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Analysis of Structural Failure of Cerucuk Galam Foundation (Galam Wood Pile Foundation) in Banjarmasin Swamp Land in Indonesia

Muhammad Deddy Huzairin, Dila Nadya Andini, Anna Oktaviana,

Department of Architecture Faculty of Engineering Lambung Mangkurat University

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ABSTRACT

The cerucuk (pile) galam foundation made from local wood is the most widely used foundation for houses in Banjarmasin which is a swamp land. The cerucuk galam foundation consists of 4 main elements, namely: columns, sunduk, lapak and galam pile. However, in recent years there have been problems that are strongly indicated to be related to this type of foundation, namely the collapse of 47 house buildings from 2018 to 2023, and many more cases of damage that did not cause a collapse. There fore it is necessary to analyze the causes of structural failure of this type of foundation, as a preliminary to a series of studies to obtain a safer type of foundation. To find out the cause, this is done through direct observations in the field, interviews with experienced carpenters, mainstream and online media, as well as calculations of the loads and stresses that occur in the model house compared to the maximum load and stress. The results of the analysis show 2 main causes of the failure of the foundation structure. First, the broken sunduk on some of the columns with the heaviest loads, which is indicated by the high bending and shear stresses exceeding the maximum stress. Second, the weathering of the galam head which causes a decrease in the maximum bearing capacity, which causes a shift or detachment of lapak from the galam head. Weathering occurs because the galam head is not completely submerged.

Keywords: foundation, sunduk, lapak, cerucuk galam, swamp land.

INTRODUCTION

The most recent estimate of global inland and coastal wetland area is in excess of 12.1 million km2, where marshes and swamps (on alluvial soils), including floodplains 2.53 million km2 [1].

The resulting wetland map covers 21.0% (396.000 km2) of Indonesia's land, including 22.9% of Kalimantan (122.000 km2) [2]. Banjarmasin is a city and the capital of South Kalimantan, Indonesia. It is located on a delta island near the junction of the Barito and Martapura rivers. The city covers an area of 98.46 km2. Slope of the city is 0.13% and the land is generally flat and low lying. The geological foundation of the city is dominated by clay and sandstone, but also includes alluvial sediments from the river. Most of Banjarmasin area is swamps (on alluvial soils) [3], where the soft soil layer has a thickness of up to 25 m, the average hard soil is found at a depth of about 40 m [4].

Banjarmasin with a population of 715,703 people in 2020 [5], has experienced significant economic growth which triggered the physical development of the city, including housing. This fast physical development has changed the swamp environment, where most of development is carried out by filling the land. There are several choices of types of foundations for swamps in Banjarmasin [6], [7], [8], [9], of which the most widely used for housing is the cerucuk galam type of foundation. This foundation is a stilt foundation, which minimizes changes to the marsh soil structure. Therefore this environmentally friendly foundation is very valuable to be maintained, preserved and developed. Cerucuk galam is a type of foundation consisting of galam wood piles (Melaleuca Leucadendron), sunduk, lapak and ulin wood columns (Eusideroxylon Zwageri).

However, in recent years there have been several cases of structural failure of residential houses, where all cases were caused by failure of the substructure or foundation. Apart from failures that caused the building to collapse, there were more cases of damage to several parts of the building, namely: cracks in masonry walls and structural subsidence in parts under walls and/or in bathrooms. From 2018 to 2023, 47 houses collapsed [10], [11], [12], [13], [14], [15]. This data was obtained from the mainstream media and online media with the condition of the house really collapsing. This data does not include collapsed houses that are not published in the media, and also does not include houses that have not collapsed but have structural damage that has the potential to collapse. All of the houses, the structural failure started from the foundation, and all of them used the same type of foundation, namely the cerucuk galam.

In order to improve and modified the foundation system used in general, firstly it is necessary to analyze the causes of failure of the cerucuk galam foundation structure in some of these residential houses.

METHODOLOGY

This research was conducted through 5 (five) stages, namely: initial identification of the causes of foundation structure failure, sample selection, model formulation for structural calculations, building load calculations, calculation of the strength of the cerucuk galam foundation elements, and drawing conclusions on the factors that caused the failure of the foundation structure.

Early identification of the causes of structural failure is carried out through direct observation in the field; interviews with several carpenters who are related to the sample or who are not related but have sufficient experience (Darma, Upin, Ancah, Apul, Bain, and Yahya); as well as from mainstream media and social media.

The selected sample is a sample that has related with houses experiencing structural failure, namely: a typical house that is one complex with a structural failure house, a typical house built by developers associated with a structural failure house, several typical houses from other developers with variations in shape and area. All of them use the same foundation system, namely cerucuk galam.

The house model that will be used as an analytical model is designed based on: the area of the house sample, the distance between the foundation columns, the dimensions and lengths and types of wood foundation elements (columns, sunduk, lapak and galam piles), the position and dimensions of the rooms, the shape of the roof, the structure and floor materials, wall structures and materials, ceiling structures and materials, and roof structures and materials.

The load calculation is calculated on each pillar of the model house foundation, where the loading are based on: Indonesian Loading Regulations for Buildings 1983 [16], Indonesian Timber Construction Regulations 1961 [17], supporting capacity of galam foundation [18], [19], [4], data and graphs of soil sondir in Banjarmasin [20].

Calculation of the strength of elements of the cerucuk galam foundation consists of several parts, with the following details:

- The strength of pile foundation is measured by maximum compressive load and critical buckling load, which is the smaller that is used.

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$Pmaks = f \cdot A$
Pm = Max load
f = Allowable compressive stress
A = Cross-sectional

$Pcr = \dfrac{\pi^2 . E . I}{L^2}$
Pm = Allowable load
π = Konstanta pi=3,1416
E = Modulus of elastisity
I = Moment of inertia
L = Length of column

- The strength of galam pile is measured by its maximum strength to withstand the load, and also its limit of strength to withstand the load resting on it (bearing capacity).

$Pmaks = fs \cdot A$
Pm = Max load
fs = Friction resistance
A = Sheath area

$f = \dfrac{P}{A}$
f = Bearing capacity
P = Compressive load
A = Cross-sectional area

- The strength of Sunduk is its strength limit to withstand the load resting on it which hits the center by calculating the limits of bending stress, shear stress and bearing capacity.
- The strength of lapak is measured by its strength limit in holding the load resting on it which hits the center by calculating the limits of bending stress, shear stress and bearing capacity.

$f_b = \dfrac{M.c}{I}$
f_b = Bending stress
M = Calculated bending moment
c = Vertical distance away from the neutral axis
I = Moment of inertia

$f_v = \dfrac{V.Q}{I.b}$
f_v = Shear stress
V = Calculated bending moment
Q = Calculated shear at specific section
I = Moment of inertia
b = Width of beam

The conclusion is based on the initial identification of the causes of structural failure and the calculation of the strength of the galam cerucuk foundation elements.

RESULTS AND DISCUSSION

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Early Identification of Causes of Structural Failure

The cerucuk galam is the foundation used in most residential houses in Banjarmasin, where the cerucuk galam consists of ulin columns, ulin sunduk, ulin lapak and galam piles, with the arrangement and shape as shown in Figure 1 below. Ulin wood (Eusideroxylon Zwageri) which is the main material for the foundation is included in classification scale 1 (very resistant) based on laboratory exposure [21]. Ulin is also termite resistant and marine borer resistant [22]. While galam (Melaleuca Leucadendron) as a pile material is included in classification scale 4 (non resistant) based on laboratory exposure [21].

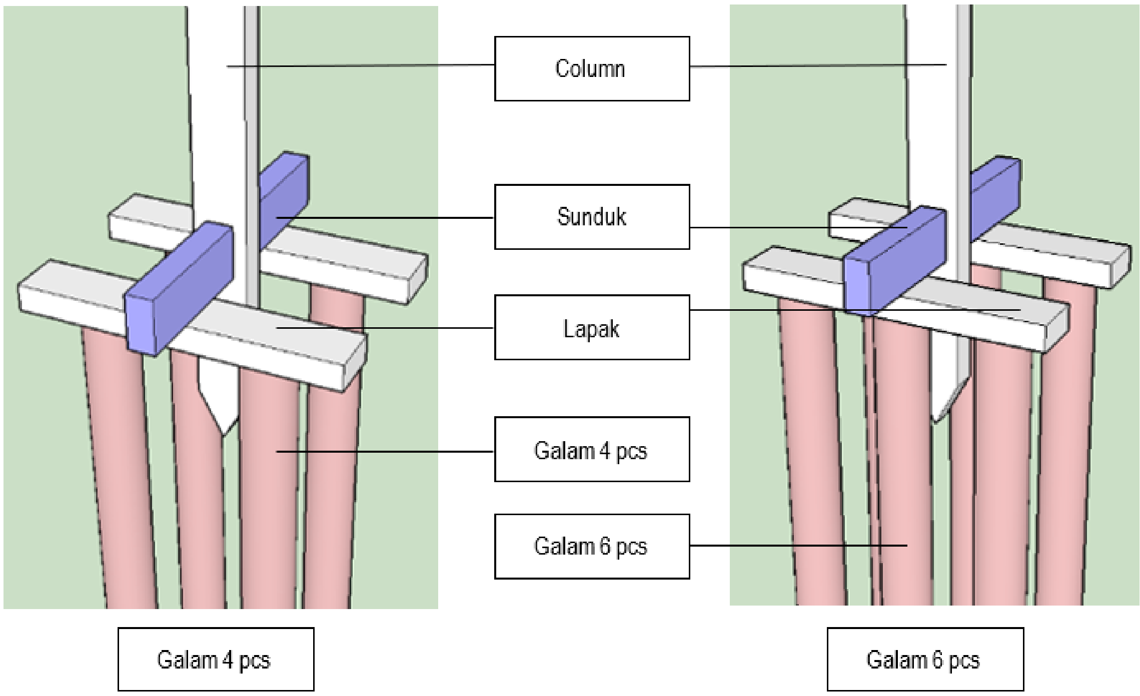

Fig. 1. Galam cerucuk foundation with 4 pieces of galam and 6 pieces of galam. Source: [8]

Initial identification concluded that structural failures all occurred at the foundation (surveys, interviews, mainstream media and online media). Of the several elements of the foundation, only a few elements were damaged. In more detail the explanation is as follows:

1. Structural failures all start from the foundation.

2. In all cases, the ulin column foundation elements were not the initial cause of structural failure. This means that at first the ulin column did not break.

3. In some cases, the lapak element begins to break (the lapak is the foundation element that acts as an intermediary between the galam piles and the sunduk). The ones that have broken are the lapak supported by 4 galam piles (not those supported by 6 galam piles). However, fracture of the lapak is the initial cause of structural failure in only a few cases, not more than 20% of cases.

4. In some cases, it begins with a broken sunduk (sunduk is an intermediary for distributing the load between the pile and the lapak). This case of broken sunduk is generally due to its small dimensions and/or the occurrence of defects in the sunduk.

5. In most cases, structural failure is due to the shift of the lapak pedestal from the galam pile, and it can also be the shift of the sunduk pedestal to the lapak. However, the shift of the sunduk pedestal against the lapakis generally caused by the shift of the lapak to the galam pile, so that the sunduk also experiences a shift.This shift was caused by several things, namely:

- Generally, due to weathering of the galam head, the lapak undergoes a change in position, either decreasing or shifting, and over time it may slip or loose its pedestal.
- Due to poor workmanship, the position between the lapak and the galam is not right in the middle, so that sometimes the lapak's position is almost separated from the galam's position.
- The occurrence of vibrations on the ground or other causes that cause movement or displacement from the galam. And because the pedestal of the lapak against the galam is only in a narrow area, it can cause the pedestal to fall off.
- The combination of 2 or all of the above individual reasons will increase the speed of the release of the lapak pedestal from the galam pile.

6. In most cases, the failure of the foundation structure starts from the galam pile, where the head or the top of the galam pile is weathered, so that the lapak experiences a decline or shift that over time separates from its pedestal. Wood, if kept dry, is an extremely durable material. Untreated wood will, however, if it becomes wet be rapidly degraded by fungi and sometimes also by bacteria [23]. This weathering of the galam head is due to the non-submersion of the galam completely, due to several things, namely: 1) since the beginning the galam has been above the ground water level; 2) the location which is in the tidal area of the river causes the galam if it is not planted deeper into the ground, at low tide it is not submerged in water. The erosion of the land surface due to river currents also causes the galam surface to rise above the water surface; 3) this third part is the error that occurs the most, namely the depth of the galam head pile is not completely submerged under ground water. And sometimes it has been submerged but does not consider the lowest tides in the dry season, so that in the dry season the head of the galam appears above the ground water surface.

7. Another element of the foundation is bracing, which in some cases lack of conformity can be the cause of structural failure. However, in general, the existing buildings have sufficient suitability. In fact, in some cases the buildings that can survive are due to the sufficient number of bracing so as to avoid the acceleration of the collapse of a building.

House Model for Structural Analysis

To calculate the strength of each element, it is determined 1 plan whose distribution of forces is representative of the plans that are usually provided by developers. The form of the plan was taken from 11 plans from several developers representing the 3 types that were most widely built, namely type 36, type 45 and type 54.

The type, position and dimensions of the space are taken that best represent all samples. The shape of the roof is in the form of roof truss and a wooden frame and a zincalume roof covering. The walls are made of stone masonry, and the floor is made of ulin board floors in thin cast concrete coated with ceramics. The ceiling is a wooden frame with a calciboard cover.

The distance between the columns is 1 meter, where the columns that support the walls are 10/10, while the other columns are 5/10. The model of the floor plan, elevation and arrangement of the columns for the model house can be seen in Figures 2, 3 and 4.

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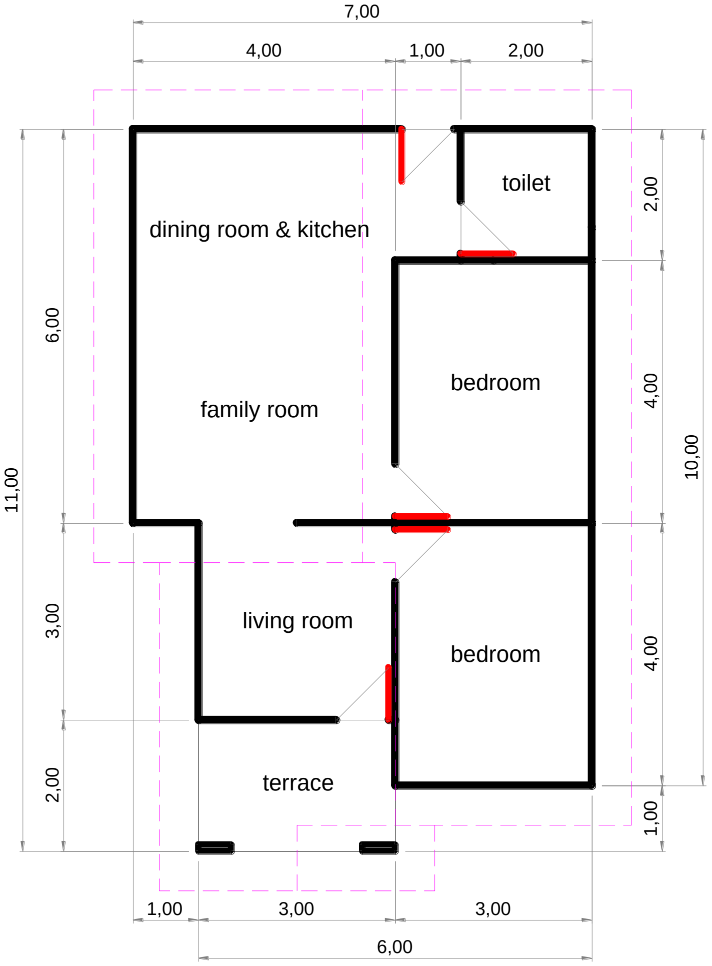
Fig. 2. Plan of model house.



Source: analisis result

Fig. 3. Elevation of model house.

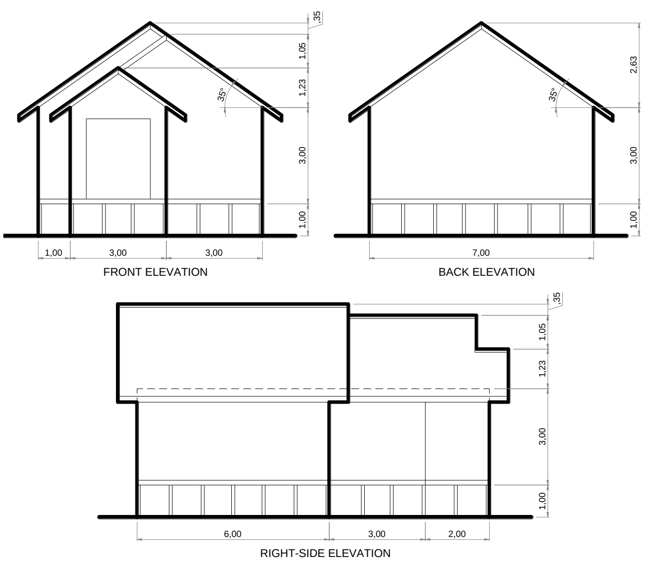


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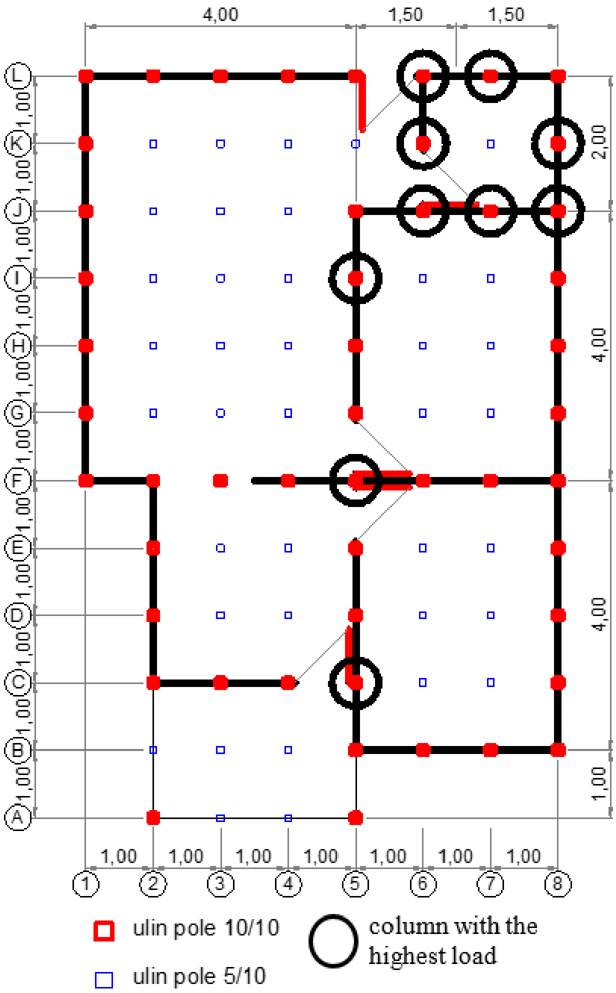
Fig. 4. Column arrangement of model house.



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Analysis of Calculation of the Strength of the Cerucuk Galam Foundation

In the analysis of this calculation there are several basics and assumptions, namely:

- The basis for the magnitude of the load is taken from several sources. For live loads, the weight of the walls, the weight of the floor, the weight of the ceiling and the weight of the roof are taken from the Indonesian Loading Regulations for Buildings 1983 [16].
- Specific gravity of meranti and ulin, modulus of elasticity, allowable stress for bending of wood, allowable stress for stresses parallel and perpendicular to wood grain, and allowable stress for shear parallel to wood grain, are taken from the 1961 Indonesian Timber Construction Regulation [17].
- The bearing capacity and adhesive resistance of the soil are obtained from various sources [18] , [4], [20].
- In the calculation it is assumed that each column stands independently, although generally several columns are bracing. The bracing will increase strength (especially bending strength) and distribute the load more evenly.
- The size of the wood is assumed to be exactly as specified, not less or more as the size on the market.
- Wood quality is assumed to be in perfect condition, without any wood defects or cracks or other flaws that are sometimes found in the market.

The table 1 is a summary of the calculation of the foundation strength, in the form of the maximum load and stress on each foundation element. Columns that only carry the floor load (not supporting the load on walls,

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ceilings and roofs) of 39 pieces, hereinafter referred to as light load columns. Columns that carry the load of floors, walls, ceilings and roofs, and partially carry the burden of wall ceramics and water (in bathrooms and toilets) of 49 pieces, hereinafter referred to as heavy-loaded columns.

Table 1. Column strength and bearing capacity of galam foundation.

No	Column & Coordinate Position (see figure 4)	Total weight (kg)	Column compressive strength	Strong bending of the column (kg)		Galam foundation	
			Max load (Pmaks=f.A) (kg)	Critical bending load direction b Pcr = (π^2EI)/L^2	Critical bending load direction h Pcr= (π^2EI)/L^2	Bearing capacity ofgalam foundatio n(kg)	Bearing capacity (f=P/A) (kg/cm2)
1	Max limit						60.00
2	Light load columns (39)						
A	Lowest (3A;4A;2B)	155.08	2,000.00	16,798.56	4,199.64	1,200	0.49
B	2K; 3K; 4K; 5K; 2J; 3J; 4J; 2I; 3I; 4I; 6I; 7I; 2H; 3H; 4H; 6H; 7H; 2G; 3G; 4G; 6G; 7G; 3E; 4E; 6E; 7E; 3D; 4D; 6D; 7D; 6C; 7C; 3B; 4B	299.76	2,000.00	16,798.56	4,199.64	1,200	0.95
C	3F	330.01	2,000.00	16,798.56	4,199.64	1,200	1.05
D	Highest (7K)	887.48	2,000.00	16,798.56	4,199.64	1,200	2.82
3	Heavy load columns (49)						
A	Lowest (2D; 2E; 8E; 1G; 8G; 1K)	686.48	4,000.00	33,597.11	33,597.11	1,800.00	1.46
B	8D; 8H	691.98	4,000.00	33,597.11	33,597.11	1,800.00	1.47
C	1H; 1J	696.11	4,000.00	33,597.11	33,597.11	1,800.00	1.48
D	8B	753.12	4,000.00	33,597.11	33,597.11	1,800.00	1.60
E	1F; 1L	758.92	4,000.00	33,597.11	33,597.11	1,800.00	1.61
F	2L; 4L; 5L	823.79	4,000.00	33,597.11	33,597.11	1,800.00	1.75
G	3L	832.04	4,000.00	33,597.11	33,597.11	1,800.00	1.76
H	5E; 5G	842.16	4,000.00	33,597.11	33,597.11	1,800.00	1.79
I	5D	847.66	4,000.00	33,597.11	33,597.11	1,800.00	1.80
J	5J	854.54	4,000.00	33,597.11	33,597.11	1,800.00	1.81
K	5H	857.29	4,000.00	33,597.11	33,597.11	1,800.00	1.82
L	6B; 7B	887.19	4,000.00	33,597.11	33,597.11	1,800.00	1.88
M	2C	909.08	4,000.00	33,597.11	33,597.11	1,800.00	1.93
N	5A	928.63	4,000.00	33,597.11	33,597.11	1,800.00	1.97
O	5B	934.62	4,000.00	33,597.11	33,597.11	1,800.00	1.98

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No	Column &Coordinate Position(see figure 4)	Total weight (kg)	Column compressive strength	Strong bending of the column (kg)		Galam foundation	
			Max load (Pmaks=f.A) (kg)	Critical bending load direction b Pcr = (π^2EI)/L^2	Critical bending load direction h Pcr= (π^2EI)/L^2	Bearing capacity of galam foundation (kg)	Bearing capacity (f=P/A) (kg/cm2)
P	8C	948.69	4,000.00	33,597.11	33,597.11	1,800.00	2.01
Q	2A	967.13	4,000.00	33,597.11	33,597.11	1,800.00	2.05
R	4F; 6F; 7F; 8I	1,061.19	4,000.00	33,597.11	33,597.11	1,800.00	2.25
S	4C	1,103.99	4,000.00	33,597.11	33,597.11	1,800.00	2.34
T	3C	1,105.37	4,000.00	33,597.11	33,597.11	1,800.00	2.34
U	8L	1,113.26	4,000.00	33,597.11	33,597.11	1,800.00	2.36
V	2F	1,120.56	4,000.00	33,597.11	33,597.11	1,800.00	2.38
W	8F	1,135.88	4,000.00	33,597.11	33,597.11	1,800.00	2.41
X	1I	1,159.59	4,000.00	33,597.11	33,597.11	1,800.00	2.46
Y	8J	1,290.32	4,000.00	33,597.11	33,597.11	1,800.00	2.74
Z	8K	1,331.93	4,000.00	33,597.11	33,597.11	1,800.00	2.83
AA	6L	1,427.63	4,000.00	33,597.11	33,597.11	1,800.00	3.03
AB	6J	1,446.00	4,000.00	33,597.11	33,597.11	1,800.00	3.07
AC	5C	1,454.67	4,000.00	33,597.11	33,597.11	1,800.00	3.09
AD	5I	1,464.98	4,000.00	33,597.11	33,597.11	1,800.00	3.11
AE	7L	1,469.24	4,000.00	33,597.11	33,597.11	1,800.00	3.12
AF	6K	1,484.86	4,000.00	33,597.11	33,597.11	1,800.00	3.15
AG	7J	1,487.61	4,000.00	33,597.11	33,597.11	1,800.00	3.16
AH	Highest (5F)	1,515.97	4,000.00	33,597.11	33,597.11	1,800.00	3.22

Source: analysis result.

From table 1 it can be seen that the galam foundation on the light load pile consists of 4 galam with an effective length of 3 m has a carrying capacity of 1,200 kg, all of which are greater than the load acting on the pile. The difference ranges from 312 kg to 1,044 kg. The difference of 312 kg is because one column at that point also holds the water load in the bathroom and toilet.

The bearing capacity in this galam ranges from 0.49 to 2.82 kg/cm2, where this value is still far below the allowable parallel fiber stress of 60.00 kg/cm2.

The galam foundation on the heavy load pile consists of 6 galam with an effective length of 3 m. It has a carrying capacity of 1,800 kg, all of which is greater than the load acting on the pile. The difference ranges from 284 kg to 1,046 kg. The difference of 284 kg and several columns whose difference is close to this figure is because the piles at these points also withstand the water load in the bathroom and toilet as well as the wall and roof loads.

The bearing capacity in this galam ranges from 1.46 to 3.22 kg/cm2, where this value is still far below the allowable parallel fiber stress of 60.00 kg/cm2.

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Column strength is measured by compressive strength and bending strength. The effective length of the column is 1.75 m. The column dimensions consist of 2 groups, namely 5/10 columns for light load columns and 10/10 columns for heavy load columns. From the calculation results obtained the maximum load for buckling is much greater than the maximum load for compression (strength of the material), therefore the benchmark is the compressive strength.

The maximum compressive strength of a 10/10 column is 4,000 kg, while the largest real load of a 10/10 column is 1,515 kg, which is still far below the maximum load limit. The comparison between the largest real load and the maximum load is 0.38. While the smallest real load compared to the maximum allowable load is 0.17.

The maximum compressive strength of the 5/10 column is 2,000 kg, where the real load of the largest 5/10 column is 887 kg, which is still below the maximum allowable load limit. The comparison between the largest real load and the maximum load is 0.44. While the smallest real load compared to the maximum allowable load is 0.08.

Table 2. Sunduk stress and lapak stress.

No	Column & Coordinate Position (see figure 4)	Total weight (kg)	Sunduk stress (kg/cm2)			Lapak stress (kg/cm2)		
			Bending stress (f=(My)/I)	Shear stress (f=(3V)/(2bh))	Bearing capacity (f=P/A)	Bending stress (f=(My)/I)	Shear stress (f=(3V)/(2bh))	Bearing capacity (f=P/A)
1	Max limit		150.00	20.00	40.00	150.00	20.00	40.00
2	Light load columns (39)							
A	Lowest (3A;4A;2B)	155.08	18.61	2.33	3.10	18.61	1.16	0.78
B	Highest (7K)	887.48	106.50	13.31	17.75	106.50	6.66	4.44
3	Heavy load columns (49)							
A	Lowest (2D; 2E; 8E; 1G; 8G; 1K)	686.48	82.38	10.30	6.86	41.19	5.15	3.43
B	Highest (5F)	1,515.97	181.92	22.74	15.16	90.96	11.37	7.58

Source: analysis result.

From table 2, the sunduk that support light load columns have the following stresses:

- The bending stress ranges from 18.61 kg/cm2 to 106.50 kg/cm2, which is still below the allowable stress for ulin bending of 150.00 kg/cm2. Great stress occurs in the columns that hold the water load in the bathroom and toilet.
- The shear stress ranges from 2.33 kg/cm2 to 13.31 kg/cm2, which is still below the allowable shear stress for ulin grain parallel to 20.00 kg/cm2. Great stress occurs in the columns that hold the water load in the bathroom and toilet.

- The bearing capacity ranges from 3.10 kg/cm2 to 17.75 kg/cm2, which is still below the allowable stress for perpendicular compression of ulin fibers of 40.00 kg/cm2. Great stress occurs in the columns that hold the water load in the bathroom and toilet.

From table 2, the sunduk that support the column with heavy loads have the following stresses:

- The bending stress ranges from 82.38 kg/cm2 to 181.92 kg/cm2, some of which exceed the allowable stress for ulin bending of 150.00 kg/cm2. The large stress that exceeds the allowable stress occurs in the pillars that support the water load in the bathroom and toilet as well as the wall and roof loads. This greater stress occurs at the pile coordinates: 6-L, 7-L, 6-K, 8-K, 6-J, 7-J, 8-J, 5-I, 5-F, and 5-C.
- The shear stress ranges from 10.30 kg/cm2 to 22.74 kg/cm2, some of which exceeds the allowable shear stress parallel to the ulin grain of 20.00 kg/cm2. Great stress occurs in the columns that support the water load in the bathroom and toilet as well as the load on the walls and roof. This greater stress occurs at the pile coordinates: 6-L, 7-L, 6-K, 8-K, 6-J, 7-J, 5-I, 5-F, and 5-C.
- The bearing capacity ranges from 6.86 kg/cm2 to 15.16 kg/cm2, which is still below the allowable stress for perpendicular compression of ulin fibers of 40.00 kg/cm2. Great stress occurs in the columns that support the water load in the bathroom and toilet as well as the load on the walls and roof.

From table 2 the lapak that support light load columns, the stresses are as follows:

- The bending stress ranges from 18.61 kg/cm2 to 106.50 kg/cm2, which is still below the allowable stress for ulin bending of 150.00 kg/cm2. Great stress occurs in the columns that hold the water load in the bathroom and toilet.
- The shear stress ranges from 1.16 kg/cm2 to 6.66 kg/cm2, which is still below the allowable shear stress for ulin grain parallel to 20.00 kg/cm2. Great stress occurs in the columns that hold the water load in the bathroom and toilet.
- The bearing capacity ranges from 0.78 kg/cm2 to 4.44 kg/cm2, which is still below the allowable stress for perpendicular compression of ulin fibers of 40.00 kg/cm2. Great stress occurs in the columns that hold the water load in the bathroom and toilet.

From table 2 the lapak that support the columns of heavy loads the stresses are as follows:

- The bending stress ranges from 41.19 kg/cm2 to 90.96 kg/cm2, which is still below the allowable stress for ulin bending of 150.00 kg/cm2. Great stress occurs on the columns that withstand the water load in the bathroom and toilet as well as the load on the walls and roof.
- The shear stress ranges from 5.15 kg/cm2 to 11.37 kg/cm2, which is still below the allowable shear stress for ulin grain parallel to 20.00 kg/cm2. Great stress occurs in the columns that support the water load in the bathroom and toilet as well as the load on the walls and roof.
- The bearing capacity ranges from 3.43 kg/cm2 to 7.58 kg/cm2, which is still below the allowable stress for perpendicular compression of ulin fibers of 40.00 kg/cm2. Great stress occurs in the columns that support the water load in the bathroom and toilet as well as the load on the walls and roof.

Conclusion Causes of the Failure of the Cerucuk Galam Foundation Structure

From the initial identification of the causes of structural failure and analysis of the calculation of the strength of the cerucuk galam foundation from the model house made, several conclusions can be drawn regarding the causes of structural failure in several houses in the swamp area in Banjarmasin, as follows:

1. Columns are not the cause of structural failure. Its compressive and flexural strength far exceeds the

load acting on it. It is possible that this strength is greater, due to the bracing between several columns which shortens the effective length of the columns and makes the joint connection type clamped.

2. The bearing capacity of galam piles is also not the cause of structural failure, because its carrying capacity exceeds the load acting on it, including the largest load.
3. The failure caused by the galam pile is not due to the lack of bearing capacity, but because the top part of the galam pile is not completely submerged in water throughout the year. This causes weathering of the galam head in a short time, which causes the galam head to lose its support strength, which in turn causes the slip or release of the lapak that rests on it.
4. Sunduk is indicated as one of the main causes of structural failure. From the results of the analysis obtained 10 columns that have a bending stress exceeding the maximum bending stress. Likewise, 9 columns have shear stresses exceeding the maximum shear stresses. The magnitude of the bending and shear stresses on the piles is due to the large load, while the biggest load elements are: masonry walls, baths and their water, and part of the roof, especially those that are supported by the truss. The actual reality in the field is that there is a possibility that the difference between bending stress and shear stress with the maximum stress is even greater, due to the size of the sunduk on the market which is smaller than the size of 5/10, where the average size on the market is currently 4/8. However, the presence of bracing that binds several columns can reduce the risk of fracture due to the large bending and shear stresses, due to a more even distribution of forces through the fitting.
5. Lapak have a bending stress that is less than the maximum bending stress, and a shear stress that is also less than the maximum shear stress. Meanwhile, the bearing capacity of the lapak is far below the maximum bearing capacity. Therefore, the lapak is less likely to be the cause of the failure of the cerucuk galam foundation structure. Except for the improper placement of the galam head or resting on the weathered galam head, the lapak can slip or shift.
6. The current scarcity of ulin causes a decline in the quality of ulin in the market. It is because the growth is not proportional to the speed of ulin needs for construction, thus it is becoming scarce [24]. These qualities are: the quality of the material such as specific gravity, defects, young wood, and the size is now getting smaller (eg: 5/10 the market size is actually the largest 4/8). This decline in the quality of ulin in the market can further worsen the strength of the foundation obtained from the theoretical calculations above.

CONCLUSION

There are 2 things that are the main causes of failure of the cerucuk galam foundation structure in the swamp land in Banjarmasin.

The first is the magnitude of the bending and shear stresses at several columns positions, especially the columns that experience a combination of loading, in addition to the floor load there is an additional load on the walls of the masonry, the bath and its water, and part of the roof, especially those affected by the support of the roof truss. This can cause the sunduk to break.

The second is the weathering of the galam head because the galam head is not completely submerged. This weathering causes a decrease in the allowable compressive stress parallel to the galam pile fiber, which causes a decrease or shift in the lapak resting on it.

To minimize the potential for foundation failure from these 2 things, there are 4 things that must be considered.

First, use a sunduk with a larger size, especially the height, at least 5/12. The choice of sunduk must ensure the quality of ulin, the absence of defects, the absence of cracks and the size according to the desired size.

Second, in the case of galam erection, it must be ensured that the top or head of the galam is below the lowest groundwater line during the peak of the dry season.

Third, reduce the largest load element. For masonry walls can be replaced with: wood/mild steel frame with calciboard or other coatings, or lightweight masonry, or other lighter materials. For the bath and its water, it can be suggested by: minimizing the size of the bath, or eliminating the bath and replacing it with an upper reservoir with a separate structure separate from the house structure. For roofs, especially those affected by the support of the truss, it is recommended: use a lightweight roof covering, for example zincalume material, or use truss and light steel frames so that the roof load is distributed more evenly but must pay attention to the strength of the truss bond with the wall or wall beams.

Fourth, use adequate bracing, especially on the columns on the outside of the building and the columns under the walls.

This research requires continuation and deepening, where there are 5 things that can be investigated after this.

First, especially for sunduks, a real loading experiment is needed that can be carried out in the laboratory, by testing samples of several sunduks on the market. So that more valid conclusions can be drawn on the average strength of the foundation elements, especially sunduk.

Second, for matters related to galam piles, a more in-depth and detailed research on 2 things is needed. First, to find out the lowest water limit at the peak of the dry season through several indicators that are easily understood by house construction actors. The second was to conduct research on the resistance of natural materials to several conditions, especially: fully submerged, partially submerged, and not completely submerged.

Third, modifying the cerucuk galam foundation system with the aim of covering its shortcomings or planning a new foundation that is safer, cheaper and easier to work with. Modification or planning of new foundations also requires direct model testing in the field.

Forth, There is another alternative in the form of a Kalang foundation which is a traditional Banjar house foundation whose reliability has been tested and is now almost no longer used [25].

Fifth, the current shortage of ulin as the main material for wooden houses [24], must be addressed through systematic and mass research and cultivation.

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