CHAPTER 36

Comparative Study of Conventional and Alu-Form (Mivan) Formwork in High-Rise Buildings

Arya Kiran Sankhe[1] and Snehjit Kumbhar[2]

ABSTRACT

Time is an essence for any construction project, especially for high-rise building where identical items of work are to be executed in sequence. In the present study it is proposed to compare efficiency, cost-effectiveness, time management, and quality of construction achieved through conventional formwork and Alu-form (Mivan) formwork in high-rise buildings. Data collected for sixty storied building such as construction speed, material wastage, labor requirements, and structural quality were analyzed using quantitative tools. Through on-site observations, interviews with construction professionals, and a detailed cost-time analysis of projects using both conventional and Alu-form formwork is carried out. A mixed-method approach was employed for this study. The results highlight that Alu-form (Mivan) formwork significantly reduces construction time and labor dependency, thereby increasing productivity. Conventional formwork, while cost-effective for small-scale projects, is less efficient in high-rise construction due to higher labor demands and slower cycle times. Although initial investment costs for Aluform are higher than conventional formwork, the long-term benefits in terms of durability and reusability offset these costs.

Keywords: Aluform formwork; Mivan technology; Conventional formwork; High-rise buildings; Construction efficiency.

1.0 Introduction

The increasing demand for high-rise buildings has made advancements in construction technology, particularly in formwork systems, which significantly impact construction speed, cost, and quality. Conventional formwork, made from timber, plywood, and steel, remains widely used due to its adaptability and cost-effectiveness for smaller projects. However, its high labor dependency, slower cycle times, and material wastage raise concerns regarding efficiency in large-scale developments. In contrast, Alu-Form formwork, an aluminum-based modular system, has gained traction for its superior reusability, faster construction cycles, and improved concrete finishes. Despite these advantages, the system's high initial costs and limited design flexibility pose challenges to its widespread adoption.

[1]*Department of Civil Engineering, Sardar Patel College of Engineering, Mumbai, Maharashtra, India*
[2]*Corresponding author; Department of Civil Engineering, Sardar Patel College of Engineering, Mumbai, Maharashtra, India (E-mail: snehjit_kumbhar@spce.ac.in)*

DOI: 10.17492/JPI/NICMAR/2507036 *ISBN: 978-93-49790-54-4*

Construction methods are commonly classified based on the formwork system used. In high-rise building construction, Conventional Formwork Systems and Aluminium Formwork Systems (Mivan) are the most preferred. In conventional formwork, loads are transferred through beams and columns, with options for post tensioned slabs. The formwork consists of props and spans, providing up to 20 repetitions, while timber alternatives offer only five repetitions, strengthening the RCC structure in approximately 20 days. This method lacks modularity, making it more suitable for basic structural layouts. In contrast, aluminium formwork systems rely on load-bearing concrete walls, allowing for modular construction. This method is particularly advantageous for projects with repetitive slab structures and is economical when around 100 repetitions are achieved, strengthening RCC structures in just 10 days. Though considered a semi-modular system, as it does not offer complete modularity, it enhances construction efficiency and reduces overall project timelines.

1.1 Cost considerations in formwork system

Cost is another critical factor when selecting a formwork system, as it directly influences the overall budget and financial feasibility of a construction project. The cost of formwork includes material procurement, labor wages, installation, maintenance, and reuse potential. Conventional formwork is initially more affordable but has higher long-term costs due to lower reusability and increased labor demand. Mivan formwork, despite its higher initial investment, becomes cost-effective in large-scale repetitive projects due to its ability to be reused up to 250-300 times, compared to 15-25 repetitions for conventional timber formwork.

1.2 Labor productivity in constructions

Labor productivity is a key factor influencing the success of construction projects, particularly in high-rise buildings where efficient workforce management directly impacts project timelines and costs. Productivity in construction is typically measured as the amount of work completed per worker per day, often expressed in square meters of shuttering or concreting per man-day. The efficiency of labor depends on various factors, including the complexity of the formwork system, availability of skilled workers, site conditions, and construction methodology. Conventional formwork, which relies heavily on skilled carpenters and manual adjustments, generally has lower productivity due to frequent reassembly and material wastage. In contrast, Mivan (Alu-Form) formwork, a prefabricated aluminum system, is designed for speed and efficiency, allowing for higher productivity with reduced labor dependency. This study focuses on determining labor productivity for both systems by analyzing the shuttering area covered per worker per day.

2.0 Literature Review

The adoption of aluminum formwork has proven to be a cost-effective and time-saving solution in construction projects. Studies have shown that Mivan technology reduces

DOI: 10.17492/JPI/NICMAR/2507036 *ISBN: 978-93-49790-54-4*

construction costs by 18-25% and shortens project duration by 20-30%, despite its 30-40% higher initial investment (Gari & Thomas, 2024). Research on MHADA projects found that Mivan technology lowers labor requirements by 30-35%, reducing costs and minimizing delays (Gopal, 2024). Its implementation in Pradhan Mantri Awas Yojna housing projects in Rudrapur, Uttarakhand, demonstrated improved construction speed and earthquake-resistant housing (Times of India - Realty NXT, 2023). A case study on the Godrej Garden Enclave project revealed that Mivan formwork saved ₹73,27,335 and reduced construction time by six months (Patil *et al.*, 2022). Studies on high-rise projects in Hong Kong indicated that aluminum formwork can reduce construction time by 30% and labor costs by 20-25% (Raymond, 2022). Similarly, research on labor productivity found that aluminum formwork achieved a maximum productivity of 10.36 sqm/man-days, though actual productivity varied depending on project conditions (Singh & Nagarajan, 2022).

However, transitioning from conventional to Mivan technology presents challenges such as higher initial investment and the need for specialized labor training (Karke & Kumathekar, 2021). Comparisons between traditional and modern formwork systems have shown that while aluminum formwork is highly efficient for large-scale projects, conventional timber and steel systems provide greater flexibility for customized designs (Karule & Kumar, 2021). The Industrialized Building System (IBS) approach in Malaysia has also demonstrated economic benefits for repetitive large-scale construction, although material limitations and skill shortages remain key barriers (Baharuddin *et al.*, 2021). Sustainable formwork systems like aluminum significantly reduce material waste and improve cost efficiency, particularly in high-density urban environments (Poon & Robin, 2018). Research on Mivan technology's impact on project timelines showed that it significantly reduces duration in high-rise projects with repetitive layouts, mainly due to reduced labor needs and reusable formwork components (Gulghane *et al.*, 2018). Fast-track construction techniques such as Mivan and Tunnel Form have been identified as essential for urban housing projects, enabling rapid construction while maintaining structural quality (Sorate & Dhiman, 2017).

Economic feasibility studies found that aluminum formwork reduces construction costs by minimizing the need for skilled labor and heavy equipment, while also ensuring high-quality finishes that eliminate the need for additional plastering (Selvan, 2016). In terms of efficiency, aluminum formwork reduces the standard floor-to-floor cycle to seven days, compared to 20 days in conventional formwork (Mathane, 2015). Research on formwork reuse highlights that aluminum formwork can be reused 250-300 times, whereas traditional timber and plywood systems degrade after only 15-25 uses, significantly lowering material costs and accelerating project completion (Gambatese & Barbosa, 2014). A study using the Line of Balance technique demonstrated that aluminum formwork effectively reduces both time and cost in multi-story buildings (Vijay *et al.*, 2019). In mass housing projects under Pradhan Mantri Awas Yojna, aluminum formwork reduced construction costs by 18.4% and saved approximately 38 days in project duration (Aditya *et al.*, 2018). Furthermore, comparative evaluations of different

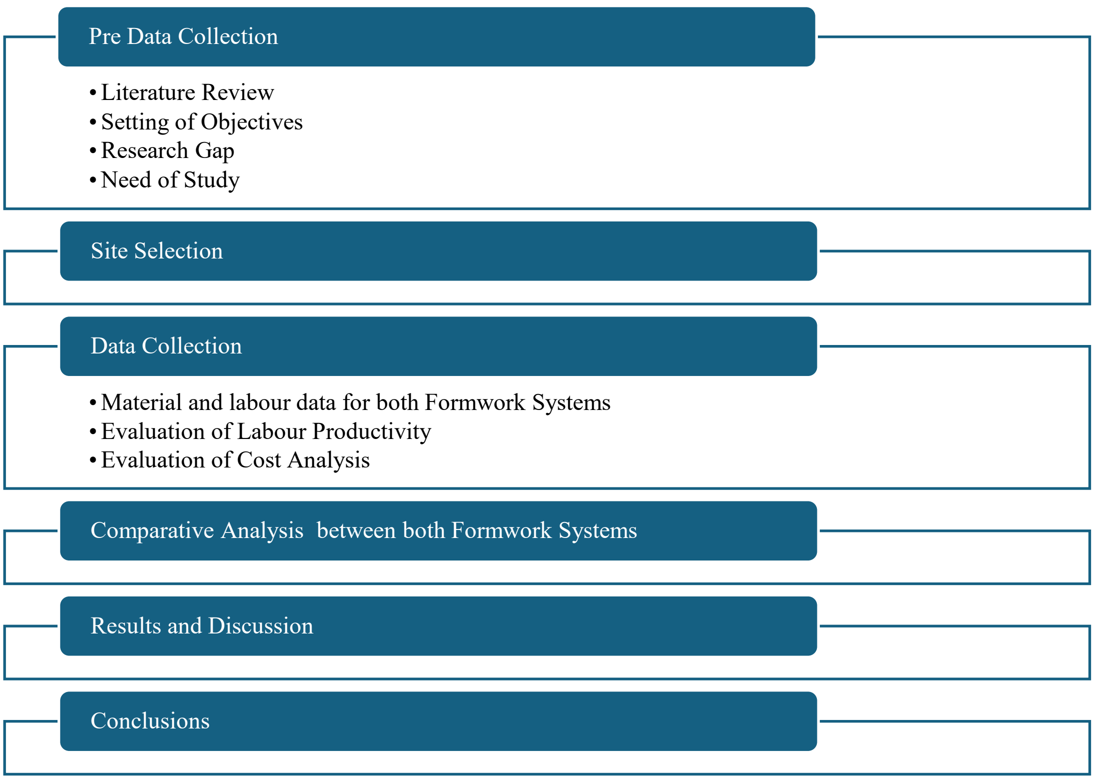
DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

formwork systems concluded that while aluminum formwork is optimal for efficiency, tunnel formwork remains the most cost-effective option, particularly for projects with a high number of repetitions (Renuka *et al.*, 2017).

3.0 Methodology

This research methodology outlines the systematic approach used to analyze and compare labor productivity and cost implications of Mivan and conventional formwork in high-rise construction. This study employs a quantitative research approach, collecting and analyzing real-time construction data from a specific high-rise project. The methodology focuses on site observations, data collection, productivity calculations, and cost analysis to derive meaningful insights (see. Figure 1).

Figure 1 : Methodology Flowchart



4.0 Site Selection

The study is conducted on Oberoi Realty's Sky City project in Borivali East, Mumbai, which consists of two identical G+65 residential towers—one constructed using aluminium

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

formwork and the other using conventional formwork. Located at 19.228825° N latitude and 72.854118° E longitude, the project spans 25 acres and features six high-rise towers offering premium 3 BHK and 4 BHK residences. The present study focuses on Towers G and H, which share the same design specifications from the 10th to the 23rd floor. Sky City is well-connected to the metro station, enhancing accessibility for residents. The structure is founded on soil with a safe bearing capacity (SBC) of 150 T/Sq.M and incorporates advanced Alu-form technology. Additionally, the project is IGBC Gold certified, ensuring eco-friendly construction, elegant architecture, and sustainable design.

5.0 Data Collection and Analysis

Cost analysis for both Aluminium (Mivan) formwork and Conventional formwork is carried out considering various parameters, including material costs, labor costs, and cycle times. The major cost components include material costs, labor costs, shuttering cycle time, cost per square meter, and shuttering usage ratio. Material costs differ significantly between the two formwork systems. Aluminium formwork requires a high initial investment but offers greater reusability (up to 200 repetitions), reducing long-term costs. It also ensures a better concrete finish, reducing plastering expenses. In contrast, conventional formwork has a lower initial cost but a shorter lifespan (10-20 repetitions), leading to higher cumulative costs over multiple floors. Additionally, it requires more timber or plywood, contributing to material waste.

Labor costs depend on the complexity and time required for assembling and dismantling each formwork system. IS 7272-1:1974 provides labor output recommendations that help estimate workforce requirements for shuttering work. Aluminium formwork enables a 4 to 7-day cycle per floor, significantly improving construction speed, whereas conventional formwork requires 10 to 14 days per floor, resulting in project delays. The cost per square meter of shuttering is derived based on material usage, labor hours, and the reusability factor. Aluminium formwork has higher efficiency, and a lower lifecycle cost compared to conventional formwork. The shuttering usage ratio, which measures the efficiency of formwork material utilization, is calculated as:

$$\text{Shuttering Usage Ratio} = \frac{\text{Quantity of shuttering done in a month}}{\text{Total shuttering available for the month}}$$

Aluminium formwork typically has a lower usage ratio due to higher reusability and faster cycle times, whereas conventional formwork has a higher usage ratio due to frequent replacements and greater material wastage. Labor productivity is assessed based on IS 7272 (Part 1 & 2) standards, which provide guidelines on labor output in building works. It is calculated using the formula:

$$\text{Productivity} = \frac{\text{Quantity of work done}}{\text{Number of Manday's}}$$

Aluminium formwork achieves higher productivity, requiring 0.2 to 0.25 man-hours per square meter due to its prefabricated modular components. In contrast, conventional formwork

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

requires 0.35 to 0.5 man-hours per square meter, reflecting a higher labor demand due to manual cutting, fixing, and dismantling processes. The quantity of work completed in a month is determined through quantity estimation. The number of laborers working each month and their average working hours are obtained from labor reports. These reports are updated daily, and a consolidated monthly labor report is prepared. Constraints affecting overall productivity are also documented. Productivity is measured in square meters per man-day. Productivity for Mivan and conventional formwork is calculated separately and tracked against target productivity set by company norms. For the Oberoi Realty project, the target productivity for conventional formwork is 2.5 sqm/man-day, while for Mivan formwork, it is 10 sqm/man-day.

5.1 Evaluation of labour productivity in conventional formwork

For the comparison of conventional formwork and Mivan formwork, we analyzed the construction plan from level 10 to level 23 for both systems. The study considered various parameters, including cost, activity duration, material types, and rates, along with different design aspects from the selected case studies.

Table 1: Productivity Calculation of Conventional Formwork

Sr. No.	Months	Qty of work done (sqm) per month A	Working hours per day B	No. of labours per month C	No of man-days per Month (1 manday's = 8hours) D	Productivity (P=A*D)
1	Aug-24	221	10	118	257.25	0.92
2	Sep-24	113	10	542	845.75	1.31
3	Ocr-24	2245	10	856	1185	1.92
4	Nov-24	5654	10	2154	2485	2.02
5	Dec-24	7845	10	2459	3311.5	2.32
6	Jan-25	7326	10	2012	2562.75	2.61
7	Feb-25	6598	10	2210	2458.5	2.41

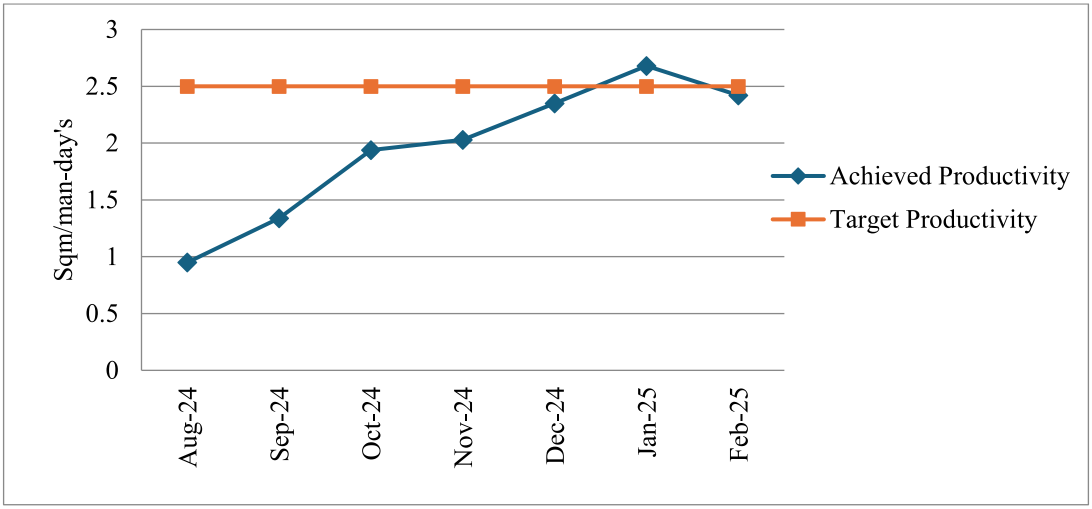
Productivity for Mivan and conventional formwork was calculated separately and tracked against the target productivity set by company norms. For the Oberoi Realty project, the target productivity for conventional formwork is 2.5 sqm/man-day, while for Mivan formwork, it is 10 sqm/man-day. Labor productivity improves from 0.94 sqm/man-day (Aug 2024) to 2.61 sqm/man-day (Jan 2025), with peak output in December (7845 sqm) (see Table 1). Achieved productivity surpasses the 2.5 sqm/man-day target in January (see Figure 2), indicating efficient labor utilization and optimized construction processes.

Productivity in conventional formwork varies depending on the structural element it is used for. Formwork for columns achieves more repetition than that for beams and slabs. The deshuttering time for columns is 24 hours, whereas for slabs, it extends up to 28 days, despite

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

covering a larger area. A higher number of repetitions increases the quantity of work completed per month, thereby improving productivity. However, adverse weather conditions, such as rain, can delay construction activities. Equipment failures, including tower crane malfunctions, further contribute to productivity losses. These constraints ultimately reduce construction efficiency and extend project timelines.

Figure 2: Variation of Productivity in Conventional Formwork from Target Productivity (Oberoi Realty – H Tower)



5.2 Shuttering usage Ratio (SUR) in conventional formwork

The shuttering usage ratio is defined as the ratio of the quantity of shuttering completed in a month to the total quantity of shuttering available for that month (see Table 2).

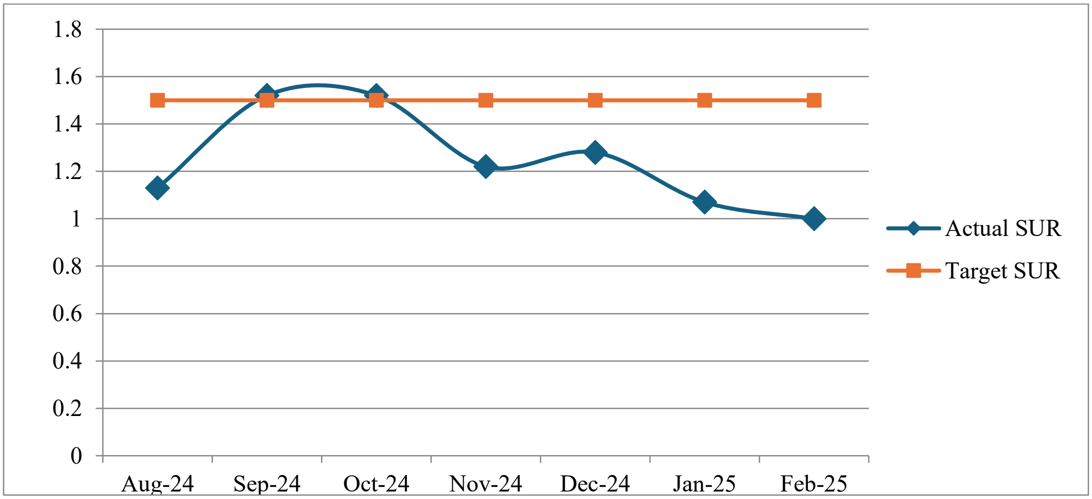
Table 2 : Shuttering Usage Ratio Calculation for Different Months in Conventional Formwork

Sr. No.	Month	Shuttering Quantity Available	Shuttering Quantity done	SUR
1	Aug-24	202	221	1.14
2	Sep-24	687	113	1.51
3	Oct-24	1543	2245	1.54
4	Nov-24	4692	5654	1.23
5	Dec-24	6187	7845	1.21
6	Jan-25	6758	7326	1.06
7	Feb-25	6402	6598	1.01

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

Table shows the variation in the shuttering usage ratio (SUR) for conventional formwork, which depends on the utilization of material per month. Shuttering material used for columns has the highest utilization, whereas slab areas cover a larger surface, leading to variations in SUR. Proper housekeeping, maintenance, and efficient material movement are essential to achieving the target SUR. If shuttering material remains idle for an extended period, the SUR decreases (see Figure 3).

Figure 3: Variation of Shuttering usage Ratio (SUR) from Target Productivity in Conventional Formwork (Oberoi Realty – H Tower)



The graph compares Actual SUR (Shuttering Utilization Ratio) with Target SUR from August 2024 to February 2025. The Target SUR remains nearly constant at around 1.5–1.54, indicating a planned utilization goal. The Actual SUR starts below the target in August 2024 (1.2), peaks around September–October 2024 (1.54), and then gradually declines, falling below 1.2 by February 2025. This suggests that while initial performance met expectations, there was a decreasing trend in utilization efficiency over time, potentially due to project delays, labor inefficiencies, or resource constraints.

5.3 Evaluation of labour productivity in Mivan formwork

The productivity calculation is done (see Table 3) for Mivan formwork, and variation is determined from target productivity. The data shows a general increasing trend from August 2024 (2.33 sqm/man-day) to December 2024 (8.73 sqm/man-day), indicating improved efficiency. However, productivity declines in January (7.21 sqm/man-day) and February 2025 (5.01 sqm/man-day), possibly due to higher labor involvement without a proportional output increase (see Figure 4). This drop was primarily caused by the Brihanmumbai Municipal

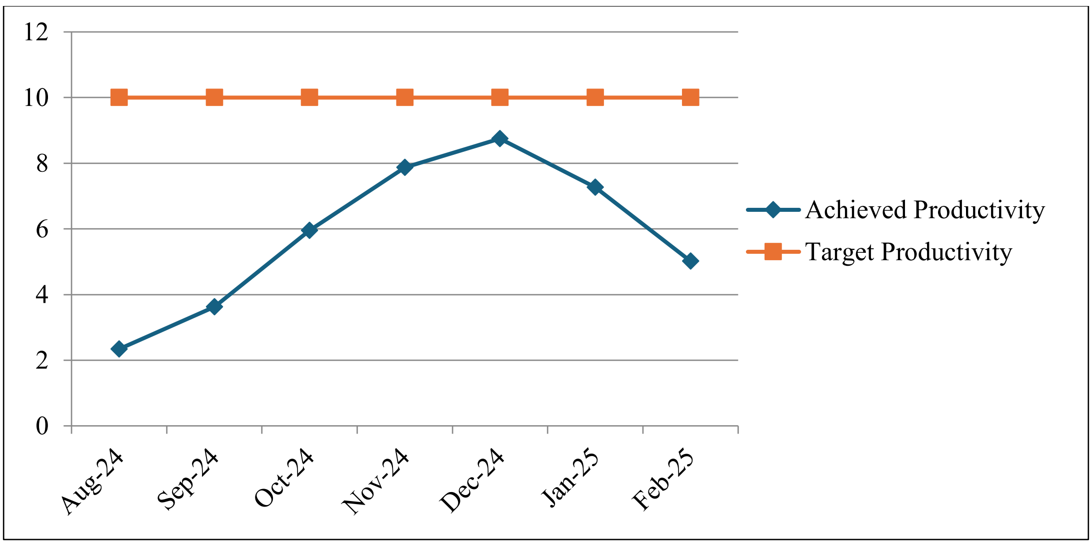
DOI: 10.17492/JPI/NICMAR/2507036 *ISBN: 978-93-49790-54-4*

Corporation (BMC) halting construction work in Borivali East and Byculla due to poor air quality, issuing stop-work notices to 78 sites and enforcing GRAP-4 guidelines.

Table 3: Productivity Calculation in Mivan Formwork

Sr. No.	Months	Qty of work done (sqm) per month A	Working hours per day B	No. of labours per month C	No of man-days per Month (1 manday's = 8hours) D	Productivity (P=a*d)
1	Aug-24	3120	10	1215	1247.55	2.33
2	Sep-24	7122	10	1596	1942.55	3.64
3	Ocr-24	19422	10	2452	3242.51	5.91
4	Nov-24	24301	10	2635	3010.05	7.84
5	Dec-24	31225	10	2756	3580.03	8.73
6	Jan-25	29012	10	3159	3946.02	7.21
7	Feb-25	16984	10	2704	3658.21	5.01

Figure 4: Variation of Productivity in Mivan Formwork from Target Productivity (Oberoi Realty – G Tower)



The variation in the productivity of Mivan formwork occurs due to several factors. Initially, productivity is low because time is required for setting out and aligning the formwork. As the number of floors increases, productivity improves due to the repetition of the same tasks. In this project, both towers have different start dates, which affects the overall productivity.

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

6.0 Method of Cubic Contents – Cost Analysis

The Cubic Contents Method is especially useful for determining the total volume of construction activity. The length, width, and depths of the building components are multiplied to give the total amount of that particular piece in this precise technique. In the case of surface plastering and other surfacing work, the total surface area is computed by multiplying the lengths by the breadth of the area to be worked on. The amount necessary to complete the work is calculated by multiplying the rate in terms of construction work by the entire quantity of work. This technology is more commonly utilized in the construction of multi-story buildings. This technology is more commonly utilized in the construction of multi-story buildings. It is more exact than the other two techniques of computation, the plinth area technique and the unit base approach.

6.1 Comparative cost analysis of mivan and conventional formwork

The comparison between conventional and Mivan (Alu-Form) construction highlights key structural differences while maintaining similar project parameters. Both use M35 grade concrete and identical steel reinforcement sizes (32mm, 25mm, 16mm, 10mm, and 8mm). However, Mivan walls (140mm & 160mm) are thinner than conventional walls (160mm & 230mm), enhancing material efficiency and carpet area. Slab thickness in Mivan varies (125mm, 150mm, 180mm), whereas it remains 150mm in conventional construction. Despite structural differences, both methods support a G+65 structure with 843.88 sq.m floor area, showcasing Mivan's material efficiency (see table 4). The cost comparison shows Mivan is ₹8,458,826 (0.122%) more expensive. While reinforcement and concreting costs are higher by ₹1.18 crore and ₹6.25 crore, it eliminates brickwork and plastering, saving ₹7.26 crore. Additionally, Mivan's formwork cost is lower at ₹41,100 due to 250 repetitions, compared to ₹4.65 lakh in conventional construction with just 10 repetitions (see table 5).

Table 4: Comparison of Items

Sr. No	Content	Conventional	Mivan
1	Concrete Grade	M35	M35
2	Thickness of Wall	160mm, 230mm	140mm, 160mm
3	Steel	40mm ,32mm, 25mm, 16mm 10mm, 8mm	40mm ,32mm, 25mm, 16mm 10mm, 8mm
4	Slab	125mm, 150mm	125mm, 150mm,180mm
5	Number of floors	G+65 (L10-23)	G+65 (L10-23)
6	Floor Area	843.88 sq. m	843.88 sq. m

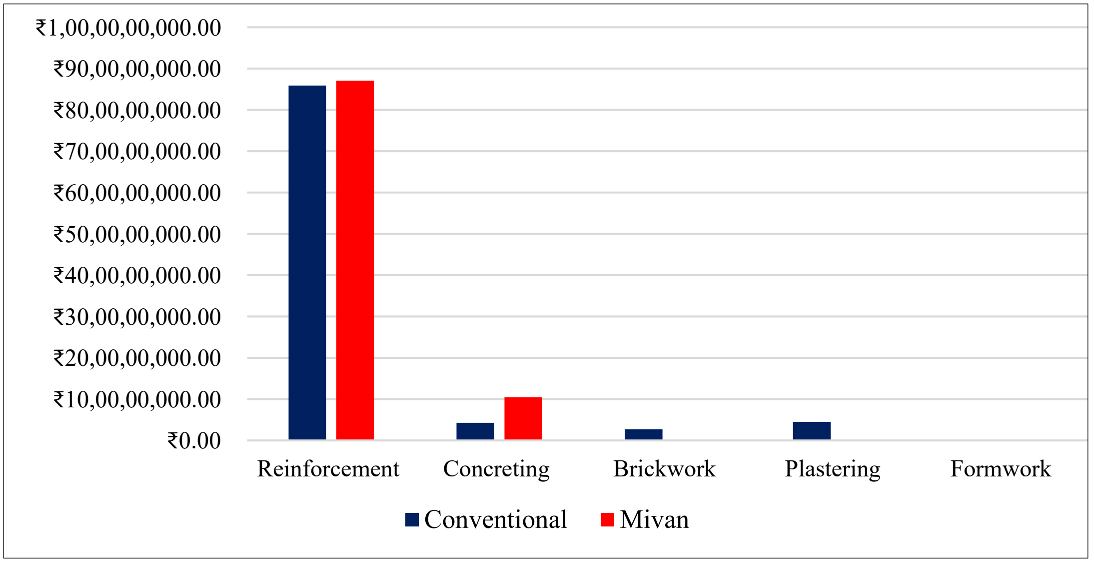
Reinforcement is the highest cost in both methods, with Mivan requiring slightly more due to its monolithic structure. Concreting costs are also higher in Mivan, as it integrates walls and slabs in a single pour.

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

Table 5: Cost Comparison between Conventional & Mivan Method

Sr. No	Particular	Conventional	Mivan	Cost Difference
1	Reinforcement	₹ 85,44,11,946.00	₹ 87,46,24,146.00	-₹ 20,212,200.00
2	Concreting	₹ 4,14,15,560.00	₹ 10,10,62,642.00	-₹ 59,647,082.00
3	Brickwork	₹ 2,74,73,752.00	₹ 0.00	₹ 2,74,73,752.00
4	Plastering	₹ 4,35,21,822.00	₹ 0.00	₹ 4,35,21,822.00
5	Formwork	₹ 4,45,982.00	₹ 41,100.00	₹ 404,882.00
	Formwork	(10 Repetitions)	(250 Repetitions)	
			Total =	= -8,458,826.00
				0.122% Uneconomical by Mivan

Figure 5: Cost Comparison between Conventional and Mivan Formwork



A key difference is in brickwork and plastering, which are absent in Mivan due to its smooth aluminum formwork. Mivan has a high initial cost but is more economical, over 250 repetitions, compared to 10 in conventional formwork. Despite higher reinforcement and concreting costs, Mivan reduces labor-intensive activities, making it ideal for large-scale projects by improving speed and quality (see, Figure 5).

7.0 Result

The comparative analysis of conventional and Alu-Form (Mivan) formwork in high-rise construction provided significant insights into their efficiency, cost-effectiveness, and labor productivity. The study results indicate the following:

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4

Labor Productivity: Mivan formwork demonstrated higher labor productivity, reaching up to 8.75 sqm/man-day compared to 2.68 sqm/man-day for conventional formwork. The increased productivity is attributed to the modular nature of Mivan, requiring fewer adjustments and skilled labor.

Construction Speed: The Mivan system enabled a faster slab cycle (5 to 7 days per floor), whereas conventional formwork required 10 to 14 days per floor. This acceleration in construction timelines leads to faster project completion.

Material Utilization: Mivan formwork showed a lower shuttering usage ratio (SUR) due to higher reusability (250 repetitions) compared to conventional formwork (10–20 repetitions). This reduced material waste and enhanced sustainability.

Cost Analysis: Despite the higher initial cost of Mivan formwork, the long-term benefits justified its application. The total cost difference between the two methods was minimal, with Mivan being only 0.122% more expensive. However, savings were achieved in labor, plastering, and brickwork costs.

Structural Quality: The Mivan system provided superior structural quality with better concrete finishes, eliminating the need for plastering. Conventional formwork required additional surface treatments, increasing labor and material costs.

8.0 Conclusions

The study concludes that while conventional formwork remains a viable option for small-scale and customized structures, Mivan formwork offers significant advantages for high-rise buildings due to its efficiency, labor productivity, and cost-effectiveness. The major conclusions drawn are:

- Mivan formwork reduces construction time and labor dependency, making it ideal for repetitive high-rise projects.
- Conventional formwork, although cheaper initially, results in higher long-term costs due to increased labor requirements and lower reusability.
- The initial investment in Mivan is justified by long-term benefits, including reduced wastage, higher productivity, and minimal surface treatment needs.

9.0 Recommendations

Adoption of Mivan formwork in high-rise projects: Due to its efficiency, developers should prefer Mivan technology for projects with repetitive floor layouts.

Training for skilled workforce: The transition to Mivan requires skilled labor for assembly and maintenance; therefore, workforce training programs should be implemented.

Cost optimization strategies: Contractors should optimize material procurement and reuse strategies to mitigate the high initial cost of Mivan formwork.

DOI: 10.17492/JPI/NICMAR/2507036 *ISBN: 978-93-49790-54-4*

Hybrid approach: For projects requiring flexibility, a combination of both formwork systems could be considered, utilizing conventional formwork for complex designs and Mivan for repetitive elements.

Further research: Future studies can explore additional case studies and real-time tracking of labor efficiency across different project phases.

References

Aditya, V., et al. (2018). Aluminium formwork impact on affordable housing under PMAY. *Housing Infrastructure Journal*, 15(2), 101–118.

Baharuddin, M., et al. (2021). Industrialized building system (IBS) and aluminium formwork adoption in Malaysia. *Engineering Economics Review*, 23(4), 215–230.

Gambatese, J., & Barbosa, J. (2014). Lifecycle analysis of timber and aluminium formwork in high-rise construction. *Sustainable Engineering Journal*, 6(3), 133–147.

Gari, N. R., & Thomas, S. (2024). Cost and time analysis of Mivan and conventional formwork systems. *Journal of Construction Engineering*, 12(3), 45–58.

Gopal, K. (2024). Evaluation of labor productivity in Mivan technology: A case study on MHADA projects. *International Journal of Civil Engineering Research*, 18(1), 75–92.

Gulghane, A., et al. (2018). Impact of Mivan formwork on high-rise project timelines. *International Journal of Structural Engineering*, 16(2), 95–110.

Karke, P., & Kumathekar, M. (2021). Challenges in transitioning from conventional to Mivan formwork in Indian construction. *International Journal of Building Technology*, 19(3), 120–134.

Karule, R., & Kumar, S. (2021). Formwork system comparison: Steel, timber, and aluminium. *Construction Practices Journal*, 17(1), 55–72.

Khan, M., & Patel, H. (2020). Advances in aluminium formwork technology for high-rise buildings. *International Journal of Construction Methods*, 21(2), 67–82.

Lee, C., & Park, J. (2020). Innovative formwork solutions for sustainable high-rise buildings. *Journal of Sustainable Construction*, 19(4), 145–162.

DOI: 10.17492/JPI/NICMAR/2507036 *ISBN: 978-93-49790-54-4*

Mathane, A. (2015). Formwork systems in multi-storey buildings: A comparative analysis. *Civil Engineering Research Review*, 8(1), 55–72.

Miller, D., & Hughes, R. (2019). The role of prefabricated formwork in reducing construction waste. *Sustainable Infrastructure Journal*, 22(1), 67–80.

Paterson, L., & Gomez, H. (2022). Comparative performance of timber and aluminium formwork in urban construction. *Urban Engineering Review*, 27(3), 120–138.

Patil, A., et al. (2022). Economic feasibility study of Mivan formwork in high-rise construction. *Construction Management Review*, 15(2), 32–48.

Poon, J., & Robin, T. (2018). Sustainable formwork systems: Economic and environmental considerations. *Green Construction Review*, 11(2), 78–95.

Ram, V., & Sinha, P. (2021). Automation in formwork systems for high-rise construction. *International Journal of Civil Engineering Advances*, 26(2), 78–95.

Raymond, L. (2022). Effect of aluminium formwork on construction efficiency in Hong Kong high-rise buildings. *Urban Construction Journal*, 20(2), 88–101.

Renuka, P., et al. (2017). Cost-effectiveness of tunnel and aluminium formwork in high-rise projects. *Building Innovation Journal*, 9(4), 187–204.

Selvan, R. (2016). Economic feasibility of aluminium formwork systems in mass housing. *Building Materials and Construction Journal*, 10(3), 89–104.

Sharma, R., & Mehta, P. (2019). A review of cost and time efficiency in modular formwork systems. *Engineering Journal of Construction Innovations*, 18(3), 150–165.

Singh, P., & Nagarajan, R. (2022). Comparative analysis of formwork systems in multi-storey residential buildings. *Building Technology Journal*, 14(4), 102–118.

Sorate, P., & Dhiman, R. (2017). Fast-track construction: A study on Mivan and tunnel formwork techniques. *Journal of Modern Construction Methods*, 13(4), 215–228.

Times of India - Realty NXT. (2023). Impact of Mivan technology on PMAY housing projects in India. Retrieved from https://www.realtynxt.com

DOI: 10.17492/JPI/NICMAR/2507036 *ISBN: 978-93-49790-54-4*

Vijay, S. *et al.* (2019). Line of balance technique for cost and time optimization in aluminium formwork projects. *Construction Planning Journal*, 22(1), 68–81.

Wong, T., & Chiu, K. (2018). Economic implications of aluminium formwork in large-scale infrastructure projects. *Journal of Construction Economics*, 14(2), 220–235.

Zhang, L., & Li, F. (2021). Influence of prefabricated formwork on structural durability in high-rise construction. *Structural Engineering and Design Journal*, 25(1), 89–110.

DOI: 10.17492/JPI/NICMAR/2507036 ISBN: 978-93-49790-54-4