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Analysis of Cantilever Beam Reinforcement Methods and Costs in the Wonderland Uluwatu Project

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Abstract

A strong and durable structure is the expectation for every building. However, in the implementation of concrete manufacturing projects, there are still many issues due to the quality of concrete not meeting the plan specifications, resulting in an inability to withstand the working load. For example, in the building construction project at Wonderland Uluwatu, the planned concrete quality for the cantilever beam was K300. However, when the hammer test was conducted at 28 days of curing, the expected quality was not achieved. So, a cantilever beam is necessary to repair and strengthen the concrete structure of the building to ensure its safety. This research compares the reinforcement methods for cantilever beams in terms of cost. Two cantilever beam reinforcement methods will be implemented: first, steel jacketing reinforcement using 8 mm and 10 mm thick steel plates; second, IWF steel reinforcement with dimensions of 500 mm x 200 mm x 10 mm x 16 mm. These reinforcement methods will be evaluated through deflection analysis and deviation analysis. The results of this study indicate that the cost of the steel jacketing reinforcement method with thicknesses of 8 mm and 10 mm amounts to Rp. 345,086,768.00. In contrast, repairing or reinforcing the cantilever beam using the IWF 500.200.10.16 steel method, assuming that the IWF is available in Bali, costs Rp. 272,515,956.00. Based on the cost calculations for each reinforcement method, it can be concluded that the IWF steel method is more economical, with a difference of Rp. 72,570,812.00.

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1 Introduction

This outdoor wedding venue was designed to take advantage of the natural scenery. To avoid obscuring the beach view around the wedding dressing table, a cantilever beam extends without columns (Asyraf et al., 2020). Cantilever beams must be carefully designed to prevent vertical or horizontal movement beyond safe limits when subjected to dead, live, or earthquake loads, given the nature of reinforced concrete structures. A strong and durable structure is the goal of every building (Suasira et al., 2022). However, many concrete construction projects still experience functional failures due to substandard concrete quality, resulting in the inability to withstand the applied loads (Agustinus & Lesmana, 2019). This is demonstrated through destructive concrete quality testing without the beam, using hammer tests and UPVT. These tests are performed on all compacted cantilevered concrete beams at several points for comparison, achieving the desired results.

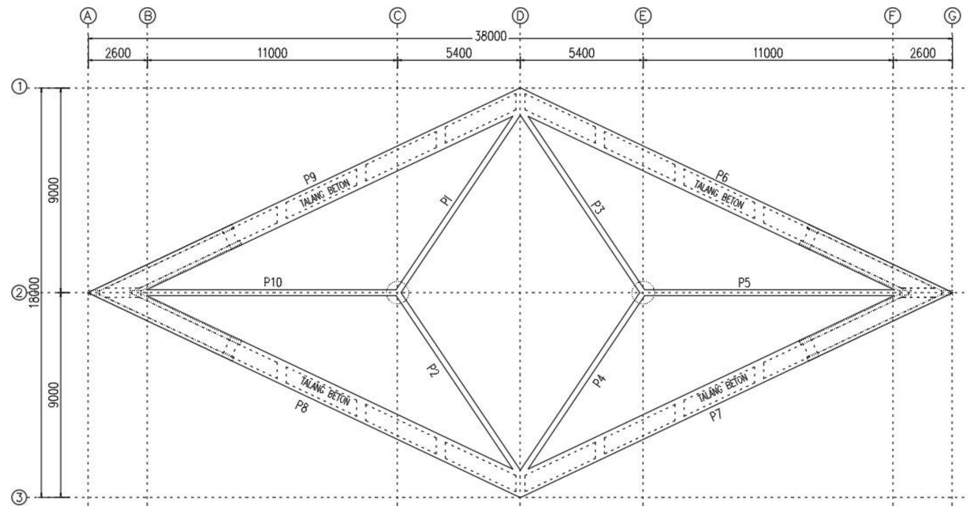
In the Wonderland Uluwatu project, the quality of the cantilever beam concrete was planned to be K300, but when the hammer test was carried out at the age of the concrete at 28 days, the planned quality was not achieved. Due to the inconsistency of the concrete quality in the field, further analysis was carried out by the planning team, and the results stated that the quality of the cantilever beam concrete was not able to accept the existing load (Fischer & Li, 2007). Therefore, the planning team suggested that repairs and reinforcement of the building's concrete structure were needed to ensure the safety of the building structure so that it could be operated immediately. The purpose of this study was to determine the cost requirements for each method of strengthening the Wonderland Uluwatu building structure. So that it can determine the most economical structural strengthening method without sacrificing the desired strength (Barad et al., 2013).

2 Materials and Methods

This research was conducted by comparing the reinforcement methods on cantilever beams in terms of cost. The existing beam is a non-prismatic cantilever beam with dimensions (1500-1000mm) x 500 mm x 250 mm x 200 mm. Based on the results of calculations and analysis of the existing structure that have been carried out, 2 structural reinforcement methods were carried out, namely by steel jacketing and adding IWF steel to the cantilever beam, and will be analyzed using the SAP2000 v.22 application (Khoeri, 2020). After obtaining the optimal reinforcement, the reinforcement will be calculated costs required for each reinforcement using AHSP 2023 Badung area. The final result of this research is to obtain the most economical reinforcement method.

3 Results and Discussions

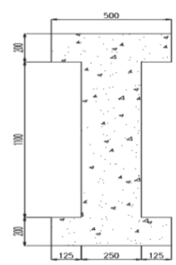
There is an existing floor plan of the Wonderland Uluwatu wedding venue, which was reviewed to have experienced quality failure in beams P1, P2, P3, and P4 according to the results of quality testing with Hammer Test and UPVT, which showed below 24.9 MPa. In analyzing a structure, it is necessary to identify the loads acting on it. The following are the results of load calculations carried out based on SNI 1727-2020 (Pala'biran et al., 2019).



Type	Information	Heavy	Unit
Dead Load	Plate Loading (1st Floor)	77	Kg/m2
	Glass Wall Loading	160	Kg/m2
	Roof Loading	10,5	Kg/m2
Living Burden	Plate Loading (1st Floor)	479	Kg/m2
	Gutter Beam Loading	100	Kg/m2
	Roof Loading	100	Kg/m2
Wind Load	Wind Press	8	Kg/m2
	Blow Wind	16	Kg/m2
Rainwater Load	Roof Loading	32	Kg/m2
	Gutter Beam Loading	58,8	Kg/m2

The structural analysis of the Wonderland Uluwatu building was conducted using SAP2000 v.22 under thefollowing conditions: Existing Condition Analysis

Detail Balok



Deflection Analysis

$$\delta_{izin}\ \mathrm{P1-P4} = \frac{l}{480} = \frac{9300}{480} = 19{,}375\ \mathrm{mm}$$

Block	Span (mm)	δ izin	δ SAP	Notes (δ izin > δ SAP)
P1	9300	19,375	31.869	NOT OK
P2	9300	19,375	30,750	NOT OK
P3	9300	19,375	31.869	NOT OK
P4	9300	19,375	30,750	NOT OK

Vibration Period
Control = $T_{SAP} < T_{max}$
= 0,3308 > 0,2526 (NOT OK)

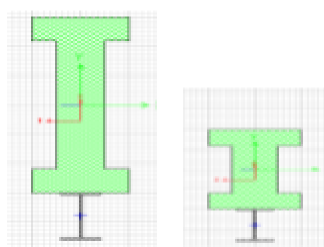
Deviation Analysis

$$\Delta_a = 0{,}015 \times h = 0{,}015 \times 4{,}5 = 0{,}0675 \text{ m}$$

Floor	**Hsx**	**δx**	**Δx**	**Δa (Ijin)**	**Control**
	(m)	**(m)**	**(m)**	**(m)**	**Δx < Δa**
Roof	4.50	0.00665	0.0029	0.0675	**OK**
LT.1	0	0	0	0	

Lantai	**Hsx**	**δy**	**Δy**	**Δa (Ijin)**	**Control**
	(m)	**(m)**	**(m)**	**(m)**	**Δx < Δa**
Atap	4.50	0.00082	0.0036	0.0675	**OK**
LT.1	0	0	0	0	

Analysis of Steel Jacketing Reinforcement Condition Reinforcement Details



Deflection Analysis

Block	Span (mm)	Thickness of Reinforcement Plate	δ izin	δ SAP	Notes (δ izin > δ SAP)
P1	9300	10	19,375	16,354	OK
P2	9300	8	19,375	16,967	OK
P3	9300	10	19,375	16,354	OK
P4	9300	8	19,375	16,967	OK

Vibration Period
Control = $T_{SAP} < T_{max}$
= 0,2159 < 0,2526 (OK)

Deflection Analysis

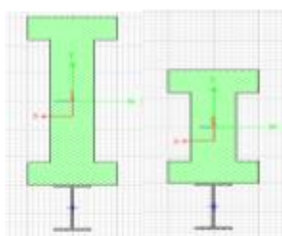
Floor	Hsx	δx	Δx	Δa (Ijin)	Control
	(m)	**(m)**	**(m)**	**(m)**	**Δx < Δa**
Roof	4.50	0.000638	0.0028	0.0675	**OK**
LT.1	0	0	0	0	
Lantai	**Hsx**	**δy**	**Δy**	**Δa (Ijin)**	**Control**
	(m)	**(m)**	**(m)**	**(m)**	**Δy < Δa**
Roof	4.50	0.000721	0.0032	0.0675	**OK**
LT.1	0	0	0	0	

Connection Requirements
A welded joint of type RD-460 AWS A5.1 E60113 with a 10 mm thick steel plate is declared capable of withstanding the loads acting on the structure. The calculation of the weld strength of this profile is as follows:

$= 39.373 \text{ Kg/mm}$ < 47.1 Kg/mm (OK)

IWF Steel Reinforcement Condition Analysis Reinforcement
Details

$$\sigma_t = \frac{3858600}{10 \times 9800}$$



Deflection Analysis

Block	Span (mm)	IWF Sizs	δ izin	δ SAP	Notes (δ izin > δ SAP)
P1	9300	500x200	19,375	17,077	OK
P2	9300	500x200	19,375	16,885	OK
P3	9300	500x200	19,375	17,077	OK
P4	9300	500x200	19,375	16,885	OK

Vibration Period
Control = $T_{SAP} < T_{max}$
= 0,2159 < 0,2526 (OK)

Deflection Analysis

Floor	Hsx	δx	Δx	Δa (Ijin)	Control
	(m)	**(m)**	**(m)**	**(m)**	**Δx < Δa**
Roof	4.50	0.000644	0.0028	0.0675	**OK**
LT.1	0	0	0	0	
Floor	**Hsy**	**δy**	**Δy**	**Δa (Ijin)**	**Control**
	(m)	**(m)**	**(m)**	**(m)**	**Δy < Δa**
Roof	4.50	0.000728	0.0032	0.0675	**OK**
LT.1	0	0	0	0	

Connection Requirements

A connection using 12 heavy-duty A-325 bolts with a diameter of 16 mm is considered capable of supporting the loads acting on the structure. The bolt strength calculation is as follows:

Plat Control

Melt = 0,75 x Ag x Fy
= 0,75 x 2800 x 240 / 1000
= 504 KN

Cracked = 0,75 x Ae x Fu
= 0,75 x (2800 - 2(16+2).10) x 370 /1000
= 677,1 KN > 385,86 KN (OK)

Prisoner Review

Rn = 0,75 x rl x Fu x m x Ab
= 0,75 x 0,6 x 825 x 1 x 200,96 / 1000
= 74,606 KN

Rn = 0,75 x 2,4 x db x t.plat x Fu plat
= 0,75 x 2,4 x 16 x 14 x 370 / 1000
= 149,184 KN

n = 12,00 x 74,606 KN
= 895,272 KN > 385,86 KN (OK)

A cost budget analysis was conducted to compare the alternatives of steel jacketing reinforcement with IWF steel reinforcement. In this analysis, cost calculations were made after calculating the volume per work item. To calculate this cost analysis, data such as the HSP for the Badung region and a material price survey were required (Mariantha, 2018). The results of the cost calculations required for each reinforcement are as follows:

4 Conclusion

Based on the analysis and calculations, the following conclusions were drawn: The cost required to repair or strengthen the cantilever beams of the Wonderland Uluwatu building structure using 8 and 10 mm thick steel jacketing is Rp345,086,768.00. Meanwhile, repairing or strengthening the cantilever beams using IWF 500.200.10.16 steel, assuming IWF is available in Bali, would cost Rp272,515,956.00. Based on the cost calculations for each reinforcement method, it can be concluded that strengthening with IWF steel is more economical, assuming IWF is available in Bali, compared to steel jacketing, by a difference of Rp72,570,812.00.

The suggestions that the author can provide from the results of the analysis that has been carried out are: In selecting a reinforcement method, it is recommended to review it from the point of view of ease of installation or architectural aspects to support the aesthetics or proportion of the building, and also to obtain more optimal results.

IWF steel reinforcement in size 500.200.10.16 is not yet available in Bali, requiring advance ordering. Therefore, further research suggests using alternative reinforcement materials such as castellated steel. In the calculation of cantilever beam reinforcement, it can be analyzed using various other structural applications to obtain more accurate results while still paying attention to existing regulations and taking into account the required reinforcement costs.

Further research is recommended to analyze the deflection in reinforcement with the residual value or the difference between the planned deflection value and the actual deflection value, and also review the shipping costs for IWF steel reinforcement.

Conflict of interest statement

The authors declared that they have no competing interests.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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