Typology of foundation in Banjar traditional architecture: The solution for house foundation in swamp land in Banjarmasin

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Abstract. In recent years in Banjarmasin there have been a number of cases of failures in house building structures, all of which have occurred in the foundation. This problem must be immediately resolved, through identifying the causes of failure to find the structure and construction model of the ideal foundation for swamp land. One of foundation structure and construction that has proven its resistance to various loads in a period of 75 years to more than 200 years on swampy land is the foundation of traditional Banjar houses. The solution to this problem will begin with the identification of the typology of the foundations of traditional houses in Banjarmasin as a swampy area with a depth of hard soil around 40 meters. The typology that is formulated is based on several variables, namely: the elements of the foundation along with the dimensions and type of material, the connection system between the foundation elements, the maximum bearing capacity of the foundation, and the position of the foundation against the tidal of ground water. The research method is carried out through detailed measurement and photographed of the research object which is also drawn to the standard of detailed engineering design (2 dimensions). The graphic data of the research object is used as the basis for formulating the typology of the Banjar traditional house foundation with variable construction elements, connection systems, bearing capacity, and position on the tidal of ground water. The variables are arranged by matrix and analyzed to get typology grouping. From the results of the study, there are 6 types of foundation system in which all types foundation consist of laid down trunks which distributes the load to the ground through columns that bearing the entire load from above. The trunk foundation is below the lowest tidal ground water line and has a greater bearing capacity than the load it delivers.

1. Introduction
There are several cases of structural failure of house structures in Banjarmasin in recent years, all of which occur in the foundation section. This problem should be resolved as quick as possible, mainly because of the safety of the community.

Meanwhile, on the other side of the city, there are also dozens of traditional Banjar houses that are more than 75 years old, still strong and hardly change their structure. These houses is acting as living laboratory of houses structure. As a structure that has stood even in the long time, with various load and weather, the traditional Banjar house structural system is a very valuable structural object for further study about the strength, efficient and effective of the building structure in the swamplands.
To solve this problem requires a series of steps, which will be divided into three stages of research activities, namely:

1) Obtaining the formulation of a traditional building structure typology, in this case focus to foundation.
2) Identification of factors causing foundation failure in several cases, and suggestions for improvement.
3) Synthesize the results of the research in stage 1 and stage 2 to formulate an improved foundation type model, as well as test the model with a scale between 1:5 to 1:10 with real loading.

This research is the first stage, ie: to obtain the formulation of a traditional building structure typology, in this case focus to foundation.

The objectives of the research, ie:

1) Inventory of the structure and construction of the foundation of the traditional Banjar house through the samples selected.
2) To calculate the strength of the foundation of the samples in terms of load-bearing strength with theoretical calculations based on mechanical engineering rules.
3) To formulate the typology and morphology of the foundation of the traditional Banjar house in Banjarmasin.

2. Methodology

This research was conducted through 5 (five) stages, namely: preparation, surveying, data compilation, analysis, and formulation.

The preparation phase consists of: making a work plan, reviewing the study area literature, and compiling the results of previous research related to the Traditional Banjar architecture.

The research is preceded by the preparatory phase, which contains: the creation of a complete work plan and literature review. Comprehensive and detailed measurements and photo shoots of samples. Collection of research materials ever done (measurement results, pictures, photos and writing). Interview with related parties, especially regarding the original form of the building foundation.

The survey stage is the data collection stage of foundation of samples of the Banjar traditional houses. The data needed is: a building plan, exterior shape of the building, the plan and detail of foundation.

Compilation of research objects using the following methods: plan drawing, foundation structure plan, foundation structure detail, structural pieces, and 3 dimensional structure; compilation of photos per sample according to grouping.

The compilation results will be arranged with a matrix, which consists of several data variables, namely: building plans, foundation elements and their dimensions and types of materials, connection systems between foundation elements, maximum bearing capacity of the foundation against loading, and the position of the foundation against the tidal zone.

3. Results and discussion

3.1. Research samples

Banjar traditional architecture is a cultural product of the Banjar Tribe which is likely to undergo evolution until it reaches a form that we can still see some of them today [1]. Therefore it is probable that the elements of traditional Banjar architecture are motivated by several tribal or group cultures that perform shape the culture of the Banjar tribe [1-3].

Some traditional Banjar architectural buildings, in the form of residential houses and mosques, can still be seen some of them today, which are scattered in several locations in South Kalimantan. The location is generally the location of the center of activities and settlements in ancient times. There was a period (there was no scientific study, probably between 1945 and 1960) where traditional Banjar architecture was no longer used as a reference in the construction of houses or places of worship. This
is indicated by the absence of buildings with traditional Banjar architectural forms that were built between 1945 and 1960 and beyond [4-6].

The research sample was taken from several sections representing several aspects, namely: aspects of building type, aspects of location, and aspects of development time and scale of function.

In terms of building type aspects, the type that will be chosen is mainly the type of Bubungan Tinggi with the addition of several other types, such as Gajah Baliku, and others. While the location of the sample will be chosen an area where there are many traditional houses, namely in the city of Banjarmasin. In terms of the age aspect of the sample, 100 years or more are taken. And in terms of functional aspects everything is a residence, with varying magnitude.

3.2. Inventory of the structure and construction of the foundation of samples
As shown in Figure 1, 8 samples are located in Banjarmasin (4 samples) (Sei Jingah, Kuin Utara and Banua Anyar), Marabahan (2 samples) and Martapura (1 sample) (Teluk Selong). All samples have been inventarised in the form of: plan, foundation plan, elevation, photos, and foundation structure in 3D.

![Figure 1. Location of the samples in South Kalimantan, Indonesia (Source: Analysis Results).](image)

3.3. Formulation the typology and morphology of the foundation of the samples
All samples show the similarity of system, element and dimension of foundation system. All samples have the same foundation system element, ie: tihang, tongkat, sunduk and kalang/kacapuri.

Tihang is a solid pillar that continues from the ground through the floor to support the truss. In all samples tihang is placed on the outer part of the building and on the part that carries the heavy load. All of the samples are made of ulin wood (Eusideroxylon Zwageri) and in general the dimensions are 10/20 or 12/25, as shown in Table 1.

Tongkat is a pole that extends only to the floor frame, where all samples are placed in the same position. Everything is made of ulin wood and in general the dimensions are 5/10.

Sunduk is a part of the structure that functions to distribute the load from above through tihang or tongkat to kalang/kacapuri and then forward it to the ground. All of the samples are made of ulin wood and generally the dimensions are 5/10 or 7/15.

Kalang or kacapuri is the main foundation component that transmits the load directly to the ground. From the sample, there are 3 kinds of kalang, namely: kalang made of kapurnaga (Calophyllum) intact

| Sample Location | Number of Samples |
|-----------------|-------------------|
| Banjarmasin     | 4                 |
| Marabahan       | 2                 |
| Martapura       | 1                 |

| Wood Material | Dimensions |
|---------------|------------|
| Ulin Wood     | 10/20      |
|               | 12/25      |
|               | 5/10       |
2 sticks side by side with a diameter of 25cm, kalang from kapurnaga wood, half a stick of one stem with a diameter of 40cm, and kalang of ulin wood with a size of 7/25. All kalang are similarly positioned and placed. Kalang made of kapurnaga is located in the swampland that submerged continuously for year, such as in Banjarmasin and Marabahan. Kalang made of ulin is located in the tidal area that sometimes submerged and sometimes dry, such as in Martapura [7].

Table 1. Elements and dimension of foundation system of 7 samples.

| No | Samples Location | FOUNDATION | COLUMN | SUNDUK |
|----|------------------|------------|--------|--------|
|    |                  | Foundation Type | Foundation Direction | Dimention | Wood Type | Information Source | Dimention | Wood Type |
| 1  | Banjarmasin      | Line/ round kacapuri | Across the building | Diameter 20-35cm | Kapurnaga | Field identification |                          |          |
| 2  | Banjarmasin      | Line/ round kacapuri | Across the building | Diameter 20-35cm | Kapurnaga | Field identification |                          |          |
| 3  | Banjarmasin      | Line/ round kacapuri | Across the building | Diameter 25cm | Kapurnaga | Interview          |                          |          |
| 4  | Banjarmasin      | Line/ round kacapuri | Across the building | Diameter 25cm | Kapurnaga | Interview          |                          |          |
| 5  | Marabahan        | Line/ round kacapuri | Across the building | Diameter 40cm | Kapurnaga | Interview          |                          |          |
| 6  | Marabahan        | Line/ round kacapuri | Across the building | Diameter 40cm | Kapurnaga | Field identification |                          |          |
| 7  | Martapura        | Line/ rectangle kacapuri | Across the building | Rectangle 7/25 | Ulin    | Field identification |                          |          |

Source: Analysis Results.

From the selected sample, it can be concluded that the foundation in the Banjar Traditional House has 6 types (3 main types plus 3 types of variants). The difference in type lies in the type of Kalang foundation used which consists of 3 types (a pair of round rods, half round rods, and square rod). The difference is also due to the direction of the Kalang foundation at the bottom of the Anjung, one is transverse to the direction of the back-front of the building, while the other is in the direction (longitudinally) to the direction of the back-front of the building.

Figure 2 shows the general form of the foundation for the traditional Banjar house.
3.4. Calculation of the strength of the foundation of the samples

To calculate the strength of the foundation of the samples in terms of load-bearing strength with theoretical calculations based on mechanical engineering rules.

In the calculation it is assumed that the direction of the working load is vertical (gravity), where all loads are concentrated on the poles (tihang and tongkat) to be forwarded to the foundation and soil. The columns that its strength is calculated is limited to the part that receives the greatest load, whose position is shown in Figure 3, which consists of 7 sections consisting of 29 posts.

Soil carrying capacity is taken from sondir data from 3 places in the swampland in Banjarmasin which was obtained from the Laboratory of Soil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat Banjarmasin. From the varied data, the lowest number is taken, where the data is taken at a depth of 30cm to 100cm below the soil surface, according to the variation in the lowest depth of the foundation (kalang). The cone resistance ranges from 2 kg/cm² to 5 kg/cm².
Figure 3. The foundation points with the highest load are used as calculation samples (Source: Analysis Results).

From theoretical calculations, it is found that all the components of the foundation have a strength level above the load acting on them. The highest load on tihang or tongkat is 1,991 kg (Table 2). The ability of kalang or kacapuri to withstand the load to channel it to the ground so that there is no decrease is also quite large, where the safety index of 1.8 for the highest load and the lowest conus penetration, is a relatively high safety index.

The ability of the tihang or tongkat to withstand axial loads still far exceeds that highest load. Likewise, the bending ability of sunduk to withstand these loads still exceeds the highest load.

The sample structure does not require additional stiffeners such as truss, due to the presence of tihang, watun and penampik plus sampayan which is the main structure (core) in a traditional Banjar house which forms a solid and rigid unit [8].
Table 2. The resume data of the load, contact area foundation kalang with ground and cone penetration.

| no | position (line) | Load centre (column) | load (v x hj) (kg) | contact area foundation kacapuri/kalang with ground (cm²) | cone penetration (kg/cm²) |
|----|-----------------|----------------------|-------------------|------------------------------------------------|--------------------------|
|    |                 |                      | min. to maks.     | min. to maks.                                   |                          |
| 1  | B1              | B1-1                 | 548.70            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B1-2                 | 727.11            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B1-3                 | 727.11            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B1-4                 | 548.70            | 1,800 to 7,200                                  | 2.00 to 5.00             |
| 2  | B2              | B2-1                 | 807.36            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B2-2                 | 1,059.45          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B2-3                 | 1,059.45          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B2-4                 | 807.36            | 1,800 to 7,200                                  | 2.00 to 5.00             |
| 3  | B3              | B3-1                 | 971.54            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B3-2                 | 1,273.91          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B3-3                 | 1,273.91          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B3-4                 | 971.54            | 1,800 to 7,200                                  | 2.00 to 5.00             |
| 4  | B4              | B4-1                 | 1,523.97          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B4-2                 | 1,990.88          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B4-3                 | 1,990.88          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B4-4                 | 1,523.97          | 1,800 to 7,200                                  | 2.00 to 5.00             |
| 5  | B5              | B5-1                 | 1,426.07          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B5-2                 | 1,864.47          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B5-3                 | 1,864.47          | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B5-4                 | 1,426.07          | 1,800 to 7,200                                  | 2.00 to 5.00             |
| 6  | B6              | B6-1                 | 684.00            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B6-2                 | 889.66            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B6-3                 | 889.66            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B6-4                 | 684.00            | 1,800 to 7,200                                  | 2.00 to 5.00             |
| 7  | B7              | B7-1                 | 603.03            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B7-2                 | 733.89            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B7-3                 | 733.89            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B7-4                 | 733.89            | 1,800 to 7,200                                  | 2.00 to 5.00             |
|    |                 | B7-5                 | 627.45            | 1,800 to 7,200                                  | 2.00 to 5.00             |

Source: Analysis Results.
All samples show similarities in the structural system of the foundation, which consists of: tihang & tongkat, sunduk, and kalang/ kacapuri.

Tihang is a solid pillar that continues from the ground through the floor to support the truss. In all samples tihang is placed on the outer part of the building and on the part that carries the heavy load. All
of the samples are made of ulin wood (Eusideroxylon Zwageri) and in general the dimensions are 10/20 or 12/25.

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Kalang in Banjarmasin and Marabahan is made of kapurnaga wood and is placed below the lowest groundwater line. While those in Martapura are made of ulin wood and are not located below the lowest groundwater line, because the area is not swampy and is dry in the summer. This shows a good understanding of the properties of wood to water.

The ability of kalang or kacapuri to withstand the load to channel it to the ground so that there is no decrease is also quite large, where the safety index of 1.8 for the highest load and the lowest conus penetration, is a relatively high safety index.

The resistance of the foundations of traditional Banjar houses for 100 years or more with no visible physical change or deterioration is made clear by theoretical calculations that show a high safety rate from the samples.

So we can conclude that the elements and system foundation exceed the minimum strength required. Therefore the system is efficient and effective for the building structure in the swamplands.

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