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Article

A First Model Foundation Design of Wood Pillar in Banjarmasin Swampland

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Abstract: Swampy land in Banjarmasin has special characteristics for building house constructions. The foundation for very low soil bearing capacity requires special treatment as well. Many building collapses are caused by foundation failures due to mismatched building loads and foundation functions, as well as construction material errors. The need for house design follows the development of building functions. Nowadays, a one-story house is no longer sufficient due to limited land. The need to elevate houses to two stories or to develop houses (renovations) often leads to foundation construction errors. The commonly used foundation, wooden pile foundation, has limited load-bearing capacity, necessitating modification steps in the form of foundation reinforcement. Several steps, including material combinations or combinations of various types of foundations, can be implemented. Therefore, a specific model is required to obtain a foundation design that can accommodate construction needs. The aim of the research is to create a foundation design model capable of reinforcing wooden pile foundations for both house construction development and as a reference for building one-story and two-story houses. In this research, field observations will be conducted at various house construction sites in Banjarmasin, both residential and individual objects. Data will be presented descriptively and analyzed to obtain an applicable model as a reference for house construction on swampy land. The model will provide an applicable depiction and will be tested against foundation construction implementation methods.

Keywords: model foundation; wood pillar; concrete foundation; banjarmasin; swampland

1. Introduction

Banjarmasin, with its swampy land, has special characteristics for house construction. Swampy land with very low soil bearing capacity, i.e., 0.2 kg/cm², uses foundation (Figure 1) construction with wooden or concrete piles (Agusniansyah & Sarbini, 2024b). This swampy land condition leads to many building collapses caused by foundation failures due to mismatched building loads and foundation functions, as well as construction material errors (Agusniansyah, 2024c). Besides the swampy land condition, house foundation construction in Banjarmasin also follows the development of building functions. With limited land, small houses that usually consist of one floor are no longer sufficient. Small house designs are often made into two stories, even on small plots (Nurfansyah et al., 2020). Additionally, house development requires renovations, which is referred to as the growing house concept. However, there is a challenge regarding the appropriate foundation design to enable house development (Agusniansyah & Sarbini, 2024b). Foundations for swampy land are certainly very different from those for hard soil (Sideri, 2017)(Makoond et al., 2024)(Russell & Hons, 2015)(Kiakojoury et al., 2023)(Careda et al., 2023), requiring a special foundation design model(Tavakoli & Kiakojoury, 2013)(Ebie et al., 2013). House development involves improving the building, such as for horizontal (sideways) or even vertical (multi-story) renovations (Mahayuddin et al., 2017)(Kiakojoury et al., 2024)(Katam et al., 2024)(Braun & Kropp, 2023). The commonly used foundation in swampy land in Banjarmasin involves the type of material used in the piles/columns of the building. There are two commonly used materials, wooden pile foundations and concrete pile foundations (Agusniansyah & Sarbini, 2024b). Wooden pile foundations are constructed using

sunduk and kalang piles. Another type of foundation used is kacapuri [5][6]. Both wooden and concrete pile foundations are combined with galam pile driving to strengthen the soil bearing capacity [7][8]. This galam pile driving requires special implementation methods during construction on this swampy land. Conditions of dry land with high water or high water levels require careful attention during implementation (Nurfansyah et al., 2020). These conditions are obstacles that cause building collapses or failures with wooden piles. The strength of wooden pile foundations is very limited, capable only of supporting light building loads [9][10][11][12]. For the latest foundation material type, concrete foundations or combinations are used (Agusniansyah & Sarbini, 2024b). However, concrete foundations are very expensive and not suitable for simple houses (Makoond et al., 2024)(Fu et al., 2023)(Canditane et al., 2023). The steps that can be taken include making improvements/reinforcements (Abdallah et al., 2024) to wooden pile foundations with a combination of wood and concrete materials.



Figure 1. Combination of Wood Pillar Foundation and Concrete Foundation.

This method requires a special design pattern related to combining foundation construction with house room design (Agusniansyah, 2024a). This forms the basis for creating a foundation design model (Agusniansyah, 2024b). The galam pile driving method is a construction technique using galam wood as the main element for foundations or piles in building structures, especially in swampy or moist soil areas. Galam is a type of wood native to South Kalimantan, Indonesia, known for its strength and resistance to decay. Let's discuss the galam pile driving method, its workings, and why it is used in construction in swampy or moist soil areas. Galam pile driving is a construction method where galam wood is used as piles or stakes to support buildings. These piles are typically driven into swampy or soft soil to provide structural support. The use of galam wood is chosen because of its resistance to moisture and its ability to withstand pressure and building loads above it.

1.1. Benefits of the Galam Pile Driving Method

Resistance to Moisture: Galam is a type of wood resistant to decay and insect attacks, making it suitable for moist or swampy soil conditions (Figure 2). **Strength and Stability:** Despite being lightweight, galam wood has sufficient strength to support building structures, making it a good choice for foundations in unstable soil. **Affordable Cost:** Compared to other construction materials, galam wood is generally more affordable, making the galam pile driving method an economical choice. **Applications of Galam Pile Driving in Construction.** The galam pile driving method is often used in various types of construction, especially in swampy or moist soil areas. Common applications include:



Figure 2. Wooden Frame of House Building on Swamp.

Stilt House Foundations: Galam piles are used to support stilt houses in swampy areas, providing stability and lifting the structure off the ground (Figure 3). **Bridges and Roads Over Swamps:** Galam piles can be used as supports for small bridges or roads in swampy areas. **Other Structures:** This method can also be applied to other buildings such as warehouses, docks, or facilities requiring strong support in moist soil.



Figure 3. Concrete foundation in swampland.

The galam pile driving method is a construction technique that relies on galam wood as piles or stakes to provide structural support, especially in swampy or moist soil areas. With proper driving processes and strong reinforcement, this method can provide stability and robustness for various types of buildings. Galam, with its resistance to decay and strength, is a suitable choice for challenging environmental conditions, making the galam pile driving method a reliable and economical construction solution.

1.2. Strength of Galam Piles

Galam wood, commonly found in South Kalimantan, Indonesia, is known for its strength and resistance to swampy soil and moist environmental conditions. These properties make it ideal for use as piles in construction, especially in foundation methods and stilt house structures. Let's explore the factors that influence the strength of galam piles and why this type of wood is a popular choice for unstable soil conditions.

1.3. Strength Characteristics of Galam Wood

Mechanical Strength: Galam has high mechanical strength, allowing it to withstand significant loads. Despite being lighter than other types of wood, galam can support heavy structures such as stilt houses and small bridges. **Resistance to Moisture and Decay:** Galam is resistant to decay due to moisture and insect attacks, a crucial factor for piles used in swampy soil or moist environments. **Compressive and Bending Strength:** Galam piles have good compressive and bending strength, enabling these piles to withstand pressure from the building above and other external loads.

1.4. Factors Influencing the Strength of Galam Piles

Wood Quality: The strength of galam piles depends on the quality of the wood used. Galam wood with a uniform texture and free from defects will be stronger and more durable. **Driving Depth:** The deeper the galam piles are driven into the ground, the more stable and strong the structure they support. Adequate depth is essential to prevent movement and provide sufficient support. Joints and

Reinforcements: Using strong joints and additional reinforcements can enhance the strength of galam piles. Proper joints ensure that the piles do not shift or crack under pressure. **Environmental Conditions:** Soil and weather conditions can affect the strength of galam piles. Very soft soil or frequently flooded areas may require special driving techniques to ensure stability.

The strength of galam piles depends on several factors, including wood quality, driving depth, construction techniques used, and environmental conditions. Due to its mechanical strength, resistance to moisture, and durability, galam is an ideal choice for foundations and structures located in swampy or moist soil environments. With proper reinforcement and driving, galam piles can provide strong and stable structural support, making it a key element in various types of construction in swampy areas and challenging environments.

1.5. Determining the Strength of Galam Pile Construction

Determining the strength of galam pile construction requires technical analysis and specific calculations. Factors such as wood quality, pile dimensions, driving depth, soil conditions, and supported load significantly influence construction strength (Agusniansyah & Sarbini, 2024a). Additionally, the type of construction used, whether for stilt houses, bridges, or other structures, also plays an important role in determining load capacity.

1.6. Factors Influencing the Strength of Galam Piles

Wood Quality: Galam is known for its strength, but the quality of the wood used is very important. Denser and defect-free wood will have a higher load capacity. **Pile Dimensions:** The larger the diameter and length of the pile, the greater the load capacity it can bear. **Driving Depth:** Deeper driving usually results in more stable support, allowing the pile to bear larger loads. **Soil Conditions:** Soil conditions are very important. Hard soil will provide better support than soft or swampy soil. **Joints and Reinforcements:** Strong joints and additional reinforcements can increase the load capacity of the construction.

1.7. Load Capacity Estimation

There is no definite number on how many tons galam piles can support, as this requires complex calculations usually conducted by civil engineers or structural experts. However, as a rough estimate, some general points that can be considered include:

Stilt House Load: For traditional stilt houses, the load can vary from several tons to more, depending on the size and weight of the house. **Bridge and Road Load:** For small bridges or roads, the load capacity needs to be greater, and additional calculations are required to ensure stability. In conclusion, to accurately determine the strength of galam pile construction in tons, complex analysis and calculations are needed, involving factors such as wood quality, pile dimensions, driving depth, soil conditions, and supported load. This process usually requires input from civil engineers or structural experts to ensure proper construction and stability.

1.8. Galam Pile Friction Strength

The friction strength of galam pile refers to the pile's ability to withstand the frictional force between the pile and the surrounding soil. This is an important aspect of construction using galam piles, especially in swampy or moist soils where friction between wood and soil greatly determines the stability and strength of the structure. Friction or frictional force occurs when the surface of the pile interacts with the surrounding soil. In the context of galam piles, friction is the force that helps keep the pile stable and not shift after being driven into the ground. The higher the friction strength, the more stable the pile and the greater the load capacity it can withstand.

1.9. Calculation Methods of Friction Strength

The friction strength of galam piles can be calculated using several approaches:

Soil Mechanics Theory: This method involves using soil mechanics concepts to calculate friction based on soil type, pile depth, and pressure. Several mathematical equations can be used to estimate frictional force. **Field Tests:** Field tests such as pressure tests can be used to measure friction strength empirically. These tests are usually conducted by civil engineers or geotechnical experts. **Friction Coefficient:** Using specific friction coefficients based on soil type and galam wood quality, friction can be calculated as the product of normal force and friction coefficient. The friction strength of galam piles is a key element in determining the stability and load capacity of structures using these piles. Factors such as wood quality, driving depth, soil conditions, and pressure affect friction. Friction calculations are usually conducted by civil engineers or geotechnical experts to ensure safe and stable structures. The friction strength of galam pile is a key element in determining the stability and load capacity of structures using these piles. Factors such as wood quality, driving depth, soil conditions, and pressure affect friction. Friction calculations are usually conducted by civil engineers or geotechnical experts to ensure the structure is safe and stable.

The presence of issues regarding how foundation reinforcement is applied to house development design models and how application steps require foundation design models as solutions for energy resistance, advanced materials, and infrastructure as part of wetland technology. This model is expected to solve building reinforcement problems on soft soil with low bearing capacity.

This research continues with field observation studies at various locations of simple house buildings, both 1 (one) and 2 (two) stories in Banjarmasin. Field data is sought as much as possible to analyze and obtain several models. The models will be tested in design with consideration of implementation methods applied in swampy soil. The aim of this research is to obtain an initial model of house design with the application of combined wooden and concrete pile foundations.

2. Methods

This study is qualitative research with a descriptive method based on literature studies and data collection through field surveys/observations. Field observation studies are emphasized more than theoretical analysis. The focus of this research is to create several foundation design models for houses based on analysis from literature study data and field observations. The models obtained will be tested against implementation methods specifically in swampy soil.

This research is a continuation of previous research that has already collected data on foundation types in swampy soils and their combinations, as well as several foundation reinforcement methods. The research stages are: identification of foundations in wetland areas, survey/field observation of foundations in Banjarmasin, analysis of foundation implementation methods, application models of house foundations on swampy soils, and finally, conclusions and recommendations.

In the initial stage, it involves a literature review of foundations used on swampy soils in Banjarmasin, the use of construction materials, connection systems, and construction implementation methods. Literature data and results from previous research are used as initial references in this study. Foundation types are identified starting from the use of materials, whether wooden pile foundations, the use of other materials such as concrete, or material combinations. Regarding the construction method, the foundation used is driven galam piles. Field data collection surveys are conducted in various housing development locations in Banjarmasin, both in housing estates and individual buildings.

2.1. Analysis

Analysis is conducted on how foundations can influence house design. The houses analyzed include both single-story and two-story buildings related to the use of building materials and the building loads borne by the foundation. Specific aspects in the analysis include: building improvement/development either horizontally (one-story laterally if there is still land) or vertically (becoming two-story). The design taken includes case studies of several house space patterns (floor plans) in both housing estates and individual buildings. Samples are chosen randomly and considered representative for model making. It will be seen how the foundation analysis is carried

out with light building loads and heavy building loads. Next, an analysis is carried out on the foundation design in the house building development process (renovation) either horizontally or vertically.

Foundation design models will be created after the analysis is conducted. The model creation is carried out in several stages starting from the initial model to the model development. If the initial model does not achieve good results, a re-survey will be conducted to obtain new data and a new analysis will be performed. Models are created using a three-dimensional (3D) method to facilitate the analysis of structural (construction) shapes and designs. The 3D models used include study sketches (miniatures) and computer animations. The goal of using study models is the possibility of obtaining spontaneous and unexpected model shapes. From the study models, 3D computer models will be created. Several models obtained from the analysis will be identified and tested against construction implementation methods. Models will be grouped based on foundation material combinations, single-story house foundation models, two-story house foundation models, and house development foundation models.

From the model results, conclusions from the analysis and research results will answer foundation problems in swampy soils in Banjarmasin. Unresolved issues will continue with recommendations for further research.

2.2. Object Description

The object describes the current state based on facts as they are. Surveys are needed to search for foundation objects in many locations. Data from objects obtained from previous research are re-identified and a comparative analysis will be conducted. To obtain foundation data, a check of foundation conditions is necessary. Because the foundation is located underground (built objects) and this condition is difficult, efforts are made to condition the land (especially waterlogged positions), soil excavation, and other necessary actions. If there are difficulties in data collection, object data is estimated based on local conditions, supplemented by interviews with owners and/or construction implementers. Surveys are conducted several times to obtain the latest and relevant object data for this research.

Data collection techniques are done through direct observation and surveys at observation locations and interviews. The data obtained are analyzed qualitatively. Survey/observation results are disclosed graphically and presented descriptively.

3. Result and Discussion

Wood Pile Foundation and Concrete Pile Foundation in Swampy Soil, consist of: Galam Piling for Foundation, Initial Model of Wood Pile Foundation and Concrete Foundation, Design Pattern of Combined Foundation. Old buildings are difficult, new buildings are easier because with design, this is the model in question.

3.1. Selection of the Use of Poles

The choice of using galam piles is closely related to foundation's piling method of galam piles or screw piles (Figure 4). If you want to stick with a series of evenly loaded galam piles, its recommend manual piling. This makes sense when expanding or renovating a house. When building a new house with wooden piles, you need to be careful when constructing it. Plan the system by preparing concrete pillars, piles, machinery, etc.

The column spacing and load in residential buildings, the concept of floors and walls, that is, the support system of a row of wooden columns, is actually conceptually understood as a uniform load. However, in the field application, there is a difference between the floor area of a low-load room and the wall area of a high-load room. This results in a difference in load. The load applied to the wall area increases, and the supporting columns that support it become smaller. This situation needs to be rectified by strengthening the supporting structure in this area.



Figure 4. Galam Piling for Foundation.

There are several galam sizes that are commonly used in field implementation (Figure 5). For fences, galams with a length of 1 meter and a diameter of 10-15 centimeters are usually used. Salt with a length of 3-5 m is used for column construction with a first floor construction load made of semi-permanent materials (wood, upright brick). Salt with a length of 6 to 9 meters is used for buildings with high loads such as : B. For two-story buildings or three-story stores.

The selection of the use of wooden piles is closely related to the piling method of the foundation, namely galam piles or piles. If you still use a row of wooden piles with the concept of uniform load, it is recommended to use manual piling. This is effective in the case of house expansion or renovation. In the case of building a new house using wooden piles, it is necessary to be precise in its implementation. The system is planned with concrete column preparation, manual or machine piling.



Figure 5. Size of Galam Wood Pile for Foundation.

The concept of column spacing and loading of the house building, floor and wall areas, namely the wooden column structure system in a row, is actually conceptually taken as an even load. However, in the field application, there is a difference in the floor area of the room with a light load in contrast to the wall area of the room that bears a heavier load. This results in a difference in load. The load on the wall area is heavier, making the columns that support it decrease. This condition must be corrected by strengthening the column construction in this area.

3.2. Galam as Piling

In field implementation (Figure 6), there are several sizes of galam that are often used considering the availability of galam in the market. Galam with a length of 1 meter with a diameter of 10-15cm is usually used for fences. Galam 3-5 m long is used for building columns, with the load of a semi-permanent 1-story building (wood, standing brick). 6-9 meters long galam is used for heavier load buildings such as 2-storey buildings and even 3-storey shop houses.



Figure 6. Galam Pile Arrangement for Foundation.

3.3. Manual and Machine Piling

Manual Pile Driving Salt piling can be done manually without using a machine (Figure 7) by inserting the galam pile driving vertically into the ground. To put the 'galam' head on the ground, you can support it by setting the pole using man body weight. Efficiency and economic factors are taken into consideration in using this method. Even for small salt settings, a distance of 1 to 4 meters can be achieved. It will certainly be more economical if the amount of maintenance is small. Another advantage of this construction method is that the space for pile driving is small and it is difficult to install pile drivers.



Figure 7. Galam piling with manual method.

Galam piling work can be done manually without a machine by sticking the galam into the ground vertically. To position the head of the galam into the ground can be helped by pounding with the weight of the human body. The consideration for using this method is the efficiency and economic factor. For small size galam piling, from 1 meter to 4 meters can still be done. With a small number of piles, it is of course more economical. In addition, narrow piling location areas or difficult to place piling machines are also an advantage of using this method.

In addition to the manual method, galam piling can also be done using piling machine (Figure 8). The main tool used is a weight or hummer (**pig's head - banjar language) with a pounding load of 100 kg to 250 kg, driven by a steel rope lifted by a load-driving machine. Mechanical methods use modern piling tools such as pile drivers that are capable of exerting greater and more consistent pressure than manual methods. This tool usually consists of a long pile mounted on a metal frame and operated by a hydraulic or pneumatic engine. It can drive the pile into the ground with adjustable force as needed.



Figure 8. Galam piling with machine method.

3.4. 2-Storey Wooden House

In fact, in many cases, wooden pile structures can also be used for two-story residential buildings, but this should be avoided for technical implementers. The strength of wooden piles is very limited, and two-story wooden buildings will bear a large load. There is no technical guarantee that multi-storey wooden buildings will last long.

Actually and often also done is the construction of wooden piles can also be for 2 (two) storey houses, but this for technical implementers should be avoided. Because the strength of wooden poles is very limited, and 2 (two) storey timber frame buildings have a large load. There is no technical guarantee that multi-storey timber frame buildings can last long.

The models of wooden columns and concrete columns

There are the types of wooden columns (Figures 9 and 10) and concrete columns. Detection of foundation development in the field is carried out using a combination of wooden and concrete columns (Figure 11). The concept of 1 meter spacing between rows of wooden columns is still used. This support system consists of a series of wooden columns conceptually designed to carry the load evenly. However, this charging concept is different from the actual application. It can be seen that

the difference in load is that the floor area of the room is smaller than the wall area of the building. When the load on the wall increases, the columns supporting the wall become smaller. To improve this situation, the support system in this area needs to be strengthened.



Figure 9. Wooden Pillar Foundation in Swampland.



Figure 10. Wood Pillar Foundation Model.

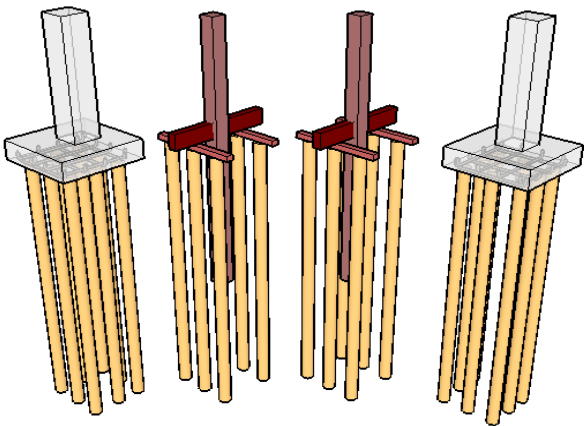


Figure 11. Combination of Wood Pillar Foundation and Concrete Foundation.

The structural system consists of rows of wooden columns that are conceptually considered to have a uniform load. However, this charging concept is different from the actual application. There is a difference in load, i.e. the floor area of the room is lighter than the wall area of the building. The load acting on the wall surface becomes larger, so the columns supporting it become smaller. This situation needs to be corrected by strengthening the column structure in this area. The pillars

supporting the wall need to be strengthened. The solution is to replace them with concrete pillars. The shortcomings of wooden columns in terms of material can certainly be overcome by using concrete columns. Concrete columns can be taller than wooden columns and are also sturdier. The advantage of prestressed concrete columns is that there is no limitation on column height and they are easily adapted to the height of wooden columns. Concrete columns are placed in certain locations, such as at the corners of building walls that receive greater loads. By adding and connecting these structures, the bearing capacity of the foundation is expected to increase. Although concrete columns are placed at specific locations, they are considered to have a unified structure. Therefore, the uniform load concept is always used and the total load carrying capacity of the building is increased.

The pillars supporting the wall need to be reinforced. The solution is to replace them with concrete columns. The lack of material for wooden columns can certainly be overcome by using concrete columns. The uniform load concept is used by combining the positions of concrete columns interspersed with wooden columns. Three rows of wooden columns are replaced with concrete columns. If the distance between rows of wooden columns is 1 m, the concrete column positions are 3 m apart.

The same load concept was used along with the location of concrete columns and wooden pillar columns in between (Figure 11). Three rows of wooden columns are replaced with concrete columns. If the distance between rows of wooden columns is 1 m, then the distance between concrete columns is 3 m, and salt columns are always used to make the foundation of wooden columns. The wooden pillar columns consist of four salt columns made of Sunduk Karan wood. This type of party arrangement uses a sequential arrangement.

Galam poles are always used to make wooden pole foundations. The wooden columns have 4 galam columns with a sunduk kalang wooden structure. The arrangement of this type of party uses a sequential arrangement. While the local galam slab foundation made of galam groups is used for concrete columns. With the condition of this group, concrete columns will certainly be able to withstand greater loads than wooden columns. This is the concept of reinforcing the columns by using concrete columns at the corners of the building. 25/25 cm concrete pillars and 90x90 cm concrete slab foundation. The idea of replacing the corner columns of a building is the same as "covering" the wooden columns with concrete columns.

Nowadays, the slab foundation of the local galam's pile group is used for concrete columns. Naturally, in this group of conditions, concrete columns are able to withstand greater loads than wooden columns. The idea is to strengthen the pillars by using concrete pillars at the corners of the building. Concrete columns 25/25 cm, concrete slab foundation 90x90 cm. The idea of replacing the corner columns of a building is similar to "covering" wooden columns with concrete columns.

Concrete columns are treated the same as wooden columns. So the horizontal structural connections of the wooden beams will be supported and fixed to the concrete columns. The upper structure, including the floor, is designed to resemble a typical timber frame. The distance between rows of wooden columns is 1 meter, the same as the distance between rows of wooden columns commonly used in residential construction. This means that the horizontal structural connections of the wooden beams are supported and attached to concrete supports. The upper structure, such as the floor, is designed to resemble a typical timber frame. The distance between rows of wooden columns is 1 (one) meter and is the same as the distance between rows of wooden columns widely used in housing construction.

Concrete columns are taller and more stable than wooden columns. The advantage of prestressed concrete columns is that there is no limitation on column height and they are easy to adjust to match the height of wooden columns. Concrete columns are installed in certain locations that receive higher loads, such as at the corners of building walls. The purpose of adding and connecting these structures is to increase the bearing capacity of the foundation. Although concrete columns are installed at specific locations, they are assumed to have a uniform structure. Therefore, the concept of uniform loading is always applied so as to increase the load carrying capacity of the entire building.

4. Conclusions

From the research results, the use of galam piles as the main foundation shows advantages in terms of efficiency and economy, especially for home renovation or expansion. However, in new building construction, careful planning is required due to the different load distribution between floor and wall areas. In field implementation, the use of galam poles of various sizes depends on the load of the building. For two-storey buildings, although possible, the strength of wooden poles is limited so their use should be avoided.

Strengthening the structure can be achieved by replacing the timber posts with concrete posts at specific locations such as the corners of walls that receive greater loads. This combination of concrete and timber poles maintains the concept of uniform load by placing concrete poles at a distance of three meters, replacing every three rows of timber poles. Thus, the bearing capacity of the foundation is significantly increased. Concrete posts are taller and more stable than timber posts, and are easily adaptable to the height of timber posts, providing an additional advantage. The overall structure is designed to have a uniform load-bearing capacity, improving the overall stability and durability of the building.

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