Technological Contexts in Developing Bamboo Wall System for Housing in Indonesia and Philippines

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Abstract. The development of bamboo wall technology for housing depends on its technological context. Reviews on a number of literatures indicated that there are some major issues about bamboo wall technology such as: construction technology, performance of construction materials, strength and durability of components and building systems. The aims of developing the technologies could be defined such as: post-disaster conditions, affordable housing, wind and earthquake resistance, weather and climate resistance. This paper will discuss about the comparison of several approaches in building bamboo wall technology in Indonesia and Philippines. In Philippines, the building technology must have optimum resistance to both typhoons and earthquakes, while in Indonesia the building must have good resistance against earthquakes. Both have a big challenge in promoting social status and long durability.

1. Introduction
1.1 Why Bamboo?
In South East Asia, bamboo has always been a readily used material. In Bangladesh and Burma, there are enormous numbers of bamboo houses with about 70% [1]. In 2003, Indonesia Agricultural Census indicates that in Indonesia there are about 4.73 million households that harvest bamboo crops for about of 37.93 million families or an average of household control of 8.03 clumps [2]. This is a potential resource to utilize bamboo as a building material and construction.

Commonly regarded as a poor man’s timber, it is a no surprise that this green grass has been used since ages. Bamboo has been able to provide shelter for families, livelihood for craftsmen and food for rural regions [3]. Bamboo is a fast-growing renewable resource [3]. With only 3-5 years to fully mature, this sustainable material has no supply problems and can be harvested readily for building material use, not like timber that needs 10-20 years for maturity. The biggest advantage of this material is that it is very cheap and in some cases free. In rural areas, even wild bamboo that is available in rural banks can be used as a building material. This allows bamboo to be harvested, carried, transferred and stored easily anywhere which saves more time and labour costs. Bamboo is easy to cut, handle and repair without the use of any sophisticated tools and it is suitable for all types of building structures and construction. Its hollow sections make bamboo a lightweight material more than any modern material today [4].
1.2 Why Plastered Bamboo Housing?

A document published by the International Strategy for Disaster Reduction (ISDR) identified four phases of shelter recovery transitions [5]. These are:

1. **Spontaneous Shelter** - This provides an interim, safe haven while the situation stabilizes. This applies in the first 72 hours.
2. **Emergency Shelter** - This provides emergency shelter and feeding to displaced populations requiring shelter. This happens in the first 60 days.
3. **Interim Housing** - This provides temporary or transitional housing with safe and secure shelter, water and power to displaced disaster victims while efforts are underway to make permanent repairs to dwelling or find other suitable permanent housing. This phase happens one year after the disaster and goes beyond.
4. **Permanent Housing** - This provides long-term, permanent housing solutions for disaster victims.

The aim is to create an upgradable housing solution from interim or transitional to permanent and durable. This can be achieved by using plastered bamboo housing construction that was originally from Colombia known as *bahareque encementado*. In Colombian construction code, it is defined as a system composed of Guadua bamboo or Guadua bamboo & timber skeleton, and a sheathing of riven Guadua estrilla boards nailed to the skeleton and covered with a cement render applied over steel mesh. According to Andry Widyowijatnoko, an Indonesian architect who has been promoting plastered bamboo housing construction said [6]:

“The development of plastered bamboo construction was also to provide a better concept of housing in emergency cases. With the prefabricated bamboo panel that could be made and stored long before disaster occurred, the quick response building can be built in a day after disaster to provide emergency shelter to the victims and can be plastered gradually on their own to become permanent.”

2. Bahareque Wall System

2.1 What Is Bahareque Wall System?

*Baharaque* is a construction technique refers to a mixed timber, bamboo, mud and or cement-mortar wall construction technique that originated in Colombia. Houses are built with a concrete base; bamboo frames with woven walls are plastered with mud or cement-mortar to create a permanent shelter. This traditional bamboo architecture not only protects the bamboo within the wall, it also improves the appearance and quality of houses specially when they are plastered and painted. The term bahareque has no precise equivalent in English. In Peru and Chile, this type of construction is called *quinca*.

2.2 Classifications of Bahareque

There are two types of *bahareque* wall construction system, hollow and solid type. Although these two have different building methodologies, they have the same skeletal framing. The framework can be made of wooden studs, wooden braces or bamboo wooden grid with bamboo strips.

2.2.1 Hollow Type

Hollow type *bahareque* is the oldest type and was used before the Spaniards conquered Colombia. These walls have a timber or bamboo frame as wall base with flattened bamboo on both sides while hollow in the middle then covered with plaster on both sides.

Using flattened bamboo or locally known as *estrilla* in Colombia, there are two types of sub classification in hollow type *bahareque* namely: single skin which is plastered only on the exterior for moisture control and extreme weather conditions while the interior is barely exposed and double skin wherein both side are plastered. Due to its hollowness of the wall it creates an air gap in between
stabilizing the air temperature in the interior. This lowers the temperature inside the house which creates a more desirable thermal comfort for human environment.

2.2.2 Solid Type

Solid type bahareque is the second type with a lot of variant woven techniques depending on what country it is made. These walls have a timber or bamboo frame with woven split bamboo covered with plaster on both sides.

Solid type bahareque has two sub classifications these are: bamboo split both horizontal strip and vertical strip which are interlaced alternatively to create a rigid reinforcement for the plaster on both sides and bamboo woven mat which are divided into bi-axial weave, tri-axial weave and multi-axial weave. Bamboo woven mat uses flattened bamboo interwoven in two, three or more directions. Unlike hollow type, this variation creates a more rigid wall system that can be used as structural load bearing member.

| Table 1. Classifications of Bahareque |
|--------------------------------------|
| Type                  | Sub type                      |
| Hollow Type           | Flattened Bamboo             |
|                       | • Single Skin                 |
|                       | • Double Skin                 |
| Solid Type            | Bamboo Split                 |
|                       | • Horizontal                  |
|                       | Bamboo Woven Mat             |
|                       | • Bi-axial                    |
|                       | • Tri-Axial                   |
|                       | • Multi-Axial                 |

2.3 Components of Bahareque

Bahareque wall construction system is composed with three components, namely; weaving patterns, wall framings and plaster composition. These three components are dependent from each other and can directly affect the structural durability of the shelter. Bahareque buildings are characterized by high flexibility when carefully constructed and well-maintained.

2.3.1 Weaving Pattern

Weaving Patterns are only applied on the second kind of bahareque wall, solid-type. Different weaving patterns have developed from vernacular architecture and traditional cultures have been documented from many studies. All these variety can be classified into three kinds; Bi-axial Weave, Tri-axial Weave and Multi-directional Weave. Bi-Axial weave consist of two directional axes arranged in horizontal and vertical patterns. Tri-Axial weave adds one more axis diagonally creating three directional axis which can be horizontal-based or vertical-based diagonal. Multi-directional weave consists of four or more axes which gives the pattern a complex design.

2.3.2 Plaster Composition

Plaster Compositions may vary from different countries but most common types mainly consists of cement. A cement plaster is a mixture of sand, Portland cement and water which is applied as masonry for interiors and exteriors to create a smooth surface finish. Some plasters use gypsum also known as plaster of Paris and some use a more natural approach made of lime. Lime plaster consists of sand, water and lime. Compared to cement plaster, lime plaster is more elastic and cracks much less,
requiring no expansion joints [8]. Compared to gypsum plaster also, lime plaster is more durable and more resistant to natural elements [8].

2.3.3 Wall Framing
Wall Framings are divided into four types: no bracing, vertical bracing, horizontal bracing and diagonal bracing. These are the basic configurations in wall system and the most practical shape in terms of building construction. Wall Framings are the framing system that holds the walls enclosure by using vertical or horizontal wall studs and or a combination of both. One important factor in wall framings is the bracing system because it holds and strengthens the stud to counter-act any structural load applied to it. These can be structural (load bearing wall) or non-structural (non-load bearing walls).

| Table 2. Components of Bahareque |
|-------------------------------|-------------------------------|
| Components                    | Sub-components                |
| Weaving Pattern               | Bi-Axial                      |
|                               | Tri-Axial                     |
|                               | Multi-Axial                   |
| Plaster Composition           | Binding Agent                 |
|                               | • Cement                      |
|                               | • Lime                        |
|                               | • Clay                        |
|                               | Structural Filler             |
|                               | • Sand                        |
|                               | Additive Fiber                |
|                               | • Animal hair                 |
|                               | • Rice husk/coir              |
|                               | • Coco huck/coir              |
|                               | • Hemp                        |
|                               | • Water                       |
| Wall Framing                  | No Bracing                    |
|                               | Vertical Bracing              |
|                               | Horizontal Bracing            |
|                               | Diagonal Bracing              |

3. Comparing Indonesia and Philippines

3.1 Bamboo Species
Most common species used by local carpenters and craftsmen in Indonesia are *Dendrocalamus latiflorus* (*bambu wulung*), *Dendrocalamus asper* (*bamboo petung*), *Gigantocloa pseudoarundinacea* (*bamboo gombong*) and *Gigantocloa atroviolacea* (*bamboo hitam*). With the wide variety of bamboo species to choose from, Indonesian artisans have explored various combinations of these species in building construction. Meanwhile in Philippines, the most common and readily available bamboo specie nationwide is *Bambusa blumeana* (*kawayang tintik*). In some regions like Mindanao, located in the southern part of the country, *Dendrocalamus asper* (*kawayang apos*) and *Dendrocalamus latiflorus* (*kawayang buho*) are abundant and used.

Comparing both countries, Indonesia has better and more bamboo specie selection that can be used in building construction. Each bamboo species have different set of physical and mechanical properties. And since Indonesian has a wide variety of bamboos to choose from, they can explore more possible combinations in bamboo construction.
3.2 Plastered Bamboo Housing
Colonial Dutch era in Indonesia introduced this kind of method in the past and is still continued to be used up until today. Many new architects in Indonesia have constructed several plastered bamboo housing in Indonesia for the past few years. Dr.-Ing. Andry Widjowijatnoko has built housing projects using bahareque wall system. To name a few these are [7]:

a. The Prototype House in di Pasir Impun, Bandung, West Java;
b. The Earthquake Refugee’s House in Sukabumi West Java;
c. The Plastered-Bamboo Wall Prototype in Environmental Bamboo Foundation, Bali;
d. The Community Learning Centre in Jatinangor, Sumedang, West Java;
e. And the Community Centre in Nagalawan, North Sumatera.

Most plastered bamboo wall systems are found in old churches that were built by the Spaniards during colonial era using a modified version of the bahareque wall. Tabique pampango as it is called in Philippines; a walling technique made of bamboo woven mat plastered with lime plaster said to be of crushed seashells mixed with molasses and egg white. Unfortunately, today fewer architects use this construction method in housing projects due to preferable conventional construction.

3.3 Disaster
The entire archipelago of Indonesia sits on the Pacific Ring of Fire and is considered as the most active seismic region in the world with approximately hundreds of active volcanoes. Due to this fact, Indonesians have high seismic activity that causes earthquakes, volcanic eruptions and tsunamis. Indonesian architecture, specifically traditional houses, adapted to these catastrophes and has been improving their structural quality for earthquake resistance over the past decades.

Philippines, on the other hand, are more exposed to tropical storms with approximately twenty tropical cyclones hit the archipelago annually. In rainy season months, June to September, are the most active months for typhoons. With this, Philippine architecture, have relied on heavy roof structures with low eaves to survive strong wind currents. Due to this fact, Philippines have huge difficulty in building wide roof structures like the bamboo architecture in Bali, Indonesia.

4. Conclusion
Indonesia and Philippines are two archipelagic countries located in tropical areas of South East Asia. Seemingly, these two nations sit on the bamboo belt of the world where Asia is considered as the richest continent of bamboos. It is no surprise that traditional and vernacular architecture used bamboo to build their houses. Bamboo construction is easy to harvest, transport, use and build. It is strong enough to resist wind and flexible enough to conform to seismic forces. Both nations are also exposed to active natural calamities that wreak havoc and destruction for thousands of inhabitants e.g. Indonesia with earthquakes and Philippines with typhoons.

Bamboo is still perceived as a “poor man’s timber” by many people. However, this perception can be changed by continually using bamboo in modern architectural design context and by conducting conference and seminars in academic sectors and as well as hands-on trainings and workshops in the communities.

Although, Philippines is behind Indonesia in terms of bamboo architecture, both countries can learn from each other through comparison and contrast of bamboo wall system of bahareque. This can be achieved by international collaboration between two countries through applied research and joint projects not just by professional architects but also by local artisans and craftsmen in the community. The author believes that this humble plant can unite not just Indonesia and Philippines but as well as the South East Asia and the world.
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