Time and Cost Efficiency Comparison of Conventional and Half-Slab Methods in High-Rise Building Construction

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Abstract

This study compares the time and direct-cost implications of conventional cast-in-place slabs and precast half-slabs for the Building Monument using quantity take-off, labor productivity, the Precedence Diagram Method, and 4D Building Information Modeling in Revit and Navisworks. The third-floor conventional slab requires 194.96 m² of formwork, 13,710.44 kg of reinforcement, and 58.49 m³ of concrete. The half-slab layout contains 88 P1 panels, 44 P1-1 panels, and 44 P1-2 panels, giving 176 installed pieces. For a standard 2.4 m × 1.2 m × 0.08 m P1 panel, 2.88 m² is the plan area and 0.2304 m³ is the concrete volume per panel. The audited third-floor direct cost is Rp156.11 million for the conventional method and Rp206.88 million for the half-slab method under the conservative assumption that the quoted Rp805,000 vendor rate applies to every installed panel. The half-slab alternative therefore has a Rp50.77 million (32.52%) direct-cost premium. Nevertheless, BIM 4D scheduling reduces the project duration from 447 to 337 days, equivalent to 110 days or 24.61%, by replacing repeated formwork activities and their removal lag with panel erection and overtopping work. The results demonstrate a time-cost trade-off and show that panel quantification, vendor quotation scope, and critical-path validation must be verified before selecting the slab method.

Keywords: 4D BIM; cost-time trade-off; half-slab; PDM; precast concrete

1. Introduction

In high-rise construction, the selected floor-slab system directly affects cycle time, labor demand, temporary works, material flow, and project cost. BIM-enabled automation for reinforced-concrete slab design has been shown to reduce design effort and human error [1], while automated BIM-based splitting of prefabricated composite slabs can improve panel manufacturability and installation planning [2]. BIM-based modular optimization further demonstrates that standardizing composite-slab units can reduce mold requirements, production complexity, and associated cost and carbon impacts [3].

Conventional cast-in-place slabs require a sequential cycle of formwork fabrication and installation, reinforcement, concrete placement, curing, and formwork dismantling. Model-based planning of concrete pours and construction joints can improve pour zoning, daily production planning, and the coordination of structural and operational constraints [4]. For reinforced-concrete construction, Revit, Microsoft Project, and Navisworks can also be integrated for schedule synchronization, clash detection, and constructability review [5]. In a related structural-system study, Hariyanto et al. [6] demonstrated that a calibrated ABAQUS model of a Vertical Shear Link reproduced the experimental peak-load response with close agreement, illustrating the importance of validating innovative solutions through measurable evidence. Complementary field-based assessment by Hariyanto et al. [14] combined accelerometer measurements with SAP2000 modelling to evaluate traffic-induced vibration in a five-story building. The selected shear-wall strengthening increased the natural frequency from 0.660 to 0.855 Hz, reinforcing the importance of validating model-based structural interventions against measured performance data.

At the project-planning level, 4D BIM links object-oriented three-dimensional models with activity schedules to make the construction sequence visually reviewable. Case-study evidence using Revit and Navisworks indicates that 4D simulation can improve communication and planning efficiency despite interoperability challenges [7]. A Navisworks Manage-based framework has also been used to identify design and planning problems that contribute to

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delay [8], while integrated 5D workflows can connect model objects with productivity, crew, duration, and cost data to improve estimate and schedule consistency [9].

For precast operations, BIM 4D can support element assembly sequencing and collision-free crane-lifting decisions [10]. Construction schedules may be linked to model objects through conventional manual procedures or more automated workflows [11]. Mixed construction processes containing both precast components and cast-in-place work require explicit representation of installation, reinforcement, overtopping, work packages, and shared resource constraints [12]. These characteristics closely represent half-slab construction, in which factory-produced panels function as the lower slab layer and permanent formwork before being completed by reinforcement and cast-in-place concrete topping.

From a structural perspective, the efficiency of a half-slab system depends on reliable composite action between the precast panel and the cast-in-place topping. Full-scale testing has shown that shear-connector configuration strongly influences interface slip, stiffness, cracking load, and ultimate capacity [13]. Experimental and numerical studies also emphasize the importance of interface surface treatment [20], shear and interface-shear transfer through lattice girders [15], and the configuration of truss-type shear connectors [16]. Consequently, a time-and-cost comparison should be accompanied by a clear distinction between the temporary pre-composite stage and the final composite structural stage.

Complementary international evidence shows that truss-reinforced half-slab systems can reduce on-site formwork, wet work, and labor requirements, although component design and prefabrication costs remain decisive [17]. Indonesian case studies likewise report project-dependent results: half-slab construction may achieve cost and time efficiencies [18], whereas another comparison found a shorter duration but a higher direct cost than the conventional method [19]. These divergent findings reinforce the need for a project-specific, quantity-audited time-cost comparison.

Against this background, this study compares conventional cast-in-place slabs and precast half-slabs for the Monument project using quantity take-off, observed and coefficient-based labor productivity, Precedence Diagram Method scheduling, direct-cost estimation, and 4D BIM in Revit and Navisworks. Both alternatives are normalized to the same floor scope, project calendar, and non-slab schedule logic. The study aims to quantify the resulting time-cost trade-off and to show how BIM-based quantity and sequence validation can support construction-method selection for geometrically complex high-rise structures.

2. Method

2.1. Data Collection

Primary data were obtained from field observations of the conventional slab work, including the work sequence, crew composition, equipment use, and observed production conditions. Secondary data comprised the Bill of Quantities/Cost Budget Plan (RAB), approved structural and shop drawings, bar-bending schedules, the baseline project schedule, Ponorogo HSPK unit-rate coefficients, material price surveys, and the half-slab vendor quotation. Quantities for both alternatives were normalized to the same floor and work scope before comparison. Schedule scenarios used the same project start date, eight-hour working day, working calendar, and non-slab activity logic so that the effect of the slab method could be isolated.

2.2. Volume Calculation

Quantities were determined directly from the approved structural drawings, bar-bending schedules, and coordinated half-slab panel layout. The conventional slab quantities included concrete, reinforcement, and formwork. Concrete volume was obtained from the slab plan area and thickness, while the formwork area covered the slab soffit and exposed edges. Reinforcement quantities were calculated based on the number, length, diameter, and unit weight of the reinforcing bars specified in the bar-bending schedule. For the half-slab alternative, the number of panels was counted according to panel type, and the concrete quantity was determined from the dimensions and thickness of each panel. A standard P1 panel measuring 2.4 m × 1.2 m × 0.08 m has a plan area of 2.88 m^2 and a concrete volume of 0.2304 m^3. The overtopping volume was determined using the effective slab area and topping thickness after deducting all openings. The third-floor layout comprises 88 P1 panels, 44 P1-1 panels, and 44 P1-2 panels, resulting in a total of 176 installed panels.

2.3. Time Analysis

Activity duration was calculated from D = Q/Pcrew, where Q is work quantity and Pcrew is daily crew output. The activity sequence was modeled using the Precedence Diagram Method with Finish-to-Start, Start-to-Start, and specified lag relationships. Both alternatives used the same eight-hour workday and project calendar. The Microsoft Project networks were linked to the Revit elements in Navisworks, following the established 4D BIM principle of connecting model objects with schedule activities [7], [11]. Activities with zero total float were identified as critical. Schedule validation compared the modeled baseline with the approved project schedule and changed only the slab-related activity durations and dependencies between the two scenarios, consistent with controlled BIM-based comparisons of mixed precast and cast-in-place processes [10], [12].

2.4. Productivity Analysis

Labor productivity was evaluated from observed output and HSPK labor coefficients. If an HSPK coefficient ki is expressed in person-days (OH) per unit of work, individual productivity is pi = 1/ki units/OH. Crew productivity was determined from the assigned number of workers and checked against the controlling trade so that the same output was not counted more than once. For field observations, productivity was calculated as P = Q/(N × T), where N is the number of workers and T is working time. OH is treated as one eight-hour person-day; therefore, values derived from HSPK are reported in units/OH rather than incorrectly interpreted as units/man-hour.

$$P = \frac{Q}{N\,x\,T}$$

In the productivity equation, P denotes completed quantity per labor input, Q is completed work volume, N is crew size, and T is the observed work duration. Activity duration is then obtained by dividing the work quantity by the verified crew output. Higher productivity indicates that a larger work quantity is completed using the same labour input, whereas additional labor or time without a corresponding increase in output lowers productivity.

2.5. Cost Estimation Analysis

Direct cost was calculated as $C_{total} = C_{material} + C_{labor} + C_{equipment} + C_{logistics}$. Material cost was the sum of quantity multiplied by unit price. Labor cost was calculated from crew size, work duration, and daily wage. Equipment cost was calculated from the number of units, operating duration, and daily rental rate. The reported Rp805,000 panel rate was applied to every installed panel and treated as a delivered-to-site vendor rate; crane operation and erection labour were calculated separately. Unit rates follow the approved RAB, Local HSPK, material surveys, and vendor quotation available for the project. Taxes, financing cost, and general project overhead were excluded from both alternatives to maintain a consistent direct-cost comparison.

2.6. Structural Modelling and Scheduling Using BIM 4D

Columns, beams, conventional slabs, and half-slab panels were modelled in Revit using the approved structural geometry. The Work Breakdown Structure and activity durations were prepared in Microsoft Project and linked to the corresponding model elements in Navisworks Manage. This software workflow is consistent with published applications that combine Revit, schedule data, and Navisworks for constructability review, clash detection, delay analysis, and integrated cost-time estimation [5], [7]-[9]. The 4D simulation was reviewed for sequence feasibility, overlap of work zones, crane access, and critical-path continuity, including the assembly and lifting considerations emphasized for precast construction [10]. Model quantities were cross-checked against the manual take-off, while the 447-day conventional baseline was compared with the 337-day half-slab scenario using the same calendar and unchanged non-slab activities.

3. Results and Discussion

3.1. Calculation of Structure Volume

In the initial stage of calculating the cost and time for floor slab analysis, a total volume calculation is carried out which includes calculating the volume of concrete, reinforcement, and formwork based on the reference shop drawing. The detailed conventional slab section drawing is shown in Figure 1

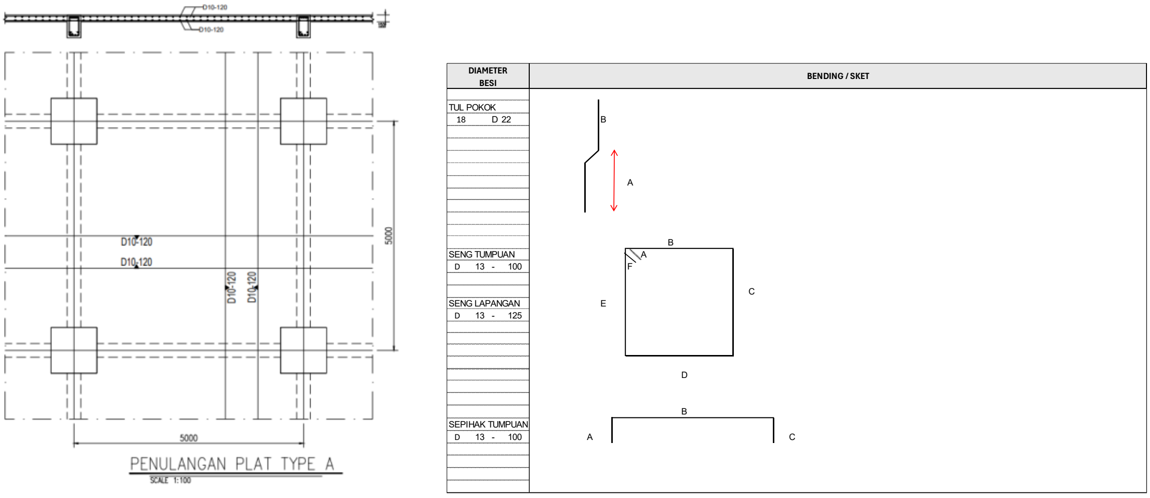
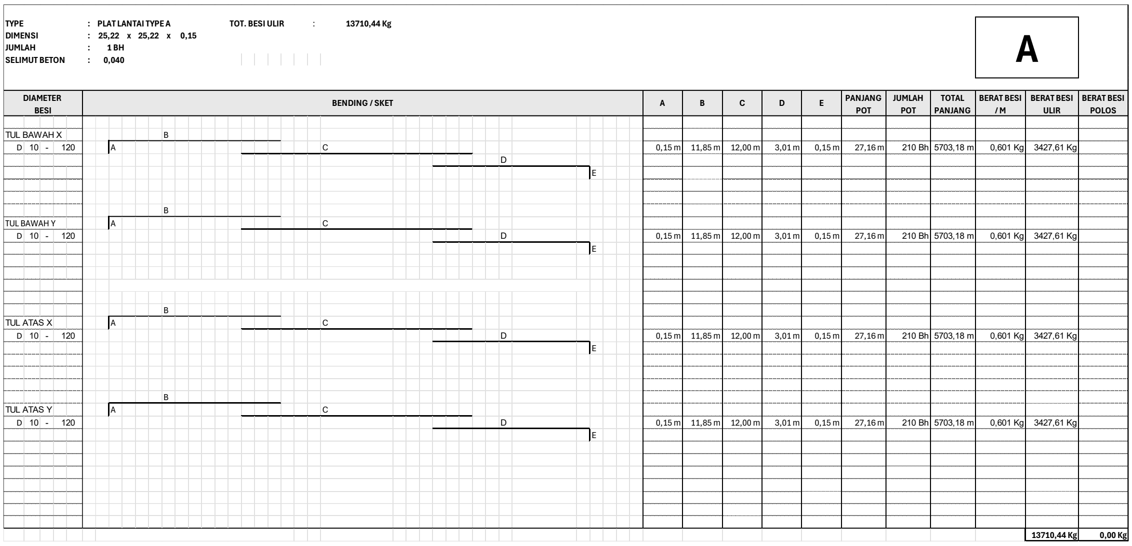


Figure 1. Structure Shop Drawing and Bar Bending Schedule



TYPE : PLAT LANTAI TYPE A   TOT. BESI ULIR : 13710,44 Kg
DIMENSI : 25,22 x 25,22 x 0,15
JUMLAH : 1 BH
SELIMUT BETON : 0,040

A

DIAMETER BESI	BENDING / SKET	A	B	C	D	E	PANJANG POT	JUMLAH POT	TOTAL PANJANG	BERAT BESI / M	BERAT BESI ULIR	BERAT BESI POLOS
TUL BAWAH X D 10 - 120	A B C D E	0,15 m	11,85 m	12,00 m	3,01 m	0,15 m	27,16 m	210 Bh	5703,18 m	0,601 Kg	3427,61 Kg	
TUL BAWAH Y D 10 - 120	A B C D E	0,15 m	11,85 m	12,00 m	3,01 m	0,15 m	27,16 m	210 Bh	5703,18 m	0,601 Kg	3427,61 Kg	
TUL ATAS X D 10 - 120	A B C D E	0,15 m	11,85 m	12,00 m	3,01 m	0,15 m	27,16 m	210 Bh	5703,18 m	0,601 Kg	3427,61 Kg	
TUL ATAS Y D 10 - 120	A B C D E	0,15 m	11,85 m	12,00 m	3,01 m	0,15 m	27,16 m	210 Bh	5703,18 m	0,601 Kg	3427,61 Kg	
											13710,44 Kg	0,00 Kg

Figure 2. Calculation of Bar Bending Schedule Slab

Figure 1displays the shop drawing of the structure and the bar bending schedule for the floor slabs in the Project. This figure provides a detailed representation of the structural elements, including the exact dimensions, location, and placement of reinforcement bars required for each floor's concrete work. The shop drawing serves as a crucial reference during the construction process, ensuring that the structural components are fabricated and assembled correctly. Figure 2 illustrates the calculations for the bar bending schedule, which is essential for determining the types, lengths, and quantities of reinforcement needed to maintain the structural integrity of the floor slabs. These calculations ensure that the reinforcement used meets the necessary strength and durability requirements specified by the design standards and regulations.

Table 1 presents a summary of the volume calculations for the floor slabs on various levels of the building, including the quantities of formwork, reinforcement steel, and concrete required. For example, the 3rd-floor slab requires 194.96 m² of formwork, 13,710.44 kg of reinforcement steel, and 58.49 m³ of concrete. This data is vital for accurate cost estimation, resource planning, and material logistics management, helping the construction team manage the project's material needs and ensure efficient use of resources throughout the construction process.

Table 1. Recapitulation of Slab Volume Calculation

Item	Formwork Area (m²)	Reinforcing Steel Quantity (kg)	Concrete Volume (m³)
Slab at 3rd Floor	194,96	13710,44	58.49
Slab at 4th Floor	230,24	5573,17	44,8
Slab at 6th Floor	230,24	5573,17	44,8
Slab at 7th Floor	230,24	5573,17	44,8
Slab at 8th Floor	230,24	5573,17	44,8
Slab at 13th Floor	234,79	11158,26	35,22
Slab at 14th Floor	420,10	22316,51	68,64

3.2. Calculation of Productivity and Duration

Table 2 provides a recap of the formwork productivity calculations for the floor slab construction in the Monument project. The table lists the various work items involved in the formwork process, such as the roles of the foreman, headworker, carpenter, and general workers, along with the respective productivity coefficients and the number of workers assigned to each task. The productivity values, calculated from the HSPK (Harga Satuan Pekerjaan Konstruksi) standards for Ponorogo, help assess the efficiency of labor utilization in the formwork process.

Table 3 summarizes the calculations for the reinforcement duration in the floor slab construction, detailing the time required for different zones on the 3rd floor. The table includes the duration of reinforcement work, broken down by zone and worker type, with total durations provided for each zone. These calculations are essential for scheduling the reinforcement installation process, and the time estimates are derived from the Ponorogo HSPK standards, which reflect the typical labor productivity in the area.

Table 2. Recapitulation of Slab Formwork Productivity Calculation

No	Item	Coefficient	Worker Productivity (m²/OH)	Number of Worker	Final Crew Productivity (m²/day)
1	Foreman	0,07	14,286	1	14.28
2	Headworker	0,07	14,286	1	14.28
3	Carpenter	0,70	1,429	8	11.42
4	Worker	0,70	1,429	8	11.42

Table 3. Recapitulation of Calculation of Reinforcing Duration

	3rd Floor	
Duration	Zone 1	Zone 2
Worker	2,64 days	2,64 days
Equipment	0,3 days	0,3 days
Total	2,94 days	2,94 days
ROUNDUP	3 days	3 days

Table 4 summarizes the crew coefficients used for reinforcement work, while Table 5 presents the formwork duration. HSPK coefficients are expressed in OH per unit of work, with one OH equal to an eight-hour person-day. The controlling crew output, rather than the sum of unrelated individual productivities, was used to calculate activity duration. For the third-floor concrete work, the total quantity is 58.49 m³, divided equally between two work zones. At a nominal mixer-truck capacity of 6 m³, ten truckloads are required. With a concrete-pump capacity of 48 m³/hour and a 0.83-hour preparation allowance, the audited pouring duration is 2.05 hours.

Table 4. Recapitulation of Slab Formwork Productivity Calculation

Item	Coefficient	Unit	Maximum Worker
Foreman	0,033	OH	1
Headworker	0,033	OH	1
Carpenter	0,33	OH	10
Worker	0,66	OH	20
	Total		32

Table 5. Recapitulation of Calculation of Formwork Duration

Work	Duration
Setting Up	1,15 days
Installing	0,69 days
Disassembling and Cleaning	0,46 days
Repairing	0,46 days
Total Duration	3 days

The calculation of concrete slab conventional is shown below

1. Preparation Duration:
   - Sampling slump from the TM = 5 minutes
   - TM replacement = 45 minutes
   - Total Preparation Duration = 5 minutes + 45 minutes = 50 minutes = 0.83 hours
2. Work Duration:
   - Concrete Pouring Volume:
     - Zone 1 = 29.245 m³
     - Zone 2 = 29.245 m³
     - Total Pouring Volume = 29.245 m³ + 29.245 m³ = 58.49 m³
   - TM Capacity = 6 m³
   - Number of mixer-truck loads = 58.49 m³ / 6 m³ = 9.75, rounded up to 10 loads
   - Bucket Capacity = 48 m³/hour
   - Concrete pump work duration = 58.49 m³ / 48 m³/hour = 1.22 hours
3. Total Work Duration:
   - Preparation Duration = 0.83 hours
   - Work duration = 1.22 hours
   - Total duration = 0.83 hours + 1.22 hours = 2.05 hours

Therefore, the total third-floor concrete-pouring duration, including the stated preparation allowance, is 2.05 hours.

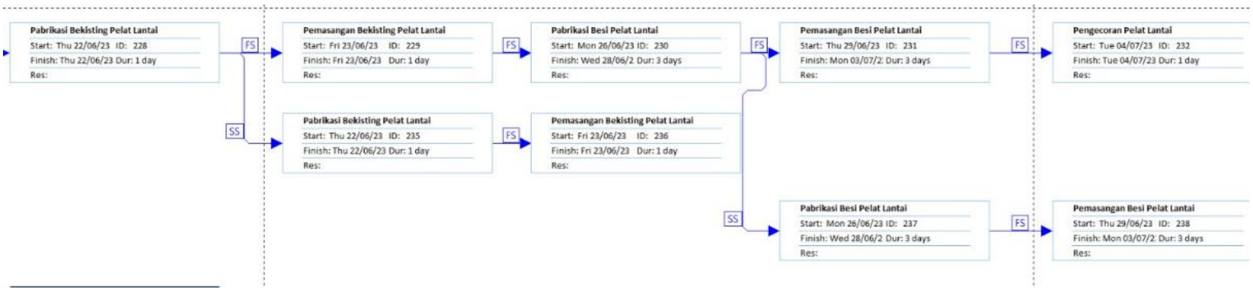


Figure 3. Network Planning Slab Construction

Figure 3 illustrates the network planning for the slab construction process, detailing the sequence of activities required for the execution of the floor slab using the conventional method. The figure presents the workflow of tasks, starting with formwork fabrication for Zone 1, which is initiated simultaneously with the formwork fabrication for Zone 2, establishing a "Start to Start" relationship. Following this, the installation of formwork for Zone 1 is scheduled to begin once the formwork for Zone 1 fabrication is completed, creating a "Finish to Start" relationship. Reinforcement fabrication for Zone 1 follows, with a "Finish to Start" dependency on the completion of formwork fabrication, and a "Start to Start" relationship with the reinforcement fabrication for Zone 2. The installation of reinforcement for Zone 1 is also dependent on the completion of the reinforcement fabrication, with a "Finish to Start" dependency. Concrete pouring for Zone 1 begins after the reinforcement installation is completed, maintaining a "Finish to Start" relationship with the reinforcement installation task. Finally, formwork dismantling for Zone 1 is scheduled to occur 7 days after the completion of the concrete pouring for Zone 1, creating a "Finish to Start" dependency with a 7-day lag. This network planning sequence is crucial for optimizing the flow of work, ensuring efficient coordination of tasks, and minimizing potential delays in the construction process.

Figure 3 shows network planning slab construction for conventional slabs, while the floor work begins with:

1. Formwork fabrication for zone 1 with predecessors *Start to Start* with formwork fabrication work for zone 2.
2. Formwork installation for zone 1 with predecessors *Finish to Start* with formwork fabrication work for zone 1.
3. Reinforcement fabrication for zone 1 with predecessors *Finish to Start* with formwork fabrication work for zone 1 and *Start to Start* with reinforcement fabrication work for zone 2.
4. Reinforcement installation for zone 1 with predecessors *Finish to Start* with reinforcement fabrication work for zone 1.
5. Concrete pouring for floor slab in zone 1 with predecessors *Finish to Start* with reinforcement installation.
6. Formwork dismantling for floor slab in zone 1 with predecessors *Finish to Start* plus 7 days (FS+7 days) with concrete pouring for floor slab in zone 1.

3.3. Calculation of Cost

Table 6 provides a detailed breakdown of the cost calculations for the slab construction process across various floors of the building. The table presents the costs associated with reinforcement, formwork, and concrete for each floor slab. For example, the cost for reinforcement on the 3rd floor slab is Rp101,271,919.78, formwork costs Rp13,143,652.00, and the concrete cost amounts to Rp41,697,000.00.

Table 6. Recapitulation of Slab Cost Calculation

No	Item	Reinforcement	Formwork	Concrete
1	Slab at 3rd Floor	Rp101.271.919,78	Rp13.143.652,00	Rp41.697.000,00
2	Slab at 4th Floor	Rp94.516.449,58	Rp11.648.085,90	Rp39.588.085,00
3	Slab at 6th Floor	Rp94.516.449,58	Rp11.648.085,90	Rp39.588.085,00
4	Slab at 7th Floor	Rp94.516.449,58	Rp11.648.085,90	Rp39.588.085,00
5	Slab at 8th Floor	Rp94.516.449,58	Rp11.648.085,90	Rp39.588.085,00
6	Slab at 13th Floor	Rp163.619.165,23	Rp11.396.048,52	Rp35.286.434,00
7	Slab at 14th Floor	Rp300.208.330,47	Rp30.333.145,57	Rp63.561.000,00

Similarly, the cost for other floors is provided, including the 4th, 6th, 7th, 8th, 13th, and 14th floors. Each cost category is broken down by the specific materials used, including reinforcement steel, formwork materials, and the quantity of concrete required for each floor. The total costs for each floor are derived from the volume of material used and the unit prices based on the project’s cost estimation guidelines.

3.4. Half-Slab Calculation

Figure 4 presents a detailed view of the PCI (Precast Concrete Industry) slab lift point, which is crucial for understanding the process of lifting and positioning the precast half-slabs during construction. The figure illustrates the required equipment and setup for lifting the precast panels into place, highlighting the various lift points along the structure. These lift points are strategically chosen to ensure that the slabs are positioned accurately and securely without compromising structural integrity during installation. The figure provides a visual representation of the process, assisting in the planning and coordination of crane movements and the necessary support for safe and efficient slab installation.

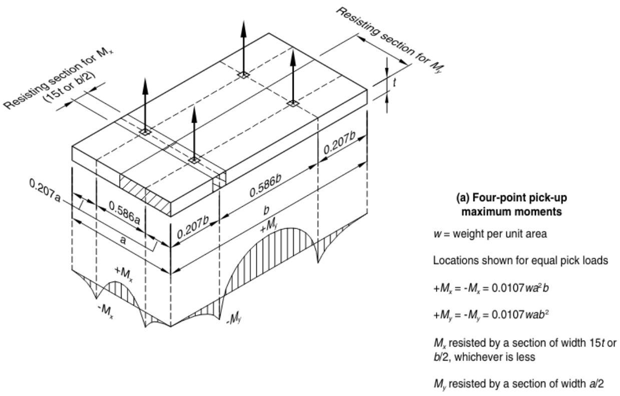


Figure 4. *PCI Slab Lift Point*

Table 7. Recapitulation of Half-Slab Flexural Capacity

PRECAST SLAB (AFTER COMPOSITE)									
No.	**Slab Type**	**Area**	**Thick mm**	**d mm**	**As used mm²**	**Ratio (ρ)**	**Rn N/mm²**	**Mn kN·m**	**φMn kN·m**
1	3rd Floor	Edge x	120	75	471,239	0,005	2,008	13,56	12,20
		Edge y	120	65	471,239	0,006	2,302	11,67	10,50
		Middle x	120	75	471,239	0,005	2,008	13,56	12,20
		Middle y	120	65	471,239	0,006	2,302	11,67	10,50
2	5 – 8th floor	Edge x	120	75	471,239	0,005	2,008	13,56	12,20
		Edge y	120	65	471,239	0,006	2,302	11,67	10,50
		Middle x	120	75	471,239	0,005	2,008	13,56	12,20
		Middle y	120	65	471,239	0,006	2,302	11,67	10,50
3	13th floor	Edge x	120	75	471,239	0,005	2,008	13,56	12,20
		Edge y	120	65	471,239	0,006	2,302	11,67	10,50
		Middle x	120	75	471,239	0,005	2,008	13,56	12,20
		Middle y	120	65	471,239	0,006	2,302	11,67	10,50
4	14th floor	Edge x	120	75	235,619	0.003	1.004	6,78	6,10
		Edge y	120	65	235,619	0.003	1.151	5,84	5,25
		Middle x	120	75	235,619	0.003	1.004	6,78	6,10
		Middle y	120	65	235,619	0.003	1.151	5,84	5,25
PRECAST SLAB (BEFORE COMPOSITE)									
No.	**Slab Type**	**Area**	**Thick mm**	**d mm**	**As used mm²**	**Ratio (ρ)**	**Rn N/mm²**	**Mn kN·m**	**φMn kN·m**
1	3rd Floor	Edge x	80	35	471,239	0,011	4,093	6,02	5,42
		Edge y	80	25	471,239	0,016	5,509	4,13	3,72
		Middle x	80	35	471,239	0,011	4,093	6,02	5,42
		Middle y	80	25	471,239	0,016	5,509	4,13	3,72
2	5 – 8th floor	Edge x	80	35	471,239	0,011	4,093	6,02	5,42
		Edge y	80	25	471,239	0,016	5,509	4,13	3,72
		Middle x	80	35	471,239	0,011	4,093	6,02	5,42
		Middle y	80	25	471,239	0,016	5,509	4,13	3,72
3	13th floor	Edge x	80	35	471,239	0,011	4,093	6,02	5,42
		Edge y	80	25	471,239	0,016	5,509	4,13	3,72
		Middle x	80	35	471,239	0,011	4,093	6,02	5,42
		Middle y	80	25	471,239	0,016	5,509	4,13	3,72
4	14th floor	Edge x	80	35	235,619	0.006	2.047	3.01	2.71
		Edge y	80	25	235,619	0.008	2.755	2.07	1.86

	Middle x	80	35	235,619	0.006	2.047	3.01	2.71
	Middle y	80	25	235,619	0.008	2.755	2.07	1.86

Table 7 distinguishes the sectional capacities before and after composite action. For the third floor after composite action, Rn is 2.008 N/mm² in the x direction and 2.302 N/mm² in the y direction; the corresponding Mn values are 13.56 and 11.67 kN·m, and phiMn values are 12.20 and 10.50 kN·m. Before composite action, Rn is 4.093 and 5.509 N/mm², Mn is 6.02 and 4.13 kN·m, and phiMn is 5.42 and 3.72 kN·m. Therefore, the value 2.008 is correctly interpreted as Rn, not Mn. The table reports sectional capacity only and does not include factored moment demand, Mu; consequently, no demand-capacity conclusion is inferred from this table alone. The increase in nominal and design moment capacity after composite action is consistent with research showing that interface condition, lattice girders, and shear-connector geometry govern the transfer of force between the precast layer and the overtopping concrete [13]-[16].

3.5. Half-Slab Volume

Figure 5 illustrates the floor plan for the precast half-slabs, showcasing the installation process for the Monument project. The slabs are installed in a one-way system, meaning that the load is carried in one direction, typically supported by beams placed in parallel alignment with the slab. This system is commonly used for efficient load distribution, where the slabs span between beams to support the structure's weight. However, due to the layout and structural demands of the building, additional secondary beams are required to provide extra support and prevent excessive deflection. These additional beams are strategically placed between the primary beams to ensure the stability and integrity of the slab system. The figure highlights the placement of these secondary beams, which are essential for distributing the load more evenly and ensuring that the precast slabs perform optimally under the applied loads.

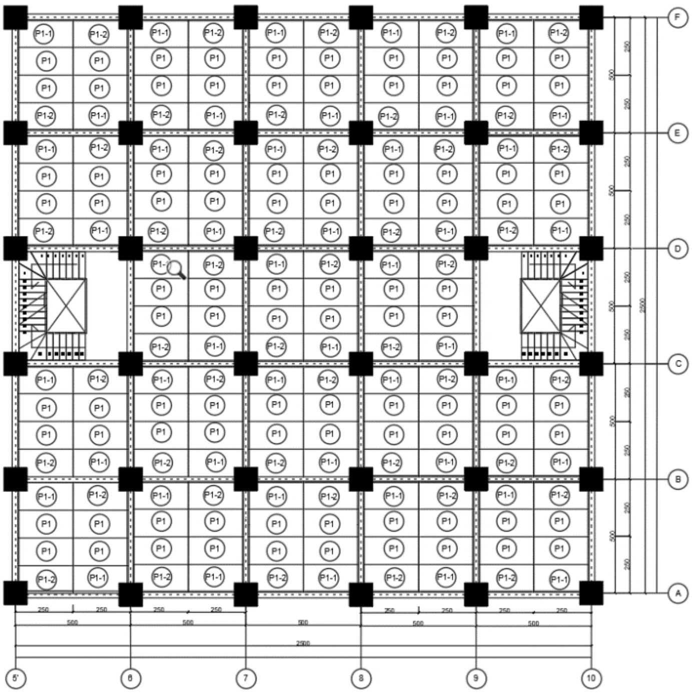


Figure 5. Precast Half-Slab Floor Plan

Table 8 separates panel plan area from concrete volume to avoid the unit error identified during review. The third-floor layout comprises 88 P1, 44 P1-1, and 44 P1-2 panels, for a total of 176 installed pieces. The standard P1 panel has a plan area of 2.88 m² and a concrete volume of 0.2304 m³ at an 80 mm thickness. Edge-panel variants use their adjusted plan areas. The resulting total third-floor panel area is 496.32 m² and the corresponding precast concrete volume is approximately 39.71 m³. These quantities are used consistently for material planning, logistics, and the audited cost comparison.

Table 8. Recapitulation of Half-Slab Panel Quantities and Concrete Volume

Floor	Type	Lx	Ly	Thickness	**Panel Area**	Pcs/Floor	**Total Panel Area**	Reinforcement	**Precast Concrete Volume**
		m	m	mm	**m²/panel**		**m²**	Kg	**m³**
3rd	P1	2.4	1.2	80	2.88	88	253.44		
	P1-1	2.4	1.2	80	2.76	44	121.44		
	P1-2	2.4	1.2	80	2.76	44	121.44		
			Total			176	496.32	14,826.39	39.71
5th	P2	2.4	1.2	80	2.88	88	253.44		
	P2-1	2.4	1.2	80	2.83	44	124.52		
	P2-2	2.4	1.2	80	2.83	44	124.52		
			Total			176	502.48	14,826.39	40.20
6th	P2	2.4	1.2	80	2.88	88	253.44		
	P2-1	2.4	1.2	80	2.83	44	124.52		
	P2-2	2.4	1.2	80	2.83	44	124.52		
			Total			176	502.48	14,826.39	40.20
7th	P2	2.4	1.2	80	2.88	88	253.44		
	P2-1	2.4	1.2	80	2.83	44	124.52		
	P2-2	2.4	1.2	80	2.83	44	124.52		
			Total			176	502.48	14,826.39	40.20
8th	P2	2.4	1.2	80	2.88	80	230.40		
	P2-1	2.4	1.2	80	2.83	40	113.20		
	P2-2	2.4	1.2	80	2.83	40	113.20		
			Total			160	456.80	14,826.39	36.54

3.6. Half-Slab Productivity

Figure 6 illustrates the network planning for the installation of the precast half-slabs, detailing the sequence of tasks involved in the construction process. The figure highlights the step-by-step workflow, beginning with the completion of beam casting, which serves as the prerequisite for installing the precast slabs. The installation process follows a Finish to Start relationship with the beam casting, ensuring that the beams are fully set before the slabs are placed. The fabrication of the overtopping reinforcement is carried out simultaneously with the beam reinforcement, represented by a Start to Start relationship, which streamlines the workflow by overlapping these tasks. Once the precast slabs and their reinforcement are positioned, the overtopping reinforcement installation begins, marked by a Finish to Start dependency. The final stage involves casting the overtopping slab after the reinforcement installation is completed, with a clear Finish to Start relationship.

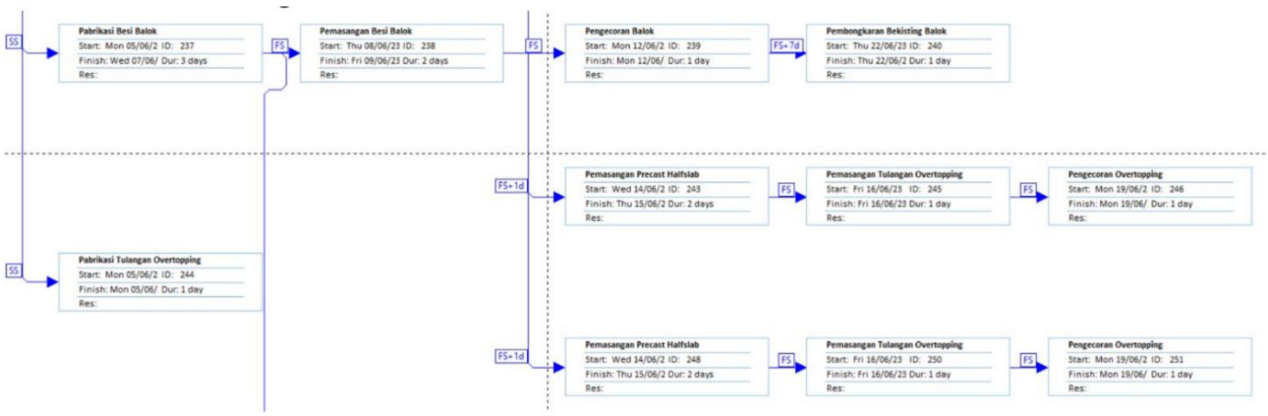


Figure 6. Network Planning Half-Slab Construction

a. The installation of the precast half-slab begins after the beam casting has been completed, with a Finish to Start predecessor relationship to the beam casting work.
b. The fabrication of overtopping reinforcement is carried out simultaneously with the fabrication of beam reinforcement, with a Start-to-Start predecessor relationship to the beam reinforcement fabrication work
c. The installation of overtopping reinforcement is carried out after the precast slab and its reinforcement have been installed, with a Finish to Start predecessor relationship to the overtopping fabrication work
d. The casting of the overtopping slab is carried out after the installation of the overtopping reinforcement is completed, with a Finish to Start predecessor relationship to the overtopping reinforcement installation work

3.7. Half-Slab Cost

3.7.1. Half-Slab Precast Erection Cost

Table 9 presents the audited third-floor precast erection cost. The layout contains 176 installed panels. Because variant-specific vendor prices were not available in the project documents, the reported vendor rate of Rp805,000 per panel was applied uniformly to P1, P1-1, and P1-2 as a conservative and reproducible assumption. Panel procurement therefore amounts to Rp141,680,000. Crane-operation and erection labor for two days total Rp1,875,000, resulting in an audited precast procurement and erection cost of Rp143,555,000.

Table 9. Audited Cost of Half-Slab Erection

Component	Item	Days	Unit Price	Cost (Rp)
Crane operator wages	1	2	Rp232,500.00	Rp465,000
Crane operator assistant	1	2	Rp80,000.00	Rp160,000
Worker	1	2	Rp80,000.00	Rp160,000
Bricklayer	1	2	Rp100,000.00	Rp200,000
Erection worker	2	2	Rp100,000.00	Rp400,000
Head mason	1	2	Rp115,000.00	Rp230,000
Foreman	1	2	Rp130,000.00	Rp260,000
Total worker wages				Rp1,875,000
	Item		**Unit Price**	**Days (Rp)**
Slab Material	176		Rp805,000.00	Rp141,680,000
Total Price for Half-Slab Erection				Rp143,555,000

3.7.2. Overtopping Slab Reinforcement Cost

Table 10 audits the overtopping reinforcement cost. Reinforcing steel is calculated as 1,985.55 kg × Rp12,000/kg = Rp23,826,600, while 29.78 m of reinforced-concrete wire rope at Rp19,000/m equals Rp565,820. Material, equipment, and labor costs are Rp24,392,420, Rp24,000,000, and Rp1,145,000, respectively. The corrected total overtopping reinforcement cost is therefore Rp49,537,420.

Table 10. Audited Overtopping Reinforcement Cost

Component	Item		Unit Price	Cost (Rp)
Reinforcing steel	1985.55		Rp12,000	Rp23,826,600
Reinforced concrete wire rope	29.78		Rp19,000	Rp565,820
Total materials				Rp24,392,420
Reinforcing steel cutter	3	1	Rp4,000,000	Rp12,000,000
Reinforcing steel bender	3	1	Rp4,000,000	Rp12,000,000
Total equipment				Rp24,000,000
Foreman	1	1	Rp130,000	Rp130,000
Head mason	1	1	Rp115,000	Rp115,000
Bricklayer	5	1	Rp100,000	Rp500,000
Workers	5	1	Rp80,000	Rp400,000
Total wages				Rp1,145,000

Total reinforcement	Rp49,537,420

3.7.3. Overtopping Casting Cost

Table 11 presents the audited overtopping casting cost. The ready-mix cost is 12.76 m³ × Rp900,000/m³ = Rp11,484,000. Equipment comprises three vibrators and one cast bucket at a total of Rp1,020,000, while labor totals Rp1,285,000. The corrected casting cost is Rp13,789,000. Combined with the audited reinforcement cost of Rp49,537,420, the total overtopping cost is Rp63,326,420.

Table 11. Audited Overtopping Casting Cost

Component	Unit		Unit Price	Cost (Rp)
Ready-mix concrete	12.76		Rp900,000	Rp11,484,000
Total materials				Rp11,484,000
Vibrator	3	1	Rp295,000	Rp885,000.00
Cast bucket	1	1	Rp135,000	Rp135,000.00
Total equipment				Rp1,020,000.00
Foreman	1	1	Rp130,000	Rp130,000.00
Head mason	1	1	Rp115,000	Rp115,000.00
Bricklayer	4	1	Rp100,000	Rp400,000.00
Workers	8	1	Rp80,000	Rp640,000.00
Total wages		1		Rp1,285,000.00
Total casting				Rp13,789,000
Total overtopping (reinforcement + casting)				Rp63,326,420

Table 12. Audited Third-Floor Direct Cost Comparison

Cost Component	**Conventional (Rp)**	**Half-Slab (Rp)**	**Difference, Half-Slab - Conventional (Rp)**
Reinforcement	101,271,920	49,537,420	-51,734,500
Formwork/precast procurement and erection	13,143,652	143,555,000	+130,411,348
Concrete/overtopping casting	41,697,000	13,789,000	-27,908,000
Total direct cost	156,112,572	206,881,420	+50,768,848 (+32.52%)

The audited comparison uses the same third-floor scope and direct-cost basis for both alternatives. The half-slab cost is Rp50.77 million (32.52%) higher under the conservative assumption that the quoted vendor rate of Rp805,000 applies uniformly to all 176 installed panels. Precast procurement and erection is the dominant cost driver and offsets the savings from reduced conventional reinforcement, formwork, and in-situ concrete work. This result reinforces findings that the economic performance of composite slabs is sensitive to panel modularization, mold repetition, logistics, and the synchronization of model quantities with cost and schedule data [2], [3], [9], [12]. Taxes, financing costs, and general project overhead are excluded from both alternatives. This project-dependent outcome is consistent with international and Indonesian evidence showing that half-slab economics depend on component design, production strategy, logistics, and project conditions, and that schedule savings may coexist with a direct-cost premium [17], [18], [19].

3.8. BIM 4D Integration and Schedule Validation

This section evaluates the integration of the Revit model, Microsoft Project schedule, and Navisworks 4D simulation. Figure 7 presents the structural model, while Figure 8 shows the time-linked model elements. The manual quantity take-off was checked against the BIM quantities before schedule simulation. Both slab alternatives used the same project calendar, start date, and non-slab activity logic. This controlled comparison allowed differences in project duration to be attributed to the slab-related activity sequence rather than unrelated schedule changes. The workflow follows published 4D BIM applications in which model objects are linked with schedule tasks to support sequence visualization, constructability checking, and planning decisions [7]-[11].

The Navisworks simulation was reviewed for model-schedule linkage, zone sequence, crane access, and activity overlap. Critical activities were identified from zero total float in the PDM network. In the conventional scenario, repeated formwork fabrication and installation, reinforcement, casting, and the formwork-removal lag formed a continuous critical sequence. In the half-slab scenario, precast erection and overtopping activities replaced most of this sequence and allowed panel-related preparation to overlap with beam work. This representation is consistent with BIM-based scheduling frameworks for mixed precast and cast-in-place construction and with BIM-supported planning of precast assembly and crane lifting [10], [12].

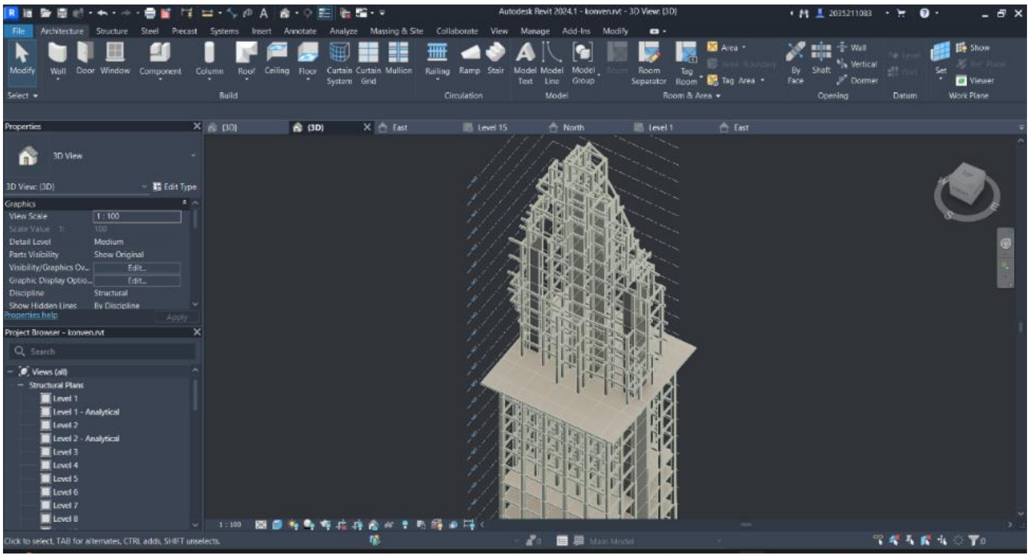


Figure 7. Revit Structure Modelling

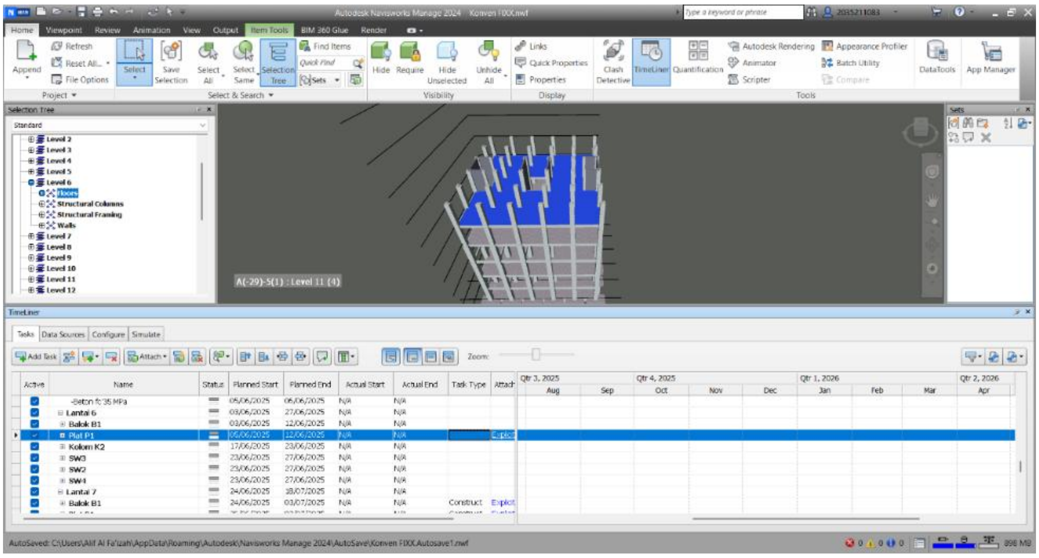


Figure 8. Navisworks Element Modelling of Structure

Figure 9 shows the coordinated half-slab quantities and time-linked Navisworks model. The BIM take-off was checked against the manual panel schedule before procurement quantities were used in the cost analysis. This verification supports material planning and site logistics while avoiding an unsupported interpretation of the 2.88 m² panel area as concrete volume.

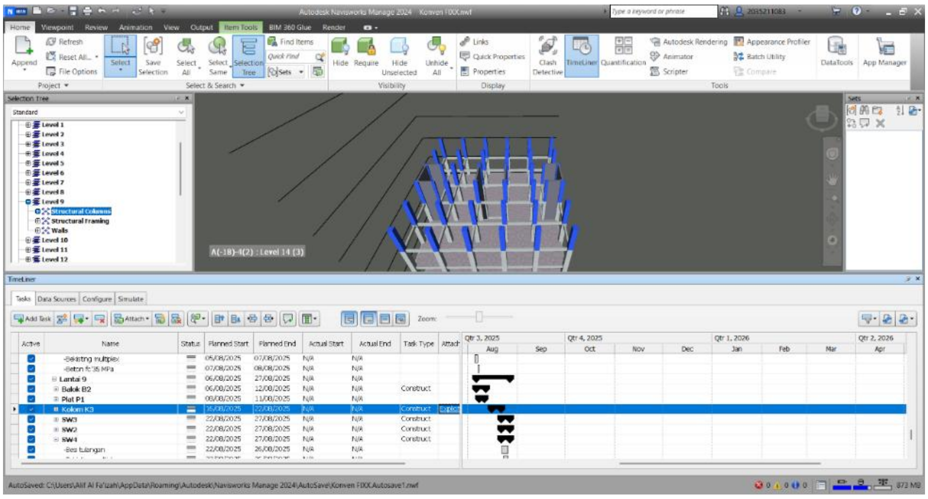


Figure 9. Half-Slab Quantity and Schedule Integration in Navisworks

The validated comparison produces a 447-day conventional baseline and a 337-day half-slab scenario. With all non-slab activities and calendars held constant, the 110-day difference corresponds to a 24.61% reduction in project duration. The reduction is associated with removal of repeated soffit-formwork activities and their dismantling lag from the critical chain, followed by shorter panel erection and overtopping sequences. The result is consistent with the broader 4D BIM literature, which reports that time-linked visualization can expose sequence conflicts, improve activity coordination, and support more reliable precast assembly planning [7], [8], [10]-[12]. However, the present result demonstrates a schedule advantage only and does not, by itself, establish a direct-cost saving.

Table 13. BIM 4D Schedule Validation Summary

Validation Item	Conventional Slab	Half-Slab	Comparison Criterion
Working calendar	8 hours/day	8 hours/day	Identical calendar
Project duration	447 days	337 days	110-day reduction
Time efficiency	Baseline	24.61% shorter	(447-337)/447 × 100%
Critical-path basis	Formwork, reinforcement, casting, and formwork-removal lag	Panel erection, overtopping reinforcement, and overtopping casting	Zero-total-float activities; non-slab logic unchanged

4. Conclusions

This study compared conventional cast-in-place and precast half-slab methods for the Monument using quantity take-off, productivity analysis, PDM scheduling, direct-cost estimation, and BIM 4D simulation. Under identical calendar and non-slab schedule assumptions, the half-slab scenario reduces the modeled project duration from 447 to 337 days, equivalent to 110 days or 24.61%. The schedule benefit arises from replacing repeated formwork and formwork-removal lag with panel erection and overtopping activities.

The audited third-floor cost comparison does not show a direct-cost saving for the half-slab alternative. Conventional work totals Rp156.11 million, whereas the half-slab alternative totals Rp206.88 million when the Rp805,000 vendor rate is applied uniformly to all 176 installed panels. The resulting Rp50.77 million difference represents a 32.52% cost premium. Precast procurement and erection is the dominant cost component, while savings in conventional reinforcement, formwork, and in-situ concrete are insufficient to offset the panel cost under the available quotation.

The half-slab method therefore presents a time-cost trade-off rather than an unconditional efficiency gain. Its selection is justified when schedule acceleration, reduced site congestion, or earlier project completion has sufficient economic value to offset the higher direct cost. The conclusion is sensitive to panel price, transport scope, crane duration, and repetition across floors; future work should evaluate variant-specific panel quotations and indirect time-related costs. BIM 4D remains useful for verifying quantities, construction sequence, and critical-path effects before a final construction-method decision is made.

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