STRUCTURAL CHARACTERISTIC OF TRADITIONAL WOODEN HOUSES IN SOUTH NIAS, INDONESIA

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ABSTRACT

Indonesia consists of many islands and is a multiracial country. Each ethnic group has their own type of traditional wooden houses. Most of them have survived against the past large earthquakes in such seismic areas. As they have been maintained by the traditional ways so far, it is worth preserving them from a historical point of view. The purpose of the present research is to evaluate the structural characteristics specific to the traditional wooden houses in the southern area in Nias island. Furthermore, the structural restoration using the traditional techniques was discussed to propose the appropriate method for the structural conservation.

The traditional wooden houses in South Nias are characterized by an elevated-floor structure. We conducted the micro-tremor measurements and architectural structural survey in Bawomataluo to study the structural characteristics of those traditional wooden houses. As the result of micro-tremor measurements, the natural frequency in span direction was lower than that in ridge direction because of wooden braces and wooden walls effect. The vibration mode shows that the rigidity distribution along the height of omosebua is irregular. Although the architectural structural form of them still remains as it used to be, we found out that the deterioration has been progressing and that the houses suffered serious damage by termite. These damages might have reduced the original seismic resistance. The present research indicates that the structural restoration should be needed to conserve the heritage structures.

Keywords: Traditional wooden houses, Micro-tremor, Conservation, Indonesia, Nias

1. INTRODUCTION

Indonesia is composed of many islands and a multiracial country. Each ethnic group has original culture. It has various types of traditional wooden houses. In the present study, we focus on the village of Bawomataluo in South Nias, Indonesia, shown in Fig. 1. As they have been maintained by the traditional ways so far, it is worth preserving them from an architectural historical point of view. Earthquakes often occurred in Indonesia. Most of them have survived against the past large earthquakes as they are constructed in consideration of seismic resistance. The village of Bawomataluo is fortress village located on the hill with the steep approaches. The omosebua (a headman lived in formerly) is center of the village shown in Fig. 2. Traditional wooden house in South Nias is a elevated-floor style. Thick columns (ex. diameter of approximately 50 cm at Omosebua, 30 cm at general house) and braces support the space of living of which two sides are of wooden thick

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walls. Some columns standing up on the floor support the roof frame shown as Fig. 3. In addition, no nails are used for construction.

**Fig. 1** Location of Bawomataruo (Reference: Google Map, Wikipedia)

**Fig. 2** Form of village (Bawomataruo) [2]  
**Fig. 3** Composition of a house [2]

## 2. MICRO-TREMOR MEASUREMENT

### 2.1. Purpose

We conducted the micro-tremor measurement at Omosebua (a headman lived in formerly) and other general houses. (See Fig. 2, Fig. 5) General houses have two kinds of roof materials; iron and sago palm leaves. As a result, the dynamic characteristics of these houses as well as the predominant periods of ground motions are evaluated.

### 2.2. Methods

Micro-tremor measurements were carried out by using 6 micro-tremor sensors, shown as Fig. 4. Sampling duration was 60 seconds for each record with sampling frequency of 100 Hz using a portable monitoring equipment of SPC-51A. Fig. 1 and Fig. 3 show the representative measuring points. When we measure the ground motion, we put sensors on the center path which is paved with stones, indicating firm ground and being effected by noise easily.

**Fig. 4** Arrangement  
**Fig. 5** Omo sebua

In addition, we conducted free vibration experiment by human power excitation. In the present paper, the span and ridge directions are defined as X and Y directions, respectively.
2.3. Results of measurement
2.3.1. Omo sebua
Transfer function from the structure to the base showed that the natural frequency in X and Y directions were 2.0 Hz and 3.1 Hz, respectively at Omo sebua. (See Fig. 6) The damping factor was calculated from the waveform of free vibration test; 2.5% and 2.1% in X and Y direction, respectively.
Fig. 10 shows the first vibration mode figured out from transfer function. It indicates that rigidity distribution along the height is irregular. Traditional houses consist of three parts; roof, floor and under-floor. Under-floor part is so stiff in both directions because of thick braces. On the other hand, there is significant difference in stiffness of structural layer of living space between X and Y directions, which is caused by the wall’s effect. It is considered that large story drift at the layer of living space in X direction can be noticed in Fig. 10. Braces are also effective in roof part in X direction, while there are no braces for Y direction.

2.3.2. General Houses
Transfer function of the micro tremor records showed that the natural frequency was 3.4 Hz in X direction at the general houses. The roof of house No.1, 2, 4 are iron and No. 3 is a roof thatched with sago palm leaves. Further survey will be needed to discuss dynamic performance of these general houses are considered to be affected by the roof’s materials. Those houses are connected by non-structural members. It is characterised by one entrance for two houses. The coupling effect was observed in X direction during the man-power excitation test, shown in Fig. 11. The predominant periods of the ground motions was evaluated to be 4.7Hz judging from the H/V spectrum.

![Coupling effect](image)

2.4. Conclusion
It was found that X direction natural frequency is lower than Y direction namely; X direction structure is more flexible for both Omosebua and the general houses. The location of braces or walls causes irregularity of rigidity distribution. In this survey, the fundamental dynamic characteristics were clarified. From this point further survey would be needed to study the earthquake resistance capacity.

3. INSPECTION ON DETERIORATION AND DEFORMATION

3.1. Purpose
Inspection on deterioration and deformation was conducted to perceive damaged parts of Omosebua. Based on it, necessity or methods of restoration is considered.

3.2. Methods
Degradation survey was conducted in five point; 1.visual observation, 2.percussion test with wooden hammer to find out decay or harm by ants, 3.using Laser Marking Equipment to probe a lean of frame or differential settlement, 4.measurement of height with laser rangefinder, 5.observing the temperature and humidity simultaneously with times and Latitude/Longitude as well as making a record with taking pictures.
3.3. Results of survey [3]

3.3.1. Foundation/Ground

However drain ditch is trenched around the structure, it does not work well. The inner part of the under-floor has high humidity, which causes deterioration in the bottom of the column.

3.3.2. Under the floor (Fig. 12)

Under the floor was very humid especially the corner of northeast which is adjacent to the house next door. It is conceivable that deterioration of the base of columns effected by humidity, while both of columns and braces have remarkable harms by ants. Approximately 30 columns have to be replaced because of it. (Fig. 10) As most of them seem to be new members or second-hand members, it is difficult to identify the members initially used.

As for the inclination and unequal settling of the columns, the inspection results have significant disparity. The maximum angle of inclination was 10/100. It is significant that particularly the pilaster columns incline much toward inside, which was caused by the Sumatra earthquake. The values of unequal settlement are also significant, including one as large as 13cm. It seems that the traditional method of column replacement caused the dispersion of deformation.

3.3.3. Space of living (Above the floor)

This is a living area on the raised floor. Significant degradation on the floor was inner inclination of side column and settlement of floor line. The inclinations of the side pillars are inward with 6/100 at the maximum. Regarding the condition of sagging floor, the central part of the hall (front-half of the house) is high, of which maximum value is as much as 16 cm. Also, damages by termites occurred to living space which located back-half of the house. It is considered that the cause for these are not only related to the damage in the under-floor structure, but also due to mutual influence between inclination of the pillars above the floor and floor-sagging.

3.3.4. Roof frame (Fig. 13)

The ridge-height is as high as 23 m from the ground. However the roof had thatched with sago palm leaves, it is currently roofed with steel sheets. These roof trusses and roof members were severely damaged by the Sumatra earthquake. In particular, due to the earthquake, part of the roof members peeled off or had apertures, which resulted to rainwater leakage to decay the roof members. In addition, termites damage has been caused, which requires urgent restoration work.

![Fig. 12 Under the floor](image1)
![Fig. 13 Roof frame](image2)

3.4. Conclusion

Although the form of traditional type remains, we found out the degradation and termite damage everywhere. Proper restoration as replacement of woods is readily necessary. Iron roof, which is more likely to cause high temperature and high humidity compared to roof thatched with sago palm leaves, accelerates deterioration of the roof trusses. It is required to reconsider the traditional technique.

4. MEASUREMENT OF DIMENSIONS

4.1. Purpose

No nails are used for the traditional houses to construct, therefore the detail of joints are important to understand the dynamic characteristics. We conducted the measurement survey to measure the details of joints.
4.2. Methods
We observed omosebua and the general houses (especially house thatched with sago) and recording details or dimensions with using tape measure and laser range finder.

4.3. Results of survey
Fig. 14 shows the parts of common passage which connect two houses of the general houses. The detail of these connections is important to evaluate the coupling effect. (cf. Fig. 11) Fig. 15 shows the joint between columns of under-floor and floor support for both Omosebua and the general houses. The structural condition of joints is mostly used penetrating beams. There are difference in numbers and dimensions of roof frame in each general house. Therefore, it is considered that each house has different natural frequency because of different height and roof materials, indicating that coupling effect would be caused, and response would be reduced during earthquakes. Further inspection would be needed.

Fig. 14 Connection between houses

Fig. 15 Joint of column and floor support [2]

5. CONCLUDING REMARKS
As a result of micro-tremor measurement, the natural frequency of traditional houses in Nias are close to Japanese traditional wooden houses. Furthermore, most of those houses survived against the past earthquakes. These two facts indicate that they have considerable earthquake resistant capacity. However, we found rigidity distribution of height is irregular. Moreover, the traditional houses have tilting that was caused by the earthquakes or aging deterioration. Such two structural problem would reduce earthquake resistant capacity of traditional houses. Our survey suggests that the traditional houses should be structurally restored.
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