
Cost And Time Analysis Of Changing River Bank Reinforcement Work From Corrugated Concrete Sheet Pile To Multipurpose Panel System

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Abstract

Riverbank reinforcement plays a vital role in maintaining slope stability and protecting nearby infrastructure. However, the commonly used Corrugated Concrete Sheet Pile (CCSP) method often faces challenges such as high costs, long construction duration, and limited availability of precast materials. As an alternative, the Concrete Panel method offers a more efficient and practical solution. This study aims to analyze the comparison of cost and time between the CCSP and Concrete Panel methods in riverbank reinforcement work. This research applies a descriptive quantitative approach by analyzing work volumes and cost data derived from the project's Bill of Quantity (BoQ) documents. Cost analysis was carried out by comparing the unit rate of each work component, while time analysis was based on the production capacity of each work item and the development of a Gantt Chart to determine the total project duration. The results indicate that the Concrete Panel method can reduce project costs by approximately Rp 1.73 billion or 8.89%, and shorten the construction duration to 102 days, which is 26 days faster or about 20.3% more efficient than the CCSP method. In addition to its cost and time efficiency, the Concrete Panel method provides advantages in installation flexibility and quality control. Therefore, adopting the Concrete Panel method can be considered an effective and sustainable alternative for riverbank reinforcement projects.

Keywords: Cost Analysis, Time Efficiency, Production Capacity, Riverbank Reinforcement, Concrete Panel.

INTRODUCTION

The development of water resources infrastructure is an essential part of the national strategic agenda to support water security, disaster management, and the development of the Nusantara Capital City (IKN). One crucial aspect of this infrastructure is riverbank reinforcement work, which functions to maintain slope stability and prevent erosion of critical structures such as intakes or weirs (Sjahri & Haryanto, 2020). In the context of national strategic projects, as outlined in the National Medium-Term Development Plan (RPJMN), the quality and speed of infrastructure implementation are key determinants of project success (Handayani, 2021).

The development of the Nusantara Capital City (IKN) in East Kalimantan is one of the largest National Strategic Projects (PSN), aimed not only at relocating the government center but also serving as a symbol of transformation toward a smart, sustainable, and climate-resilient city of the future (Puspitaningrum, 2023). In its implementation, basic infrastructure such as road networks, bridges, water structures, and other supporting facilities form the main foundation that must be completed efficiently and in an integrated manner. One of the main challenges of the IKN project is the limited project execution time, the high volume of simultaneous construction work, and the need for flexibility in implementation methods. Therefore, technical execution strategies are required that not only accelerate the work but also maintain quality and cost efficiency (Wirawan & Susanti, 2022).

In the raw water intake infrastructure project in the Sepaku River area, the presence of supplementary structures such as riverbank reinforcements is crucial to support foundation stability and prevent damage from water scouring or soil landslides. One important structural component is the bank reinforcement wall located alongside bridges and riverbanks. Its primary function is to act as a lateral support for soil embankments and to protect main structures against hydraulic and geotechnical forces. The effectiveness of the riverbank reinforcement construction method significantly affects the overall progress of the project in terms of technical aspects, schedule, and quality. Therefore, selecting a reinforcement method that is suitable, adaptive to field conditions, and cost-efficient is a critical factor for project success (Haris, Widyawati, & Fitriani, 2022).

The use of Corrugated Concrete Sheet Pile (CCSP) is a widely used solution for riverbank reinforcement in large-scale infrastructure projects due to its rigidity, durability, and ability to resist lateral soil pressure and water load effectively. However, in practice, the CCSP method also has limitations that can hinder project progress, especially under dynamic field conditions. Installing CCSP requires specialized heavy equipment, precise installation skills, and sufficiently stable soil conditions for optimal pile driving (Arif & Irawan, 2022). Moreover, the availability of CCSP materials depends heavily on precast factory supply, which in IKN-area projects often experiences delays due to high demand. Additionally, price spikes and incompatibility with soft soil conditions can lead to increased costs and inefficient execution time (Putra & Lestari, 2020). These challenges highlight the need to evaluate alternative methods that are more adaptive and efficient. In projects with tight execution timelines like IKN, conventional methods may pose serious obstacles that require solutions.

As a solution to the limitations of the CCSP method, an alternative approach implemented in the Sepaku Intake project is the use of a Multipurpose Panel System produced directly on-site. This method combines the modular principle of precast systems with the flexibility of field production, reducing dependence on factory supply and speeding up installation. With concrete elements cast and assembled on-site, this system overcomes logistical barriers, shortens material lead time, and optimizes quality control under direct supervision of field personnel (Suryapratama, Purnomo, & Berliana, 2024). Moreover, this method minimizes dependency on weather conditions and supports accelerated implementation in large-scale projects with tight deadlines, such as the IKN infrastructure development (Santoso, 2020).

Cost and schedule analysis are crucial aspects in decision-making regarding changes in construction methods, including riverbank reinforcement work. In the context of the Sepaku Intake project, the change from CCSP to the Multipurpose Panel System needs to be based on a comprehensive evaluation of its impact on cost efficiency and schedule acceleration (Anugerahanto & Adistana, 2021). Cost efficiency encompasses not only direct costs, such as materials and labor, but also indirect costs, such as risks of delays, rework, and contractual implications. Meanwhile, schedule acceleration provides added value through optimal resource utilization, project duration reduction, and minimized penalty risks due to delays (Kharina & Sambowo, 2019). Therefore, a thorough analysis of these two aspects is necessary to ensure that the chosen method is technically and economically feasible.

Based on this background, this study aims to analyze the change in riverbank reinforcement method from CCSP to the Multipurpose Panel System (SPS) in the Sepaku River Intake and Transmission Pipeline Infrastructure Project. This method change was driven by tight project schedules and high construction quality requirements. The use of Corrugated Sheet Piles was deemed less efficient in meeting time targets and carried quality risks due to dependency on field and weather conditions. Therefore, the adoption of precast methods was considered a viable alternative to accelerate implementation without compromising quality. The findings of this study are expected to provide practical recommendations for construction practitioners in selecting optimal work methods, thereby improving efficiency and quality in the execution of road and bridge infrastructure projects in Indonesia.

RESEARCH METHODS

The development of water resources infrastructure is an essential part of the national strategic agenda to support water security, disaster management, and the development of the Nusantara Capital City (IKN). One crucial aspect of this infrastructure is riverbank reinforcement work, which functions to maintain slope stability and prevent erosion of critical structures such as intakes or weirs (Sjahri & Haryanto, 2020). In the context of national strategic projects, as outlined in the National Medium-

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RESULTS AND DISCUSSION

Implementation Cost Analysis

Budget Plan for Implementing Corrugated Concrete Sheet Pile Reinforcement

The Implementation Budget Plan (RAP) for riverbank reinforcement using the Corrugated Concrete Sheet Pile (CCSP) method is prepared based on work volume data and actual unit prices obtained from field implementation. The RAP is designed to calculate the total cost required to complete the work using the CCSP method, which will later be compared with an alternative method, the Multipurpose Panel System (SPS).

The RAP preparation refers to the project Bill of Quantity (BoQ) and the applicable Unit Price Analysis (AHSP) for the Sepaku River Intake project. The analysis is conducted empirically based on actual field conditions, ensuring that the results reflect realistic values for project execution.

The main components of the RAP include four cost groups:

- a. Material Costs, including precast corrugated concrete, steel reinforcement, cement, sand, and other supporting materials.
- b. Labor Costs, covering preparation, fabrication, and on-site installation work.
- c. Equipment Costs, such as cranes, excavators, dump trucks, and vibrators, calculated based on operating hours and equipment productivity.
- d. Supporting and General Costs, including mobilization, supervision, and indirect project costs.

Summary of Costs for Cliff Reinforcement Work Using the Corrugated Concrete Sheet Pile (CCSP) Method

The summary cost calculation for the Corrugated Concrete Sheet Pile (CCSP) system is based on the volume and unit price analysis (harsat) for each work component outlined previously.

The following is a summary of CCSP work costs based on the Implementation Budget Plan (RAP):

Table 1. Summary of Corrugated Concrete Sheet Pile Work Costs

No	Work Description	CCSP RAP				Price per m
		SPAN LENGTH 682.5 M'				
		Unit	Volume	Unit Price	Total	
I	Sheet Pile Work					
1	Procurement & Installation of Sheet Pile	m	8,190.00	1,585,170.00	12,982,542,300.00	19,022,040.00
2	Sheet Pile Chipping / Trimming	Point	683.00	326,111.00	222,733,813.00	326,349.91
II	Geotextile Work					
1	Procurement & Installation of Geotextile	m ²	1,365.00	81,159.85	110,783,195.25	162,319.70
III	Spun Pile Work					
1	Concrete Spun Pile Ø300 C Bottom 12 m	m	4,095.00	391,840.33	1,604,586,167.51	2,351,042.00
2	Spun Pile Chipping / Trimming	Point	342.00	297,277.49	101,668,901.58	148,965.42
IV	Pile Cap Work					
1	Pile Cap Formwork	m ²	791.70	238,727.32	189,000,419.24	276,923.69
2	Pile Cap Reinforcement	kg	18,188.63	14,504.28	263,812,909.82	386,539.06
3	Concrete Casting K-225	m ³	189.74	1,622,215.23	307,791,006.66	450,975.83
4	Lean Concrete (Working Floor) K-125	m ³	39.25	940,141.67	36,900,560.55	54,066.76
V	Anchor Work					
1	Steel Waling Beam	kg	3,753.75	25,537.00	95,859,513.75	140,453.50
2	Pile Cap Reinforcement	kg	19,724.25	14,504.28	286,086,044.79	419,173.69
3	Concrete Casting K-225	m ³	429.98	1,622,215.23	697,520,104.60	1,022,007.48
VI	Capping Beam Work					
1	Capping Beam Formwork	m ²	1,525.39	238,727.32	364,152,266.65	533,556.43
2	Capping Beam Reinforcement	kg	102,651.41	14,504.28	1,488,884,793.03	2,181,516.18
3	Concrete Casting K-225	m ³	429.98	1,622,215.23	697,520,104.60	1,022,007.48
	TOTAL				19,449,842,101.03	28,497,937.14

The summary results show that:

- 1) The total cost of strengthening the 682.5-meter-long bank using the Corrugated Concrete Sheet Pile (CCSP) system reached IDR 19.45 billion, with an average cost of IDR 28.50 million per meter (m).
- 2) The largest cost component came from the procurement and driving of sheet piles, followed by the capping beam and waling beam work as the main structural binding elements.
- 3) The CCSP system has high construction costs due to the use of reinforced concrete materials and intensive field work, but offers superior long-term stability and durability in soft soil conditions and riverbanks with high water pressure.

Comparative Analysis of Planned and Actual Costs for the CCSP Method

Based on the Implementation Budget Plan (RAP) calculations in the previous sub-chapter, the total cost of implementing the 682.5-meter-long Corrugated Concrete Sheet Pile (CCSP) cliff reinforcement project reached Rp 19,449,842,101.03, equivalent to Rp 28,497,937.14 per meter (m). However, this figure represents a significant increase compared to the initial budget (RAP plan) prepared during the initial project planning stage, which was Rp 15,439,755,601.73, or Rp 22,622,352.50 per meter.

Table 2. Comparison of Planned and Actual CCSP Costs

NO	DESCRIPTION	LONG (m')	TOTAL COST (Rp.)	COST PER M' (Rp.)
1	Initial RAP (Plan)	682,5	15.439.755.601	22.622.352
2	Actual RAP (Realization)	682,5	19.449.842.101	28.497.937
	DEVIATION		4.010.086.499	
	% DEVIATION		+ 25,97 %	

The Rp 4.01 billion ($\pm 26\%$) cost increase from the initial plan was primarily due to external factors beyond the project implementer's control, namely:

- 1) Increased prices of construction materials in the IKN area, particularly ready-mix concrete, reinforcing steel, and geotextiles, due to high simultaneous demand from numerous national strategic projects in the area.
 - 2) Increased transportation and logistics costs, as the supply of key materials (precast concrete, steel, and cement) originates from Balikpapan and Samarinda, while road access and logistics infrastructure remain limited.
 - 3) Increased costs of heavy equipment and non-subsidized diesel fuel, which directly impact piling, casting, and equipment mobilization in the field.
 - 4) Adjustments in wages for skilled construction labor, particularly specialist workers such as blacksmiths and vibro hammer operators, due to increased labor demand for the IKN project.
- Therefore, a comparative analysis of the costs and time efficiency of an alternative system, the Multipurpose Panel System (SPS), is necessary to assess the most effective method for similar project conditions in the IKN area.

Budget Plan for Implementing Multipurpose Panel (Concrete Panel) Cliff Reinforcement

The Multipurpose Panel (SPS) cliff reinforcement project is an alternative retaining wall construction technology based on modular precast concrete, designed to provide cost and time efficiencies compared to the Corrugated Concrete Sheet Pile (CCSP) method.

Summary of Cliff Reinforcement Project Costs Using the Multipurpose Panel (Concrete Panel) Method

This summary outlines all components of the cliff reinforcement system using the Precast Concrete Multipurpose Panel (SPS) method. This method integrates precast elements such as SPS panels, LBB beams, steel interlocks, concrete joints, geotextiles, and capping beams into a single, rigid, stable, and time-efficient structure.

The following table summarizes the costs required for the Concrete Panel project:

Table 3. Summary of SPS Project Costs

No	Work Description	CCSP RAP			
		SPAN LENGTH 682.5 M'			
		Unit	Volume	Unit Price	Total
I	Precast SPS Panel Work Size 600.150-30 (K-350)				
1	K-350 Grade Concrete for Panel	Unit	840.00	3,087,583.89	2,593,570,467.60
2	Panel Reinforcement Work	Unit	840.00	3,767,395.43	3,164,612,161.20
3	Panel Moulding Work	Unit	15.00	39,234,268.09	588,514,021.35
4	Production Contract Labor	Unit	840.00	1,250,000.00	1,050,000,000.00
5	Panel Mobilization Cost	Unit	840.00	1,323,986.64	1,112,148,777.60
II	LBB Beam Work 30×30 (5.4 m)				
1	LBB Beam 30×30 (5.4 m)	Unit	324.00	3,792,219.45	1,228,679,103.00
2	(Including Concrete Casting, Formwork, Reinforcement)				
III	SPS Steel Interlock Work				
1	SPS Interlock – WF 250.125.6.9	Pcs	864.00	1,837,800.00	1,587,859,200.00
IV	SPS Panel Installation Work				
1	Panel Installation Labor	Unit	840.00	1,500,000.00	1,260,000,000.00
2	Assembling + Erection Interlock (2 pcs) + LBB (3 pcs)	Unit	108.00	1,750,000.00	189,000,000.00
3	H-Beam Fabrication	Unit	216.00	500,000.00	108,000,000.00
V	SPS Steel Interlock Casting Work				
1	SPS Interlock Column Work	m ³	226.80	3,485,887.37	790,599,256.28
2	(Including Concrete Casting, Formwork, Reinforcement)				
VI	Non-Woven Geotextile Layer (G300)				
1	Non-Woven Geotextile	m ²	11,107.69	40,000.00	444,307,500.00
2	Geotextile Installation Labor	m ²	10,578.75	10,000.00	105,787,500.00
VII	Capping Beam Work				
1	Capping Beam Work				

interfering with other work phases. This indicates that the SPS method's scheduling is more flexible and adaptable to the division of work segments in the field.

Therefore, it can be concluded that overlapping activities are the main factor contributing to the SPS method's faster implementation duration compared to the comparison method. The SPS method's ability to accommodate concurrent work significantly contributes to the project's time efficiency.

With a total completion time of 102 calendar days, the Multipurpose Panel System (SPS) method demonstrates an efficient, systematic, and easily controlled work pattern. Work stages are integrated between the precast yard and the field, resulting in an effective and measurable construction implementation system.

Cost and Time Efficiency Analysis of Cliff Reinforcement Work

Cost Efficiency of Cliff Reinforcement Work

Construction value-added analysis aims to identify the difference between the implementation costs (RAP) incurred by the contractor and the contract costs (RAB) paid by the project owner. A positive difference between these two values reflects the project's added value or profit margin, which can also be interpreted as an indicator of the economic efficiency of the work implementation.

The analysis is conducted using the general equation:

$$\text{Profit or Added Value} = \text{RAB} - \text{RAP}$$

$$\text{Efficiency Margin} = ((\text{RAB} - \text{RAP}) / \text{RAB}) \times 100\%$$

This calculation illustrates the level of cost efficiency resulting from the implementation method, as well as the contractor's ability to manage resources to achieve a reasonable and competitive profit.

Table 7. Comparative Cost Efficiency of Cliff Reinforcement

NO	REINFORCEMENT METHOD	RAP TOTAL (Rp.)	RAB TOTAL (Rp.)	DEVIATION	MARGIN (%)
1.	Corrugated Concrete Sheet Pile (Planing)	15.439.755.601	25.075.035.318	9.635.279.717	38.43
2.	Corrugated Concrete Sheet Pile (Realization)	19.449.842.101	25.075.035.318	5.625.193.217	22.43
3.	Multipurpose Panel System	17.720.623.651	26.128.284.061	8.407.660.410	32.18
Deviation of Initial Planned CCSP with Realization				-4.010.086.500	
Deviation of CCSP Realization with Multipurpose Panel System				Rp 1.729.218.449,08	

From the analysis above, several important conclusions can be drawn:

There was a decrease in profit margin of IDR 4.01 billion between the initial CCSP plan and the actual CCSP.

This decrease in margin from 38.43% to 22.43% was due to:

- Increased prices of concrete and steel materials due to high demand in the IKN area,
- Delays in implementation, which impacted indirect costs (overhead),
- Increased costs for heavy equipment rental and material transportation.

The implementation of the SPS method resulted in cost savings of approximately IDR 1.73 billion compared to the actual CCSP method.

This occurred because:

- Most of the SPS structural elements (panels, interlocks, and compression beams) were prefabricated, reducing mobilization costs and installation time on the ground,
- Reduced use of heavy equipment for piling and drilling work.

With an efficiency margin of 32.18%, the Multipurpose Panel System (SPS) method proved to be more economically stable than the actual CCSP.



Figure 1. Comparative Graph of Cliff Reinforcement Cost Efficiency

Comparison of Implementation Time between the CCSP and SPS Methods

This comparative analysis was conducted to determine the level of time efficiency between the two cliff reinforcement implementation methods.

Comparative Analysis

1. Total Implementation Duration

- The CCSP method requires 128 calendar days (± 18 weeks), while the SPS method can be completed in 102 calendar days (± 15 weeks).
- Thus, the SPS system provides a time savings of approximately 26 days, or $\pm 20.3\%$ faster than the conventional system.

2. Implementation Characteristics

- CCSP is sequential, meaning each work stage must be completed before the next stage begins. This results in significant waiting times between projects.
- SPS is parallel and overlapping, meaning the fabrication process at the precast yard can be carried out simultaneously with installation work in the field, thereby reducing waiting times.

3. Time Efficiency

- The main efficiencies of the SPS method come from:
 - Fabrication in a precast yard, which is independent of field conditions.
 - Use of a modular system that speeds up field installation.
 - Overlap between tasks (e.g., fabrication, installation, and grouting are carried out simultaneously at different stages).

4. Field Conditions and Risks

- In CCSP, most of the work is carried out in river areas with narrow and soft ground conditions, which can potentially cause logistical and safety issues.
- In SPS, fieldwork is reduced by 40–50%, reducing the risk of weather disruptions, equipment delays, and field errors.

5. Critical Path

- The critical path for the CCSP method consists of:
 - Sheet Pile Driving → Spun Pile Driving → Pile Cap → Wailing Beam → Capping Beam
- The critical path for the SPS method consists of:
 - Panel Fabrication → Panel Production → Panel Installation (Layers 1–4) → Interlock Formwork → Interlock Joint Casting
- This difference in critical paths shows that the SPS is more stable in terms of duration, because some of the critical work is carried out in a controlled factory environment (precast yard).

Conclusions of the Comparative Analysis

6. The total implementation duration of the SPS method (102 days) is 26 days shorter than the CCSP method (128 days).
7. The SPS implementation pattern is more efficient because there is overlap between work and the production process occurs simultaneously between the precast yard and the field.
8. SPS has lower field risks because 60–70% of the work is carried out in a controlled area.
9. The critical path of SPS is shorter and more stable than CCSP, thus reducing the potential for delays.
10. Based on time analysis, the Multipurpose Panel System (SPS) method is more efficient in terms of duration and implementation management, and is suitable for projects with tight deadlines such as the Sepaku Intake.

Based on the results of the comparative analysis, the Multipurpose Panel System (SPS) method has been proven to provide a construction time efficiency of approximately 20% compared to the conventional Corrugated Concrete Sheet Pile (CCSP) method. The overlapping pattern between work and the precast modular system are key factors in accelerating construction without compromising the quality and stability of the structure.

CONCLUSION

Based on the analysis and discussion conducted in this study, the following conclusions can be drawn:

1. Differences in Implementation Methods and Work Sequence
The difference in implementation methods between Corrugated Concrete Sheet Piles (CCSP) and Multipurpose Panel Systems (SPS) lies in the construction process. CCSP uses precast concrete elements driven by heavy equipment and is highly dependent on factory material supplies, weather conditions, and equipment availability, making it susceptible to logistical and time constraints. In contrast, SPS employs an on-site casting concept, allowing production and installation to be carried out in parallel, providing greater flexibility to field conditions and time efficiency.
2. Comparison of Work Costs
 - a. The cost required for Corrugated Concrete Work is IDR 28,497,937.14 per m².
 - b. The cost required for Multipurpose Panel Systems (SPS) is IDR 25,964,283.7 per m².
 - c. The Cost Budget Plan (RAB) for the 682.5-meter Corrugated Concrete Sheet Pile (CCSP) cliff reinforcement project is Rp 25,075,035,318.57, while for the SPS method, it is Rp 26,128,284,061.17.
3. Comparison of Work Time
The CCSP method required 128 calendar days to complete, while the SPS method only required 102 calendar days.
4. Cost and Time Efficiency Analysis
Based on the combined analysis of cost and implementation time, the results are as follows:
 - a. In terms of costs, the SPS method resulted in savings of Rp 1,729,218,449 (\approx 8.9%) compared to the CCSP method. Furthermore, the CCSP method experienced a cost overrun of 25.97% over the initial Implementation Budget Plan (RAP). Financially, the SPS method also demonstrated a higher profit ratio, at 32.18%, compared to 22.43% for the CCSP, indicating greater efficiency and profitability.

In terms of implementation time, the SPS required 102 calendar days, 26 days shorter, or approximately 20.3% faster than the CCSP. This efficiency was achieved because the panel production and installation processes could be carried out in parallel (overlapping activities), minimizing dependence on weather conditions and material supply.

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