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BIM-Based Quantity Take-off for Reinforced Concrete Structure Works in Educational Building Construction Project

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ABSTRACT

The use of Building Information Modeling (BIM) in Indonesia is still limited and not yet common. One of the benefits of Building Information Modeling (BIM) is to improve efficiency in calculating the amount of work. Quantity Take-off calculations are often done conventionally by measuring shop drawings manually, which can lead to errors due to inaccuracies and complexities in calculating the volume of work. One software that can assist in designing, simulating, and visualizing buildings is Autodesk Revit software. The calculation process is done by converting 2D Detailed Engineering Design (DED) drawings into 3D drawings using Revit 2024 software. The case study of this research is the Construction Project of the Guest House Building at the University of Riau, Pekanbaru City, Riau Province. The research process involves modeling based on references from shop drawings, followed by performing quantity take-off calculations on the building structure work. The output of the modeling shows the results of calculating the volume of concrete needed for the building structure and the quantity of steel reinforcement from the building structure. Based on the calculation results, the volume of concrete needed for the conventional method is 391.197 m3, which when multiplied by AHSP results in a total cost of Rp 762,376,997.19. Meanwhile, the total volume using Autodesk Revit 2024 is 318,213 m3 with a total cost of Rp 620,942.778,00. For the reinforcement work of the structure, the Autodesk Revit calculation results in Rp 1,952.501.845,31, while the results from the conventional method amount to Rp 3,697.279.792,12. It can be concluded that the calculation results using Building Information Modeling (BIM) method are smaller than the calculations using the conventional method.

Keywords: *Building Information Modeling (BIM); Quantity Take-off; Autodesk Revit; Structural Work; Construction Cost Estimation.*

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INTRODUCTION

Infrastructure projects play a crucial role in economic transformation in the Industry 4.0 era. Indonesia is one of the largest construction markets in Asia, and its construction sector contributes significantly to national economic activity. However, rapid technological development also requires the industry to adopt sustainable digital practices that improve efficiency, project delivery, and infrastructure quality. Building Information Modeling (BIM) and related digital workflows support information integration, coordination, and more efficient project delivery in the architecture, engineering, and construction industry [1], [2].

The Indonesian government has taken various steps to address challenges in infrastructure development, including regulations related to the implementation of Building Information Modeling (BIM) in the construction sector. Law No. 2 of 2017 on Construction Services authorizes the Central Government to develop standards for construction materials, equipment, and innovative construction technologies [3]. In addition, Minister of Public Works and Public Housing Regulation No. 22/PRT/M/2018 on State Building Construction requires BIM for complex state buildings with an area exceeding 2,000 m² and more than two floors [4].

One application of Building Information Modeling is quantity take-off (QTO), which is the process of measuring and determining the quantities of materials, components, and work required to complete a construction project [5]. Accurate material quantity planning requires detailed and consistent volume calculations. BIM-based QTO can improve speed and reliability compared with traditional 2D take-off, although the quality and completeness of the model remain important limiting factors [6].

Riau University is one of the universities with an A accreditation in Indonesia and the only one in Riau Province. This status is attributed to the completeness of facilities provided, including a hospital, clinic, mosque, sports facilities, shopping areas, and a cooperative. In 2023, Riau University undertook the construction of several buildings, including the Guest House building. This two-story building has a total area of 2156 square meters.

This research is based on issues identified during the construction of the Guest House building at the University of Riau, where the BIM concept had not been implemented for quantity take-off or structural work-volume calculations. The study develops a 3D model of reinforced-concrete structural elements, including pile caps, tie beams, columns, and beams, using Autodesk Revit, and compares the resulting quantities with conventional calculations. Previous BIM-based QTO studies emphasize that model verification, an appropriate level of detail, and consistent modeling rules are required before quantities can be extracted reliably [7], [8].

METHOD

The research begins with a literature review on quantity take-off (QTO) using Building Information Modeling (BIM). Secondary project data were then collected as the basis for developing the structural model in Autodesk Revit. The Detailed Engineering Design (DED) drawings were used as the modeling reference. After the Guest House structural model was completed, concrete and reinforcement quantities were extracted and compared with manual or conventional calculations. BIM-based cost-estimation systems can link model quantities directly to work items and unit prices, improving consistency in the estimating process [9], [10].

Cost estimation in this study uses the Analysis of Unit Price of Work (AHSP). The AHSP for concrete refers to SNI 2835:2008, while the prices of goods and services refer to the 2023 Standard Prices of Goods and Services of the Pekanbaru City Government. Because the completeness of model information directly affects the bill of quantities and cost output, the model and project documents were checked before the two calculation methods were compared [11].

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Table 1. Unit price analysis for 1 m³ of 26.4 MPa concrete (K-300) with a slump of 12 ± 2 cm

No.	Description	Code	Unit	Coefficient	Unit Price (IDR)	Total Price (IDR)
A	**Labor**					
	General worker	L01	person-day	1.65	100,000.00	165,000.00
	Mason	L02	person-day	0.275	140,000.00	38,500.00
	Head worker	L03	person-day	0.028	170,000.00	4,760.00
	Foreman	L04	person-day	0.083	180,000.00	14,940.00
					Labor subtotal	**223,200.00**
B	**Materials**					
	Portland cement (PC)		kg	413	2,400.00	991,200.00
	Concrete sand (CS)		m³	0.49	291,400.00	142,786.00
	Gravel (max. 30 mm)		m³	0.76	345,000.00	262,200.00
	Water		L	215	350.00	75,250.00
					Materials subtotal	**1,471,436.00**
C	**Equipment**					
					Equipment subtotal	**0.00**
					D. Subtotal (A + B + C)	**1,694,636.00**
					E. Overhead and profit (15% × D)	**254,195.40**
					F. Unit price of work (D + E)	**1,948,831.40**

Table 2. Unit price analysis for 1 kg of reinforcement work with bar diameter < 12 mm

No.	Description	Code	Unit	Coefficient	Unit Price (IDR)	Total Price (IDR)
A	**Labor**					
	General worker	L01	person-day	0.0016	100,000.00	160.00
	Steel fixer	L02	person-day	0.0016	140,000.00	224.00
	Head worker	L03	person-day	0.00016	170,000.00	27.20
	Foreman	L04	person-day	0.00016	180,000.00	28.80
					Labor subtotal	**440.00**
B	**Materials**					
	Deformed reinforcing steel (BjTS)	M.60.a	kg	1.02	18,200.00	18,564.00
	Binding wire	M.72	kg	0.028	35,400.00	991.20
					Materials subtotal	**19,555.20**
C	**Equipment**					
					Equipment subtotal	**0.00**
					D. Subtotal (A + B + C)	**19,995.20**
					E. Overhead and profit (15% × D)	**2,999.28**
					F. Unit price of work (D + E)	**22,994.48**

Table 3. Unit price analysis for 1 kg of reinforcement work with bar diameter > 12 mm

No.	Description	Code	Unit	Coefficient	Unit Price (IDR)	Total Price (IDR)
A	**Labor**					
	General worker	L01	person-day	0.0016	100,000.00	160.00
	Steel fixer	L02	person-day	0.0016	140,000.00	224.00
	Head worker	L03	person-day	0.00016	170,000.00	27.20
	Foreman	L04	person-day	0.00016	180,000.00	28.80
					Labor subtotal	**440.00**
B	**Materials**					
	Deformed reinforcing steel (BjTS)	M.60.a	kg	1.02	18,200.00	18,564.00

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No.	Description	Code	Unit	Coefficient	Unit Price (IDR)	Total Price (IDR)
	Binding wire	M.72	kg	0.028	35,400.00	991.20
					Materials subtotal	**19,555.20**
C	**Equipment**					
	Bar cutter	To.25.c	day	0.04	125,000.00	5,000.00
	Bar bender	To.25.a	day	0.04	125,000.00	5,000.00
					Equipment subtotal	**10,000.00**
					D. Subtotal (A + B + C)	**29,995.20**
					E. Overhead and profit (15% × D)	**4,499.28**
					F. Unit price of work (D + E)	**34,494.48**

The efficiency calculation of comparing the two methods can use the following equation:

$$\text{Efficiency} = \frac{\text{Difference}}{\text{Conventional Volume}}\ x\ 100\%$$

RESULTS AND DISCUSSION

Building Modeling

In this research, the project data were modeled using Autodesk Revit. The following steps follow established BIM-based QTO modeling guidelines [7], [8]:

1. Create a file to start a project by opening the Autodesk Revit software first, then there will be an initial display, then select new, then structure template, and click ok.

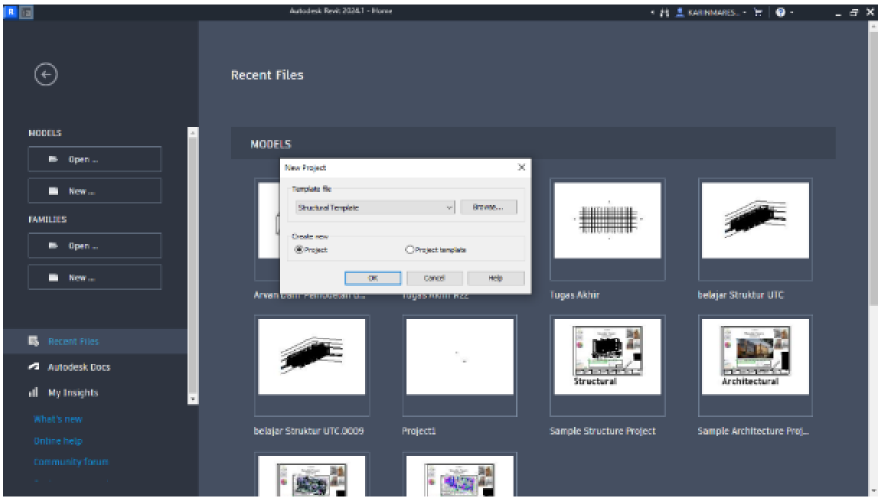

Figure 1. Initial Display in Autodesk Revit Software

2. Perform basic settings or unit settings by selecting the manage toolbar, then selecting project units, and adjusting the units as desired. Since millimeters (mm) are used in shop drawings, millimeters (mm) are used in modeling.

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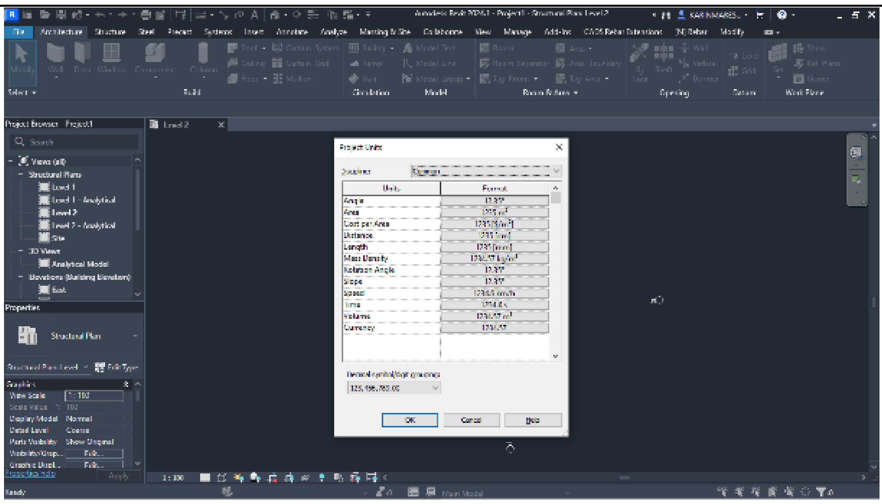
Figure 2. Setting Project Units

3. Create a grid or reference lines to facilitate modeling. This can be done by selecting the structure toolbar, choosing grid, and then creating grids or lines as shown in the image.

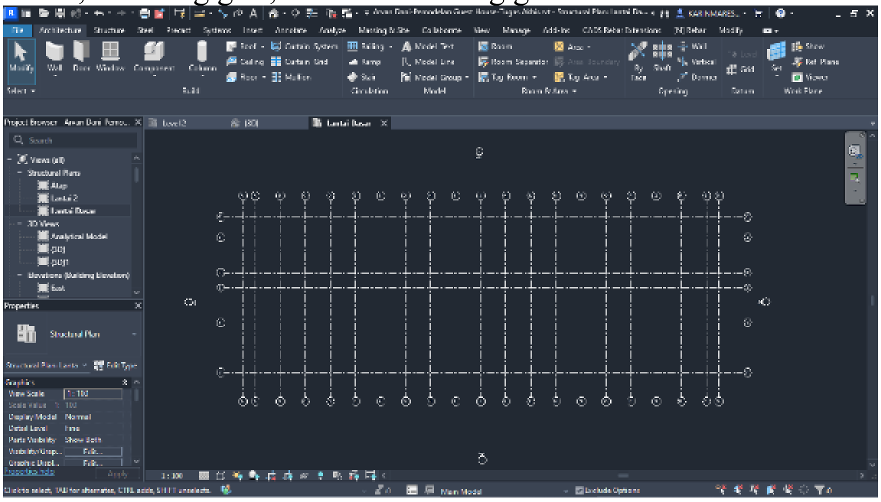
Figure 3. Creating Grid or Reference Lines

4. Establish levels as references to determine the height of a building. This can be done by selecting one of the building elevations, choosing a level, and inputting the level according to the shop drawing.

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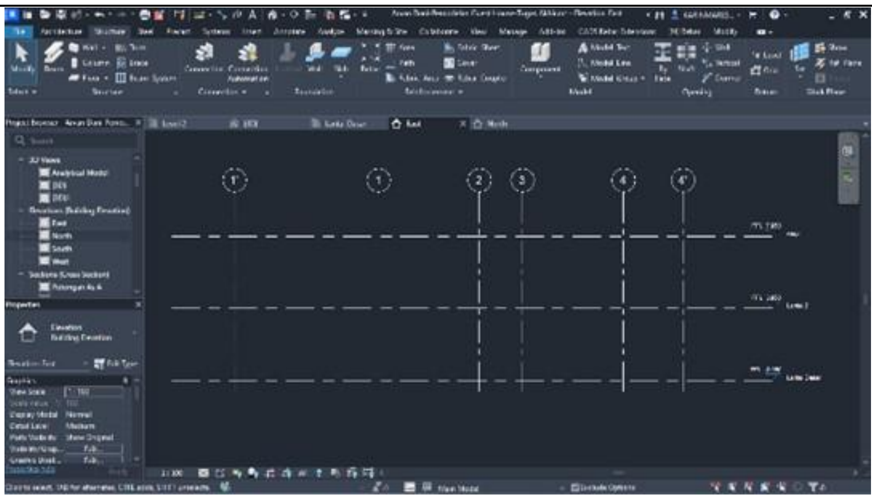
Figure 4. Creating Building Levels or Elevations

5. Create families for each structural element according to the plan. This involves selecting the structure toolbar, choosing structural foundation for foundations, beam for tie beams and beams, and column for columns.

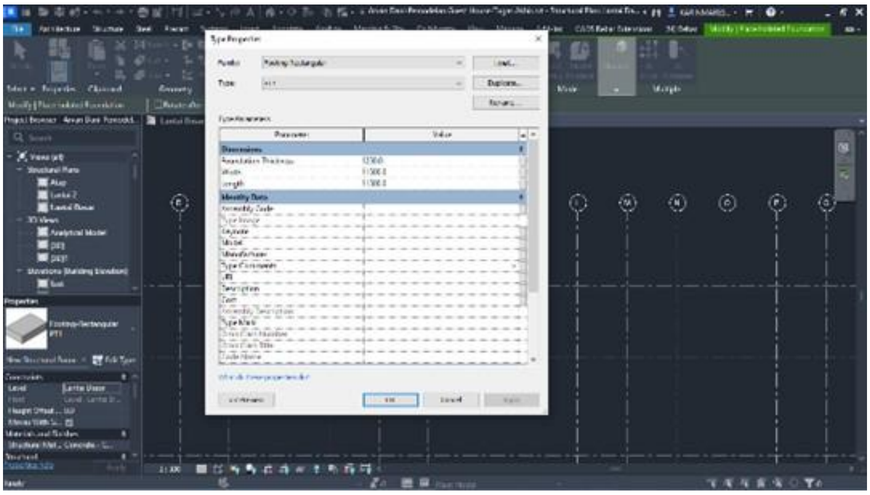
Figure 5. Creating Structural Element Families

6. Model each structural element according to the plan.

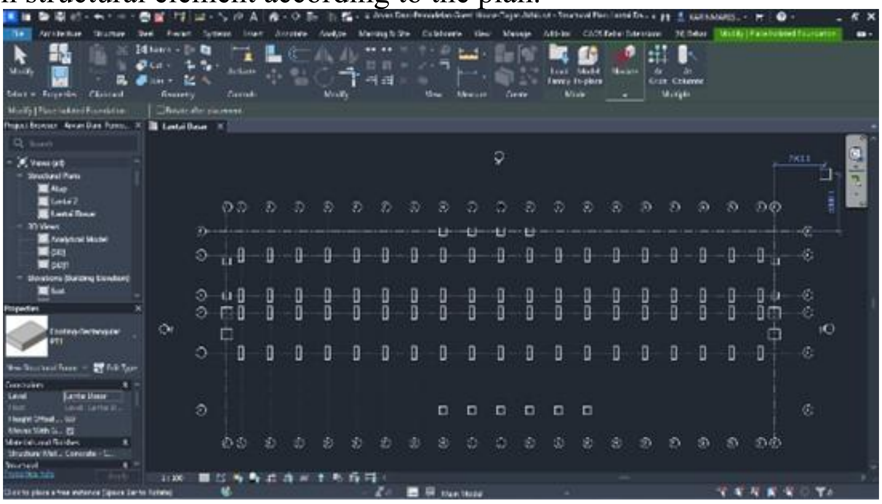

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Figure 6. Structural Modeling

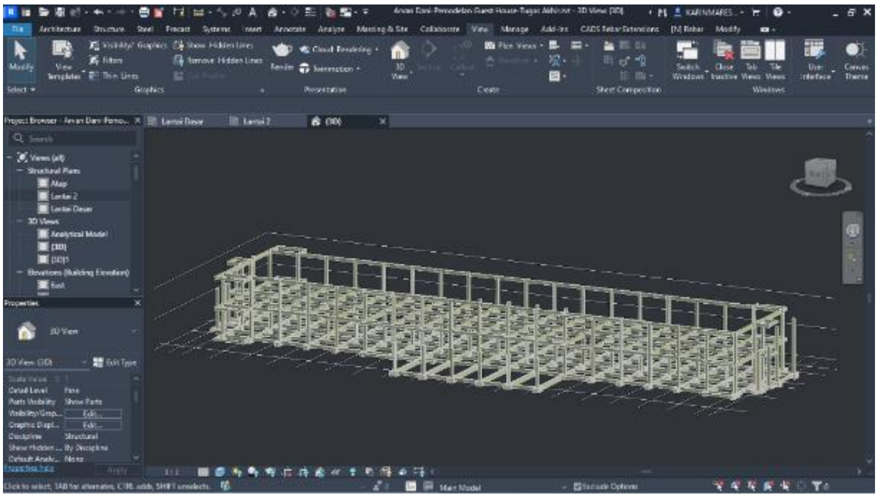

Figure 7. Structural Modeling Results

7. Performing foundation reinforcement modeling by creating a section first to make cuts to facilitate work on foundation reinforcement. Next, click on the rebar and input the main and stirrup reinforcement according to the design plan.

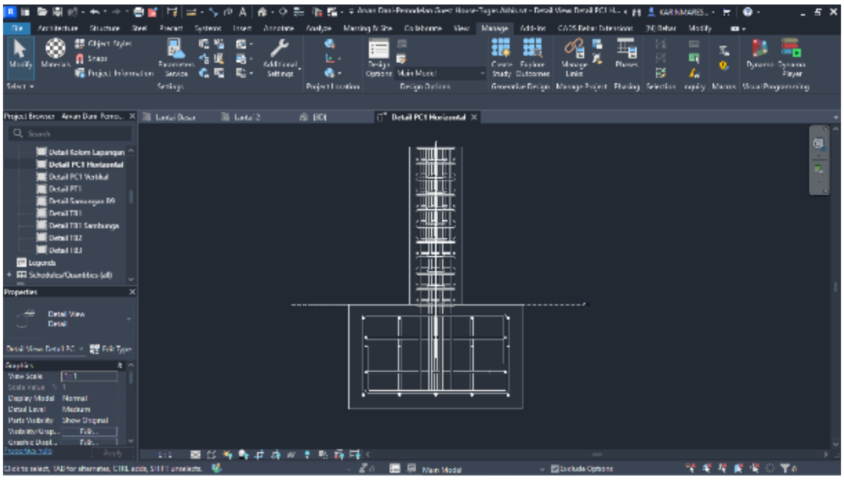

Figure 8. Reinforcement Modeling

8. Performing reinforcement tie beam modeling by creating a section first to make cuts to facilitate work on tie beam reinforcement. Next, click on the rebar and input the main and stirrup reinforcement according to the design plan.

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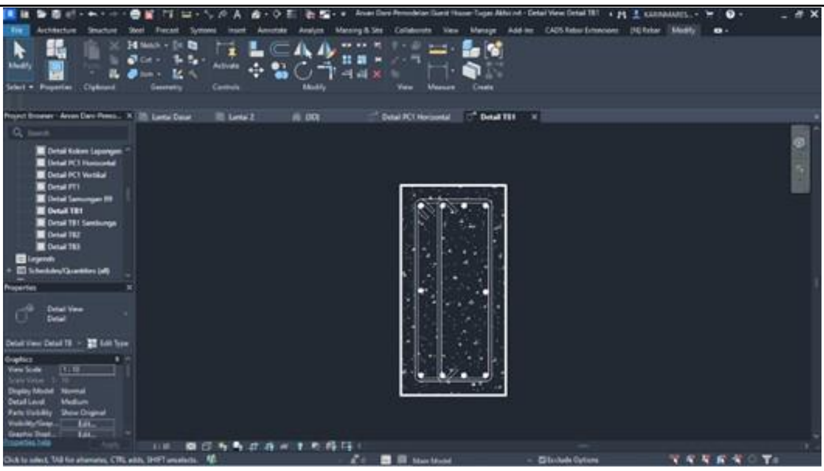
Figure 9. Tie Beam Reinforcement

9. Performing column reinforcement modeling by creating a section first to make cuts to facilitate work on column reinforcement. Next, click on the rebar and input the main and stirrup reinforcement according to the design plan.

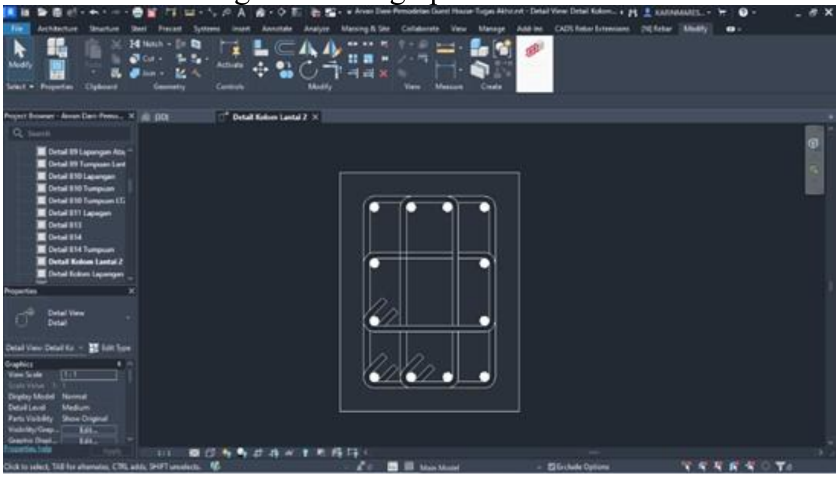
Figure 10. Column Reinforcement

10. Performing beam reinforcement modeling by creating a section first to make cuts to facilitate work on beam reinforcement. Next, click on the rebar and input the main and stirrup reinforcement according to the design plan.

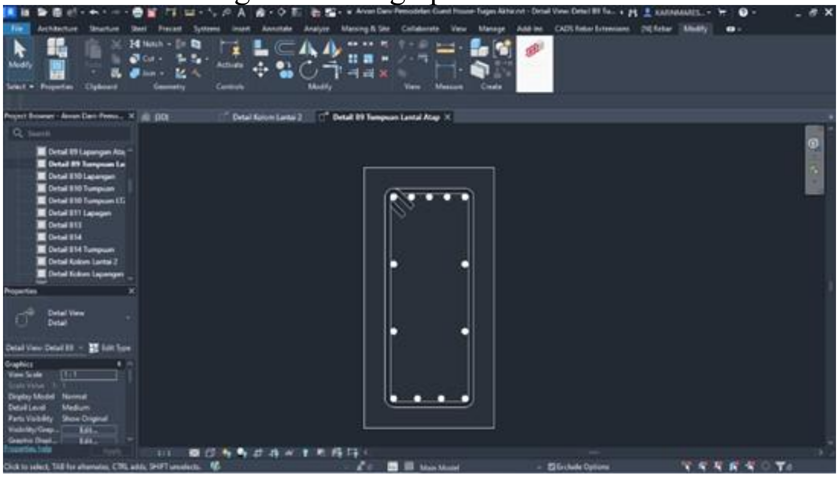
Figure 11. Beam Reinforcement

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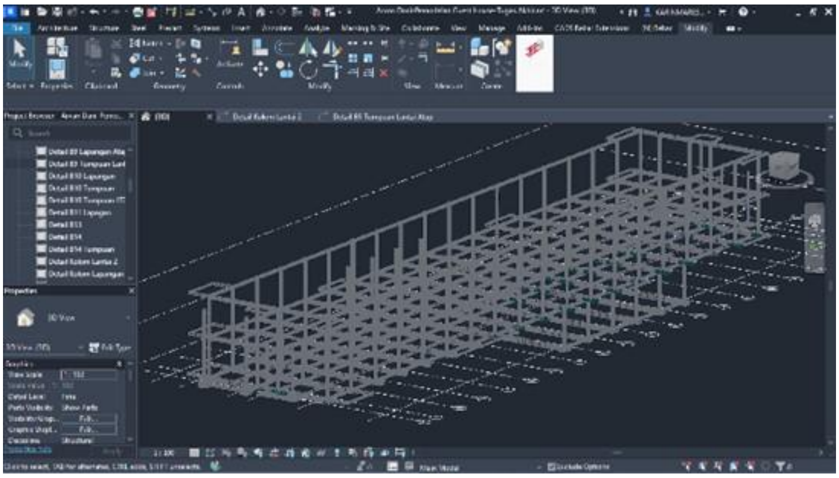
Figure 12. Reinforcement Modeling Results

Discussion

After performing 3D modeling and subsequently conducting quantity take-off calculations using Autodesk Revit software, here is the summary of the quantity take-off calculation results using Autodesk Revit:

Table 4. Concrete quantity take-off using BIM

No.	Work Description	Unit	Unit Price (IDR/m³)	Revit Volume (m³)	Revit Concrete Cost (IDR)
A	**Pile-cap concrete work**				
1	Pile cap (PC1), 1000 × 1000 × 600 mm	m³	1,948,831.40	8.400	16,370,183.76
2	Pile cap (PC2), 1800 × 600 × 600 mm	m³	1,948,831.40	49.248	95,976,048.79
B	**Tie-beam concrete work**				
1	Tie beam (TB1), 600 × 300 mm	m³	1,948,831.40	36.510	71,157,570.45
2	Tie beam (TB2), 500 × 300 mm	m³	1,948,831.40	36.260	71,468,922.29
3	Tie beam (TB3), 400 × 200 mm	m³	1,948,831.40	10.660	20,766,747.40
C	**Column concrete work**				
1	Concrete column (K6), 400 × 300 mm	m³	1,948,831.40	69.444	135,334,647.70
D	**Beam concrete work**				
1	Concrete beam (B6), 300 × 250 mm	m³	1,948,831.40	7.962	15,517,463.45
2	Concrete beam (B8), 500 × 300 mm	m³	1,948,831.40	29.640	57,768,326.70
3	Concrete beam (B9), 500 × 250 mm	m³	1,948,831.40	3.100	6,041,377.34
4	Concrete beam (B10), 400 × 250 mm	m³	1,948,831.40	25.160	49,032,598.02
5	Concrete beam (B11), 400 × 200 mm	m³	1,948,831.40	10.064	19,613,039.21
6	Concrete beam (B12), 300 × 150 mm	m³	1,948,831.40	6.075	11,839,150.76
7	Concrete beam (B13), 300 × 250 mm	m³	1,948,831.40	2.550	4,969,520.07
8	Concrete beam (B14), 400 × 300 mm	m³	1,948,831.40	18.240	35,546,684.74
9	Concrete beam (Bk), 400 × 200 mm	m³	1,948,831.40	4.900	9,540,497.32
			Total structural concrete volume	**318.213**	
				Total concrete cost	**620,942,778.00**

Table 5. Reinforcement quantity take-off using BIM

No.	Work Description	Unit Price (IDR/kg)	Autodesk Revit Calculation: Total Length (m)	Autodesk Revit Calculation: Steel Weight (kg)	Revit Rebar Cost (IDR)
A	**Pile-cap reinforcement**				
1	**Pile cap (PC1), 1000 × 1000 × 600 mm**				
	Top reinforcement (D16)	34,494.48	189.000	298.242	10,287,702.70

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No.	Work Description	Unit Price (IDR/kg)	Autodesk Revit Calculation: Total Length (m)	Autodesk Revit Calculation: Steel Weight (kg)	Revit Rebar Cost (IDR)
	Bottom reinforcement (D16)	34,494.48	190.750	301.004	10,382,959.21
	Stirrups (D16)	34,494.48	99.400	156.853	5,410,569.57
2	**Pile cap (PC2), 1800 × 600 × 600 mm**				
	Top reinforcement (D16)	34,494.48	1,320.500	2,083.749	71,877,838.21
	Bottom reinforcement (D19)	34,494.48	1,841.100	4,098.289	141,368,334.15
	Stirrups (D16)	34,494.48	657.400	1,037.377	35,783,787.08
B	**Tie-beam reinforcement**				
1	**Tie beam (TB1), 600 × 300 mm**				
	Longitudinal reinforcement (D16)	34,494.48	3,393.600	5,355.101	184,721,417.44
	Stirrups (D10)	22,994.48	3,673.575	2,265.956	51,119,191.22
2	**Tie beam (TB2), 500 × 300 mm**				
	Longitudinal reinforcement (D16)	34,494.48	4,121.325	6,503.451	224,333,155.28
	Stirrups (D10)	22,994.48	2,954.350	1,822.834	41,915,118.81
3	**Tie beam (TB3), 400 × 200 mm**				
	Longitudinal reinforcement (D16)	34,494.48	612.750	966.920	33,353,385.35
	Stirrups (D10)	22,994.48	1,069.350	659.789	15,171,503.81
C	**Column reinforcement**				
1	**Concrete column (K6), Level 1, 400 × 300 mm**				
	Vertical reinforcement (D16)	34,494.48	6,503.850	10,263.075	354,019,445.67
	Stirrups (D10)	22,994.48	10,985.200	6,777.868	155,853,559.37
2	**Concrete column (K6), Level 2, 400 × 300 mm**				
	Vertical reinforcement (D16)	34,494.48	1,974.000	3,114.972	107,449,339.35
	Stirrups (D10)	22,994.48	4,592.400	2,833.511	65,155,107.42
D	**Beam reinforcement**				
1	**Concrete beam (B6), 300 × 250 mm**				
	Longitudinal reinforcement (D16)	34,494.48	514.850	812.443	28,024,464.22
	Stirrups (D10)	22,994.48	923.950	570.077	13,108,627.62
2	**Concrete beam (B8), 500 × 300 mm**				
	Longitudinal reinforcement (D16)	34,494.48	1,576.450	2,487.638	85,809,782.69
	Stirrups (D10)	22,994.48	2,718.900	1,677.561	38,574,649.76
3	**Concrete beam (B9), 500 × 250 mm**				
	Longitudinal reinforcement (D13)	34,494.48	359.800	567.764	19,584,737.74
	Stirrups (D10)	22,994.48	317.500	195.898	4,504,561.15
4	**Concrete beam (B10), 400 × 250 mm**				
	Longitudinal reinforcement (D13)	34,494.48	1,989.025	2,072.564	71,429,019.17
	Stirrups (D10)	22,994.48	2,713.200	1,674.044	38,493,780.47
5	**Concrete beam (B11), 400 × 200 mm**				
	Longitudinal reinforcement (D13)	34,494.48	636.975	1,005.147	34,672,007.57
	Stirrups (D10)	22,994.48	1,227.400	757.306	17,413,853.07
6	**Concrete beam (B12), 300 × 150 mm**				
	Longitudinal reinforcement (D13)	34,494.48	752.700	1,187.761	40,971,184.26
	Stirrups (D10)	22,994.48	753.300	464.768	10,687,514.68
7	**Concrete beam (B13), 300 × 250 mm**				

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No.	Work Description	Unit Price (IDR/kg)	Autodesk Revit Calculation: Total Length (m)	Autodesk Revit Calculation: Steel Weight (kg)	Revit Rebar Cost (IDR)
	Longitudinal reinforcement (D13)	34,494.48	208.250	216.997	7,485,181.43
	Stirrups (D10)	22,994.48	312.375	192.735	4,431,849.73
8	**Concrete beam (B14), 400 × 300 mm**				
	Longitudinal reinforcement (D13)	34,494.48	1,229.775	1,281.426	44,202,108.01
	Stirrups (D10)	22,994.48	1,835.350	1,132.411	26,039,200.94
9	**Concrete beam (Bk), 400 × 200 mm**				
	Longitudinal reinforcement (D13)	34,494.48	356.100	561.926	19,383,338.27
	Stirrups (D10)	22,994.48	454.350	280.334	6,446,133.41
		Total reinforcement quantity	**60,809.550**	**63,453.651**	
				Total reinforcement cost	**1,952,501,845.31**

After conducting a recapitulation of the quantity take-off calculations using Autodesk Revit, it is necessary to compare the results by summarizing the calculations using conventional methods. Below are the summarized results of the conventional method calculations:

Table 6. Concrete quantity take-off using the conventional method

No.	Work Description	Unit	Unit Price (IDR/m³)	Project Volume (m³)	Project Concrete Cost (IDR)
A	**Pile-cap concrete work**				
1	Pile cap (PC1), 1000 × 1000 × 600 mm	m³	1,948,831.40	6.300	12,277,637.82
2	Pile cap (PC2), 1800 × 600 × 600 mm	m³	1,948,831.40	75.240	146,630,074.54
B	**Tie-beam concrete work**				
1	Tie beam (TB1), 600 × 300 mm	m³	1,948,831.40	76.311	148,717,272.97
2	Tie beam (TB2), 500 × 300 mm	m³	1,948,831.40	27.230	53,066,679.02
3	Tie beam (TB3), 400 × 200 mm	m³	1,948,831.40	13.488	26,285,837.92
C	**Column concrete work**				
1	Concrete column (K6), 400 × 300 mm	m³	1,948,831.40	73.099	142,457,626.51
D	**Beam concrete work**				
1	Concrete beam (B6), 300 × 250 mm	m³	1,948,831.40		-
2	Concrete beam (B8), 500 × 300 mm	m³	1,948,831.40	54.150	105,529,220.31
3	Concrete beam (B9), 500 × 250 mm	m³	1,948,831.40	3.375	6,577,305.98
4	Concrete beam (B10), 400 × 250 mm	m³	1,948,831.40	23.020	44,862,098.83
5	Concrete beam (B11), 400 × 200 mm	m³	1,948,831.40	10.080	19,644,220.51
6	Concrete beam (B12), 300 × 150 mm	m³	1,948,831.40	8.100	15,783,534.34
7	Concrete beam (B13), 300 × 250 mm	m³	1,948,831.40	2.708	5,277,435.43
8	Concrete beam (B14), 400 × 300 mm	m³	1,948,831.40	18.096	35,266,053.01
9	Concrete beam (Bk), 400 × 200 mm	m³	1,948,831.40		-
			Total structural concrete volume	**391.197**	
				Total concrete cost	**762,376,997.19**

Table 7. Reinforcement quantity take-off using the conventional method

No.	Work Description	Unit Price (IDR/kg)	Project Calculation: Total Length (m)	Project Calculation: Steel Weight (kg)	Project Rebar Cost (IDR)
A	**Pile-cap reinforcement**				
1	**Pile cap (PC1), 1000 × 1000 × 600 mm**				
	Top reinforcement (D16)	34,494.48	355.600	561.137	19,356,129.02
	Bottom reinforcement (D16)	34,494.48	355.600	561.137	19,356,129.02
	Stirrups (D16)	34,494.48	110.320	174.085	6,004,971.55
2	**Pile cap (PC2), 1800 × 600 × 600 mm**				

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No.	Work Description	Unit Price (IDR/kg)	Project Calculation: Total Length (m)	Project Calculation: Steel Weight (kg)	Project Rebar Cost (IDR)
	Top reinforcement (D16)	34,494.48	6,007.040	9,479.109	326,976,935.82
	Bottom reinforcement (D19)	34,494.48	10,762.613	23,957.577	826,404,160.67
	Stirrups (D16)	34,494.48	963.680	1,520.687	52,455,307.31
B	**Tie-beam reinforcement**				
1	**Tie beam (TB1), 600 × 300 mm**				
	Longitudinal reinforcement (D16)	34,494.48	9,632.453	21,441.841	739,625,155.54
	Stirrups (D10)	22,994.48	7,103.040	4,382.576	100,775,056.18
2	**Tie beam (TB2), 500 × 300 mm**				
	Longitudinal reinforcement (D16)	34,494.48	3,592.633	5,717.652	197,227,432.56
	Stirrups (D10)	22,994.48	3,518.080	2,170.655	49,913,082.98
3	**Tie beam (TB3), 400 × 200 mm**				
	Longitudinal reinforcement (D16)	34,494.48	2,492.640	5,548.617	191,396,658.13
	Stirrups (D10)	22,994.48	1,900.800	1,172.794	26,967,788.18
C	**Column reinforcement**				
1	**Concrete column (K6), Level 1, 400 × 300 mm**				
	Vertical reinforcement (D16)	34,494.48	5,459.520	8,615.123	297,174,188.02
	Stirrups (D10)	22,994.48	9,330.840	5,757.128	132,382,164.65
2	**Concrete column (K6), Level 2, 400 × 300 mm**				
	Vertical reinforcement (D16)	34,494.48	2,439.360	3,849.310	132,779,946.81
	Stirrups (D10)	22,994.48	4,271.400	2,635.454	60,600,894.29
D	**Beam reinforcement**				
1	**Concrete beam (B6), 300 × 250 mm**				
	Longitudinal reinforcement (D13)	34,494.48			
	Stirrups (D10)	22,994.48			
2	**Concrete beam (B8), 500 × 300 mm**				
	Longitudinal reinforcement (D16)	34,494.48	2,348.847	3,706.480	127,853,100.23
	Stirrups (D10)	22,994.48	5,234.120	3,229.452	74,259,569.42
3	**Concrete beam (B9), 500 × 250 mm**				
	Longitudinal reinforcement (D13)	34,494.48	132.960	138.544	4,779,003.24
	Stirrups (D10)	22,994.48	507.840	313.337	7,205,021.38
4	**Concrete beam (B10), 400 × 250 mm**				
	Longitudinal reinforcement (D13)	34,494.48	1,742.754	2,182.859	75,296,586.12
	Stirrups (D10)	22,994.48	2,396.000	1,478.332	33,993,475.61
5	**Concrete beam (B11), 400 × 200 mm**				
	Longitudinal reinforcement (D13)	34,494.48	758.140	1,137.138	39,224,984.00
	Stirrups (D10)	22,994.48	984.000	607.128	13,960,592.65
6	**Concrete beam (B12), 300 × 150 mm**				
	Longitudinal reinforcement (D13)	34,494.48	648.900	713.666	24,617,537.56
	Stirrups (D10)	22,994.48	1,360.800	839.614	19,306,487.33
7	**Concrete beam (B13), 300 × 250 mm**				
	Longitudinal reinforcement (D13)	34,494.48	316.983	500.200	17,254,138.90
	Stirrups (D10)	22,994.48	518.320	319.308	7,342,321.42
8	**Concrete beam (B14), 400 × 300 mm**				
	Longitudinal reinforcement (D13)	34,494.48	1,223.224	1,292.819	44,595,119.14

No.	Work Description	Unit Price (IDR/kg)	Project Calculation: Total Length (m)	Project Calculation: Steel Weight (kg)	Project Rebar Cost (IDR)
	Stirrups (D10)	22,994.48	1,987.360	1,226.201	28,195,854.37
9	**Concrete beam (Bk), 400 × 200 mm**				
	Longitudinal reinforcement (D13)	34,494.48			
	Stirrups (D10)	22,994.48			
	Total reinforcement quantity		**88,455.867**	**115,229.960**	
	Total reinforcement cost				**3,697,279,792.12**

There are differences between the quantity take-off values for structural work calculated using Building Information Modeling (BIM) method and conventional methods. The quantity take-off value for the project calculation is higher compared to the quantity take-off calculation using Building Information Modeling (BIM) method with the assistance of Autodesk Revit. There are several possible factors causing these differences, such as human error or incomplete data or information in project documents like Detailed Engineering Design (DED) obtained from the project. It could also be due to the analysis of quantity take-off estimation for structural work between project documents and Autodesk Revit software analysis using different references. Conventional project calculations use 2D DED references, while the analysis with Autodesk Revit software uses a 3D model reference based on the DED project document using Autodesk Revit software. The material volume needs are less detailed due to being confined to 2D drawings, some input data errors, and many project calculations counting from one tie As to another or confidentiality of project calculations. In contrast, Autodesk Revit software calculates from edge to edge, avoiding overlapping calculations between different structural components. Similar studies show that discrepancies may result from different modeling approaches, compound elements, and insufficient object detail [12], [13].

The most influential factor causing differences in calculation results between conventional methods and Building Information Modeling (BIM) in this study is the inconsistency between drawings and calculation data or human error factors, leading to less accurate conventional calculations. However, in this study, the quantity take-off calculation results are derived from 3D modeling using Autodesk Revit software. By using Autodesk Revit, the building's shop drawings are modeled in 3D, making the material volume requirements more detailed. This indicates that the use of Building Information Modeling (BIM) can provide detailed quantity take-off calculation outputs, reducing material waste. Autodesk Revit can model structural elements well and are easy to understand, making 3D modeling helpful for analysis and corrections in case of volume differences, minimizing errors due to human error during calculations. The geometry and semantic consistency of BIM objects strongly influence automated QTO accuracy and compliance with measurement rules [14].

Looking at the total costs, there is a cost difference between Autodesk Revit calculations and conventional project calculations, even though the same unit price is used in Autodesk Revit calculations. The calculation result using Autodesk Revit for structural work is Rp 620,942,778.00, while the conventional calculation result is Rp 762,376,997.19. The difference is Rp 141,434,219.19, meaning that the Building Information Modeling (BIM) calculation with Autodesk Revit is 18.55% more cost-effective than conventional methods. An analysis found the reasons for the difference between conventional and Revit calculations. For instance, in the tie beam element TB1 analysis, a human error was found in the conventional calculation where the span length from one tie As to another in the TB1 element on the drawing was 2.4 meters, but it was input as 10 meters in the conventional calculation, resulting in an additional volume of 39.801 m3. Similarly, for tie beam element TB3, which had the same issue as TB1, an error or human error occurred in the conventional calculation where the span from one tie As to another in the TB3 element on the drawing should have been 4 meters, but it was input as 5 meters, resulting in a small increase of 2.828 m3.

For structural reinforcement work, the quantity take-off calculation result using Autodesk Revit is Rp 1,952,501,845.31, while the conventional method calculation result is Rp 3,697,279,792.12. The difference between these two results is Rp 1,744,777,946.81, meaning that the Building Information Modeling (BIM) method is 47.19% more cost-effective than conventional methods. An analysis found that the differences between conventional and Revit calculations were due to incorrect rebar sizes that did not match between the drawing and the data input in the conventional calculation. There were six structural elements where the rebar sizes did not match the drawing, including tie beam element TB1, where the longitudinal reinforcement should have been D16 rebar, but in the conventional calculation, it was input as D19 rebar. The rebar weights for D16 and D19 are different, so the discrepancy between the drawing and the input data in the conventional calculation resulted in excess rebar weight. Another reason for the difference in reinforcement calculation results between conventional and Revit calculations is that in the conventional reinforcement calculation, some rebar quantities were multiplied by 2, doubling the total amount of rebar.

The advantages of using Building Information Modeling (BIM) in estimation include utilizing materials effectively and efficiently in structural work and minimizing waste. The application of Building Information Modeling (BIM) in supporting the estimation of structural work costs with Autodesk Revit software provides outputs displaying 3D buildings and quantity take-off results along with information according to the technical specifications input during the modeling process. With the Building Information Modeling (BIM) method, quantity take-off calculations not only enhance accuracy in volume calculations but also save costs. Recent automated BIM-QTO systems also show that model checking and quantity visualization can improve reliability and support rapid cost-control decisions [15].

CONCLUSION

In the research on the application of Building Information Modeling (BIM) concept to support the estimation of structural work costs, the following conclusions can be drawn. The use of Building Information Modeling (BIM) results in a smaller volume, as 3D modeling can provide detailed material quantity take-offs, thus reducing waste material and saving costs.

The use of the Building Information Modeling (BIM) 3D concept with Autodesk Revit software resulted in a cost difference of Rp 141,434,219.19 for structural work, meaning that calculations using the Building Information Modeling (BIM) concept with Autodesk Revit are 18.55% more cost-effective compared to conventional methods. The use of the Building Information Modeling (BIM) 3D concept with Autodesk Revit software resulted in a cost difference of Rp 1,744,777,946.81 for structural reinforcement work, meaning that calculations using the Building Information Modeling (BIM) concept with Autodesk Revit are 47.19% more cost-effective compared to conventional methods.

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