madang was used for drying the rice and red pepper, and save crop. The Madang is white in color. When Madang color is changed to white from its regular ground yellow soiled color, the test result showed different. When Madang is white, the sunlight reflects smoothly inside more than 50lux in every nook and corner.

![Daylight Difference](image)

*Figure 5. Sarangbang Daylight Difference*

Daylight Factor (DF) indicates percentage of outdoor light under overcast skies that is available indoors (McMullan and Seeley, 2007). Azimuth represents the horizontal angle of
the sun relative to true north. This angle is always positive in a clockwise direction from north, and is usually given in the range $0 < \text{azi} < 180^\circ$ (http://squ1.org/wiki/Solar_Position). Altitude represents the vertical angle the sun makes with the horizontal ground plane. It is given as an angle in the range $0 < \text{alt} < 90^\circ$.

4.2. WIND FLOW AND AIR FLOW

The replication of the mountain-like wraps in traditional Korean architecture behind the north protects against the strong wind during the winter. In addition, the windows and door size on the north pace are smaller than the south pace. Also, the traditional sliding door of Yeongyeongdang can be opened 100% of the open space, unlike the modern glass door (Kim, D.K., 2000). During the summer, the open door offers enough air inside. Moreover, for the wind flow from the southwest in the summer, the building layout was so well suited to the each room. The rear mountain offers protection against the Siberia wind from the north. Diurnal airflow in the valley cools the temperature during the summer. During the summer, the wind flows from the southwest, and women’s quarter, placed on the west, the building stays backward, and men’s quarter, place on the east, stays frontward. Ecotect offers the prevailing wind data that visualize the wind flow as below.

![Wind Frequency Diagrams](image)

1) Spring: March 1 ~ May 31  
2) Summer: June 1 ~ August 31

3) Autumn: September 1 ~ November 31  
4) Winter: December 1 ~ February 28

*Figure 6. Prevailing Winds, Wind Frequency (Hrs)*

Besides the wind consideration, Seonhyangjae, library, is tilted toward the southwest, towards the bottom floor of Numaru. Numaru is a special reception room in the sarangch’ae, master’s quarters. The sarangch’ae raises about 70 centimeters higher than other rooms. The gap between the Numaru floor and the ground provides the wind flow towards Seonhyangjae. The Seonhyangjae faces west, and in summer, the sunshine strikes the building at sunset. An additional roof structure was installed at the outside of the building to prevent strong sunshine from coming into the room, and it adds an oil-papered blind on the bottom of roof eaves (http://www.ocp.go.kr: Nov 2007). During sunset on august 23, from 2:00 to 5:30, an additional roof structure dose not perfectly enclose the strong sunlight, but covers two third of the sunlight.
4.3. THERMAL PERFORMANCE

Thermal performance is related to materials, windows and doors sizes, height, length and many other factors. Most materials are environmentally friendly and flexible. The Yeongyeongdang employed the Kan measurement which is equal to the width of the span between columns. The width of the span varies in length from 1.8 meters to 2.8 meters. It is the basic unit of measurement used in traditional Korean dwellings. The modular measure depends on the local environment. They used not only the fine and straight trees, but they also used bent tree for building. This saved labor fee and preserved trees.

The ondol system utilizes the heat of smoke from an enclosed furnace. Excess heat from the furnace passes through flues located beneath the floor to a chimney at the other end of the room or rooms. The furnace is most commonly located in the kitchen, and it heats the rooms. The ondol system does not create any pollution or dust since the smoke pass through the flues to heat the pang and ventilate through an external chimney (Inaji and Virgilio, 1998). The roof is very thick, almost over thirty centimeters, which can preserve the heat in the light and keep the heat of ondol.

The oiled-paper used for sliding doors preserves the thermo energy and allows the fresh air to circulate inside. For the experiment data of oil-paper and the red soil regarding the U-Value (W/¡3.k), solar absorption and reflectance, the approximate quantity were used with similar materials. In this result, during the spring, summer, and autumn, the thermal performance is within the comfort zone. The satisfy degrees order that man’s masters’ quarter is first, the women’s quarter is second, the south pace servant quarter is third, and the west quarter is last. U Value indicates Thermal Transmittance (BTU/[hr x ft² x ºF]) or W/¡3.k), Measure of heat transferred through a building assembly Reciprocal of total R Value – (1/U). The higher the U value goes the greater the insulation value increases. (McMullan and Seeley: 2007). The following diagram shows the thermal performance of main building of Yeongyeongdang.
5. Discussion

The modeling and visualization result of Yeongyeongdang through Ecotect software defines how Yeongyeongdang controls sunlight and daylight, shading, wind flow, and the thermal performance. The eaves length encloses the sunlight during the summer from May 6th to August 23rd, and the additional roof with oiled-paper blinds in the Seonhyangjae, which faces west, perfectly prevents strong sunshine at sunset. The eaves of each building sufficiently were considered the sunlight and shading, and the eaves design was not focused only the summer solstice. The focus date was the summer end date, August 23, which is the last hottest day. The radiance classifies how much the white garden supply the daylight inside room. The prevailing wind helps to look at Yeongyeongdang’s layout well.

Through Ecotect, recorded climate resources can refer back as far as to 1961. This makes it impossible to recreate exactly the same climate conditions when Yeongyeongdang was actually built in the 19th century. However, the climate data from the Korea Meteorological Administration shows that the climate have changed rapidly after 1980, and the summer had been getting longer about half a day for a year. Through Ecotect, climate data can be assessed to 1961 data rather than to the recent climate data. It allows to view the climate data of Yeongyeongdang before the drastic changes. Still this has been one of technical hindrances for the analysis of Yeongyeongdang.

In this research, Ecotect, the environmental analysis tool, sheds some lights on our understanding of the environmental principles embedded in the original design of Yeongyeongdang, which could have been forgotten in its current building layout. Ecotect was employed for realizing Yeongyeongdang on the broad range of simulation. The simulation allows us to analyze the design of Yeongyeongdang, which is required for maximizing environmental values. The outcomes from the analysis provide that this traditional Korean Architecture, Yeongyeongdang, was built with incorporating various ecological factors into its basic design and layout, which are heavily influenced by social and cultural structure. It confirms that as a vernacular architecture, Yeongyeongdang satisfies the environmental, cultural and historical requirements in which the architecture exists (Sin: 2000, Zu: 2003).

References

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