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PROTECTING BAMBOO COLUMN FROM HUMIDITY WITH POROUS PEDESTAL FOUNDATION. CASE STUDY OF SUDIMORO, MUNTILAN, CENTRAL JAVA, INDONESIA

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ABSTRACT

Bamboo has been used for a long time as a material for simple to complex structures. Many advantages of bamboo as a building material makes it suitable for buildings in disaster-prone areas. Bamboo is however prone to humidity, which could cause fungi and moss to emerge and endanger the building structure. Pedestal foundation made of concrete or stone is often used to reduce this risk as for its action as a barrier of direct contact between soil and bamboo. Nevertheless, water from damp soil or rainwater can still penetrate the foundation by capillary transmission through the foundation's pores. This research proposed a hollow pedestal foundation model with larger pores and compared its ability to reduce moisture on bamboo columns to an ordinary pedestal foundation. The case study is a temporary post-disaster housing project of 13 houses in Muntilan, Central Java, Indonesia, which was built on an active rice field. Visual examination showed that after 5 years of occupancy, bamboo houses built on hollow pedestal foundations still firmly stood without apparent attacks of fungi or overgrowing mold, whereas the moisture measurement showed that the usage of hollow pedestal foundation could reduce the humidity level in the bamboo column almost twice as fast compared to solid pedestal foundation.

Keywords: Bamboo columns; concrete foundation; hollow pedestal.

INTRODUCTION

Bamboo as a Prominent Building Material in Indonesia

Countries located nearby the equatorial line are accustomed to a hot and humid climate, with an average temperature of 32.2° C and high atmospheric pressure (D.K. Ching, 1975). Indonesia, also an equatorial country, has a tropical wet climate affected by monsoon winds. This climate features wet and dry seasons with fluctuating rainfall rate in both seasons and general relative humidity above 80% (Smith, 1973).

One of the commonly used materials for building construction in this area is bamboo. Besides its abundance in nature, it can also be used as a permanent structure (D.K. Ching, 1975). Other advantages of using bamboo as a building material are its mechanical characteristics, flexibility, fast growth rate, low mass, and low price (Mangunwijaya, 1997). It is expected that a billion people live in bamboo homes worldwide (UPT Woodworking Center, 2012). Bamboo is also a preferred material for disaster-prone areas due to its lightness and flexibility (Mangunwijaya, 1997). A bamboo pavilion exhibited in World EXPO 2010 in Shanghai showed the international recognition of bamboo as a high-performance building material with a small ecological footprint, thus suitable for sustainable buildings (Mangunwijaya, 1997).

However, as a natural material, bamboo contains a fair percentage of starch, which poses danger as insects could consume its timber. Bamboo is also prone to humidity, which could cause fungi and moss to emerge. Due to this reason, bamboo couldn't be used as foundation material as it is easily rotten when directly exposed to soil moisture (Frick, 2004).

Bamboo has been used for a long time as material for simple to complex structures. Sacred elements/ parts of traditional buildings in Asia and America were also found to be made from bamboo (Mangunwijaya, 1997).

In Indonesia, bamboo could be found in several traditional buildings. In Sumbawa traditional house, the house column was made of bamboo, supported by a stone pedestal. Bamboo was also used as a roof truss. Bamboo can also be found as building wall and column in Bale Kodong, a type of traditional house in Lombok. Here, bamboo as the column is also supported by a stone pedestal (Frick, 2004).

Pedestal Foundation Used for Bamboo Buildings

A pedestal foundation is a compression element which carries the loads from supported elements like columns, statues, etc. to footing below the ground (Sudarwanto & Murtomo, 2012). Besides carrying the load, pedestals are provided to avoid direct contact between soil and metal elements or wood elements as they may easily be affected by the moisture conditions of soil and result in corrosion or weathering.

A traditional pedestal foundation has the majority of its parts placed above the ground. In traditional buildings of Indonesia such as in the Sumatran Batak area (e.g. Minangkabau, Toraja, Nias), traditional pedestals can still be found in its original form made of natural stone. In general, people create pedestals from stone and carve them into a trapezoid-like shape to give bigger strength and reduce buckling (Sudarwanto & Murtomo, 2012). In some areas such as Kudus, Wonogiri, and Wonosari, pedestals are made of hardwood such as teak. Nevertheless, more pedestal variations have developed over the years and now pedestals made of concrete are more popular. More pedestal shapes are also known, such as cylindrical, round, multilevel balloons and so on.

Humidity Problems and Theory

In locations where water is inundating or in open areas with high rainfall rate, buildings usually use a solid, above-the-ground foundation to distance it from the highest water level. However, many building materials for foundation, such as natural stones and many artificial construction materials (bricks, mortar, concrete, etc.) are generally composed of a certain volume of empty space in the form of pores, cavities, and cracks of various shapes and sizes (Borelli, 1999). This means that water can still reach through building material by the capillary rise of ground moisture, rain, and condensation of air humidity (Arnold, 1982).

When the rain comes, water actually came into contact, was being absorbed, and then stored at the base of the solid foundation. When the rain stops, water from the base continues to climb up through the pores of the foundation by the principal of capillary force. This condition is less favorable for wood or bamboo poles above the foundation which are susceptible to fungi and insect attack. Fungi will start growing when the moisture rate of the wood exceeds 20% (Suranto, 2002).

Ioannou et al. (2009) tried to model the capillary water absorption behavior of porous limestone using different liquids. They observed that the large pore structure reduces the capillary water absorption ability in contrast with to small pore structure.

Due to the prominence of bamboo-based structure in many tropical countries and beyond, it is important to understand how to increase bamboo’s durability as a building material upon an area with a high level of soil moisture. This research proposed a pedestal foundation model with larger pores and explored its ability to reduce moisture on bamboo columns. One of the means to do so is by experimenting with a ‘hollow’ pedestal, which was filled by medium-sized (2-3 cm) gravel, thus implementing the theory of ‘larger’ pore size to reduce capillary water absorption.

The case study for the research is a temporary post-disaster housing project of 13 houses in Sudimoro village of Muntilan Regency, Central Java, Indonesia. All houses which were built on an active rice field and used the hollow pedestal foundation model. Their durability has already been tested on a real-life condition. Visual examination and bamboo column moisture measurement were carried out to determine the moisture-reducing efficiency of the proposed model relative to the widely used solid pedestal foundation.

CASE STUDY: HOLLOW PEDESTAL FOUNDATION FOR TEMPORARY HOUSING

Post-disaster Condition of Sudimoro, Muntilan

This research was conducted on a bamboo house that has been constructed since 2011 in Sudimoro village, Muntilan sub-district, Central Java province, Indonesia. The cold lava flood from Mt. Merapi's eruption in 2010 has wiped away houses and villages around the area and brought to the surface the immediate need for relocation. One proposed location was an active rice field, which would be used again after the temporary relocation period (approximately 5 years) ended. In order to not disturb the fine irrigation system of the rice field, the temporary houses would be elevated. Bamboo was used as the main material for its easy construction and high availability. The temporary elevated houses could be constructed in over 3 months only, and mainframes for a single house could be constructed in 2 days. Documentation of the temporary housing complex could be seen in Figure 1.

The presence of water puddles in rice fields in addition to high rainfall rate was an obstacle to the durability of bamboo-based housing. The solid pedestal foundation would still likely transmit humidity to the bamboo; therefore, a different prototype of pedestal foundation was proposed for this project in an attempt to reduce direct contact of bamboo columns and the wet soil and the capillary water movement.

Fig. 1. Bamboo Temporary Housing Complex using Hollow Pedestal

Fig. 2. Hollow Pedestal Foundation Construction Process and Placement on the Site

Fig. 3. Hollow Pedestal Foundation Before and After the Bamboo Column was Put on top

Construction of the Hollow Pedestal

The temporary housing facility needed to be built in a rapid process, which required the building materials to come from easily obtained sources, for example, bamboo as the main structure and walls, and metal roof plates for the roofing. A common concrete sewer pipe with a diameter of 20 cm and a length of 100 cm was selected as the prototype for the hollow pedestal foundation. Documentation of the construction of the hollow pedestal is provided in Figure 2. Furthermore, illustration on the pedestal before and after it was put in connection with the bamboo column is seen in Figure 3.

In details, the pipe was divided into two parts, resulting in 50 cm length of each pedestal model. The hollow part of the concrete pipe was filled with gravel or split stones 2-3 cm in size. The gravel and stone filling were pressed and compacted so that it could firmly withstand the load of the building. The compaction process was done without additional cement or other binding material in between. This was done to maintain the cavities between the gravels and fillings and reduce the capillary absorption ability of the foundation.

Then, the 50 cm long pipe was put with buried 20 cm deep below the ground. The remaining 30 cm could be seen above the ground. The bamboo column was put on the top end of the pedestal. In the rainy season, the water level would to about 20 cm from the ground, leaving a 10 cm distance between the bamboo column and the highest water surface level. In this condition, there was still a remaining distance between the bamboo and the water. It is important to keep the bamboo as least humid as possible, as by maintaining bamboo's humidity at below 20%, the destructive fungus' growth will be halted (Suranto, 2002). Illustration on these details is provided in Figure 4.

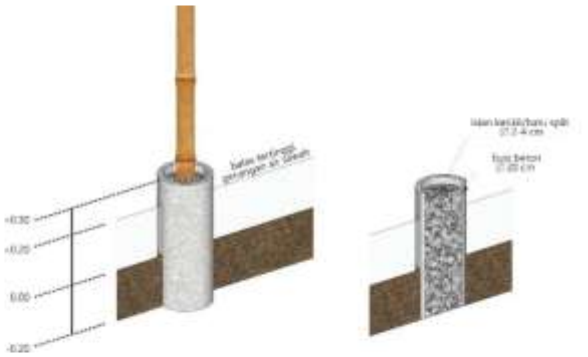

Fig. 4. Cross-section of the hollow pedestal foundation (right).

Comparative Solid Pedestal Model

In this study, a solid pedestal model was needed as a comparison to measure the ability of the hollow pedestal in lowering the moisture to the safe limit. The comparison model was made by modifying the hollow model by adding an additional layer of plate rock with the same altitude (30 cm) from the ground, changing the previously hollow pedestal into a solid one. Illustration of this modification is provided in Figure 5.

To get the drying speed measurement result, a surface wetting test was carried out. Each sample was moistened with the same volume of water in the same section and height of the bamboo column. The results of the measurement of drying speed of the bamboo above the pedestals would then be compared to each other, to determine the ability of hollow pedestal foundation to maintain the humidity level of the column it supported. This humidity measurement used the GANN HT-85-T humidity gauge. Before the measurement day, the location has been showered by rain, which has influenced the humidity level of the columns. Measurement of bamboo moisture was carried out at three points, namely at the top, middle, and bottom parts of it.

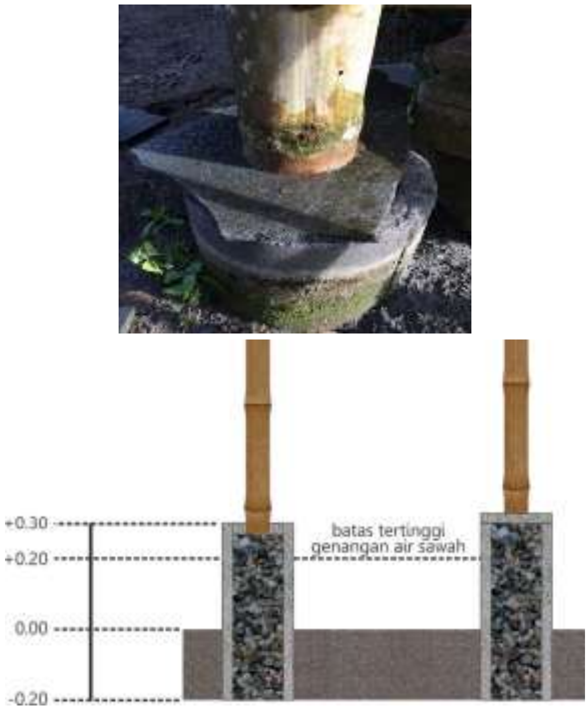

Fig. 5. Solid Pedestal as Comparison Model (left). Cross-Section of Hollow Pedestal and Solid Pedestal (right).

RESULT AND DISCUSSION

Visual Examination

The hollow sewer pipe was made from a mixture of cement and sand. The small pores of the concrete material allowed groundwater seepage from the bottom towards the top. The seepage left visible traces of fungus and moss at the pedestal, as seen in Figure 6. The results of the visual examination showed that the water seepage infiltrated the pedestal up to the upper surface. The traces of seepage, however, wasn't visible in the gravel filling. The surface of the gravel and the bamboo pole which came into contact with the gravel was dry.

Fig. 6. Growing Moss on Hollow Pedestal

Moisture Measurement Before Additional Treatment of Wetting

The results of moisture measurement of bamboo columns on top of a hollow pedestal without any additional treatment can be seen in Table 1 below. There were three measurement points: top, middle, and bottom for each sample. The measurement results in several samples showed different humidity values. This could happen because bamboo materials have different fiber density values, even in different stems of the same tree. Table 1 showed that the lowest moisture level was found at the top of the bamboo column. The top part of bamboo column had the least contact with water seepage; therefore, it could be said that in normal condition (relative humidity in the air: 80%), the material moisture was around 16 to 18 M%.

Table 1. Result of Moisture Measurement (in M%)

Measurement points	Bamboo column on hollow pedestals			Average value
	1	2	3	
Top	17.0	18.0	19.9	18.3
Middle	17.2	20.9	22.8	20.3
Bottom	17.4	24.9	29.3	23.7

The measurement result provided a data that most parts of the bamboo column on the hollow pedestal foundation model were located within the safe humidity limit of 20%, even though the pedestal was located on wet soil. In reality, almost no fungi could be seen on the columns for 6 years since its construction time.

Moisture Measurement after Additional Treatment of Wetting

The moisture measurement result on hollow and solid pedestal foundations after additional wetting treatment can be seen in Table 2.

Table 2. Result of Moisture Measurement after Wetting (in M%)

Measurement points		Measurement time			
		16.30	17.00	17.30	18.00
Solid pedestal foundation	Top	20.1	20.0	19.7	18.9
	Middle	21.9	20.8	20.7	20.4
	Bottom	73.7	66.8	63.9	59.3
Hollow pedestal foundation	Top	20.5	20.3	19.8	19.5
	Middle	22.7	21.9	21.7	21.5
	Bottom	72.1	50.7	48.7	41.2

From the table, it could be seen that after the treatment, moisture level at each section of the samples increased. However, the bottom part of the columns had a specifically high increase of moisture levels to above 70% as the water was sprayed on the pedestals only, thus affecting the bottom part more than the middle or top parts. Therefore, the following analysis would focus on the change of moisture at the bottom parts of the bamboo column.

In the first 30 minutes interval after the wetting treatment, the different speed of moisture decreased between the bottom part on the solid pedestal foundation and the hollow pedestal foundation became apparent. At 17.00, the moisture level of the column's bottom part on the solid pedestal foundation was 66.8%, 6.9% less from the initial measurement. Meanwhile, the moisture level of the column's bottom part on the hollow pedestal foundation was 66.8%, 21.4% less from the initial measurement. After 90 minutes, the moisture level of the column's bottom part on the solid pedestal foundation was 59.3 %, 14.4% less from the initial measurement at 16.30. On the other hand, the moisture level of the column's bottom part on the hollow pedestal foundation was 41.2 %, 30.9% less from the initial measurement at 16.30.

CONCLUSION

Since it was constructed in 2011, the bamboo-based temporary housing facility in Sudimoro, Muntilan, Central Java was still firmly standing, without considerable disturbance from mushroom, termites or other pests. The proposed hollow pedestal model which consisted of compacted gravels was indeed able to support the bamboo columns above it. Its simple construction could also be dismantled without leaving much waste, resulting in less environmental pollution.

The same compacted gravel which was the core idea of hollow pedestal foundation was proven effective to maintain the moisture level of the tested bamboo column at the safe level. Even though the pedestal was overgrown by moss and fungi, the gravel compound inside it was kept dry. This indicated that the concrete material with small pores became an appropriate medium for water absorption through the capillary method. On the other hand, the gravel compound of hollow pedestal foundation had larger pores, thus prevented the water absorption process from the bottom up and as a result protected the bamboo column above it.

The measurement and analysis results showed that in 90 minutes after wetting, the hollow pedestal model was able to reduce bamboo moisture from 72.1% to 41.2%, while the solid pedestal model was only able to reduce bamboo moisture from 73.7% to 59.3%. From this result, it could be said that the moisture level on the bottom part of bamboo columns supported by hollow pedestal foundation decreased twice as fast as those supported by solid pedestal foundation.

Finally, findings in this research revealed the potential of hollow pedestal foundation in reducing the moisture of structure above it, which is substantial especially for structures built on damp or wetland. Future research could be focused on improving the effectiveness of the pedestal and formulating optimal dimension of the foundation model to increase the sustainable value of the foundation.

Patent

The work from this research resulted in a registered patent as follows:

Patent registration number: P00201304548

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Patent type: Paten Sederhana */ simple patent*

Patent issue authority: The Ministry of Law and Human Rights, Republic of Indonesia

Patent holder: UNIVERSITAS GADJAH MADA, LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT (LPPM), Kantor Pusat Pelayanan HaKI UGM, Lt. III Sayap Selatan, Bulaksumur, Yogyakarta, Indonesia

Invention name: Umpak Berongga

Inventor name: Dr.-Ing. Ir. Eugenius Pradipto

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