

Cost Analysis of Construction Between Pre-Tensioned Girder Beams and Box Culverts in the Design of the Kedungpeluk Bridge

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ABSTRACT:

The Kedungpeluk Bridge, located in Sidoarjo Regency, was constructed in 1984 and collapsed in 2024 due to age and structural damage. Initially, the bridge was designed using prestressed concrete beams; however, the design was later modified to a Box Culvert to expedite the construction process. This study aims to compare the efficiency of both designs in terms of cost and construction time. The data used in this analysis include project drawings, Cost Estimate (RAB), S-curve, progress reports, literature, and other secondary data. This study was conducted using a quantitative approach that compared the costs and time of both designs. The results showed that the construction cost of the Box Culvert design reached Rp 1,440,254,544.83, while the cost for prestressed concrete beams was Rp 1,912,436,195.15. These findings indicate that the Box Culvert design offers significant cost efficiency, which can positively contribute to budget allocation for regional infrastructure development. Based on the research findings, it is recommended that the Box Culvert design be considered as a more effective alternative in similar conditions, while still considering cost efficiency, implementation time, and the functional requirements of the project. These findings are expected to serve as a reference for the government and civil engineering practitioners in planning more optimal bridge infrastructure.

Keywords: Box Culvert; Prestressed Concrete Beam; Cost Efficiency; Construction Time; Bridge Infrastructure

INTRODUCTION

Infrastructure development is one of the crucial elements in improving the quality of life and supporting economic growth in a region (Behr, 2021). Bridges, as a major component of transportation infrastructure, play a very important role in ensuring connectivity and mobility between regions. In this era of globalization, the need for reliable, safe, and efficient infrastructure is increasingly urgent (Zabaal, 2022). According to Chien and Shih (2018), modern bridge design must consider various aspects, such as safety, cost efficiency, construction time, and environmental sustainability. However, in many developing countries, budget constraints and limited resources often pose significant challenges in constructing bridges that meet international standards (Wisconsin Department of Transportation, 2025).

The accident that occurred on the Kedungpeluk Bridge in Sidoarjo Regency in 2024 is a clear example of the challenges faced in infrastructure management. The damage was caused by various factors, including the bridge's age, which had exceeded its economic lifespan, an initial design that was not fully suited to the loads it faced, and a lack of regular maintenance (Sumarno,

2020). Additionally, rapid population growth and urbanization have placed additional strain on transportation infrastructure, including bridges, accelerating the structural degradation process (Kiely and Park, 2017).

The impacts of these issues are significant, both socially and economically. The collapse of the Kedungpeluk Bridge has cut off transportation access between Kedungpeluk Village and surrounding areas, disrupting local economic activities (Barker, 2018). The community now has to deal with increased travel time and transportation costs, while the government is faced with the need to allocate a large budget for emergency repairs (Widianto, 2022). In addition, the lack of adequate transportation can worsen economic disparities between regions and reduce the quality of life of the local community.

In this study, two main variables are analyzed: the cost and time required for bridge construction (Prestressed Concrete Institute, 2015). Construction costs include all expenses necessary to complete the project, from materials to labor. Meanwhile, the time required refers to the duration needed to complete the project from start to finish (Hanie Teki Tjendani, 2023). This study focuses on two bridge designs, namely prestressed concrete beams and box culverts, each of which has advantages and disadvantages. Prestressed concrete beams are typically used for longer spans, although they require longer implementation times and higher costs. On the other hand, the box culvert design offers a shorter implementation time and lower costs but is more suitable for short to medium spans (Rinaldi and Saputra, 2020).

This study contributes new insights by conducting a comparative analysis between the two bridge designs from the perspectives of cost and construction time. Unlike previous studies by Alya Risdiyanti and Siswoyo (2018), which focused on comparing conventional and precast methods, this study considers specific designs, namely Box Culverts and precast concrete beams. In this study, more detailed data, including the Cost Estimate (RAB) and S-curve, were used to provide a deeper understanding of the efficiency of both designs in the context of the Kedungpeluk Bridge.

This research has high urgency, rooted in the urgent need to provide safe and efficient transportation access for the residents of Kedungpeluk Village. With the continuously increasing population and the growing complexity of economic activities, the construction of a reliable bridge has become a top priority. Additionally, the importance of cost and time efficiency in infrastructure development cannot be overlooked, as these factors play a significant role in optimizing government budget allocation and minimizing disruptions to community activities during the construction process.

The primary objective of this study is to analyze the costs required for the construction of a bridge using box culverts and prestressed concrete (Lutfi, 2025). This study offers significant benefits across multiple stakeholders. For civil engineering students, it serves as a practical case study to enhance their understanding of comparative design analysis methods, focusing on cost and time efficiency. For government agencies, the research provides evidence-based recommendations to optimize infrastructure investments, ensuring future projects adopt designs that maximize value without compromising quality. Civil engineering practitioners can leverage

the findings as a reference when selecting bridge designs tailored to specific site conditions and project demands. Lastly, the local community stands to benefit from accelerated infrastructure development, which will restore critical connectivity, reduce transportation costs, and improve overall socio-economic well-being. By addressing both technical and practical considerations, this study contributes to more informed decision-making in infrastructure planning and execution.

METHOD

This research adopted a qualitative approach with a descriptive method to analyze the efficiency of two bridge designs, namely *Box Culvert* and prestressed concrete beams, in the context of the Kedungpeluk Bridge project. The method aimed to provide an in-depth understanding of the influence of cost and construction time on infrastructure development, focusing on the specific conditions at the research site.

The study was conducted in Kedungpeluk Village, Candi District, Sidoarjo Regency, where the bridge served as a main connector between regions. Data collection took place from November to December 2024, during which field data such as the *Rencana Anggaran Biaya* (RAB) and S-curve were accessed from the contractor and project consultant.

The population included all parties involved in the Kedungpeluk Bridge construction project: the Public Works, Roads, and Water Resources Department (PUBMSDA) of Sidoarjo District, the implementing contractor, the supervising consultant, and the local community. The research sample consisted of relevant secondary data, including project drawings, Cost Budget Plans (RAB), progress reports, and project schedules.

The main instruments were project documents, including the RAB, S-curve, and progress reports. The data were analyzed descriptively to evaluate the cost and time efficiency of each design. Additionally, unstructured interviews with relevant stakeholders were conducted to gain insights into the design selection process and challenges encountered during construction.

This study covers several key aspects, namely:

- 1) Construction Costs: A comparative analysis of the total costs between the Box Culvert design and the pre-stressed concrete beam design.
- 2) Construction Time: Evaluation of the construction duration of each design based on S-curve data.
- 3) Project Efficiency: Measuring efficiency in terms of cost and time to provide the best design recommendation.

Data was collected through two main methods, namely:

1. Document Study: Collecting secondary data in the form of RAB, S-curves, and work progress reports.
2. Interviews: Involving interviews with contractors and supervisory consultants to supplement information not available in written documents.

Data is analyzed through three main stages:

1. Data Organization: Organizing data into a structured format to facilitate analysis.

2. Variable Comparison: Comparing the costs and implementation times of two designs based on available data.
3. Interpretation of Findings: Interpreting the results of the analysis to develop the most efficient design recommendations.

RESULTS AND DISCUSSION

This research focuses on the Kedungpeluk Bridge located in Candi District, Sidoarjo Regency. With a span length of 18 meters and a width of 7.2 meters, this bridge serves as the main connector between the surrounding areas (Heldens, 2025). The data collected in this study includes project documents such as the Budget Plan (RAB) and S-curve, as well as additional information obtained through interviews with contractors and consultants. Additionally, this study compares two bridge designs—Box Culvert and pre-stressed concrete beams—to analyze the cost comparison between the two options (Hogan, 2015).

The Box Culvert design was chosen because its features allow for faster and more economical construction, especially for short to medium spans. On the other hand, pre-stressed concrete beams are more suitable for long spans, although they require more time and money. Based on the Bill of Quantities (BQ), the budget for the Box Culvert design is Rp. 1,440,254,544.83, while the pre-stressed concrete beam design reaches Rp. 1,912,436,195.15. In terms of time, the Box Culvert requires a construction period of 10 weeks, which is faster than the 14 weeks needed for pre-stressed concrete beams.

This study utilizes secondary data, including:

- 1) Project Cost Estimate (RAB): Summary of costs for each bridge design.
- 2) S-Curve: Project implementation schedule for construction duration analysis.
- 3) Supporting Documents: Project drawings and progress reports.

The analysis results show that the construction cost of the bridge structure (*Box Culvert* type) is Rp. 1,440,254,544.83, while the construction cost of the alternative bridge (*Pre-stressed Concrete Beam* type) is Rp. 1,912,436,195.15. These findings support the recommendation to use the Box Culvert design for similar infrastructure projects in the future.

The construction of the Kedungpeluk Bridge is an important solution to meet the urgent need for safe and efficient transportation access. The collapse of the old bridge has disrupted local mobility and increased transportation costs. By selecting a design that is efficient in terms of cost and time, we can minimize the social and economic impacts caused. Research indicates that the Box Culvert design, which can be implemented 28.57% faster than the use of precast concrete beams, offers the best solution for emergency situations like this (Widianto, 2022).

The collapse of the old bridge was caused by its age exceeding its service life and the design being incompatible with the current load and environmental conditions. To address this issue, the best solution is to build a new bridge with a more efficient design that aligns with current field requirements. Data indicates that the Box Culvert design offers significant economic benefits, with cost savings of Rp 472,181,650.67 or approximately 24.69% (Fragkakis, 2015). Thus, this solution

is not only financially effective but also allows the surrounding community to use the bridge immediately.

This study aligns with the findings of Risdiyanti and Siswoyo (2018), which indicate that the precast method has better construction speed compared to conventional methods. However, this study expands the scope by comparing two specific designs—Box Culvert and pre-stressed concrete beams—in the context of bridge infrastructure. The analysis results indicate that the Box Culvert is more efficient for short to medium spans, consistent with the recommendations of Rinaldi and Saputra (2020) regarding design efficiency for specific conditions (Federal Highway Administration, 2017).

Table 1. Summary of the Budget Plan for the Construction of a Prestressed Concrete Beam Bridge

STRUCTURE				
Long pole foundation work				
Provision of Prepressed Concrete Piles with a diameter of 500 mm	M'	504,00	713.062,14	359.383.318,58
Pre-Pressed Concrete Pile Piling 500 mm diameter	M'	504,00	75.000,00	37.800.000,00
Pile Cap, Abutment, Treble Plate Job				
Concrete structure, fc'30 MPa	M3	188,00	1.412.643,33	265.576.946,46
Concrete structure, fc'20 MPa	M3	241,00	1.262.463,50	304.253.704,53
Concrete, fc'10 MPa	M3	7,00	1.182.144,18	8.275.009,27
Plain Rebar Steel-BjTP 280	Kg	31.465,56	18.487,06	581.705.827,81
BJTS 420A Fin Reinforcement Steel	Kg	1.302,84	19.049,03	24.817.841,11
Precast Beam Work				
Provision of Type I Girder Precast Unit Span 18.4 meters	Bh	5,00	126.900.000,00	634.500.000,00
Installation of Type I Girder Precast Unit Span 18.4 meters	Bh	5,00	4.293.487,78	21.467.438,90
Prestressed Concrete for Edge Diaphragm fc' 45 MPa including Pe	Bh	8,00	675.971,35	5.407.770,83
Prestressed Concrete for Middle Diaphragm fc' 45 MPa including Pe	Bh	12,00	675.971,35	8.111.656,24
Precast Plate Jobs				
Precast Plate Deck Preparation	Bh	72,00	810.000,00	58.320.000,00
TOTAL				1.912.436.195,15

Source: Researcher's Analysis, 2024

Table 2. Summary of the Budget Cost Plan (RAB) for Box Culvert Bridge Structure Construction

STRUCTURE				
Terucuk Foundation Work				
Pile Foundation, Preparation and Piling	M'	2.898,60	28.084,38	81.405.369,38
Pile Cap, Abutment, Treble Plate Job				
Concrete structure, fc'30 MPa	M3	152,62	1.510.429,46	230.521.744,45
Concrete structure, fc'20 MPa	M3	10,09	1.269.642,12	12.810.689,01
Plain Rebar Steel-BjTP 280	Kg	1.539,12	17.119,44	26.348.868,65
BJTS 420A Fin Reinforcement Steel	Kg	4.246,96	17.685,94	75.111.469,13

Pekerjaan Pondasi Tiang Pancang	Nilai	Bobot (%)	Durasi	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Penyediaan Tiang Pancang Beton Pratekan Pracetak diameter 500 mm	359.383.318,58	15,56	4	3,890		3,890	3,890	3,890									
Pemancangan Tiang Pancang Beton Pratekan Pracetak diameter .500 Mm	37.800.000,00	1,64	2			0,818			0,818								
Beton struktur, fc'30 MPa	265.576.946,46	11,50	8		1,437			1,437		1,437	1,437	1,437	1,437	1,437	1,437	1,437	
Beton struktur, fc'20 MPa	304.253.704,53	13,17	6						2,196	2,196	2,196	2,196	2,196		2,196		
Beton, fc'10 Mpa	8.275.009,27	0,36	2						0,179	0,179							
Baja Tulangan Polos-BjTP 280	581.705.827,81	25,19	6							4,198	4,198	4,198	4,198	4,198	4,198		
Baja Tulangan Sirip BjTS 420A	24.817.841,11	1,07	4									0,269	0,269			0,269	0,269
Penyediaan Unit Pracetak Gelagar Tipe I Bentang 18,4 meter	634.500.000,00	27,47	4									6,87	6,87	6,87	6,87		
Pemasangan Unit Pracetak Gelagar Tipe I Bentang 18,4 meter	21.467.438,90	0,93	1									0,929					
Beton Pratekan untuk Diafragma Tepi fc' 45 MPa termasuk Pe	5.407.770,83	0,23	1									0,234					
Beton Pratekan untuk Diafragma Tengah fc' 45 MPa termasuk	8.111.656,24	0,35	1										0,351				
Penyediaan Deck Plat Precast	58.320.000,00	2,53	2											1,263	1,263		
	2.309.619.513,73	100,00		3,890	1,437	4,708	3,890	5,327	3,193	8,010	7,831	16,131	15,318	13,766	14,524	1,706	0,269
				3,890	5,327	10,036	13,926	19,253	22,446	30,456	38,287	54,418	70	83,502	98,025	99,731	100,000

Table 2. S-Curve Graph for Prestressed Concrete Beam Bridges

Source: Researcher's Analysis, 2024

The curve indicates that the Box Culvert design achieves faster completion, enabling more efficient resource mobilization.

Table 4. Comparison of Structural Work Cost Estimates

PRESTRESSED BEAM BRIDGE TYPE STRUCTURE WORK				
File Foundation Work				
Provision of Prepressed Concrete Piles with a diameter of 500 mm	M'	504,00	713.062,14	359.383.318,58
Pre-Pressed Concrete Pile Piling 500 mm diameter	M'	504,00	75.000,00	37.800.000,00
Job File Cap, Abutment, Stepping Plate				
Concrete structure, fc'30 MPa	M3	188,00	1.412.643,33	265.576.946,46
Concrete structure, fc'20 MPa	M3	241,00	1.262.463,50	304.253.704,53
Concrete, fc'10 MPa	M3	7,00	1.182.144,18	8.275.009,27
Plain Rebar Steel-BjTP 280	Kg	31.465,56	18.487,06	581.705.827,81
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Precast Beam Work				
Provision of Type I Girder Precast Unit Span 18.4 meters	Bh	5,00	126.900.000,00	634.500.000,00
Installation of Type I Girder Precast Unit Span 18.4 meters	Bh	5,00	4.293.487,78	21.467.438,90
Prestressed Concrete for Edge Diaphragm fc'45 MPa including Pe	Bh	8,00	675.971,35	5.407.770,83
Prestressed Concrete for Middle Diaphragm fc'45 MPa including Pe	Bh	12,00	675.971,35	8.111.656,24
Precast Plate Jobs				
Precast Plate Deck Preparation	Bh	72,00	810.000,00	58.320.000,00
TOTAL NUMBER				1.912.436.195,15
BOX CULVERT BRIDGE TYPE STRUCTURE WORK				
Terucuk Foundation Work				
Pile Foundation, Preparation and Piling	M'	2.898,60	28.084,38	81.405.369,38
Job File Cap, Abutment, Stepping Plate				
Concrete structure, fc'30 MPa	M3	152,62	1.510.429,46	230.521.744,45
Concrete structure, fc'20 MPa	M3	10,09	1.269.642,12	12.810.689,01
Plain Rebar Steel-BjTP 280	Kg	1.539,12	17.119,44	26.348.868,65

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BJTS 420A Fin Reinforcement Steel	Kg	4.246,96	17.685,94	75.111.469,13
Welded Wire Mesh	Kg	4.151,65	19.899,69	82.616.537,61
Box Culvert Jobs				
Procurement & installation of DUB 600.300 - 120 cm Fc'35 MPa (G.20 Ton) (Type A)	Bh	6,00	53.967.002,00	323.802.012,00
Procurement & installation of DUB 600.300 - 120 cm Fc'35 MPa (G.20 Ton) (Type B)	Bh	8,00	56.975.502,00	455.804.016,00
Procurement & installation of DUB 600.300 - 120 cm Fc'35 MPa (Type C)	Bh	2,00	58.309.802,00	116.619.604,00
Procurement & installation of DUB 600.300 - 120 cm Fc'35 MPa (Type D)	Bh	2,00	58.309.802,00	116.619.604,00
TOTAL NUMBER				1.440.254.544,83

Source: Researcher's Analysis, 2024

This study successfully addressed the urgency and main issues, namely cost comparison. The construction cost of the structural work (Box Culvert type) is Rp. 1,440,254,544.83 (One Billion Four Hundred Forty-Two Million Two Hundred Fifty-Four Thousand Five Hundred Forty-Four commas Eighty-Three Rupiah) while the construction cost of the alternative bridge (pre-stressed concrete beam type) is Rp. 1,912,436,195.15 (One billion nine hundred twelve million four hundred thirty-six thousand one hundred ninety-five point fifteen rupiah) The impact is not only significant from a technical standpoint but also encompasses social and economic aspects, making it an optimal choice for similar infrastructure needs (County Materials Corporation, 2019).

CONCLUSION

This study aims to determine the cost differences between the design of a box culvert bridge and a prestressed concrete beam in the construction of the Kedungpeluk Bridge. The main findings indicate that the construction cost of structural work (Box Culvert type) is Rp. 1,440,254,544.83 (One Billion Four Hundred Forty Million Two Hundred Fifty-Four Thousand Five Hundred Forty-Four Commas Eighty-Three Rupiah) and the construction cost of the alternative bridge (type: Prestressed Concrete Beam) is Rp. 1,912,436,195.15 (One Billion Nine Hundred Twelve Million Four Hundred Thirty-Six Thousand One Hundred Ninety-Five Rupiah and Fifteen Cents). This study makes a significant contribution to supporting future infrastructure design decisions, especially in addressing urgent situations such as bridge collapses. The importance of this research lies in its comprehensive analytical approach, which includes RAB data, S-curves, and interviews with relevant parties. However, this study also has limitations, as it focuses solely on cost and time aspects without delving deeper into structural analysis and environmental impacts. Therefore, further research is highly recommended to explore alternative bridge designs that are more environmentally friendly and have a longer service life. Additionally, examining the implementation of designs on a larger project scale could be an interesting topic to enhance overall transportation infrastructure efficiency.

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