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COMPARATIVE ANALYSIS OF PRESTRESSED GIRDER BEAM METHOD AND BOX CULVERT ON TERMS OF CONSTRUCTION COSTS FOR KEDUNGPELUK BRIDGE DESIGN

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ABSTRACT

The Kedungpeluk Bridge in Sidoarjo Regency collapsed in 2024 due to structural damage, prompting a need for efficient reconstruction methods. This study compared the cost efficiency and implementation time of two bridge designs—pre-stressed concrete beams and Box Culvert. The research used a quantitative approach to collect secondary data from project drawings, cost budget plans (RAB), and S-curves, alongside unstructured interviews with stakeholders. Findings revealed that the Box Culvert design was more cost-effective, requiring Rp. 1,440,254,544.83, compared to Rp. 1,912,436,195.15 for the pre-stressed concrete beams, resulting in a 24.69% cost savings. Moreover, construction with the Box Culvert design was completed in 10 weeks, 28.57% faster than the 14 weeks for the alternative design. These results highlight the Box Culvert as a superior choice for similar infrastructure projects, addressing urgent community needs for reliable transportation. The implications of this research extend to civil engineering practitioners and government agencies, providing a practical reference for future bridge designs that prioritize cost efficiency and timely implementation, thereby promoting enhanced connectivity and economic growth in the region. Further research is recommended to explore environmentally friendly designs and assess long-term performance in various contexts.

Keywords: *Box Culvert, Prestressed Concrete Beam, Cost Efficiency, Execution Time, Bridge Infrastructure*

INTRODUCTION

The development of construction with a significant cost will affect the complexity of the work and materials used; it is necessary to improve the project management system in terms of engineering or planning appropriate scheduling methods, controlling and managing project costs, and efficient work methods, so that it can help manage the implementation of construction projects (Hatefi & Tamošaitiene, 2018; Moavenzadeh, 2022). Effectively, according to Hanie Teki Tjendani. The bridge is one of the critical infrastructure elements that function to connect two areas separated by physical obstacles such as rivers, ravines, or even differences in height above ground level. In the context of infrastructure development, bridge design has a vital role because it concerns not only functional and aesthetic aspects but also safety, reliability, and resistance to loads and environmental conditions. With the increasing volume of transportation and complexity of terrain, efficient and effective bridge planning and design are becoming increasingly crucial (Chen & Duan, 2014; Hartono, 2021).

Bridge design involves various civil engineering disciplines, including structural mechanics, materials engineering, and dynamic load analysis. Along with technological advances, multiple innovations in bridge design have been introduced to improve efficiency, reduce construction costs, and extend the bridge's life. Therefore, an in-depth understanding of the basic principles of bridge design and an evaluation of the various existing design approaches are crucial in developing an optimal design. Although many studies have been conducted on bridge design and construction, many new challenges have emerged along with the growing needs of modern transportation and changing environmental conditions, such as increasing vehicle loads, climate change, and increasingly complex development policies. Therefore, this study aims to provide a comprehensive review of the various methods and techniques used in bridge design, focusing on analyzing the most widely used bridge types in civil engineering practice.

This research will also address the challenges engineers face in designing bridges that meet technical requirements and can withstand increasingly extreme conditions. To this end, the study covers not only structural design but also external factors that affect bridge durability, such as changes in vehicle loads, earthquake impacts, and increasingly uncertain environmental factors.

Infrastructure development is one of the key elements in improving people's quality of life and supporting the economic growth of a region. Bridges, as one of the main components of transportation infrastructure, are essential in ensuring connectivity and mobility between areas. In this era of globalization, the need for reliable, safe, and efficient infrastructure is increasingly urgent (Amarachi, 2024; Astawa et al., 2024; Hussain, 2019; Salim & Negara, 2018)According to Chien and Shih, modern bridge design must consider safety, cost efficiency, implementation time, and environmental sustainability. However, in many developing countries, limited budgets and resources are often a significant obstacle to developing bridge infrastructure that meets international standards.

Bridge design is one of the most essential branches of civil engineering, supporting mobility and connectivity between regions. Bridges connect places separated by natural obstacles, such as rivers, valleys, or highways. The bridge design process must consider various technical, social, and environmental factors. (Danielsen et al., 2022; Hailemariam & Nuramo, 2023; Zhong et al., 2024). This article will discuss the basic principles of bridge design and evaluate the various design approaches used in civil engineering practice. Basic Principles of Bridge Design *Safety* is the most critical aspect of bridge design. The bridge must be able to withstand the various loads it receives, be it vehicle loads, pedestrians, or dynamic loads such as wind, earthquakes, or water currents. Therefore, each element of the bridge structure (such as abutments, step plates, decks, and foundations) must be designed with a considerable safety factor in mind. Structural analysis and the use of appropriate materials are instrumental in achieving the desired level of safety. Strength: The bridge design must ensure that all structural components have sufficient strength to withstand the loads that occur during their lifetime. This involves calculating the strength of the material (concrete, steel, or composite) and the design of structural elements such as beams, columns, and cables to ensure that they will not suffer damage or failure during operation.

The collapse of the Kedungpeluk bridge in Sidoarjo Regency in 2024 is a clear example of the challenges in infrastructure management. The damage that occurred was caused by several factors, including the age of the bridge, which exceeded its economic service life, the initial design, which was not in accordance with the evolving loads and environmental conditions, and the lack of periodic maintenance. In addition, rapid population growth and urbanization increase pressure on transportation infrastructure, including bridges, thus accelerating the process of structural degradation.

The impact of these problems is significant, both socially and economically. When the Kedungpeluk bridge collapsed, transportation access between Kedungpeluk village and the surrounding area was cut off, disrupting local economic activity. The community experienced increased travel time and transportation costs, while the government had to allocate a large budget for emergency repairs (Widianto, 2022). In addition, the unavailability of adequate transportation access can exacerbate economic disparities between regions and reduce the quality of life of local communities.

In the context of this study, the two main variables analyzed are the cost and implementation time of bridge construction. Construction costs include all expenses required to complete the project, from materials to labor, while implementation time refers to the duration required to complete the project from start to finish (Miles, 2019; Nugraha, 2020; Prabowo & Nugroho, 2019; Rinaldi & Saputra, 2020; Setiawan, 2023; Shillito & Schaffer, 2020; Sumarno, 2020; Widianto, 2022). This research focuses on two bridge designs, namely pre-stressed concrete beams and Box Culvert, each with advantages and disadvantages. Prestressed concrete beam designs are generally used for bridges with longer spans, but require longer implementation times and higher costs. In contrast, the Box Culvert design offers faster execution times and lower costs, but is more suitable for short to medium spans (Rinaldi & Saputra, 2020).

In the implementation of a project, planning and management aspects are essential factors that influence the project's success. The relationship between cost and time, often referred to as the "triple constraint" or project triangle, is the element of cost, quality, and time. Two of these three elements are interconnected and have an effect on the other two components; if one changes, it will affect the other, and changes in one aspect will have an impact on the other. An understanding of the relationship between these two elements is necessary to realize the overall success of project activities.

This research provides a new contribution by conducting a comparative analysis between two bridge designs—Box Culvert and pre-stressed concrete beams—focusing on cost and implementation time. Previous studies, such as the one by Risdiyanti & Siswoyo (2018), primarily compared conventional and precast methods without examining specific designs. This study utilizes detailed data, including the Cost Budget Plan (RAB) and S-curves, to enhance understanding of the efficiency of both designs in the context of Kedungpeluk Bridge. The urgency of this research stems from the need for safe and efficient transportation infrastructure in Kedungpeluk Village, which is driven by a growing population and economic activity. It aims to evaluate the cost efficiency of the two designs, contributing valuable insights for civil engineering students, providing recommendations for the government on efficient infrastructure designs, serving as a reference for civil engineering practitioners in design selection, and supporting community efforts in accelerating infrastructure development to enhance connectivity and welfare.

METHOD

The research utilized an analytical method with a quantitative data approach to compare the efficiency of two bridge designs—Box Culvert and pre-stressed concrete beams—within the Kedungpeluk Bridge project. This approach involved collecting secondary data from consultants and contractors, including RAB data, S-curves, and project drawings. The study aimed to analyze how cost and implementation time impacted infrastructure development success, focusing on specific site conditions. Conducted in Kedungpeluk Village, Sidoarjo District, from November to December 2024, the research involved direct access to field data from the implementing contractor and project consultant.

The study population included all stakeholders in the Kedungpeluk Bridge construction, such as the Sidoarjo Regency PUBMSDA Office, the implementing contractor, and the supervisory consultant. The research sample comprised secondary data, such as project documents and progress reports. The analysis employed a descriptive approach to evaluate each design's cost efficiency and implementation time. Additionally, unstructured stakeholder interviews provided more profound insights into design selection and construction constraints, contributing valuable information for assessing infrastructure project management.

This research covers several key aspects, namely:

1. **Construction Cost**: Comparative total cost analysis between Box Culvert and prestressed concrete beam designs.
2. **Project Efficiency**: Measuring efficiency in terms of cost and time to provide the best design recommendations.

Data was collected through two primary methods, namely:

1. **Document Study**: Collecting secondary data in the form of RAB, S-curves, and work progress reports.
2. **Interviews**: Interviews with contractors and supervision consultants are conducted to supplement information not available in written documents.
3. Data was analyzed through three main stages:
4. **Data Organization**: Organizing data in a structured format to facilitate analysis.
5. **Variable Comparison**: Comparing the cost and execution time of two designs based on available data.
6. **Interpretation of Findings**: Interpret the analysis results to develop the most efficient design recommendations.

RESULTS AND DISCUSSION

This research focuses on the Kedungpeluk Bridge in Candi District, Sidoarjo Regency. The bridge has a span length of 18 meters and a width of 7.2 meters and serves as the main link between the surrounding areas. The research data includes project documents, such as RAB and S-curves, and additional information from interviews with contractors and consultants. The study compared two bridge designs, namely Box Culvert and pre-stressed concrete beams, to determine the cost efficiency and implementation time.

The Box Culvert design was chosen because it allows faster and more economical construction for short to medium spans. In contrast, pre-stressed concrete beams are more suitable for long spans but require more time and cost. The RAB data shows that the Box Culvert design requires an Rp budget. 1,440,254,544.83, while the prestressed concrete beam design requires Rp. 1,912,436,195.15. In terms of time, the Box Culvert design requires 10 weeks, which is faster than 14 weeks for the pre-stressed concrete beams.

This research uses secondary data, which includes:

1. Project RAB: Recapitulation of costs for each bridge design.
2. S-curve: Project implementation schedule for construction duration analysis.
3. Supporting Documents: Project drawings and work progress reports.

The analysis shows that the Box Culvert design is more cost-efficient, with savings of Rp. 472,181,650.67, or 24.69%. In terms of time, this design is also superior, with a 28.57% faster duration than the prestressed concrete beam design. These findings support the recommendation to use the Box Culvert design for similar infrastructure projects in the future.

The construction of Kedungpeluk Bridge solved the urgent need to provide safe and efficient transportation access. Based on the background, the collapse of the old bridge resulted in the disruption of local community mobility and increased transportation costs. By choosing an efficient design, both in terms of price and time, the resulting social and economic impacts can be minimized. This research showed that a Box Culvert design, with a 28.57% faster execution time than pre-stressed concrete beams, provided the best solution for this urgent situation (Widianto, 2022).

The collapse of old bridges is caused by age beyond the service life and design mismatches with current loads and environmental conditions. The solution is to build a new bridge using a more efficient design that matches field needs. Data shows that the Box Culvert design is more economical with Rp cost savings. 472,181,650.67 or 24.69%. This solution is not only financially effective, but also allows the bridge to be used more quickly by the surrounding community.

Choosing a Box Culvert design significantly impacts the community and government. From a social perspective, transportation access quickly returns to normal, supporting local economic activity and improving community welfare. Financially, budget savings can be allocated to other infrastructure projects, expanding development benefits.

This research is in line with the findings of Risdiyanti & Siswoyo (2018) who showed that the precast method is faster than the conventional method. However, this study broadens the scope by comparing two specific designs, namely Box Culvert and pre-stressed concrete beams, in the context of bridge infrastructure. The results show that the Box Culvert is more efficient for short to medium spans, supporting Rinaldi & Saputra (2020) recommendation regarding design efficiency for specific conditions.

Table 1. Recapitulation of the Budget Plan for the Prestressed Beam type bridge structure work

Structure	Unit	Volume	Unit Price (Rp)	Amount (Rp)
Pile Foundation Work				
Provision of 500 mm diameter Precast Prestressed Concrete Piles	m	712	360.383	318.580.000
Piling of 500 mm diameter Precast Prestressed Concrete Piles	m	504	750.000	378.000.000
Pile Cap, Abutment, Stepping Plate				
Structural concrete, f'c 30 MPa	m^3	188	1.412.643	265.576.946
Structural concrete, f'c 20 MPa	m^3	241	1.262.464	304.253.705
Concrete, f'c 10 MPa	m^3	7	1.182.144	8.275.009
Plain Reinforcing Steel BjTP 280	kg	31.466	18.487	581.705.828
BjTS 420 Fin Reinforcing Steel	kg	1.303	19.049	24.817.841
Precast Beam Work				
Provision of 18.4-meter Span Type Girder Precast Unit	bh	5	126.900.000	634.500.000
Erection of 18.4-meter Span Type Girder Precast Unit	bh	5	4.293.488	21.467.439
Prestressed Concrete for Edge Diaphragms f'c 45 MPa including Mops	bh	8	675.971	5.407.771
Prestressed Concrete for Center Diaphragm f'c 45 MPa including	bh	12	675.971	8.111.656
Precast Plate Work				

Provision of Precast Deck Plate	bh	72	810.000	58.320.000
				IDR 1,912,436,198.15

Source: Processed by Researcher, 2024

Table 2. Recapitulation of the Cost Budget Plan (RAB) of the Box Culvert bridge type structure work

Structure	Unit	Volume	Unit Price (Rp)	Amount (Rp)
Funnel Foundation Work				
Pile Foundations, Supply and Piling	m	2898,6	28.084	81.405.369
Pile Cap, Abutment, Stepping Plate Works				
Structural concrete, f'c 30 MPa	m^3	152,62	1.510.429	230.521.744
Structural concrete, f'c 20 MPa	m^3	100,9	1.269.642	12.810.689
Plain Reinforcing Steel BjTP 280	kg	1539,12	17.119	26.348.869
BjTS 420A Fin Reinforcing Steel	kg	4246,96	17.686	75.111.469
Welded Wire Mesh	kg	4151,65	20.000	82.616.538
Box Culvert Work				
Procurement and installation of DUB 600,300 - 120 cm Fc' 35 Mpa (G.20 Ton) (Type A)	bh	600	53.967	323.802.012
Procurement and installation of DUB 600,300 - 120 cm Fc' 35 Mpa (G.20 Ton) (Type B)	bh	800	56.976	456.804.016
Procurement and installation of DUB 600,300 - 120 cm Fc' 35 MPa	bh	2	58.310	116.619.604
Procurement and installation of DUB 600,300 - 120 cm Fc' 35 MPa	bh	200	58.310	116.619.604
				Rp. 1,440,254,544.83

Source: Processed by Researcher, 2024

Table 3. Cost and time comparison between the two designs:

Parameters	Box Culvert	Prestressed Concrete Beams
Cost (Rp)	1.440.254.544,83	1.912.436.195,15
Implementation Time (weeks)	10	14
Cost Efficiency (%)	24,69%	-
Time Efficiency (%)	28,57%	-

Source: Processed by Researcher, 2024

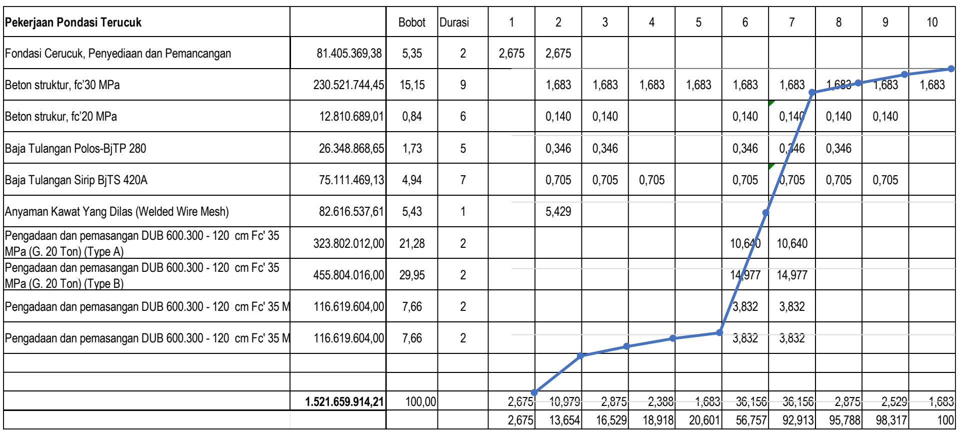
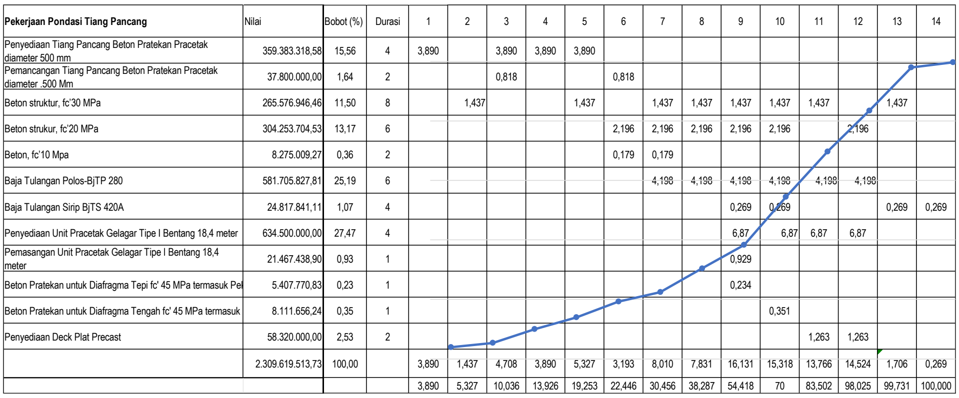


Figure 1. Box Culvert Bridge S-Curve Chart

Source: Processed by Researcher, 2024



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	
Beton strukur, 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 Pel	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

Figure 2. S-Curve Graph of Prestressed Beam Type Bridge

Source: Processed by Researcher, 2024

The curve shows that the Box Culvert design was completed faster, allowing more efficient resource mobilization.

Table 6. RAB Comparison of Structural Works

PRESTRESSED BEAM TYPE BRIDGE STRUCTURE WORK				
Structure	**Unit**	**Volume**	**Unit Price (Rp)**	**Amount (Rp)**
Pile Foundation Work				
Provision of 500 mm diameter Precast Prestressed Concrete Piles	m	712	360.383	318.580.000
Piling of 500 mm diameter Precast Prestressed Concrete Piles	m	504	750.000	378.000.000
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BOX CULVERT BRIDGE TYPE STRUCTURAL WORK				
Structure	**Unit**	**Volume**	**Unit Price (Rp)**	**Amount (Rp)**
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Procurement and installation of DUB 600,300 - 120 cm Fc' 35 MPa	bh	200	58.310	116.619.604
				Rp. 1,440,254,544.83

Source: Processed by Researcher, 2024

Comparing the construction costs of the two types of bridges, it was concluded that the cost of building the existing bridge (Box Culvert type) was the lowest. This research successfully answers the urgency and main problem of choosing the right design for cost and time efficiency in constructing the Kedungpeluk Bridge. The results show that the Box Culvert design is superior to pre-stressed concrete beams. The impact is not only technically significant but also includes social and economic aspects, making it an optimal choice for similar infrastructure needs.

CONCLUSION

This study aims to compare the cost efficiency of the Box Culvert bridge design and pre-stressed concrete beams in the construction of the Kedungpeluk Bridge. The main findings show that the Box Culvert design is more cost efficient, saving 24.69%. This study significantly contributes to future infrastructure design decisions, especially in urgent conditions such as bridge collapse. The significance of the study lies in the comprehensive analysis approach, which includes RAB data, S-curves, and interviews with relevant parties. However, this research has a limited scope that only covers cost and time aspects, without considering structural analysis and environmental impacts in depth. Further research is recommended to explore alternative bridge designs that are environmentally friendly and have a longer service life. In addition, the study of design implementation on a larger project scale can also be an interesting topic to support the efficiency of transportation infrastructure more broadly.

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