Field Measurement and Degradation Rate Analysis of Thermal Insulation Performance by Elapsed Year of Public Building Outer Walls in Korea

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***Abstract*—In this research, the thermal insulation performance of a public building's outer walls in which the same finishing materials were used was measured in the field, taking into account their elapsed year. Based on the measurement results, the degradation rate of thermal insulation according to the outer walls' age was analyzed and the thermal insulation degradation curve was derived. As results of the research, the outer walls' U-value decreases over time by up to 69.74% compared to the annual reference U-value, which indicates the degradation of thermal insulation performance causes the aging of the outer walls. Based on the field measurement data, this research then derived the thermal insulation degradation curve according to the outer walls' age. Under the current circumstances where improving the thermal insulation performance is increasingly considered as an effective solution of reducing energy for the existing buildings. This research is significant in that it quantitatively derives degradation data of the thermal insulation performance depending on the actual outer walls' elapsed years.**

***Index Terms*—thermal insulation, U-Value, field measurement, outer walls, public buildings, heat flow meter method**

I. Introduction

Remodeling is increasingly considered as an effective approach to improve energy performance of about 6.8 million aged buildings [1]. In particular, remodeling in the building sector utilizes physical shapes or appearances of building structures to enhance energy performance, without using additional energy [2].

As outer walls are the part where heat gain and loss frequently occur, enhancing the thermal insulation performance of outer walls can minimize unnecessary heating and air-conditioning energy consumption. To increase the insulation performance of outer walls, first of all, quantitative data on the degradation of thermal insulation performance of outer walls should be obtained. In this regard, this research aims to derive the degradation rate of thermal insulation performance of outer walls according to their elapsed year, based on the data acquired from field measurement. The research results are expected to serve as basic reference to predict time for performance improvement based on the age of outer walls.

Manuscript received May 12, 2015; revised October 26, 2015.

II. The Flow of Study

Thermal insulation performance of building walls can be determined by U-value, which is the heat penetration rate of a wall. The lower the U-value is, the higher the insulation performance is. In this research, field measurement was performed in January through February, in accordance with ISO9869-1, international standard for measuring U-values of outer walls, in order to analyze the decrease of thermal insulation performance by age of outer walls.

Four buildings which applied the same exterior finishing materials and have similar purposes and operation hours (9 am to 6 pm) were selected as measurement subjects; however, their ages were different: 0-5 years, 5-15 years, 15-25 years, and more than 25 years. Then, the measurements were analyzed and compared with the standard U-values as of the construction completion date to derive the thermal insulation performance decrease rate of outer walls and the relevant curve.

TABLE I. The Annual Standard U-Value (unit: $W/m^2 \cdot K$)

Trial year	Standard U-Value
1987	below 0.76
1992~1999	below 0.65
2001~2008	below 0.58
2010	below 0.45
2014	below 0.34

To analyze the degree of performance degradation depending on the age of outer walls by comparison between the current U-value and the standard U-value, the standard U-value by year was studied. The Table I shows standard U-values of outer walls of building structures located in the southern part of South Korea [3].

doi: 10.18178/ijscer.5.1.1-4

Thermal insulation standards for each part of building structures were established in accordance with the rules and regulations on installation of building structures and over time, the standards are strictly revised and supplemented.

III. Field Measurement Method and Results

The Table II shows instruments needed to perform field measurement of outer walls' thermal insulation performance by using a heat flow meter specified in ISO9689-1 [4]. U-value field measurement procedures and test methods according to ISO9689-1 are as follows:

TABLE II. Field Measuring Equipment of U-Value

Measuring Equipment	Function
	① Data logger
	② Heat flow meter & Indoor temperature sensor
	③ Outdoor temperature sensor
	④ Adapter
	⑤ Silicon paste putty

To minimize the influence of solar radiation on outer walls, the northward outer walls were selected to be measured. An infrared camera was used to identify the temperatures of outer walls' surfaces, and parts where there was no heat bridge and crack were selected. Ambient temperature sensor was fixed out of the window, the gaps between windows and walls were sealed with masking tape to prevent outside air from incoming. As a heat blow meter was embedded with an interior temperature sensor, it must not be installed near heating apparatus.

The heat blow meter was attached on the interior with silicon paste putty around it. During the measurement period, the room should be empty, so access other than the purpose of heater operation was prohibited.

The exteriors of the subject buildings are finished with painting finishing materials, which are a heavyweight structure, whose specific heat per unit area is 20kJ/m^2 or higher. ISO9869-1 specifies that in the case of heavyweight structures, the measurement period of the U-values should be analyzed with integer multiple of 24 hours and the measurement hours should be at least 72 hours. If R-value obtained from the last measurement is within ±5% of that obtained 24 hours ago, the measurement should be closed. In fact, some heavyweight structures require correction of heat flux, but if the measurement conditions were sufficiently met, the correction is not necessarily required [5]. As described in ISO9869-1, more-than 72hours measurement does not require heat flux correction, so in this research, measurement hours were set to 96-120 hours and 15-minute intervals to ensure high reliability. To derive U-values of the outer walls, the Average method was used, which was specified in Section 7.1 of ISO9869-1. The relevant formula is as the following Eq 1.

$$U = \frac{\sum_{j=1}^{n} q_j}{\sum_{i=1}^{n} (T_{ij} - T_{ej})} \tag{1}$$

U=Thermal transmittance [W/m^2 ·K]

q=Density of heat flow rate [W/m^2]

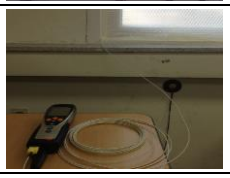
Ti=Interior environmental temperature [℃]

Te=Exterior environmental temperature [℃]

j=Frequency of measure

Table III shows overview of the subject buildings and the measurement results of the outer walls obtained by using a heat flow meter and the Average method described in ISO9869-1.

TABLE III. Overview of the Target Buildings and Field Measurement Results [7]

		Case 1	Case 2	Case 3	Case 4
Cases appearance					
Measuring equipment installation					
Construction year		1984	1992	2004	2012
Area/floors		661.3m^2/2	682.8m^2/2	998.6m^2/2	1217.3m^2/4
Measuring time (hours)		2.23~2.28 (120 hours)	2.4~2.9 (120 hours)	2.9~2.14 (96 hours)	1.24~1.29 (120 hours)
U-Value [W/m^2 K]	Min	0.012	0.002	0.16	0.042
	Avg	1.29	1.08	0.61	0.54
	Max	7.37	6.74	4.54	1.97
	SD	1.52	0.51	0.65	0.31

The more aged building showed the higher max U-value. And recently constructed buildings had smaller standard deviations of U-values and lower max U-values, which indicated the higher thermal insulation performance produces the moderate U-value.

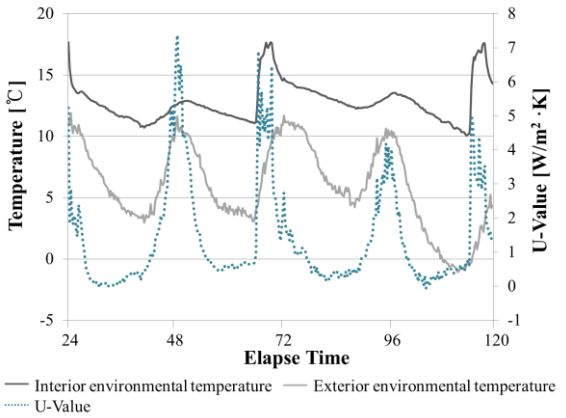


Figure 1. Analysis of measuring value: Case1

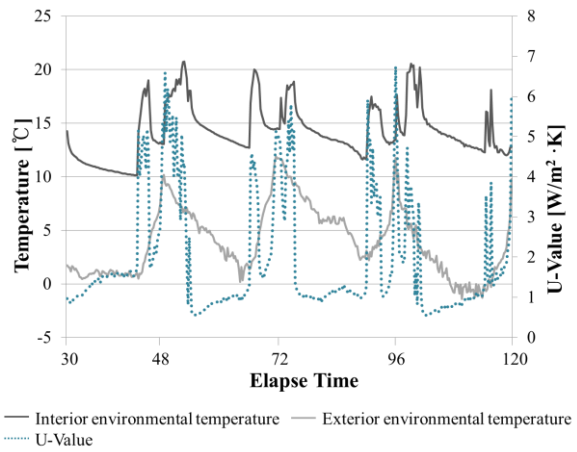


Figure 2. Analysis of measuring value: Case2

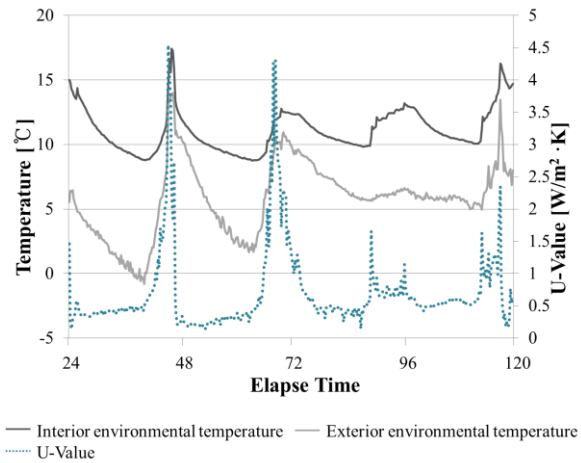


Figure 3. Analysis of measuring value : Case3

IV. ANALYSIS

As the indoor heating temperature of Korean public buildings in winter season is recommended to be set to 18℃, the increase and decrease of indoor temperatures of the subject buildings are deemed to be similar.

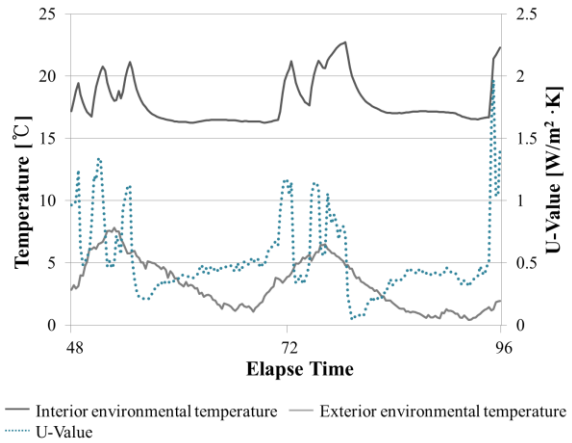


Figure 4. Analysis of measuring value: Case4

The Fig. 1-Fig. 4 shows the analysis results of the U-values of the building outer walls. From 6 am when temperatures of interior walls began to rise, U-value started to climb. Between noon to 2 pm when both exterior and interior temperatures increase due to operation of the heater, at a point when the difference between exterior and interior temperatures was minimum, U-value was at the highest.

In Case 1, the case where U-value was negative (-) was found. It is, first, because the indoor temperatures became lower than interior walls' temperatures due to the turning off the heater. Second, the outer walls of the heavyweight were considered to be affected by stored heat due to solar radiation, thus negative (-) values were excluded when calculating U-values [6]. As more recently constructed buildings have better thermal insulation performance and thus indoor temperatures are less affected by outside air temperatures, U-values are considered to have moderate changes.

Analysis of U-values by elapsed year is shown in Fig. 5. Higher U-value means lower performance. U-values of Case 1 and Case 2 are 1.29W/m^2·K and 1.08W/m^2·K, respectively, which are 69.74% and 66.15% higher than the standard U-values

(Case 1: 0.76W/m^2·K, Case 2: 0.65W/m^2·K). That indicates the performance decreases. In Cases 1 and 2, as the buildings are older than 15 years, it is considered that the thermal insulation performance has been degraded and therefore, improvement is urgent.

The building in Case 3 was constructed 11 years ago, but its U-value is not significantly different from when the building was constructed, so it is deemed that with supplemented thermal insulation standards, this building secures safe insulation performance.

Based on the field measurements, the decrease curve per time of thermal insulation performance of the outer walls using painting finishing materials was derived and the curve is as the following Fig. 6. Since thermal insulation remodeling has not been conducted for the subject buildings, the curve falls to the right without any bouncing point, and it is an exponential curve, which

means performance decrease is sharp over time. According to the curve, thermal insulation performance of public buildings using painting finishing materials does not meet the annual standard U-value, and although the annual standard U-value is mitigated from 6.6 years (approx. 80 months) after the completion of construction, thermal insulation performance continues to decrease.

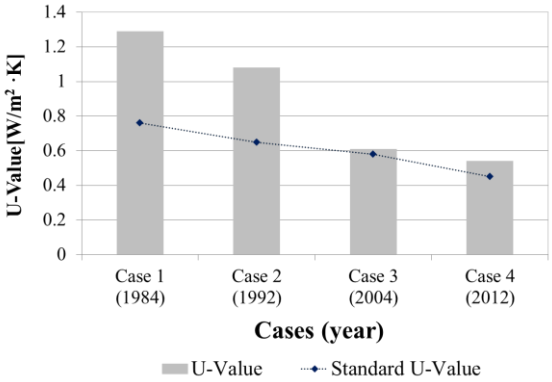


Figure 5. The Annual standard U-Value and Target buildings U-Value

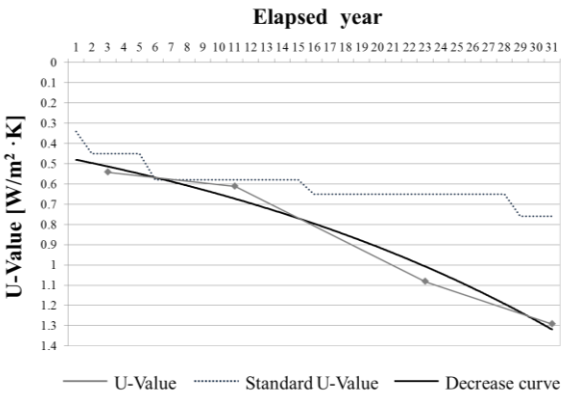


Figure 6. Derive a decrease curve of thermal insulation performance by elapsed year

V. Conclusion

Public buildings applying painting materials were selected as research subjects to perform field measurement of thermal insulation performance, and their elapsed years were classified into four time periods. The indicator of thermal insulation performance is U-values, which show similar pattern with the increase and decrease of indoor and outdoor temperatures, thus it is considered that U-values are most affected by temperatures. Additionally, more recently constructed buildings had smaller standard deviations of U-values, showing relatively smaller differences among measurements.

As a result of analysis of the performance degradation rates by elapsed years of outer walls, the insulation performance of outer walls aged more than 15 years decreased by 68% on average compared to the annual standard U-value. Then, based on the measurements, the degradation curve of thermal insulation performance by elapsed year was derived to analyze the performance decrease pattern. In the case of structures applying above-15-aged painting finishing materials, decrease of the outer walls' thermal insulation performance causes energy loss, so thermal insulation remodeling plan should be established as early as possible and carry out remodeling of outer walls at least partially.

Further research will be identifying types of exterior materials applied to public buildings and measuring thermal insulation performance of outer walls for each exterior material.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (NRF-2013R1A2A1A01014020).

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Ex-Situ Conservation on Nusantara Architecture: Implementation and Challenges (An Overview towards TMII and Stübing Freilichtmuseum)

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***Abstract*—Many traditional houses that are still persist in some area of Indonesia is in the verge of extinction. Salvation effort was aroused in order to save civilization heritage, national identity, and local wisdom for future generations. One way is reviving efforts about conserving a la ex-situ in the form of open-air museum. This paper aims to describe critically the implementation of ex-situ conservation towards endangered traditional houses in the form of museum. Critical frameworks that have been built in this research should be as a muse in evolving sustainable open-air museum particularly in Indonesia. By taking case in Stübing freilichmuseum in Austria and Taman Mini Indonesia Indah (TMII) Jakarta, Indonesia, identified some common thread by juxtaposing each cases in order to produce a guideline (practical framework) that can be used as the blue book for the preservation of traditional houses of Indonesia. From the results it was indicated that the problem of mentality and behavior is the main factor why many traditional houses better abandoned and left extinct. Technically, the management is also a challenge that needs improvement in order to increase the quality of Indonesian museum, especially open-air museum. Therefore, the presence of this research is expected to push up the creation of policies that support the preservation of traditional houses to be more planned, integrated and organized**

***Index Terms*—ex-situ conservation, open-air museum, traditional house**

I. Introduction

Handling the traditional architecture now has a big hand as the basis for the development of modern architecture in next future. Various efforts were done to maintain the traditional architecture, for example by conservation. During this time, the conservation of traditional houses is often done and still holds on conservation in the site itself. However, we are not aware that this type of conservation itself has drawbacks the terms of maintaining condition of object per object. Moreover, if the house was secluded, surrounded by modern lifestyle pressures, and distantly of transportation access. Here, questions about the re-evaluation of vernacularism particularly conservation are insisting.

In facts, traditional houses in every parts of the world deal with the brink of extinction. The number of traditional wooden houses has dropped sharply due to many aspects such as the rapid spread of new building materials, declining of agriculture, and urban migration. People are preferred let the historical value of all forms of their traditional houses and relics abandoned in their village. Whereas, throughout its modesty, many features can be traced from it for future such as wind catchers, element of shading and natural lighting, thermal insulation, methods in using local building materials and natural techniques that were used for air cooling. Not surprisingly because there is a gap between technological problem and cultural issues where modern people prefer living without dust and smoke [1].

Likewise occurred with traditional houses in Indonesia. The need for conservation of traditional houses began to burst in the last decade. One of the biggest achievements of the traditional houses reconstruction projects was initiated by *Yayasan Rumah Asuh* Program. However, due to constrained funding and support, this project only focused on several customhouses that still occupied by its community. But, how about the abandoned house? Kemper [2] was suggested open-air museum. When the traditional building cannot be kept by the people surround, rather than leave decay, it should consider that open-air museum perhaps the only way to make it sustain.

Conserve the building in the term of open-air museum itself is not much different from conserving the plants a la ex-situ. Endangered plants in its habitat conserved ex situ to the same new condition with the original place. But, conserving the plant to a new site usually only consider the climatic aspect and soil conditions. Architecturally, according to ICOMOS (New Zealand charter 2010), the purpose in conserving heritage building is to care for places of cultural heritage value. So that, people and its culture should also have to be considered. Exhaustive conservation of traditional architecture carried out intensively since China Charter in 2000 to clarify earlier charters and put traditional architecture as a reserve to be considered in the field of conservation [3].

II. Literature Reviews

In many developed countries, no doubt, the museum becomes an instrument that has a strategic role to strengthening community identity. Concern of nation identity to culture growth has reflected in the awareness

Manuscript received September 1, 2015; revised October 15, 2015.

doi: 10.18178/ijscer.5.1.5-11

and public interest to visit museum in developed countries. Of course, these conditions cannot be separated from the role of culture experts who put the museum as part of a social institution, as well as a vehicle to provide an overview and education of development of nature and human culture to the public [4].

Unfortunately, museum always predicated as a place to lay down the past and tends to be artifact based which has tasks collecting, preserving and presenting. While, during the improvement, open-air museum exists and have offer more roles based on combination of indoors and outdoor activity [5].

In his essay, Kemper [6] defined open-air museum as a safe place to put ancient monuments from extinction. This kind of ancient monuments further detailed as pre-industrial architecture where wooden traditional building became dominantly at the age and conditioned realistically either the form or the contain to make visitors realize that the building might have existed.

Commonly, open-air museum are consists of wooden building so that located where wood abundantly existed due to minimizes damage caused by the relocation. The constraints of authenticity in the relocation become a major issue in settling open-air museum. On the other hand, Kemper [7] stated that folk-culture plays an important roles as well as coloring the atmosphere of open-air museum. Therefore, in the reconstruction process which is started from dismantled, transported, reconstructed and maintained, the whole process should have to be reflected with how the ancient keep it maintained in order to keep the essence of the culture. The traditional building reserve many valuable information of how the culture developed and maintained due to as Rapoport said that ‘folk-culture is the direct and unself-conscious translation’ which transformed into the form of value of the house [8].

The Association of European Open Air Museums (AEOM), an organization of important open air museums in Europe defines Open-air Museums as “scientific collections in the open air of various types of structures, which, as constructional and functional entities, illustrate settlement patterns, dwellings, economy and technology” [9]. Even in the small scales, a group of building completely or partially, also can be considered as open-air museum since copies or true to scale reconstructions are rebuilt after original patterns, are properly furnished and opened to the public. These concessions can be made only under the condition that: “the original buildings of the type portrayed are no longer available (and) the copies or reconstructions are made according to the strictest scientific methods” [10].

III. Method

This paper proposes an overview about condition of the most comprehensive open-air museum in Austria, Stübing freilichtmuseum and compared with Taman Mini Indonesia Indah (TMII) in Jakarta. The purpose of this overview is to gain an image about method that can be made and implemented in order to underlining the importance of ex-situ conservation.

The main reason both objects chosen is the biggest one and comprehensively considered as showing numerous collections of the traditional houses than any open-air museum of each country. Also, it is nevertheless advantageous to restrict the scope in general to Stübing freilichtmuseum among 58 open-air museum [11] which had been classified all over Austria because it could be regarded as the best place to put conservation issues and its solving toward traditional building in Indonesia. On the other hand, many architectural features discussed here regarding conservation issues may seems can be compared and scientifically sound to draw conclusions from the comparisons.

In Indonesia, example naturally will raise from phenomenon of current condition of open-air museum at there. As we all know, there are many examples of Indonesia open-air museum but mostly as in-situ museum that the collection only consists traditional features of the area. One of the biggest ex-situ open-air museums in Indonesia is Taman Mini Indonesia Indah (TMII). Despite of some phenomena in its establishment, it will be the main consideration in this research in order to gain information critically regarding the opportunities and the challenges.

IV. Results and Discussion

Local wisdom is a manifestation of humanity value, implemented in life, symbolized as identity and characterizes a nation. Therefore, local wisdom should strengthen continuously in order to maintain the identity of a nation.

Currently, the movement to revive local wisdom began erupted. Identity that manifested as a house consciously is a form of self-actualization. Not surprisingly, the houses that commonly encountered in the residential complex which was originally built in same shape, but once inhabited could be different, not merely the physical term (shape, colors, ornaments, etc.), but also the behavior which is formed at there. Dominantly, the occupants reflected this identity as a result of the childhood life that dissolved in the domain of cultural system that experienced. Mostly, this is the aspect that characterizes our traditional houses.

Over the ages, these identities getting dimmer annihilated by sparkling globalization. Traditional/custom houses as a reflection of culture seems allowed to 'live reticent, eke died reluctant'. While so many lessons could be learned from traditional house. The principle of life, mutual cooperation, modesty, culture, respect for nature, and sustainable technology were stored to be learned from traditional houses. At least the spirit to appreciate the heritage of the ancestors reflected in the way we appreciate the history of our nation. Rather than romantic depictions of old buildings with invented histories in spurious and contrived settings, vernacular architecture in the developing world needs respect and support, with encouragement for its continued use of renewable resources, passive climatic modifications, spatial organization based on social structures and scale according to the need [12]. Therefore, need a fervent

effort to save these 'remaining and scattered' traditional houses from extinction and situated more secure and well maintained, such as through the open-air museum.

Yet, as in a museum management particularly at open-air museum that requires more space and costs, internal and external challenges often become a bottleneck in the improvement. Issues around technical problem in moving the collection must be followed by the readiness in maintenance afterwards. Oliver stated '*conservation is frequently seen as a technological problem and it is true that the preservation of old materials, the keeping of venerable buildings in good repair is a technical matter*'. *But fundamentally, conservation is a cultural problem* [13].

In this case, the mentality of a society in appreciating culture can be seen from how they cherish their local wisdom. Most cultures overcast because no longer used as a patron in life. The original identity often left biased, mixed with modernism of capitalization. Also, political situation that creates practical policies with imaging intention. Not surprisingly, the conservation itself is now seen merely as maintaining job solely for the purpose of commercialism, especially in Europe [14].

In Indonesia itself, there are several factors that hinder conservation issue, that is:

1. Overly attention from government and related organizations (professional or NGO) for the 'traditional' building in urban area, which in fact it is a relic of colonialism. This attention is a result that embodiment general definition of preservation and also the form of the ambiguity of identity experienced by Indonesian people toward what the traditional building is, the effect of hundreds years of colonization.
2. Funding constraints and lack of effort in managing cultures. The government is less prioritizing in supporting preservation of the traditional house. While, in addition rich in historical values and meaning of life, traditional houses has abounded vocabularies of sustainable way of life.
3. The existence of TMII not adequately represent the shape of the building due to using new material and just prioritize the form, which is actually the authenticity of shape also questionable because as we know all of the houses in the archipelago itself has a wide range of transformations.
4. Mental map majority of Indonesian people are paying less attention to localism and more liberate outside view modernizing their thinking. This is an example where the concept of conservation not only encounters with values, in fact, the way of life become the main factor of culture degradation [15].

To be closer with the phenomenon, below described the comparison between TMII and Stübing freilicthmuseum.

A. Taman Mini Indonesia Indah (TMII)

Symbolizing culture authorization by the government at that time, many people said that Taman Mini Indonesia Indah (TMII) was the symbol of power of New Order (*Orde Baru*). As a prestige symbol, lot of effort sought in developing TMII as a miniature of Indonesia. TMII became one of the most famous icon and makes Jakarta as a business center, government and entertainment. It was not complete visit Jakarta without visit TMII.

According to Barliana [16], in the reign of President Suharto, hubbub of revolution was replaced with the pace of development. Orderly development was raised to create the dignity of the nation. Unfortunately, this spirit built by creating "mass fear". Anyone who refused development for and in the name of "public interest" would be guilty and was considered as enemy of the nation. However, the development that occurred during Soeharto's era was supposed not describes the diversity of archipelago in general. The spirit of nationalism that marked by the pentagon-roofed mosques construction throughout Indonesia which is adopted from *joglo*, describes the hegemony of *javanisation* distributed to the entire nation. Denotes uniformity of vernacular architecture and termed as modernizing architecture in orthodox way of view. And thus, Taman Mini Indonesia Indah (TMII) was conceived as unifying concept and be expected, reflects the *Bhinneka Tunggal Ika* [1], but woefully, traditional architecture features at there were shown 'artificial', and then positioned in Jakarta as a form of administrative entity [17].

As a prestigious project which initiated on 1972 by Mrs. Tien Soeharto (President Soeharto's wife), TMII really became the main attention because the peaks of culture of each province being there. By visiting TMII, it was represented completely visited throughout Indonesia. Even vast budget was disbursed to make any representations traditional houses at there to be the best. Not surprisingly if the expression feels 'excessive' than the original.

Overall, all of the traditional houses (pavilions)[2] at TMII have a same shape. As seen on Fig. 1, all building shaped as replica of traditional house. Larger sized in order to load typical exhibition objects such as dioramas, assortment of bridal wear, woven, crafts, traditional musical instruments, and information about tourism.

[1] *Bhinneka Tunggal Ika* is the official national motto of Indonesia. The phrase is Old Javanese translated as "Unity in Diversity".

[2] Called as pavilion because in addition to the traditional house pavilion of each province, in TMII also there are some thematic museums such as, Museum of Indonesia, Museum Pusaka, Museum of Transportation etc. (More information at http://www.tamanmini.com/tmii.php)