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Comparison of sliding and conventional formworks in dam tunnel at the Meninting Dam in West Nusa Tenggara

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Abstract

Tunnels are underground structures that are longer than the width of the excavation. The Meninting Dam tunnel work is one of the main jobs with a very high level of difficulty. This tunnel has a length of 243.44 m and a diameter of 9.4 m. The Meninting Dam Tunnel has a function as a temporary diversion of water from the river to the tunnel so that the main structure of the Meninting Dam is not disturbed by river flow. The tunnel concreting work consists of 3 (three) items, namely reinforcement, formwork and concrete casting. Of the three work items, the work that has the potential to be accelerated is formwork. In the Meninting Dam development project there are two types of formwork, namely conventional formwork and sliding form formwork. Based on the results of calculating the cost, time and quality requirements of the comparison of using conventional formwork with sliding form formwork, it is found that the difference in costs obtained using conventional formwork cheaper than sliding form formwork, and the time difference required in completing the formwork work using conventional formwork and sliding form formwork is 83 (eighty three) days and the quality comparison that has been obtained is that conventional formwork is not neat, not smooth and leaves a lot of wood waste while the quality of sliding form formwork is tidier, smoother and leaves no waste.

Keywords: Tunnel; Meninting Dam; Conventional Formwork; Sliding Formwork

1. Introduction

In the construction of the Meninting Dam project, this is one of the projects whose implementation uses concrete molds or sliding form formwork. The technique of making concrete molds was initially carried out conventionally by utilizing simple and easy-to-obtain equipment and materials. In line with the development of the times, construction in Indonesia began to follow suit and look for better methods, including choosing the type of concrete form. Currently, large construction projects are increasingly popular with the use of prefabricated formwork, which is a formwork system in which parts of the formwork have been made on site or made in a factory with a custom system according to the design of the customer. For work on dam projects, most of them are custom because they have different designs and sizes. One of the manufactured formwork products to be reviewed is an engineering system using a movable iron plate material (sliding form).

Of the several work items carried out, tunnel work is one of the main jobs with a high degree of difficulty. The circumvention tunnel is part of the meninting dam which has a function as a diversion channel or diversion of river flow before the core work of the dam, namely the main dam, is carried out. The location of the tunnel is to the right of the main dam towards the downstream, and is at an elevation of +147.80 to +145.00 with a design slope of 0.00805 m with a layer of rock that covers the type of volcanic break, tufan sand and rock alternating sand, volcanic breccia stone and the length of the tunnel is 388.504 m.The implementation of tunnel concreting consists of 3 (three) work items, namely reinforcement, formwork and pouring of concrete.

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2. Research methods

The methods in this research of analysis and compare the use of sliding form formwork with conventional formwork in terms of cost, quality and time in circumvention tunnels in the Meninting Dam Development Project in West Lombok, West Nusa Tenggara.

3. Results

3.1. Comparative Analysis of Implementation Methods

The implementation method is a systematic implementation description in a good and correct way. The selection of the implementation method greatly influences the course of construction activities starting from preparation, installation to the final result.

Choosing the right method will have an impact on time management and construction costs. Because methods, costs and time in construction activities are bound to each other. In this study, the authors analyzed the comparison of the use of sliding form formwork and conventional formwork in Meninting Dam circumvention building tunnels.

3.2. Implementation method of sliding form formwork

Sliding forms are formwork elements made in a factory, most of the components are made of steel. This formwork is intended for repeated use of the same size.

Formwork stands and slides on wheels on level ground or on steel tracks (rails) with sleepers arranged over inverted curves. This formwork is effective for relatively straight and long tunnels.

The philosophy of how the sliding form works is that its dimensions can be expanded during the casting process and can be easily shifted to the next concrete casting location by using a motor that is mounted on 2 (two) sides of the portal leg (left and right). The following is a method for implementing sliding form formwork.

3.3. Conventional formwork execution method

Conventional formwork is formwork that uses the main materials in the form of wood, multiplex, and boards. During the process, formwork is installed according to the dimensions of the structure to be built. After the concrete has hardened, the formwork is dismantled one by one for each part. So this conventional formwork is generally only used for 2 (two) to 3 (three) times the work taking into account the components that can still be used in the next process.

3.4. Cost Comparison Analysis

Cost analysis is needed to determine the amount of costs required for each implementation method used in the implementation of construction projects. To get a cost comparison analysis between sliding form formwork and conventional formwork is to process the data obtained from the Meninting Dam Project.

Project costs which consist of direct costs and indirect costs have a relationship with time and tend to be contradictory. If the project implementation time is accelerated, it will result in an increase in direct costs but a decrease in indirect costs (Sudarsana, 2008).

3.5. Direct cost

Direct costs are all costs that are directly related to construction work in the field. Direct costs can be obtained by multiplying the volume/quantity of a job by the unit cost of the job. Direct costs include:

- Cost of materials and materials
- Wages Cost
- Tool costs

3.5.1. Indirect costs

Indirect costs are additional costs that must be incurred in carrying out activities or work but are not directly related to the costs of materials, equipment and labor. Indirect costs include:

- General overhead costs
- Project overhead costs

Data that can be processed include work volume, analysis of work unit prices and budget plans.

3.6. Job volume

Work volume is the amount of area in a structural component work that is measured in square meters. Calculation of the volume of work in this study was carried out by calculating the total surface area of the tunnel to be cast. Based on the results of calculations based on the working drawings of the Meninting Dam construction project, then matched with the volume of the Meninting Dam project engineering team, basically the volume of sliding form formwork and conventional formwork is the same.

Table 1 Volume of formwork work

No	Work item	Unit	Volume
1	Tunnel Length	m'	243,44
2	Steel formwork (sliding form) for tunnels	m^2	5353,42
3	Steel formwork (sliding form) for tunnels/segments	m^2	6,10
4	The number of segments in the circumvention tunnel	bh	40

3.7. Unit price analysis

Unit price analysis is a way of calculating the unit price of construction work which is translated into multiplication of the need for building materials, wages for work and equipment with prices for building materials, standard wages for workers and rental/purchase prices for equipment to complete per unit of construction work.

Analysis is a formulation to determine the price and wages of each job in unit form. In the list of budgets, the amount of each part of the work is arranged as mentioned in the bestek, successively regarding the explanation of the parts. If the number of units is obtained (eg content or volume in m^3 and area in m^2), then this number is multiplied by the unit price of each type of work. Furthermore, the sum of all the parts is the budget for building costs.

3.8. Time Comparison Analysis

Time comparison analysis was carried out to determine the time required for each type of formwork for the formwork installation process per segment. Time analysis of conventional formwork and sliding form formwork uses work volume data, unit price analysis, installation time and production capacity of workers based on field observations on the Meninting Dam construction project.

Table 2 Installation times

No	Field work items	Installation time per segment (Days)	
		Sliding Forms	**conventional**
1	Formwork settings	14	1
2	Formwork installation	2	3

3.9. Quality Comparison Analysis

Quality or quality has a definition that varies from conventional to more strategic. The conventional definition of quality usually describes the direct characteristics of a product such as: performance, reliability, ease of use, aesthetics and so on. The definition of a quality strategy is something that is able to meet the desires or needs of customers (meeting the needs of customers).

Comparative analysis in terms of quality in this study was seen from several classifications, the quality comparisons taken represented in terms of formwork strength, durable quality, and concrete molding results from formwork work.

The quality/outcome of concrete prints has criteria that are defined as whether or not the column surface is smooth or not produced by a type of formwork, and whether or not there is damage to the concrete molds produced by a type of formwork.

4. Discussion

4.1. Calculation of Sliding Form Formwork and Conventional Formwork Work Volume

From the calculation above, it can be concluded that the area of sliding form formwork and conventional formwork is the same. These calculations were obtained from observations in the field where the author discussed with the Meninting Dam project engineering team. The conclusion of these calculations can be seen in Table 3.

Table 3 Formwork area

No	Work item	Unit	Volume
1	Tunnel length	m'	243,44
2	Formwork area for tunnels	m^2	5353,42
3	Segment formwork length	m^2	6,10
4	The number of segments in the circumvention tunnel	bh	40.00
5	Segment formwork area	m^2	133,835

4.2. Calculation of Cost Analysis

Cost analysis calculations include materials, labor wages, and tools obtained from the analysis of unit work results (AHSP) for sliding form formwork and conventional formwork. The unit price analysis (AHSP) has an index of materials, wages for labor and tools. AHSP itself refers to the analysis of the contractor's bid unit price at the time of the tender.

4.2.1. The price difference between sliding form formwork and conventional formwork

Sliding form formwork and conventional formwork have their respective advantages and disadvantages. In terms of costs, sliding form formwork is much more expensive than conventional formwork, due to several influencing factors, especially in terms of work materials. Price comparison between sliding form formwork and conventional formwork can be seen in Table 4.

Table 4 Price difference

No	Work item	Unit	Total price
1	Steel formwork (sliding form) for tunnels	m^2	2,399,757,398.47
2	Exposed formwork type A (Conventional)	m^2	1,627,019,756.36
Price gap		IDR 772,737,642.11	

4.3. Calculation of Time Analysis

Table 5 Implementation time

No	Work item	Execution time (days)
1	Steel formwork (sliding form) for tunnels	63
2	Exposed formwork type A (Conventional)	150
time difference		87

Based on the implementation plan schedule made by the contractor on the time schedule (s-curve), the time needed to complete the formwork work is 10 months of implementation.

From the results of the time analysis it can be concluded that the sliding form formwork is fast in the casting process because the tool only moves forward and does not need to be set again. Setup is only done once at the start. The time for carrying out the sliding form formwork work can be seen in Table 5.

4.4. Quality Comparison Analysis

Comparative analysis in terms of quality in this study was seen from several classifications, the quality comparisons taken represented in terms of formwork strength, durable quality, and concrete molding results from formwork work.

The quality/outcome of concrete prints has criteria that are defined as whether or not the column surface is smooth or not produced by a type of formwork, and whether or not there is damage to the concrete molds produced by a type of formwork.

Comparative analysis in terms of quality in this study was seen from several classifications, the quality comparisons taken represented in terms of formwork strength, durable quality, and concrete molding results from formwork work. Comparison Comparative analysis of quality in sliding form formwork and conventional formwork can be seen in Table 6.

Table 6 Comparison of quality

No	Comparison Items	Formwork Type		Note
		Sliding forms	**conventional**	
1	Formwork settings		√	More practical and faster conventional
2	Casting cycle	√	√	The casting cycle is the same
3	Reusable materials	√		Sliding form formwork can be used repeatedly
4	Design	√	√	Design according to tunnel conditions
5	Green Construction	√		Conventional formwork creates material waste
6	Quality	√		The quality of the concrete produced by the sliding form formwork is smoother and neater
7	Accessibility	√	√	Access to work is the same as using the emergency stairs
8	Formwork dismantling	√		Easier dismantling of sliding form formwork

4.5. Comparative Analysis of Cost, Time and Quality

Based on the results of the analysis of the cost, time and quality requirements, the comparison of the use of sliding form formwork and conventional formwork can be concluded in table 7 below.

Table 7 Comparison of cost, time and quality

No	Comparison items	Formwork Type		Information
		Sliding forms	**conventional**	
1	Cost	IDR 2,399,757,398.47	IDR 1,627,019,756.36	Difference IDR 772,737,642.11 (sliding form is more expensive)
2	Time	63 days	150 days	87 days difference (faster sliding form, so it can do other critical track work)
3	Quality	Neat and smooth	Not neat and smooth	The sliding form formwork is neater and the casting results are smoother

5. Conclusion

- Based on volume calculations assisted by the Meninting Dam Engineering team, the volume of sliding form formwork and conventional formwork is 5,353.415 m^2. The volume of both formwork is the same.
- Based on the cost comparison analysis that the researchers have done, the price for sliding form formwork is Rp. 2,399,757,398.47 and the price for conventional formwork is Rp. 1,627,019,756.36. It can be concluded that the price difference between sliding form formwork and conventional formwork is Rp. 772,737. 642,11. The cost of conventional formwork is cheaper than sliding form formwork.
- Based on the time comparison analysis that the researchers did, the results showed that the implementation time for sliding form formwork was 63 days and the conventional formwork implementation time was 150 days. It can be concluded that the difference in implementation time between sliding form formwork and conventional formwork was 87 days. Implementation time of sliding form formwork is faster than conventional formwork,so that it can do other critical path work
- Based on the quality comparison analysis that the researchers have done, the results show that the quality of sliding form formwork is neater and smoother and the quality of conventional formwork is less neat and smooth, it can be concluded that sliding form formwork is neater and smoother than conventional formwork.
- Based on the three analyzes of cost, time and quality, the use of sliding form formwork is superior to conventional formwork, because it saves time and the final result of the concrete form is very neat.
    - The advantages of sliding form formwork:
    - Faster execution or processing time
    - The casting results from the sliding form formwork are neater and smoother
    - Leave no wood waste or trash
    - Sliding form formwork can be used repeatedly
- Disadvantages of sliding form formwork:
    - The cost of sliding form formwork is more expensive than conventional formwork
- Advantages of conventional formwork:
    - The cost of conventional formwork is cheaper than sliding form formwork
    - Disadvantages of sliding form formwork:
    - The implementation time of conventional formwork is longer than that of sliding form formwork
    - Casting results from conventional formwork are still not neat and smooth
    - Conventional formwork leaves wood waste or garbage
    - Conventional formwork is limited to repeated use

Compliance with ethical standards

Disclosure of conflict of interest

No Conflict of interest to be disclosed.

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