

A Study on Microclimate Control Method for Vernacular Housing

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ABSTRACT: As the concept of sustainable development becomes prominent due to generation of various environmental problems, development of methods for the use of passive energy is being demanded. In order to find such passive design methods, this study examined the characteristics of vernacular housing formation in terms of its important aspect microclimate to understand how vernacular housing controls and utilizes passive energy.

For passive design methods, various principles adapting energy to architectures using passive means such as expansion of heating value during winter season and protection against wind, pent roof during summer season, improved ventilation, thermal insulation ability of structures, thermal characteristics of materials, arrangement of architectures, thermal exchange according to changes in underground temperature, and daylight were applied.

Keywords: Vernacular Housing, Vernacular Design, Microclimate, Passive Design

1. INTRODUCTION

1.1 Experimental Purpose and Background

The concept of sustainable development for protection of natural environment through resource and energy conservation are becoming increasingly important because of a series of recent environment problems such as air pollution and global warming. Buildings are spending more than 1/3 of total energy consumption in the world, and such a severe energy consumption of buildings is caused by rapid increase in energy use because of air-conditioning and heating. This not only increases

environmental stress but also has a significant impact on problems like exhaustion of fossil energies.

Accordingly, development of methods for use of passive energy and high-efficiency energy use was deemed necessary to achieve energy saving for housing including apartment buildings. This study tried to consider and investigate the vernacular design, an original design method that includes past regional experience, climate and tradition, as a solution for the method to use passive energy.

The purpose of this study is to reflect such requirements of the era, look into the

concept and types of vernacular design, and extract housing method considering the microclimate under the premise that design methods for maximization of passive energy use and energy conservation are most strongly related to the corresponding region or site and microclimate factors.

1.2 Experimental Scope and Method

Experimental scope and method of this study are as follows. First, this study examined the concept and fundamental characteristics of vernacular design in terms of microclimate. Second, experimental frame was presented through classification of various types of vernacular housing according to climate zones. Third, this study tried to provide development course of housing for modern construction by deriving a housing method that accommodates microclimate through analogies of material application, architectural solution, forms of space and mass, and energy conservation method.

2. Concept and Characteristics of Vernacular Design

2.1. Concept of Vernacular Design

The word 'vernacular' is called 'tosok' in Korean language and its denotation is 'of the climate, nation, home country, and local' or as a dialect of a specific region. Edward Lucie Smith uses the word to represent 'characteristics shown by regional tradition' in his "History of Industrial Design." The meaning of vernacular gradually changed to designate the tradition and folk tradition established to adapt to the environmental conditions of a region, and today it is used to explain various design fields such as visual aspects and architectures.¹

That is, the word vernacular is an output of countless trial and error and modification

feedback processes by non-experts and common people for adaptation to the surrounding environment and establishment of better living conditions. In other words, the word had been developed and improved with influence from region's unique and traditional customs, rules, and climatic environment. Vernacular design can be defined as 'a design that is suitable for the microclimate and natural features of a region developed by unspecified many individuals in ordinary and customary ways.'²

Microclimate is the most important aspect of vernacular design, and Amos Rapoport mentioned the importance of microclimate in vernacular design. He indicated temperature, humidity, and precipitation as microclimate conditions that affect human living.³ These factors must be balanced in the viewpoint that they are environmental stimulus for comfortable life of human beings, and in that respect architecture called the house can be considered as a device to control the environment.⁴ Denotation of microclimate is 'physical aspects of the climate of a small, specific place within an area or small-scale regional climate such as temperature, humidity, wind direction and wind velocity caused by surrounding buildings, trees and topography.' Formation of microclimate is shown by solar irradiance, wind type, wind velocity and direction change, moisture control in air, and absorption and emission of energy, and is classified into light environment, air environment and thermal environment according to the principles of nature.⁵

² Kim, Ja-Kyung, A Study on Regional Ecological Architecture Based on Vernacular Design, Journal of Korean Institute of Interior Design, Volume 14 Series 49, April 2005, p.38

³ Amos Rapoport, House Form and Culture, Youlhwadang, 1985, p.127, recited

⁴ Kim, Young-Ki, Aesthetic Sense of Koreans, Changji Publisher, 1985, pp.255-265

⁵ Park, Dae-Hoon, A Study on Microclimate Control Aspect of Apartment Houses, Master's Thesis for Konkuk University, 2001, p.20

¹ Lee Hee-Jung, A Study on Style of Expression and Design Process of Vernacular Design, Master's Thesis for Ewha Womans University, 1996, pp.4-5, recited

2.2. Characteristics of Vernacular Design

Looking at vernacular design from the perspective of microclimate conditions, the efforts of human beings to adapt to temperature, humidity, solar irradiance, precipitation and wind are shown through a specific field called architecture. Vernacular housing began as a concept of refuge for environmental conditions and its main purpose was to protect human beings from severe climate condition. Environment creates a lifestyle composed of various accumulated behavior patterns of a specific group of people living in a specific region, and such behavior patterns are formed in many types and their structures. Therefore, the correlation between life form and environment is a major factor for decision of shape, structure and material of architectures.⁶

Different climatic zones resulted in different civilizations. Climatic factors were shown directly in human life because they constructed housing that was suitable for microclimate conditions of their region using the shape matched well with the nature and materials from the nature. For example, regional architectures that accommodate for climatic and geological conditions of a region, developed by the people of that region using unique materials from the region, traditional technologies and housing type and style created by an unknown architect with traditional tools, were born. Although vernacular design lacks formal planning and conscious reasoning, mysterious perfectness and clarity undetectable in modern designs are included. That is because vernacular design was made in response to the climate and endemic, allowing the most suitable architecture type to be drawn out.⁷

⁶ <http://blog.naver.com/yaquablue>

[Architecture] Vernacular Architecture (Tosok) by Mandarin

⁷ Kwon, Young-Gill, 16 Issues in Space Design, International, 2001, Lesson 10 - Climatic Design, 'What is Vernacular?', recited

3. Classification and Microclimate Control Method for Vernacular Housing

3.1 Characteristics of Vernacular Housing

As mentioned above, the main purpose of vernacular housing was to protect against severe climatic conditions. That is, vernacular housing was designed using a method that can control the temperature, humidity, precipitation and wind. For the design of housing, coldness, radiation heat of the ground and atmosphere, wind and water drainage were considered, and the structure and material were primarily taken into consideration for withstanding the microclimate of the region since houses come into direct contact with surrounding microclimate.

The roof is designed in various ways according to the relationship between the climate and materials available in the region. Also, the microclimate decides the slope of the roof, and that slope is also related deeply with the region's typical materials. Since roof design follows geological conditions of the region, appearance of roof are often similar in different places of the world with similar climate. Therefore, roof design is more closely related to science than culture, civilization and history. The wisdom of vernacular design that aims for thermal insulation by avoiding the wind and considers air ventilation is an example of human efforts to overcome climatic conditions.⁸

As an example of vernacular wisdom for ventilation, Eskimos decide the location of igloos using cracks under high cliffs where the cold wind of the coast. Also, in order to achieve effective buffering against the wind, they install one main entrance that is halfway into the ground and connect each igloo only through internal passageways. In Switzerland, Mexico, Canada and Ireland, northern walls are sometimes designed to be buried more than halfway in the ground to

⁸ Kwon, Young-Gill, *ibid*, Lesson 10 - Climatic Design, Culture and Climatic Factors

avoid the north wind. Thatched roof of Normandy, where westerlies are strong, has a shape similar to a ship turned upside down, has the pointy end towards west and the tail end towards east, providing protection against wind and rain at the same time.⁹

An example of vernacular wisdom for ventilation is the device called bad-gir attached in every room of village houses in Hyderabad Sind of western Pakistan. Bad-gir, with over 500 years of history, is an air-conditioning system attached on the roof that makes the wind direction always identical and draws the wind into the house by attaching a diamond shaped wind scooper on diagonal chimney. Diverse forms can be found in regions where climate is less important, but the characteristic of vernacular housing is that it usually has high adaptability to climate and endemic.

Roof made with thatch, air space and mud is an example of thermal insulation. Thatch is in charge of water table and protects the mud from being carried away, and thatch, air space and mud are excellent lagging materials that reduce radiation heat and temperature loss. Structure of private houses exhibits an instinctive sensibility for collection and storing of energies. Shape of the house contributes to the collection of light, heat, wind and water.¹⁰

3.1 Types of Vernacular Housing for Each Microclimate

According to geography, climatic zones of the world are classified into 5 types such as tropical, temperate, polar, subpolar and arid zones. In this study, climatic zones were divided into 4 types including high temperature and arid region, high temperature and humid region, temperate region and cold region using retrieval.

In high temperature and arid region, temperature is high during the day and it drops radically at night. Therefore, materials with large thermal capacity such as brick,

mud and stone are used to absorb heat during the day and radiate it at night in order to maintain pleasant room temperature, and for maximization of such effect number and size of windows are kept small. In cases of houses in Aegean Islands and Santorini Island of the Mediterranean, number and size of windows are small and they are positioned deep inside the interior. This was taken from the fact that the temperature drops as the flow velocity of air quickens. They tend to minimize the exposure to atmosphere in order to promote insulation effect and delay the speed of heat conduction, and it is shown by crowded settlement of houses. Clustered houses share wall surfaces and the interior space effectively blocks the sunlight using shades and shadows.

In high temperature and humid region, temperature is high, the gap between high and low temperatures during the day is small, and humidity is high. The region is characterized by architectures with small heat capacity and narrow and long walls geometrically scattered that help allow maximum crossed ventilation. By having an open space, main functions of walls are not fully exhibited, and the wall resembles the structure of net in consideration of ventilation as a countermeasure against high temperature. In addition, umbrella-like roof that allows quick removal of humidity and free space are shown in the humid region.

In temperate region, large windows are installed for sympathy with natural environment except for places where winds blow hard. Traditional housing of Korea belongs to this category. Korean houses were designed to move the center of living to rooms and hall according to seasons and developed a unique structure that integrated under-floor heating from the north and hall culture from the south. Requirements of climates were mixed together with the conditions and culture of the region to be

⁹ Lee Hee-Jung, *ibid*, pp.25-26

¹⁰ Lee Hee-Jung, *ibid*, p.27

reflected on the shape and form and architectures.¹¹

In cold regions where the snowy and cold winter with strong wind continues, houses are characterized by dense plane and layout to prevent heat loss, minimization of exposure area and insulation effect using insulators. In order to avoid severe wind during the winter season, igloos of Eskimos are located where cold wind does not blow and have just one half-underground entrance for each complex and curved entry tunnels. Farmhouses in North Iceland have high and open frontal roofs for utilization of solar heat and side and rear roofs connected to hills and blocked by the surface of the ground for thermal insulation through mud and grass.

In vernacular architecture, methods of environmental control for solving problems of ventilation, heating and cooling are found in architectural aspects, location, direction and materials. Also, harmony with natural landscape is achieved through shape and material, and physical harmony of the nature is found in the structure of space and material.¹² Characteristics of the climate and shapes, materials, and structures required in vernacular housing for each of representative climate zones were organized as shown in **Table I**¹³ below.

Table I : Classification of Vernacular Housing According to Climate Zones

High temperature and arid region	
Climate Characteristics	• Difference of daily range between day and night is very big • Dense direct rays of the sun • Low relative humidity • High temperature during the day, and sometimes low temperature during the night • Climate changes during summer and temporary strong wind • Low annual precipitation • Sometimes contains the most of dusts in the air • Northwest Africa, Egypt highlands, Andes, desert region of Indian desert, New Mexico and more

¹¹ Kwon, Young-Gill, ibid, Lesson 10 - Climatic Design, Culture and Climatic Factors

¹² Kim, Ja-Kyung, ibid p.41

¹³ Lee Hee-Jung, ibid, pp.33-52

Requirements	• A material with large heat capacity is needed to solve the difference in daily range -Absorbs heat during the day, reproduces heat during the night • Protects heat during the day, needs a shade • Minimizes heat filed up heat of the interior • Minimization of ventilating sultry time of the hot day is needed	
	Material	• Uses material that has large heat capacity such as adobe brick, mud, soil, and rock
	Shape	• Create a neutral space - a way to save cold air in the night more efficiently • Nearly all windows do not exist, or reduces the number of windows • Reflects radiation as much as possible by using white or bright color • Minimizes the precise and geometrical surface which is exposed to the outside • Forms a close-packed habitation group to reduce direct rays of the sun through shadows, which is created from close buildings.
	Construction	• Doubled roof, doubled wall, thick wall structure-delays it by weakening heat change. • Build a ventilation system for inflow of window,
	Energy	• Use of geothermal energy • Evaporation cooling, earth cooling, air flow • Transmission of heat transfer and interception of hot wind
• Sudan: Mesakin Quisar cluster dwelling : 5 huts with a thick adobe wall formed with court, and shadow is created from a lattice fence		
Example		
High temperature and humid region		
Climate Characteristics	• Temperature is high and there is no significant difference between the daily range and the annual range • Tropical climate with severe rainfalls and high humidity • Strong radiation and the tropical nights phenomenon • Natural heat controlling is hard • Africa, Monsoon Asia, Australia, Polynesia, Amazon and etc.	
Requirements	• Maximum shades and minimum heat capacity structure, which is for protecting reproduction of heat accompanied by that. • Maximum ventilation and material is needed to remove humidity • Rooftop structure as a preparation for many rains • Securing freshness based on protection against heat and controlling air current	
Construction Method	Material	• It is necessary to use materials for ventilation, and use a weaved structured • Use a non-conductible material for radiation- use a material with many spiracles that does not absorb heat [thatch, reed, soil, wood (bamboo)]
	Shape	• Geometrically dispersed and independent in a long shaped form with minimum walls • Easy ventilation with arrangement of big tents • The key point is to make the best

		advantages of natural ventilation with earth, direction and structure.	
	Construction	• A roof is very important for structure: Most of the roof shapes are like an umbrella by putting a thatched roof on the top of a simple ring_higher roofs are needed • Functions of wall are mostly lost: a wall panel weaved with textiles can be rolled up • A structure for shades is necessary • Removes humidity, prevents flood, and protects people from insects and animals by raising the floor structure	
	Energy	• An open building with low heat capacity for maximum crossing ventilation	
Example			
Temperate Regions			
Climate Characteristics	• Characteristics of 4-season climate • High annual range and humidity • Low daily range and precipitation • Various microclimate characteristics • Wide range of strength for radiation • Mediterranean sea, Latin America, China, Japan, Korea, and regions of Asia		
Requirements	• Measures for extreme climate changes of summer and winter are needed • Construction materials of double-structure with thermal insulation effect is required • Consider the microclimate		
Construction Method	Material	• There are many houses made out of rocks, bricks, or woods with an inclined roof	
	Shape	• A balanced building which works as a trap for the sun in winter and as a shelter with shades in summer • Large windows: It is extroverted through communication with natural environment • A long shape is preferred to the east and west side, and has a open flats • A windbreak is used to keep the cold wind	
	Construction	• Structural diversity and freeness compared to the other regions • A gentle slop of roof is used to efficiently protect the wind • Indian Teepee - With a rod for wind	
Example			
Cold region			
Climate Characteristics	• Low annual temperature • Low daily range, and precipitation • Very cold winter with wild wind and snow • Long frozen period • Scandinavia, Himalaya, North America and etc.		
Requirements	• Requires a building structure that is closed and allows insulation for cold winter season • A structure to protect the loss of heat is needed • A structure to keep the strong wind is needed		
	Material	• Using heavy materials with thermal insulation effect	

Construction Method		Use of insulator - wood, leather of animal, ice brick, soil grass
	Shape	- Dense plane and arrangement to protect loss of heat - Minimizing surface area of the building which is exposed to the outside - A roof is low at the north side, the roof is high the front is opened to use solar energy
	Construction	- Polars require a building structure that has a good insulation ability - Eskimo igloo, North Europe soil-grass rooftop log house - High slop of roof is structured to protect the loss of heat - Igloo: Forms an arched shape of entrance tunnel to protect the wind and makes a warm layer by adhering leathers on the ceiling - Underground system: Entrance is lower than the position of living space, so hot air does not escape
Example	Energy	- Prevention of ventilation and air leakage - With walls being attached to the hill, roof and wall can protect the cold with lumps from surfaces of the land
	Example	

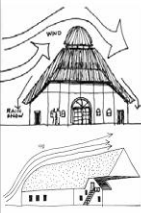
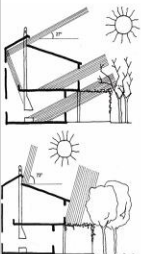
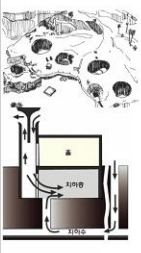
3.3 Microclimate Control Method for Vernacular Housing

Based on vernacular housing for each climatic zone examined in previous sections, the authors of this study aim to find a passive design method that provides healthy and pleasant environment and maximizes the use of 'passive energy' by controlling the microclimate. For passive design methods, various principles adapting energy to architectures using passive means such as expansion of heating value during winter season and protection against wind, pent roof during summer season, improved ventilation, thermal insulation ability of structures, thermal characteristics of materials, arrangement of architectures, thermal exchange according to changes in underground temperature, and daylight were applied¹⁴, and in that respect, layout, architecture form, use of solar energy, use of geothermal energy, insulation, passive ventilation, passive cooling and sunblind were organized as Table II¹⁵ shown below.

¹⁴ Park, Dae-Hoon, ibid, p.19

¹⁵ Kim, Ja-Kyung, ibid, p.42, recited

Table II: Microclimate Control System of Vernacular Housing

Classification	Region	Microclimate control system	Example
Position	-Can be applied according to the climate condition	-Layout using landform such as hills and terraces: landform makes it advantageous for enclosure, sunshine, view and wind direction and has high density -Cooling with water as heating medium by living around lakes and rivers, and dense housing layout for insulation effect and creation of shades -Hills facing the south to control wind direction	
Construction Shape	-Can be applied according to the climate condition	-Surface area is increased to consider large opening for ventilation in regions that require cooling during summer season -Contained and small surface area in cold region to minimize heat loss -Different roof forms according to climate conditions	
Usage of Solar Energy	- Temperate region - Cold region	-The most basic direct acquisition method in passive solar system and southern direction is taken -Sun→interior space→heat storage→radiation allows storing of heat during day and releasing of stored heat at night -Sunblind device to block solar heat during summer season	 -Housing of Andalusia region of Spain
Usage of Geothermal	-High temperature and arid region -Cold region	-Underground architecture built using the underground space, and soil and rock utilized as insulators or coolants: protection against typhoon, radiation, noise, quake, and strong wind -Passive cooling system using underground air: system that realizes preheating and precooling effects through a tube buried 3m below the ground, cool tube method of Iran	
Thermal Insulation	- Temperate region - Cold region	-Thermal insulation through insulating building materials: grass roof, log, mud, snow and leather -Insulation with dual structure -Prevention of heat loss using structure: placing the roof after digging the ground, same structure as igloo in which hot air does not escape, udegi of Ulleung Island, underground housing -Traditional heating method of Korea, the underfloor heating system using a hypocaust	
Natural Airin	-High temperature and humid region	-Comfort Ventilation: a method in which thermal pleasure is created by evaporating the sweat on the skin by bringing the outside air. Begins on the surface of ground	

g and Ventilation	-High temperature and arid region	and is characterized by creation of shades with large windows and long eaves, formation of veranda, minimization of wall, making of roof window for ventilation, and use of materials that allow air to flow (high temperature humid region) -Convective Cooling: A method of ventilation cooling in which the outside air during the night is brought inside and stored in a weight container and used during the day through ventilation -Chimney effect, wind hole, ventilating hole, wind tower, and atrium space	
Natural Air Cooling	-High temperature and arid region -High temperature and humid region	-High temperature arid region uses radiation cooling method using the courtyard and air cooling tower method -High temperature humid region induces fast air circulation through vents on roof and wall, utilization of cool air from ground and water to promote ventilation cooling method	 Natural cooling method of Saudi Arabia using courtyard
Shade	-High temperature and arid region -High temperature and humid region - Temperate region	-In tropical regions where humidity is high, structure must take into consideration the necessity of sunblind and lighting - Use of wall that allows the wind to go through by standing bamboo or reed vertically resolves the problems of sunblind and lighting at the same time - India and Pakistan use permeable screens - Lattice window of Arab - Veranda covered up in lattice in Zanzibar -Low eaves, broad veranda and white roof allow light rays to spread out evenly and helps lighting -Awning for housing of Yokut tribe in southern California	

Cases provided in the table are partial, and they are a group of representative case images in the world. It can be inferred that vernacular housing utilizes ventilation, heating, cooling, use of passive energy and preservation of passive energy by applying methods to block or accept the microclimate condition according to the status of the region.

4. CONCLUSION

This study started out by recognizing the need of housing plan to use passive energy and by considering the methods to use passive energy through the microclimate, which is an important aspect of vernacular design that reflects the climate and tradition

of the region. During the process, climatic zone was classified into high temperature arid region, high temperature humid region, temperate region and cold region, and requirements of climatic characteristics for each region and methods to control the microclimate condition through material, shape, structure and energy were investigated. Layout, architecture form, use of solar energy, use of geothermal energy, insulation, passive ventilation, passive cooling and sunblind were used to extract passive design methods for use of passive energy in vernacular housing. That is, as the authors began by looking at vernacular design and analyzed the correlation between the microclimate and vernacular housing to find the method of design for use of passive energy, the following conclusion could be drawn.

Houses in high temperature arid region utilize the methods such as minimization of surface area through crowded positioning of houses (layout), cold air circulation using courtyard (architecture form), small number and size of windows to prevent insolation and heat transfer (architecture form), use of vent for inflow of wind (passive ventilation and air-flow), double wall and double roof for minimized heat change (passive cooling), and permeable screening of sunlight through creation of shade by clustering (sunblind).

Houses in high temperature humid region utilize the methods such as open positioning for passive ventilation (layout), high sloped roof and independent narrow, long form with geometrical scattering (architecture form), use of minimized wall and materials that have low conductivity (passive ventilation and air-flow), high floor construction and vent on wall and roof with high slope (passive cooling), and awning, low eaves and lattice windows to block sunlight (sunblind).

Houses in temperate region utilize the methods such as dense positioning with the use of sloped land and waterside for prevention of heat loss (layout), open plane with long form and roof with gentle slope

(architecture form), penetrating veranda or hall (passive ventilation), high floor construction (passive cooling), use of roof with gentle slope, shelter belt, dual structure and insulation material to block the wind (thermal insulation), and low eaves (sunblind). Houses in cold region utilize the methods such as use of ground surrounded by hills or terraces (layout), small surface area and sloped roof for minimization of heat loss (architecture form), high roof and open front (use of solar energy), blockage of wind through underground space (protection against wind), and insulation effect through insulators and dual structure (thermal insulation).

In terms of housing plan, study on vernacular design is like an instinct to go back to the passive. It is identical to modern design movements to find suitable designs for each region so that human beings can live harmoniously with the nature. Further studies on the passive design method found from microclimate control in vernacular design through modern reinterpretation are necessary to apply such method in modern housing.

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