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The Analysis Study of Strength on Concrete Formwork Wood Construction

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ABSTRACT

The clean water intake building was built along with a service bridge that functions as accessibility. This bridge is made using reinforced concrete structures and piles. The concrete casting uses traditional formwork with wood materials. This study aims to determine the strength of the formwork and the sequence of installation. The stages of the study include field data observation, drawing into technical structural drawings, strength analysis, and drawing conclusions. The results obtained are in the form of a formwork structure load flow scheme that works on construction. Then obtained the cross-sectional capacity of the retaining beam (galam wood) which is can withstand the bending moment, shear force, and deflection of the casting load. Likewise, the girders (ironwood) and steel hangers withstand the construction load on them. In addition, the size of the ironwood used can be reduced to a smaller size of 8x8 cm, resulting in savings in implementation costs.

1. INTRODUCTION

Samarinda is a city with a fairly dense population, with a city area of 717.4 km2 in 2020 it is recorded that it has a total population of 886,806 people [1]. The high population increases the need for clean water in Samarinda City. According to PDAM Samarinda City data, the need for clean water in 2020 is 3.134 liters/second, of which 2.241 liters/second is used for domestic needs and 207 liters/second for non-domestic needs [2]. To increase the demand for clean water for Samarinda City, PDAM Samarinda City together with the Government of Samarinda City have increased the number of drinking water supply systems, one of which was built in Sungai Kapih Village, Sambutan District, Samarinda City. This study was conducted on the project.

This system is a supply of drinking water that utilizes springs (such as rivers or dams) to make clean water suitable for consumption [3]. In this project, water is planned to be taken directly by the intake from the Mahakam river for further processing. To collect water from the river, a water pump is needed. This pump is placed on top of a building that juts towards the river. For that we need to build a service bridge.

The service bridge is made using concrete construction with a steel pile foundation, where the work is carried out over the river so that formwork is needed for the casting work. This work process needs to be analyzed based on concrete work standards. Formwork itself is a mold that is made in such a way as to hold and give shape to the concrete from the newly poured concrete until the concrete hardens [4]. Formwork is a construction structure that is temporary, but will determine the success of a construction. Formwork used in concrete work must pay attention to several aspects. The first aspect is the quality of the formwork and the second aspect is safety for the construction workers, namely the strength of the concrete so it does not collapse [5, 6]. In addition, the factors for choosing the formwork method in a construction project must pay attention to the condition of the building structure to be worked on, the area of the building and the availability of materials and tools [7-9]. The formwork system classification consists of traditional, flexible and recyclable. Traditional formwork systems use wood or metal materials, as described [6]. The formwork beam used in the project is galam wood. Galam wood (Melaleuca Cajaputi) is a wood that is still often used in construction, one of which is as a retaining beam. [10]. Galam wood has varying levels of strength and durability. This wood is classified as class II wood [11]. Wood has good physical and mechanical properties compared to other materials [12]. Wood is able to withstand tensile, compressive and bending stresses. In addition, wood is also able to dampen vibrations [13]. The use of galam wood as formwork retaining beams is a traditional method and is widely used, especially in Kalimantan and Sumatra [14]. In terms of cost, the use of wooden formwork is 19% more expensive than using metal/modern formwork [15, 16]. In addition, traditional formwork made of wood requires extensive labor to cut and assemble the formwork structure, has a short life span and cannot maintain its shape when exposed to loads [17-19]. In contrast, research conducted [20] shows that the use of traditional wood formwork systems is still more economically profitable. In addition, modern formwork is easier to shape and has a certain strength. The effect of the cost of formwork work on the cost of concrete structure work is something that must be planned so that formwork work is more economical [21, 22]. In research by providing accidental loads on formwork, it is known that the shorter the failure time of the structure, the clearer the remaining dynamic response [23]. In other studies, the types of loads that are taken into account include static loads, fatigue and dynamic impact loads [24].

Each project has its own uniqueness, in this project a load flow system is obtained in the form of dead loads in the form of cast concrete and other loads that are retained by the formwork system and are forwarded to the pile foundation. By using the loading path, the strength of the formwork construction can be analyzed against its durability, stiffness, and safety [25, 26].

In Figure 1, the use of galam wood as formwork support beams is not arranged systematically. The use of galam wood as formwork beams was used without going through analysis and no shop drawings were used as a reference so that the installation was irregular. Thus, construction safety is not guaranteed, which can result in construction collapse, and lead to the use of materials that are not effective, causing wastage of building materials and relatively expensive work costs. Furthermore, the evaluation of the implementation of casting is determined by the formwork construction system used. Therefore it is necessary to analyze the strength of the formwork. From this analysis it will be known the process of installing formwork construction systematically. In addition, an evaluation of the reinforced concrete work was carried out.

Figure 1. The use of galam wood as formwork which is not arranged systematically

2. METHOD

This research was conducted in several stages which can be seen in Figure 2. The first stage took primary data directly in the field in the form of photographs, notes and other additional information. In addition, secondary data was obtained in the form of working drawings, work implementation methods, time schedules and concrete test results. Then, the data is processed and re-drawn in the form of technical drawings.

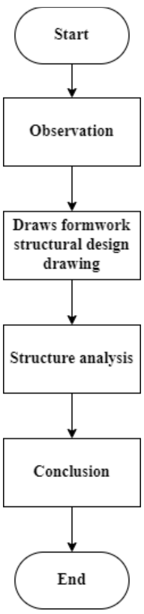

Figure 2. Study stages flow chart

After that, an analysis of the technical data that has been obtained is carried out. Analysis was carried out on the formwork construction system which includes moulds/references, retaining systems made of galam wood, supports made of ironwood and hangers made of reinforcing steel.

The final stage carried out the discussion and drawing conclusions.

3. RESULT

3.1 Formwork installation method

In this project, the formwork installation was carried out using the traditional system as shown in Figure 3, where the upper part of the formwork was made of 12 mm plywood material [27]. Then the load is distributed by the galam wood. The stages of implementation are as follows.

Figure 3. Formwork installation process

Stage 1, on the pile, hooks are provided on both sides as a support for ironwood. Ironwood measuring 10 x 10 cm is placed crosswise. Steel hook measuring ⌀16 mm functions as a hanger. See the description in Figure 4.

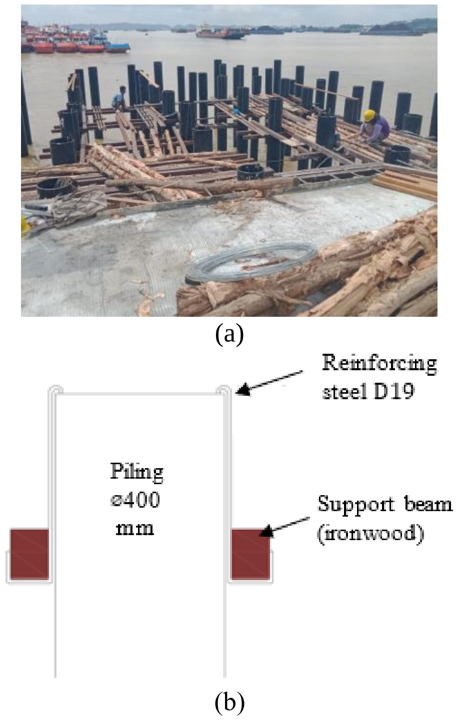

Figure 4. (a) The process of hanging ironwood and (b) hanger model as ironwood pedestal

Stage 2, after the ironwood is installed which functions as a pedestal to place the galam wood. Galam wood measuring ⌀80 mm is arranged lengthwise as much as ± 8 pieces in each segment.

Stage 3, after the galam wood is attached to the top, the galam wood is arranged with a relatively smaller size. Galam wood measuring ⌀50-60 mm is arranged crosswise. This wood functions as a load distribution of the load on it (concrete load and formwork load). See the description in Figure 5.

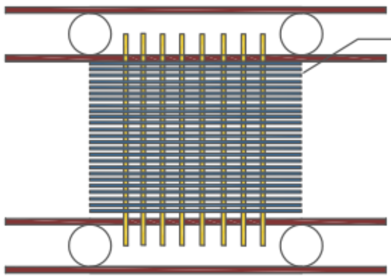

Figure 5. Formwork structure model

The stages of implementation described above show that the installation of the formwork construction system is technically sequential. In this way, clear working drawings and installation methods can be made.

3.2 Retaining beam analysis

Material and construction technical data are as follows:

Formwork board thickness (h)	=0.012 m
Floor plate width (L)	=2.4 m
Formwork board width (b)	=2.5 m
Floor plate height (h1)	=0.3 m
Wood density (G)	=5,400 N/m^3
Beam width (b)	=0.3 m
Distance between locations (ℓ)	=2.3 m
Beam height (h2)	=0.35 m

From Figure 6 it is known that the structural model with the cross-sectional area of the concrete slab. The concrete beams rest directly on the pile foundation. Galam wood holds the weight of the floor slab. The cross-sectional area of the plate is obtained A=0.72 m^2.

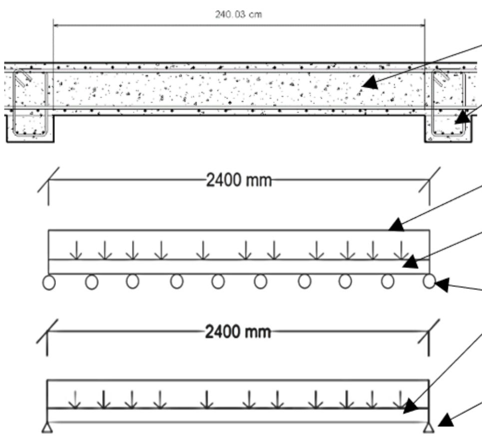

Figure 6. Modeling the formwork structure into a placement system

The weight of formwork boards can be calculated by the following equation.

$$Q_{bek} = b \times h \times G \quad (1)$$

Q_{bek}=2.5 m · 0.012 m · 5,400 N/m^3
= 16.2 N/m

Evenly distributed dead load (Q) is obtained from the cross-sectional area multiplied by the unit weight of fresh concrete, density (D)=24,000 N/m^3 [28].

$$Q = (A \times D) + Q_{bek} \quad (2)$$

Q=(0.72 × 24,000) + 162
= 17.442 N/m

The uniform load (q) acting on the retaining beam structure is calculated by dividing the dead load by the number of galams (n galams), so:

q=17,442 / 10
=1744.2 N/m

The placement reaction (Rav) and maximum moment (M) can be calculated as follows:

$$R_v = \frac{1}{2} \times q \times l \quad (3)$$

Rv=$\frac{1}{2}$ × 1744.2 × 2.3
= 2005.8 N

$$M = \frac{1}{8} \times q \times l^2 \quad (4)$$

M = $\frac{1}{8}$ × 1744,2 × 2.3^2
= 1153.3 Nm

Factored load is calculated by the equation:

$$Mu = \frac{1{,}4 \times M}{\lambda} \quad (5)$$

$$Vu = \frac{1{,}4 \times R_v}{\lambda} \quad (6)$$

where, λ is the time factor=0.6.

$Mu = \frac{1.4 \times 1153.3}{0.6}$
= 269,110 Nmm

$V = \frac{1.4 \times 2005.8}{0.6}$
= 4680,27 N

After obtaining the ultimate load, the strength and safety of the formwork retaining beam can be controlled. The formwork retaining beam data is taken from SNI 7973-2013 [29].

The average diameter of galam wood (d)=80 mm
Wood Elastic Modulus (E'05)=19,569.92 MPa
F'b=54 MPa
F't=50 MPa
F'v=6.1 MPa
F'c=41 MPa

Control of bending can use the equation

$$F'b_{ter} = Cm \times Ct \times Cf \times F'b \quad (7)$$

Description,
Cm=Wet service correction factor=0.85
Ct=temperature correction factor=1.0
Cf=Shape correction factor=1.40

So,

$$F'b_{ter} = 0.85 \times 1,0 \times 1,40 \times 54$$
$$= 64.26 \text{ MPa}$$

While the circular cross-sectional modulus of the rod is

$$W = \frac{\pi \times D^3}{32} \quad (8)$$

$$W = \frac{\pi \times 80^3}{32}$$
$$= 50,240 \text{ mm}^3$$

The bending control [30] is declared safe provided that the ultimate moment load (Mu) is smaller than the moment cross-sectional capacity of the beam. Calculated by the following equation:

$$\text{Mu} \leq (0.85 \times \text{W} \times F'b_{ter}) \quad (9)$$

$$2,691,100 \text{ Nmm} \leq (0.85 \times 50,240 \times 64.26)$$
$$2,691,100 \text{ Nmm} \leq 2,744,159 \text{ Nmm}$$

Control of shear can use the equation:

$$F'v_{ter} = Cm \times Ct \times Cf \times F'v \quad (10)$$

Description:
Cm = Wet service correction factor=0.97
Ct = temperature correction factor=1.0
Cf = shear stress correction factor=1.67

$$F'v_{ter} = 0.97 \times 1.0 \times 1.67 \times 6.1$$
$$= 9.88 \text{ MPa}$$

Shear control is declared safe when the ultimate shear load (Vu) is less than the shear capacity of the beam, calculated by the following equation.

$$V_u \leq 0,75 \times (\frac{3}{4} \times \pi \times r^2) \times F'v_{ter} \quad (11)$$

$$\text{Vu} \leq 0.75 \times (\frac{3}{4} \times \pi \times 402) \times 9.88$$
$$4,680.27 \text{ N} \leq 27,924.81 \text{ N}$$

Deflection control is declared safe if the resulting deflection (δx) is smaller than the permissible deflection (ℓ/300). For beams with two placements calculated by the following calculation.

$$\delta_x = \frac{5 \times q \times l^4}{384 \times E_{05} \times I} \quad (12)$$

$$I = \frac{\pi \times D^4}{64} \quad (13)$$

$$I = \frac{\pi \times 80^4}{64}$$
$$= 2,009,600 \text{ mm}^4$$

which, I is the moment of inertia of the circular section, then:

$$\delta_x = \frac{5 \times 0,17 \times 2300^4}{384 \times 19569,92 \times 2009600}$$
$$= 1.62 \text{mm}$$

While the clearance deflection (ℓ/300)=8.33 mm.

Because δx is smaller than ℓ/300, thus the formwork beams are safe against deflection.

Retaining beams can withstand loads in the form of formwork boards, cast concrete and casting process loads. This can be seen from the cross-sectional capacity that is greater than the force acting and the deflection that occurs.

3.3 Support beam analysis

After the calculation of the load on the galam wood bearing structure is safe, then the load is transferred to the ironwood wood laying structure. This structure is modeled in a two-laying structure as shown in the following Figure 7.

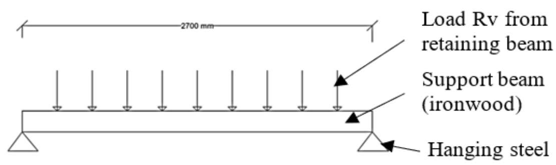

Figure 7. Modeling the ironwood supporting beam structure into a placement system

The supporting beams in the form of ironwood are subjected to control analysis for bending, shearing and deflection as identical to the calculation of the retaining beam (galam). The data that has been obtained are.

P=2.005.8 N
Vu=8,327.81 N
Distance between placements (ℓ)=2.7 m
Ironwood width (b)=50 mm
Ironwood height (h)=50 mm

Ironwood is classified as class I strength wood and has a quality code of E25 [31]. From SNI 7973-2013 obtained.

E'05=24.719 MPa
F'b =49.6 MPa
F'c =36 MPa
F't=46.4 MPa
F'v=5.2 MPa

The control for bending is obtained by the following values.

M=7.947 N m
Mu=1,854,303 N mm
$F'b_{ter}$=59.02 MPa

The cross section of an ironwood beam is square, so the section modulus is calculated using the following formula.

$$W = \frac{1}{6} \times b \times h^2 \quad (14)$$

$$W = \frac{1}{6} \times 100 \times 100^2$$
$$= 166{,}666.7 \text{ mm}^3$$

The bending control of ironwood beams obtained the following values.

$$Mu \leq 0.85 \times W \times F'b_{ter}$$
$$1{,}854{,}303 \text{ Nmm} \leq 0.85 \times 166{,}666.7 \times 59.02$$
$$1{,}854{,}303 \text{ Nmm} \leq 8{,}361{,}733 \text{ Nmm}$$

The shear control of ironwood beams obtained the following values.

$$F'v_{ter} = 8.42 \text{ MPa}$$

$$Vu \leq 0.75 \times (\frac{2}{3} \times b \times h) \times F'v\text{-}ter$$
$$4{,}680.27 \text{ N} \leq 0.75 \times (\frac{2}{3} \times 100 \times 100) \times 8.42$$
$$4{,}680.27 \text{ N} \leq 42{,}100 \text{ N}$$

Control the deflection of ironwood beams, with the following calculations.

$$I = \frac{1}{12} \times b \times h^3 \quad (15)$$

$$I = \frac{1}{12} \times 100 \times 100^3$$
$$= 8{,}333{,}333 \text{ mm}^4$$

where, I is the moment of inertia of the square section. Deflection can be calculated as follows.

$$\delta_x = \frac{5 \times 0.087 \times 2{,}700^4}{384 \times 24{,}719.92 \times 8{,}333{,}333}$$
$$= 0.29 \text{ mm}$$

While the allowable deflection (ℓ/300)=9 mm, the formwork support beam is safe against deflection.

Support beams can withstand the load of the retaining beam construction. This can be seen from the cross-sectional capacity that is greater than the force acting and the deflection that occurs. In the analysis of the bending moment, it can be seen that the cross-sectional capacity is very large compared to the acting force.

3.4 Hanging steel analysis

The steel rod as ironwood hanger serves to hold the entire load calculated by the following equation.

$$T_u \leq 0.90 \times As \times fy \quad (16)$$

in which, *Tu* is the ultimate tensile force acting on the rod, obtained from the force *Rv*.

Known,

Diameter of reinforcement (d)=19 mm
Area of reinforcement (As)=283.4 mm^2
The yield stress of steel fy=240 MPa

found,

$$T_u = \frac{1}{2} \times q \times l^2$$
$$= 2{,}354.67 \text{ N}$$

$$2{,}354.67 \text{ N} \leq 0{,}90 \times 283.4 \times 240$$
$$2{,}354.67 \text{ N} \leq 2{,}712.96 \text{ N}$$

Suspension steel is able to withstand the load of the girder construction. This can be seen from the steel cross-section having a greater tensile stress than the acting force.

From the analysis above, it was found that the entire formwork structure system was safe. Even so, the girders can be optimized to be 80x80 mm (market size for Samarinda City). The capacity of the cross section to withstand bending is 4,281,207 N.mm, the shear section capacity is 26,944 N and the deflection is 0.71 mm. This result is still greater than the working load. By reducing the size can save formwork material costs. This is very relevant to previous research that the use of traditional formwork beams has a higher cost [15].

In the current era, the use of disposable scaffolding and formwork is inappropriate and can cause waste after project activities are completed. The use of scaffolding and formwork that can be used repeatedly is the right solution, one of which is to overcome environmental pollution and save costs as shown in Figure 8 below [32]. In addition, the formwork construction method must be chosen significantly so as not to affect the cost, time and quality of the construction [33].

Figure 8. Modern formwork systems use formwork made of iron

4. CONCLUSION

The load flow mechanism of the structure from the formwork to the piles can be described, the dead loads originating from the reinforced concrete are forwarded to the distribution beams. The load is distributed to the retaining beam. The load from the retaining beam is then transmitted to the supporting beam. The load from the girders is transferred to the foundation through the steel hangers.

In general, the construction of traditional wooden formwork is able to withstand casting loads and meet cross-sectional capacity requirements. However, the girders can optimize the use of material from ironwood 10x10 cm to 8x8 cm.

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NOMENCLATURE

Q	Uniform load, N/m
Rv	Placement reaction, N
M	moment, N.m
Mu	Ultimate moment, N.m
V	Shear force, N
Vu	Ultimate shear moment, Nu
I	Moment of inertia, mm^4
W	modulus section, mm^3
Tu	Ultimate tensile force, N
E’05	modulus of elasticity of wood, N/mm^2
λ	wood time factor, 0.6
δ	defliction, mm
⌀	diameter, mm