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Comparative Analysis of Aluminum Formwork and Conventional Formwork on the Success of the Structural Work Quality

Yehezkiel Rivaldo Widjaya[1], I Nyoman Dita Pahang Putra[2]
[1,2]Faculty of Engineering and Science, Pembangunan Nasional "Veteran" of University, Jawa Timur, Indonesia

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ABSTRAK

Inovasi bekisting dalam dunia konstruksi terus mengalami perkembangan, salah satunya adalah bekisting aluminium (aluminium formwork). Ditemukan adanya perbedaan hasil mutu pekerjaan struktur bekisting aluminium dan konvensional maka perlu dilakukan analisis terkait hal tersebut. Metode yang digunakan adalah dengan melakukan analisis hasil kuesioner dan wawancara tenaga ahli. Analisis yang dilakukan bertujuan untuk mengetahui hasil pekerjaan struktur bekisting aluminium dan konvensional terhadap keberhasilan pekerjaan struktur serta perbedaannya dengan menggunakan model regresi linear berganda. Hasil penelitian menunjukkan bahwa pengaruh hasil pekerjaan struktur bekisting aluminium dan konvensional terhadap tingkat keberhasilan mutu pekerjaan struktur pada proyek pembangunan Stadion Kabupaten Kediri dapat diidentifikasi melalui persamaan regresi Y = 3,946 + 0,564 X1 + 0,392 X2 + 0,155 X3 - 0,328 X4 – 0,443 X5 – 0,030 X6 dengan nilai Adjusted R Square sebesar 0,949. Artinya, semakin banyak hasil pekerjaan struktur bekisting aluminium, maka keberhasilan mutu pekerjaan struktur semakin meningkat. Selain itu, terdapat perbedaan hasil mutu pekerjaan struktur antara bekisting aluminium dan konvensional pada proyek pembangunan Stadion Kabupaten Kediri dengan selisih rata-rata penerimaan sebesar 5,08%. Berdasarkan parameter, mutu pekerjaan struktur bekisting aluminium lebih unggul dibandingkan mutu pekerjaan struktur bekisting konvensional.

ABSTRACT

Formwork innovations in the world of construction continue to develop, one of which is aluminum formwork. It was found that there were differences in the quality of work on aluminum and conventional formwork structures, so it was necessary to carry out an analysis regarding this matter. The method used is to analyze the results of questionnaires and expert interviews. The analysis carried out aims to determine the results of work on aluminum and conventional formwork structures on the success of structural work and the differences using a multiple linear regression model. The results of the research show that the influence of the results of aluminum and conventional formwork structures on the level of success of the quality of structural work on the Kediri Regency Stadium construction project can be identified through the regression equation Y = 3.946 + 0.564 X1 + 0.392 X2 + 0.155 with an Adjusted R Square value of 0.949. This means that the more aluminum formwork structural work results, the more successful the quality of the structural work will be. Apart from that, there is a difference in the quality of structural work between aluminum and conventional formwork on the Kediri Regency Stadium construction project with an average difference in acceptance of 5.08%. Based on parameters, the quality of work on aluminum formwork structures is superior to the quality of work on conventional formwork structures.

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Corresponding Author:

Yehezkiel Rivaldo Widjaya
Faculty of Engineering and Science, Pembangunan Nasional "Veteran" of University, Jawa Timur, Indonesia
Email: yehezkielrivaldo.2909@gmail.com

1. INTRODUCTION

The stadium is a building used as a venue for football matches or other events equipped with a field or stage, as well as seating and standing areas for spectators [1]. Structural function holds crucial significance in a project, especially in the context of stadium construction. Structural work is divided into three phases: reinforcement installation, formwork installation, and casting. Formwork is a temporary tool used to support the weight during the casting and forming process of concrete [2]. The formwork cycle consists of a series of time durations for formwork installation, reinforcement installation, concrete casting, concrete curing, formwork dismantling, and formwork relocation [3].

One of the latest innovations is a formwork system manufactured in factories, with most of its elements and materials made of aluminum. The purpose of this formwork system is its reusable nature for various types of work with different sizes and volumes [4]. Aluminum formwork is a formwork system designed to shape in-situ concrete structures of a building. It is made of strong aluminum panels, with a thickness of four millimeters, joined through welding methods. All panels are reinforced using a simple pin arrangement system through holes in each panel at predetermined intervals. Below are the advantages and disadvantages of aluminum formwork. The advantages of aluminum formwork include independence from heavy lifting equipment and can be handled by workers, supporting large-scale construction acceleration, dimensional accuracy and suitability, durable component system that can be reused multiple times, ensuring quality on the surface of structures such as columns, beams, and slabs. The disadvantages of aluminum formwork are high initial investment costs, requiring more components, expensive formwork repair costs if damage occurs, higher risk of theft, and requiring more space for placement and sorting [5].

Conventional formwork is formwork made with wood, plywood, or boards as its main materials. In its implementation method, the position and size of the formwork will be adjusted based on the working drawings and the dimensions of the structure to be built, and then the formwork can be dismantled after the concrete structure has hardened, usually within 3-7 days [6]. Conventional formwork has advantages and disadvantages as follows. The advantages of conventional formwork include easily accessible materials, relatively low costs, not requiring skilled labor, and many workers already familiar with this conventional formwork method. The disadvantages of conventional formwork include non-durable wood materials that cannot be reused, imprecise shapes produced, generating a lot of wood and nail waste, and long times required for dismantling and installation [7].

In quality management standards, it emphasizes that every activity is carried out through the PDCA cycle, which is Plan (Planning), Do (Execution), Check (Inspection), Action (Corrective Action) [8]. In the construction of the Kediri Regency Stadium, differences in the quality results of aluminum and conventional formwork structural work were found. Because of these differences in quality, it is necessary to analyze the results of the structural work in the construction project of the Kediri Regency Stadium to determine the influence of the results of aluminum and conventional formwork structural work on the level of success of structural work quality and the differences in quality results of structural work between aluminum and conventional formwork, and so forth.

2. METHOD

Quantitative methods with statistical analysis are used in this research, namely hypothesis testing, to determine the results of aluminum and conventional formwork structural work on the success of structural work in the construction project of Kediri Regency Stadium. Quantitative research is a method to uncover knowledge by analyzing information about a subject using data in the form of numbers or numeric values [9]. Operational definition is an explanation related to the variables being studied and is operational in nature, as well as related to the process of analyzing those variables [10], as can be seen in the following Table 1.

Table 1. Operational Definition of Variables

No.	Research Variable	Definition
1	Result of Aluminum Formwork Column Work (X1)	The outcome of the column structural work process that utilizes aluminum formwork as the mold.
2	Result of Aluminum Formwork Beam Work (X2)	The outcome of the beam structural work process that utilizes aluminum formwork as the mold.
3	Result of Aluminum Formwork Floor Slab Work (X3)	The outcome of the floor slab structural work process that utilizes aluminum formwork as the mold.
4	Result of Conventional Formwork Column Work (X4)	The outcome of the column structural work process that utilizes conventional formwork as the mold.
5	Result of Conventional Formwork Beam Work (X5)	The outcome of the beam structural work process that utilizes conventional formwork as the mold
6	Result of Conventional Formwork Floor Slab Work (X6)	The outcome of the floor slab structural work process that utilizes conventional formwork as the mold.
7	Quality Success in Structural Work (Y1)	The achievement of quality targets set in the planning, construction, and use of structures in a building.

This research is conducted on the Design and Build project of Kediri Regency Stadium for the Fiscal Year 2023 located at Jl. Semeru, Dusun Pojok, Desa Bulusari, Kecamatan Tarokan, Kabupaten Kediri. Primary data used are in the form of questionnaires and interviews. The questionnaire will be used to determine the suitability of the structural work results with the quality parameters under investigation. The questionnaire will be distributed to 8 experts,

namely 2 quality control personnel, 3 field supervisors, 2 engineers, and 1 General Superintendent (GSP). Interviews will be conducted with the quality control team to determine the acceptance of the structural work results. Secondary data refers to the type of data not directly obtained by the researcher from its source, but obtained through documents or other intermediaries [11]. The secondary data used include quality target master data from PT. PP Urban and previous literature studies. Below is a literature review of quality target parameters presented in Table 2.

Table 2. Recapitulation of Quality Work Target Parameters

Target Parameters		Source
Concrete Column and Beam Structure	Without a footing at the connection	Quality Target PT. PP Urban (2023), Yahya et al (2019) [13], Hansen et al (2020) [14], Building and Construction Authority (2014) [18]
	Non-slip at the corners	Quality Target PT. PP Urban (2023), Yahya et al (2019) [13], ACI 347.3R-13 (2014) [17]
	No corrosion	Quality Target PT. PP Urban (2023), SNI 2847:2019 (2019) [15], ACI 347.3R-13 (2014) [17]
	Vertical alignment of columns / horizontal alignment of beams according to specifications	Quality Target PT. PP Urban (2023), Pebria and Putra (2024) [12], Yahya et al (2019) [13], Hansen et al (2020) [14], Building and Construction Authority (2014) [18], Ballast (2007) [19]
	No cracks	Quality Target PT. PP Urban (2023), Pebria and Putra (2024) [12], SNI 2847:2019 (2019) [15], Building and Construction Authority (2014) [18]
	Column / beam position according to shop drawings	Quality Target PT. PP Urban (2023), Pebria and Putra (2024) [12]
	Smoothness of column surface	Yahya et al (2019) [13]
	Coarse aggregates not visible	Yahya et al (2019) [13], Building and Construction Authority (2014) [18]
	Surface cleanliness	Yahya et al (2019) [13], Hansen et al (2020) [14], ACI 347.3R-13 (2014) [17], Building and Construction Authority (2014) [18]
	Workmanship tidiness	Hansen et al (2020) [14]
	Color uniformity	ACI 347.3R-13 (2014) [17]
Concrete Floor Slab Structure	Flat surface with no water puddles	Quality Target PT. PP Urban (2023), Pebria and Putra (2024) [12], Yahya et al (2019) [13], ACI 302.1R-15 (2015) [16], Building and Construction Authority (2014) [18]
	No leakage	Quality Target PT. PP Urban (2023), Pebria and Putra (2024) [12]

	Even joints with no cracks	Quality Target PT. PP Urban (2023), Pebria and Putra (2024) [12], Yahya et al (2019) [13]. ACI 302.1R-15 (2015) [16]
	Elevation accuracy	ACI 302.1R-15 (2015) [16]
	Coarse aggregates not visible	Yahya et al (2019) [13]
	Surface cleanliness	Yahya et al (2019) [13], Hansen et al (2020) [14], Building and Construction Authority (2014)
	Workmanship tidiness	Hansen et al (2020) [14]

The research instrument can be evaluated through two stages of testing, namely validity testing and reliability testing. This study uses Cronbach's Alpha value with a high degree of reliability, where the test result should be greater than or equal to 0.70. This is followed by classical assumption tests, namely normality test, multicollinearity test, and heteroskedasticity test. To obtain an equation, multiple linear regression analysis is conducted, and coefficient of determination testing is performed to determine the feasibility of a model.

3. RESULTS AND DISCUSSION

3.1 Test of Research Instruments

3.1.1 Validity Analysis

The validity of the data was tested by conducting a bivariate correlation approach using IBM SPSS Statistics Version 25. The results of the validity analysis indicate that all variables in the research instrument are valid.

3.1.2 Reliability Analysis

The reliability of the data was analyzed by conducting a reliability analysis approach using IBM SPSS Statistics Version 25. The results of the reliability analysis indicate that all variables obtained a Cronbach's Alpha value > 0.70. This suggests that the research instrument has a high level of reliability and can proceed with classical assumption testing.

3.2 Test of Classical Assumption3.2.1 Normality Test

This test was conducted by performing a one-sample Kolmogorov-Smirnov test using IBM SPSS Statistics Version 25. From the test, a value of Sig. > 0.05 was obtained. This indicates that all variables and data are normally distributed. The normality test graph can be seen in Figure 1 below.

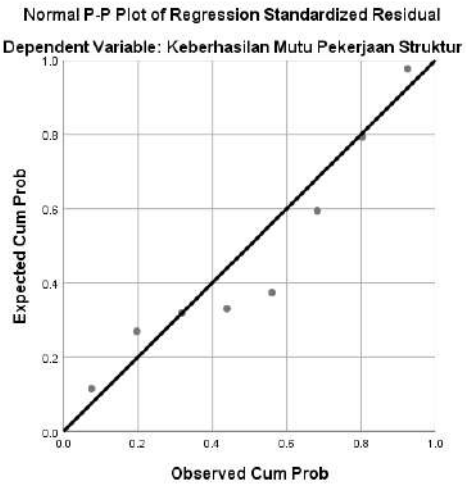

Figure 1. Normality Test Graph

The normality test graph indicates that the data used in this research is normally distributed.

3.2.2 Multicollinearity Test

This test was conducted by performing collinearity statistics in IBM SPSS Statistics Version 25. The results of the test indicate that there is no multicollinearity.

3.2.3 Heteroscedasticity Test

This test was conducted by performing a Glejser test in IBM SPSS Statistics Version 25. The results of the test indicate that no heteroscedasticity was found.

3.3 Multiple Linear Regression Analysis

This test was conducted using IBM SPSS Statistics Version 25. The results indicate that the combined (simultaneous) effects of aluminum and conventional formwork column, beam, and floor slab structural work on the quality success of structural work can be seen in Table 3 below.

Table 3. Results of Multiple Linear Regression Analysis

	Coefficients[a]					
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	3.946	.025		155.862	.004
	X1	.564	.002	1.198	226.742	.003
	X2	.392	.002	.954	231.767	.003
	X3	.155	.003	.213	51.297	.012
	X4	-.328	.002	-.934	-182.228	.003
	X5	-.443	.002	-1.110	-216.689	.003
	X6	-.030	.002	-.043	-12.703	.038

a. Dependent Variable: Success of Structural Work Quality

Based on Table 3, the regression equation obtained is Y = 3.946 + 0.564 X1 + 0.392 X2 + 0.155 X3 - 0.328 X4 - 0.443 X5 - 0.030 X6. This means that the more aluminum formwork structural work results, the higher the quality success of the structural work. Additionally, the more conventional formwork structural work results, the lower the quality success of the structural work. The results of the coefficient of determination testing can also be seen in Table 4 below.

Table 4. Results of Coefficient of Determination Testing

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.976[a]	.953	.949	.072
a. Preditors: (Constant), X6, X3, X4, X5, X2, X1				

Based on Table 4, it indicates that 94.9% of the quality success of structural work is influenced by the variables from the model that have been researched and investigated in the model. An F-test has also been conducted and the results can be seen in Table 5 below.

Table 5. Results of F-test

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	41.598	6	6.933	242.034	.002[b]
	Residual	.381	1	0.15		
	Total	41.598	7			

a. Dependent Variable: Y1
b. Predictors: (Constant), X6, X3, X4, X5, X2, X1

Based on Table 5, the ANOVA test results indicate that the generated regression equation is appropriate and suitable for use with a value of Sig. < 0.05.

3.4 Analysis of Aluminum Formwork Structural Work Results

Based on interviews with the quality control team, the average acceptance of aluminum formwork structural work results is 94.35%, with an average acceptance with repairs of 5.65%, and there is no rejection of aluminum formwork structural work results.

3.5 Analysis of Conventional Formwork Structural Work Results

Based on interviews with the quality control team, the average acceptance of conventional formwork structural work results is 89.27%, with an average acceptance with repairs of 9.6%, and 1.13% rejection of conventional formwork structural work results.

3.6 Analysis of Comparison between Aluminum and Conventional Formwork Structural Work Results

Based on interviews with the quality control team, the aluminum formwork structural work results have an average acceptance percentage of 94.35%, acceptance with repairs at

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5.65%, and no rejection of aluminum formwork structural work results. Meanwhile, the conventional formwork structural work results have an average acceptance of 89.27%, acceptance with repairs at 9.6%, and 1.13% rejection of conventional formwork structural work results. The comparison results can be seen in Figure 2 below.

Figure 2. Graphical Comparison of Aluminum and Conventional Formwork Structural Work Results

Based on Figure 2, the difference in average acceptance of structural work results between aluminum and conventional formwork is 5.08%. This means that the aluminum formwork structural work results are better and comply with the parameters under investigation compared to the conventional formwork structural work results. Additionally, there are no rejections in the aluminum formwork structural work results, while there is a rejection rate of 1.13% in the conventional formwork structural work results. For the percentage comparison graph of acceptance of aluminum and conventional formwork column structural work results, it can be seen in Figure 3 below.

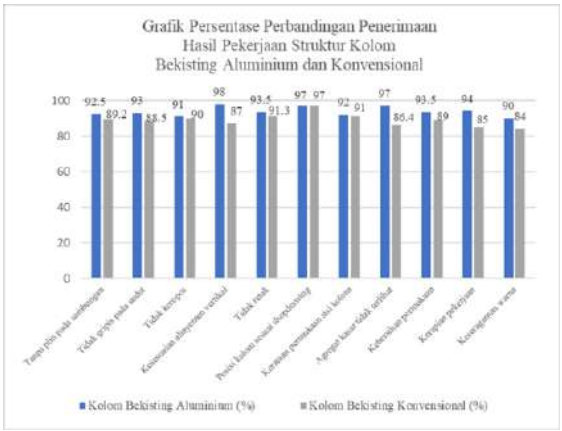

Figure 3. Percentage Comparison Graph of Acceptance of Aluminum and Conventional Formwork Column Structural Work Results

Based on Figure 3, the largest difference is found in the vertical alignment suitability parameter, which is 9%. This can be interpreted as aluminum formwork columns being better at meeting the tolerance limits for inclination, which is ±5 mm for floor-to-floor height, because aluminum formwork has strong and precise components, preventing shifting during casting that could lead to inclination in column structures. For the percentage comparison graph of

acceptance of aluminum and conventional formwork beam structural work results, it can be seen in Figure 4 below.

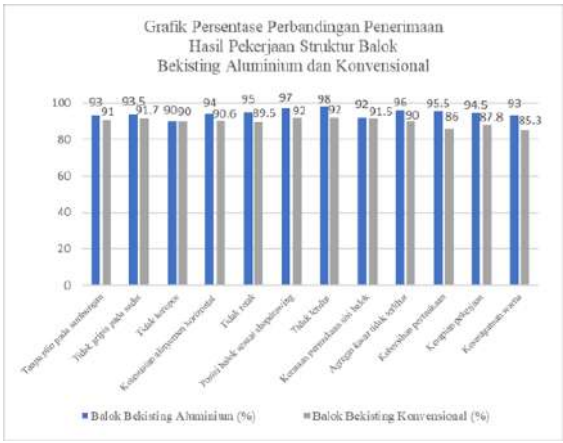

Figure 4. Percentage Comparison Graph of Acceptance of Aluminum and Conventional Formwork Beam Structural Work Results

Based on Figure 4, the largest difference is found in the surface cleanliness parameter, which is 9.5%. This can be interpreted as the surface cleanliness of aluminum formwork beam structures being better because aluminum formwork uses aluminum as its main component, so there are no leftover formwork residues. Meanwhile, 14% of conventional formwork beam structures still do not meet this requirement due to the presence of leftover boards or other formwork components on the beam structures. For the percentage comparison graph of acceptance of aluminum and conventional formwork floor slab structural work results, it can be seen in Figure 5 below.

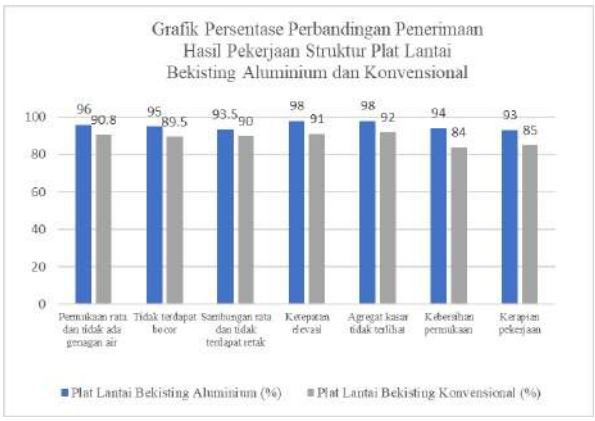

Figure 5. Percentage Comparison Graph of Acceptance of Aluminum and Conventional Formwork Floor Slab Structural Work Results

Based on Figure 5, the largest difference is found in the surface cleanliness parameter, which is 10%. This can be interpreted as the surface cleanliness of aluminum formwork floor slab structures being better because aluminum formwork uses aluminum as its main component, so there are no leftover formwork residues. Meanwhile, 16% of conventional formwork floor slab structures still do not meet this requirement due to the presence of leftover boards or other formwork components, especially on the underside of the floor slab structures.

4. CONCLUSION

Based on the research results, the influence of aluminum and conventional formwork structural work results on the quality success level of structural work in the construction project of Kediri District Stadium can be identified through the regression equation Y = 3.946 + 0.564 X1 + 0.392 X2 + 0.155 X3 - 0.328 X4 - 0.443 X5 - 0.030 X6 with an Adjusted R Square value of 0.949, indicating that the model is acceptable. This means that the more aluminum formwork structural work results, the higher the quality success of structural work. Additionally, the more conventional formwork structural work results, the lower the quality success of structural work.

There is a difference in the quality of structural work results between aluminum and conventional formwork in the construction project of Kediri District Stadium, with an average acceptance difference of 5.08%. Based on the parameters, the quality of aluminum formwork structural work is superior to conventional formwork structural work. For future construction projects, consideration can be given to the type of formwork to be used to achieve optimal quality of structural work.

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