Flexible architecture: bamboo as a tool for children to play in urban kampung

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Abstract. Due to the dense population and increase of development, urban kampung in Indonesia is facing a problem of limited children's play spaces. Flexible architecture with its movable principle is expected to be a solution by creating children's playing tool that is built among the dense urban kampung. Bamboo is the staple material because it is local, able to regenerate quickly, lightweight, and affordable. By using the exploratory method, this research tries to reveal the previously hidden aspects by evaluating all processes of design-build of three created children's playing tools. These playing tools can be built in the kampung after three processes of apart-and-reassemble. However, there are several questions which need to be discussed further; the right configuration between the component and the joint of the bamboo, to make apart-and-reassemble process more effective in a dense urban kampung, and also how to make bamboo's structure able to survive better under rainy seasons and surface humidity.

1. Background

An urban kampung is a form of urban settlement which is found in Indonesia. *According to Harjoko (2013), kampung as a noun refers to a settlement in a village. In contemporary meanings, the word kampung also refers to a settlement in the city that has similar physical charateristics to those in a village. In this sense, it also refers to densely populated urban settlement with poor infrastructure and sanitation. The word kampung is also to refer to squatter settlement. This latter type usually occupies marginal land, such as along riverbanks, railway lines, and abandoned private land, including land owned by the government* [1]. In general, urban kampung is characterized as a densely populated settlement which does not leave enough space nor have proper infrastructure, that is occupied by middle-to-low class society with strong social bond and higher communal activities. However, nowadays urban kampung is facing a complicated problem which is the lack of public open space. The lack of public open space in kampung as a place for communal activities and children's play area is due to massive construction as a result of growing number of population. In consequence, public open space left is the narrow alley or the temporary lot [2]. Therefore, accurate approach and design solution are needed to solve this problem.

Flexible architecture is an approach of architecture which can accommodate human's need to move, be mobile, change and adapt. One principle in flexible architecture is movability, which is the ability to build a building in one location without being permanent so that it can be moved to another location.*Kronenburg (2007) stated that facilities that once had to be provided in a fixed location in order to operate can, and in some cases must, be provided in different places in order to work effectively* [3].Facing the limited temporary space problem, this flexible architecture especially the one related to movability is considered accurate to be applied in design-build of public facilities in urban kampung. Movable children's playing tool can be easily moved to another location anytime if the location is needed.Bamboo is one of local materials which is recently "back in business" and popular in any usage. As a local material in Indonesia, it has several advantages such as:light-weight, easy to get, affordable and (has) unique feature. When planting, it also releases oxygen into the air, the ability that cannot be

performed by other materials like steel, plastic and concrete. For the reasons, bamboo has been widely known as sustainable building materials [4] [5] [2]. Previous research indicated that structures which use bamboo material are highly resistant to earthquake and storm [6]. These advantages hypothetically make it ideal for flexible architecture material which is applicable in urban kampung. Sukmo et al (2015) through case-design study method stated that bamboo is the right material public space adaptive design at alleys in urban kampung [2]. Unfortunately, in that study, the bamboo stated was not really placed inside the kampung. It is concluded from secondary analysis of bamboo's property, construction, and cost value. Therefore, it needs more proof (*I suggest: examination or pengujian rather than pembuktian*) of the real usage of bamboo in narrow spaces in urban kampung. For this reason, by using exploratory approach, this study is conducted to gain deeper understanding of the usage of bamboo for flexible architecture material in urban kampung.

2. Theoretical Review

One reason why flexible architecture exists is due to the necessity which comes from outside of human body. Kronenburg (2007) stated that*The requirement for flexibility stems not just from desire and possibility, but also from necessity* [3]. *Since human kind first came into existence we have been nomadic creatures, leading lives that are closely bound to the movement of the wild animals that fed and clothed us, moving with seasons, transporting light-weight, mobile, multi-use home-made tools (including buildings) with man* [3]. From this context, the movability principle exists as a form or derivative concept of flexible architecture. *Movable buildings can be defined as buildings specifically designed to move from place to place so that they can fulfill their function better. In some cases mobility is absolutely necessary for them to fulfil their function at all. A building designed for responsive living, during its occupation, might be moved from one place to another or changed in shape or structure — the walls might fold; floors shift; staircases extend; lighting, colours and surface textures metamorphose. Parts of the building could extend or even leave the site completely, or the entire facility could roll, float or fly to a different location* [3].

According to Kronenburg (2007) there are three methods to create movable building. They are: (1) portable methode, (2) demountable methode and (3) modular system. *Portable Methode is to transport building in one piece. It is the most straightforward strategy for moving a building. This 'portable' method has the clear advantage of the building being almost instantly available for use once it arrives at its new location. Demountable methode is to transport a building in limited number of dedicated parts, and then quickly assembled on it places no limit on the size of the finished building or its geographical location. The downside of this method is that the building will not be in use as quickly as a portable type and its deployment process, as well as being slower, will also be more costly* [3]. Modular System / a componentized system, is where the building is transported in a form of smallest modular units. Variety of use of the three methods is vastly used in architecture field with its advantages and disadvantages. However, some previous researches said that the application of flexible architecture principle will gain advantages in several aspects. Schenider (2005) at least stated that application of flexible principle in housing design (flexible housing) is financially beneficial in long term [7].

Bamboo is a building material that is generally used for traditional construction in Southeast Asia. Today, there have been found at least 700 types of bamboo in the world, where half of them are found in Southeast Asia. This material is basically a giant grass that comes from sub family *bambusoideae* and family *Poaceae* or *Gramineae*.Physical characteristics of bamboo which has cavity inside it, tubular form and segments on its stem make it has ideal physical strength for building construction. In the current trials of tensile strength, bamboo surprisingly outperforms most of other materials, even reinforcement steel [6]. However, it does not mean that it does not have weaknesses. In general, this material is less durable than wood. The lifetime of an untreated bamboo can vary between 1 and 15 years depending on conditions, depending on variety [5]. This material can be more durable if it is built upon dry/non-humid land surface. Not only that, making joints in bamboo is rather difficult because bamboo is hollow, tapered, has nodes at varying distances and it is not perfectly circular [8]. Although it has many weaknesses, many literatures mention that, with right construction technique and design,

those problems can be solved. In other words, the use of bamboo as flexible architecture material in urban kampung is supposed to be conducted well.

3. Method

As it has been explained before, bamboo is a potential material for flexible architecture construction, but until today there have been no empirical research which states that the construction is ideal to be used in dense and narrow environment like urban kampung. Lacking preliminary data, this research uses exploratory approach. The exploratory approach is ideal to be used in research with lack of preliminary data or even no previous researches [9]. The aim of exploratory research is to identify the boundaries of the environment in which the problems, opportunities or situations of interest are likely to reside, and to identify the salient factors or variables that might be found there and be of relevance to the research [9]. In this study, several flexible architecture products made of bamboos are designed and built to be placed in a real location which is a dense urban kampung located in Kelurahan Tugu Cimanggis, Depok City. Based on observation and interview towards several respondents, this kampung is lacking proper playing facilities that makes it suitable to be flexible architecture bamboo products placement object.

Design of flexible architecture products in this kampung was conducted by the students of Tectonic Architecture subject in Architecture Department of University of Indonesia. Design was made adjusting the surface condition and residents need of play space which was gained through limited interview. The design was made into a realistic form by the students and skilled craftsmen. These flexible architecture products made of bamboo were then testified through the three-time apart-and-reassemble process, which the last reassembly was done in Kampung Kelurahan Tugu Cimanggis, Depok City.The aim of this exploratory study is not to discover whether the products will be succeeded or not, but more to identify the variables related to the whole process. These variables will be the primary data for the next researches. The limitation of this study is the discussion which focuses only on technology aspect related to the bamboo material as flexible architecture products.

4. Process

4.1. Joint exploration

The flexible and movable architecture principle is used as a main reference in designing. With concerns on the current condition of urban kampung which are generally narrow and have difficult access to transportation, the type of joint which will be discussed in this paper is the knock-down joint. The knock-down system is closely related to how to compose and connect the partial parts to become a whole unity. Thus, it is crucial for students to have a complete understanding on joints in designing. In this paper, exploration on bamboo joints is conducted using a PVC (Polyvinyl Chloride) pipe which functions as a substitute material for the bamboo. The PVC pipe was chosen as a substitute material due to its similarity to the bamboo in terms of characteristics where both materials are cylindric in shape with a hollow in the middle section. The type of joints discussed in this study will correspond to those presented by Heinz Frick (2004) which is divided into two categories: peg joint and bonded joint [10]. The objective of this stage is to provide students with the opportunity to fully comprehend both the pros and cons of each joint.

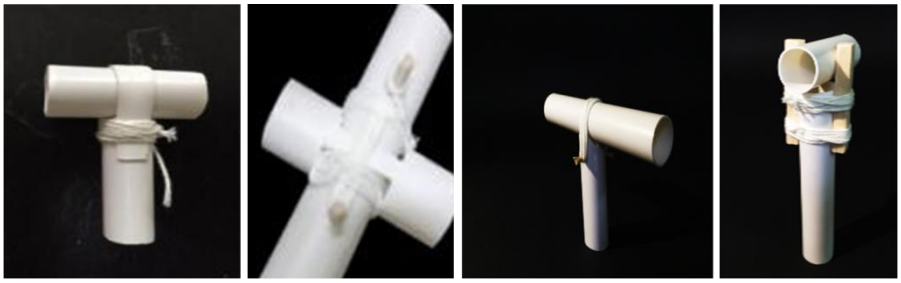

Figure 1. several variations of peg joints and bonded joints using PVC pipe as a substitute material

The various types of basic joints are then developed into advanced joints using bamboo as its material, while the type of joint still uses the same peg and bonded joints. The strength of these joints is tested using several different human-loads as the main source coming from several different angles and directions. The main concern on these manual testing is the potential cracks formed on the bamboo.

Figure 2. Documentation of the testing and evaluation process on the bamboo joints

4.2 Design in accordance to the context of kampung

The next phase is the design development of children's playground. The design created for the playground will be based on the context of the kampung site along with the types of joints which have been discussed in the previous stage. There are three different designs generated in this phase which are *Kakuna, Bambooklung*, and *Monkeyboo*. Each of these designs are located in three different sites with each functioning differently and having different constructions (see table 1). With the flexible architecture which is movable in urban kampung as their main principle, each and every one of the three designs are constructed into several separate segments which will be convenient to move in narrow areas around the urban kampung.

Figure 3. Computer illustration of *Monkeyboo* (left), *Kakuna* (middle), and *Bambooklung* (right)

Table 1. Table of comparison on the design of *Monkeyboo, Kakuna,* and *Bambooklung.*

Design	Function	Site morphology of urban kampung	Segments of components
Monkeyboo	A playground which provides monkeybar or climbing areas and also serves as a community gathering space	The site is an empty area with a space of 30 sqm	2 units of large column components 4 units of small column components 1 pedestal component 18 roof truss structure and column components 8 pieces of loose bar 7 units of bamboo shingle structure to be used as roof coating
Kakuna	A playground which provides slides for children	The site is an elongated space which is parallel to the main road of the neighborhood	1 slide ramp component 1 seating component 1 foothold component 1 slide component 6 pieces of roof column components 1 piece of roof component 2 pieces of railing components
Bambooklung	The playground provides a musical tunnel using bamboo as musical instruments	The site is an alley inside the kampung with a 2-meter width	1 wall structure component 1 roof coating component 2 vertical components 1 set of bamboo sticks as *angklung*

4.3 Construction process

Bamboo used as this flexible architecture product material is *temen* (*Gigantochloa Atter)* and *hitam* (*Gigantochloa Verticillata*) which have been preserved beforehand using soaking method for 1-2 weeks. According to the previous study, *Gigantochloa Atter* has the best mechanical performance value (tensile strength and modules of elasticity) among all five types of bamboo usually found in Indonesia [11]. This bamboo is used for *Kakuna* and *Monkeyboo* design because both of these designs bear more physical load (human). On the other hand, *Gigantochloa Verticillata* is picked not because of its strength. It is picked because of its characteristic which can produce loud voice when it's knocked, so that it is perfect for *Bambooklung* design. Every construction stage is conducted by the students along with the assistance of skilled bamboo craftsmen and is conducted at the *Akademi Bambu Nusantara (ABN,* Bamboo Academy) workshop, Serpong, Banten. After the flexible products have been assembled, they are dismantled and taken apart to be reassembled in the Engineering Faculty of University of Indonesia, Depok. By conducting the complete process of apart-and-reassemble as many as three times, it is expected that the observation and evaluation of the movability aspect can be fully implemented.

4.4 Post-construction Evaluation

After passing the construction process, it is understood that the joint system can be dismantled and reassembled well and properly as proven through the structures which do not show any structure failures in both the structure and the joints used in all of the construction process. Cutting and making the bamboo structures into smaller components has also proven to be a lot more convenient and easier to pass through narrow areas inside the urban kampung. However, the more separate components there are, the more difficult the assembling process is. Students as the constructor showed signs of difficulty during the process of reassembling *Monkeyboo* which consists of 40 separate components. The reassembling process of *Monkeyboo* took two days to complete while, on the other hand, *Kakuna* and *Bambooklung* only took two hours to reassemble.

Figure 4. *The construction process of the bamboo-based flexible architecture product*

Figure 5. The final results of *Monkeyboo* (lef), *Kakuna* (middle) and *Bambooklung* (right) bamboo structure

The most unexpected result from the evaluation was in fact not on its movability but on the vulnerability of the bamboo towards water and humidity. All of the design products have been adjusted to a preliminary literature on how to make bamboo resistant to weather where all the bamboo has been preserved and all the structures are applied roof coating (except for *Monkeyboo*). The hollow inside the bamboo sticks are also placed with camphor to make it even more resistant to the weather. According to the bamboo craftsmen, these steps should help in creating the bamboo more resistant to humidity. However, organisms such as termites, ants and fungus are now found on the legs of each model, causing the bamboo stick to wear out. Early indications show that the cause may be the heavy rain in the area and also the surface of the ground which are humid con-blocks.

Figure 6. Damage on the bamboo sticks caused by the weather and humidity on the surface of the ground.

5. Discussion

The flexible architecture approach which is movable is currently valued as very relevant and contextual to the conditions of urban kampung such as the kampung of Kelurahan Tugu, Depok, where the city faces special issues with limited and non-permanent spaces. As a movable building, this children's playing tool in Pal Depok kampung can be moved to a different location to anticipate if at any time the area is evicted to be used as a different function. The movability performance in this study is applied through the demountable method system which is 'to transport a building in limited number of dedicated parts' [3]. As previously stated, the main point of this exploratory study is to generate new questions which can be further developed and pursued into future research. Therefore, based on the study conducted on the realization of the three flexible architecture bamboo models, there are several question variables which can be further analyzed as follow.

First, movability through the knock-down system needs to pay attention to two important aspects; (1) components and (2) joints. In terms of components, the structure should be able to be exploded into smaller components. Units of the components will clearly have different shapes and functions but shall maintain light and convenient characteristics to be mobile inside an urban kampung. In terms of joints, they shall be "alive", meaning that the joints can be taken apart and reassembled but still retain strong and rigid structures. Components which are bigger create a faster apart-and-reassemble process on the joints but results in a more difficult components distribution process due to its heavy weight. On the other hand, components which are made into many smaller parts will simplify the distribution process but will result in a longer process in connecting the joints. Advanced study is needed to get a right configuration between 'component' and 'joint' design. Not only that, exploration can be done by replacing temen bamboo that is previously used into other type of lighter bamboo. Temen bamboo is a bamboo with greatest/heaviest density among 5 types of bamboo found in Indonesia [11]. By studying the use of other bamboos, it can make the structure lighter and easy to install and move in urban kampung.

Next step is how to prepare bamboo structure which is resistant to weather and high humidity in urban kampung. Bamboo preservation using natural soaking method is proven less effective for urban kampung environment. Further study can be done by using chemical preservation which is more effective such as: borax boric acid usage through immersion technic method, gravitational or vertical soak diffusion, and injection using compressor machine. However, the use of chemicals in the preservation process arises various questions and debates about the impact of the waste water to the environment [4]. Thus, further study needs to be completed with deeper exploration towards roof cover design and structure's legs so that the bamboo construction is safe and resistant towards rain and the humidity of the land surface.

6. Conclusion

This exploratory study is conducted not to conclude a new scientific proof but only to help create a path for the future advanced research. However, previous studies so far still prove that flexible architecture with the use of bamboo can be an accurate solution as a response towards the spatial situation in an urban kampung. Through the movability, movable structure is supposed to be able to solve the spatial problem of urban kampung which is limited, dense, and temporary because the structure can be moved to another location at any time if the previous location are going to be used for different function. The use of bamboo as a local material through flexible architecture is also relevant for urban kampung situation because it can be fabricated, assembled, taken care of, and fixed even by its residents. The conclusion is, of course, temporary because it needs advanced proofs and studies to be able to answer new questions that arise from this exploratory research.

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