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Structural Design of Aluminium Formwork and Comparison with Conventional Formwork in High-Rise Building

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Abstract: *The use of formwork systems is an essential component in the construction industry, providing temporary moulds for concrete placement. The selection of an appropriate formwork system can significantly impact the efficiency and quality of construction, particularly in high-rise buildings. This paper focuses on the structural design of aluminium formwork and compares it with conventional formwork systems in high-rise building construction. The study aims to highlight the advantages of aluminium formwork in terms of speed, cost-effectiveness, sustainability, and structural performance. Additionally, it discusses the challenges associated with its implementation and presents recommendations for optimizing the use of aluminium formwork in high-rise buildings.*

Keywords: Aluminium formwork, conventional formwork, structural design, high-rise building, comparison, speed, cost-effectiveness, sustainability, structural performance, challenges, implementation, recommendations

I. INTRODUCTION

The construction industry relies on effective formwork systems for the successful execution of high-rise building projects. Formwork plays a crucial role in providing temporary moulds for concrete placement, ensuring structural integrity and dimensional accuracy. The selection of an appropriate formwork system significantly impacts the efficiency, cost-effectiveness, and overall quality of construction. In recent years, aluminium formwork has emerged as a viable alternative to conventional formwork systems due to its numerous advantages.

In every year the construction industry provides new techniques up to date. The aluminium formwork construction technique is a new technique in the construction industry. This type of construction provides speed, high strength and quality of the structure. Aluminium formwork another name is Mivan technology. The construction industry is one of the biggest industries in the whole world. The contribution of this industry towards the global GDP is enormous. In recent years due to globalization and advancement in technologies there has been a tremendous development in the construction industry. However, despite of the boom in construction activities the scenario on the housing front remains far from satisfactory.

This paper focuses on the structural design of aluminium formwork and its comparison with conventional formwork systems in the context of highrise building construction. Aluminium formwork systems are composed of lightweight, durable, and reusable components that facilitate faster construction cycles and improved productivity. The inherent properties of aluminium, such as its high strength- toweight ratio and corrosion resistance, make it an ideal material for formwork applications.

The primary objective of this study is to highlight the benefits of aluminium formwork and provide insights into its structural design considerations. By examining the design aspects, including material properties, component configurations, load calculations, connection details, and safety measures, a comprehensive understanding of the technical elements involved in aluminium formwork can be obtained.

Furthermore, this paper conducts a comparative analysis to evaluate the advantages of aluminium formwork over conventional formwork systems. Factors such as construction speed, cost-effectiveness, sustainability, structural performance, labour requirements, and quality control are examined to assess the superiority of aluminium formwork. The findings of this analysis will serve as evidence for the efficiency and effectiveness of aluminium formwork in high-rise building construction.

Despite the numerous advantages offered by aluminium formwork, its implementation may present certain challenges. This paper aims to address these challenges, including initial investment and procurement, adaptability to architectural changes, skilled labour requirements, maintenance and reusability, as well as disassembly and reclamation procedures. By identifying and providing recommendations to overcome these challenges, the successful integration of aluminium formwork in high- rise building projects can be ensured.

This paper aims to provide a comprehensive understanding of the structural design considerations of aluminium formwork, conduct a comparative analysis of its benefits, address implementation challenges, and offer recommendations for optimal usage. By embracing aluminium formwork, the construction industry can achieve improved efficiency, costeffectiveness, sustainability, and structural performance in high-rise building projects.

1.1 Advantages of aluminium formwork used in Highrise Building:

1. Connection Details: Proper connection details, such as pins, locks, or wedges, are essential for securely joining the formwork components. These connections should provide stability during concrete pouring and ensure accurate positioning.
2. Safety Measures: The design of aluminium formwork incorporates safety features to protect workers during construction. This includes guardrails, access platforms, and other fall protection systems.
3. Formwork Joints: Joints between formwork panels must be properly designed and sealed to prevent leakage of fresh concrete. These joints should ensure tight connections, resulting in seamless concrete surfaces.
4. Reusability: Aluminium formwork is highly reusable due to its durable nature. Proper design considerations are given to facilitate easy dismantling, transportation, and reassembly for future projects.
5. Formwork Stability: The structural design of aluminium formwork focuses on providing stability against vertical and horizontal loads. Adequate bracing and reinforcement systems are employed to maintain the formwork's rigidity during concrete placement
6. Tolerances and Accuracy: Aluminium formwork systems are designed to achieve precise dimensions, ensuring accuracy and quality in the construction of high-rise buildings. This results in consistent floor heights, wall thickness, and overall structural alignment.
7. Integration with Building Services: The design of aluminium formwork allows for the integration of building services such as electrical and plumbing systems. Precise cut-outs and provisions are incorporated into the formwork to facilitate these installations.
8. Quality Control: Strict quality control measures are implemented in the manufacturing and assembly of aluminium formwork components. This ensures that the formwork meets industry standards and specifications for structural integrity and safety.
9. High quality formwork ensures consistence of dimensions.
10. On removal of mould a high-quality concrete finish is produced to accurate tolerances and verticality.
11. Total system forms the complete concrete structures.
12. Custom designed to suit project requirements. Unsurpassed construction speed.
13. Panels can be reused up to 250 time Can be erected using unskilled labour.

1.2 Structural Design of Aluminium Formwork:

The structural design of aluminium formwork involves several key considerations and factors that contribute to its efficiency and effectiveness in high-rise building construction. Here are the important points to understand in the structural design of aluminium formwork:

1. Material Selection: Aluminium formwork utilizes lightweight and durable aluminium alloy as the primary material. The selection of high-grade aluminium ensures the formwork's strength, stability, and longevity.
2. System Components: Aluminium formwork systems consist of various components, including panels, beams, props, connectors, and accessories. These components are designed to interlock and provide a robust framework for concrete placement.
3. Panel Configuration: The panels of aluminium formwork are engineered to be modular and interchangeable. They are available in different sizes and shapes to accommodate varying architectural requirements.
4. Load Calculation: The structural design of aluminium formwork involves determining the loads imposed by the concrete, reinforcement, and other construction materials. Load calculations are crucial for ensuring the formwork's stability and structural integrity.
5. Sustainability Considerations: The lightweight and reusable nature of aluminium formwork contribute to its sustainability. It reduces material waste, energy consumption, and carbon footprint compared to conventional formwork systems.

II. DESIGN OF COMPONENTS OF ALUMINIUM FORMWORK

Components:

Wall Components

- Wall Panel (WP)
- External Corner (EC)
- Rocker (RK)
- Internal Corner (IC)
- Kicker (K)
- Pin and Wedge

Beam Components

- Beam Panel (BP)
- Beam Internal Corners
- Beam bottom panels (SBE)
- Soffit Corner Internal (SCI)& Soffit Length (SL)
- Column Collar (CC)
- Soffit Corner External (SCE)

a) Slab Components

- Slab Panel (SP)
- Central prop (cp)
- Mid / End Beam (MB / EB)
- Slab Corner (SC)
- End Prop Head (EP)
- Prop Length (PL)
- Wall Panel
- Prop Length (PL)

i. Wall Panel

Start from 50 mm
Above from Floor Level.
Width Varies from 50 to 600 mm.
Some Standard Lengths.: 2050, 2250, 2400, 2450

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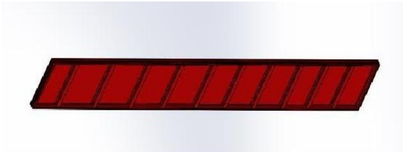
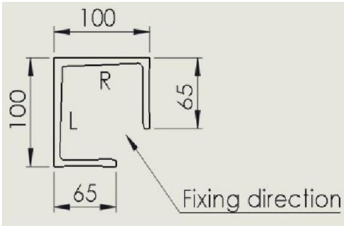
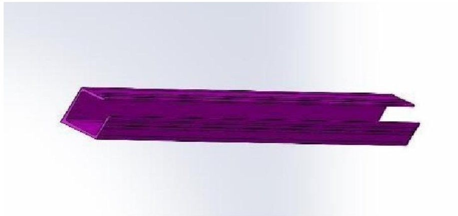
ii. Internal Corner

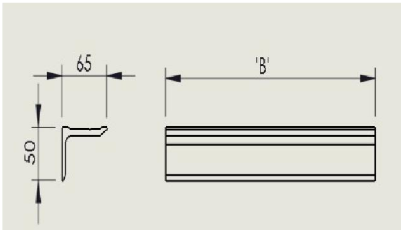


Section 100 x 100
Start 50 mm
Above from floor level.

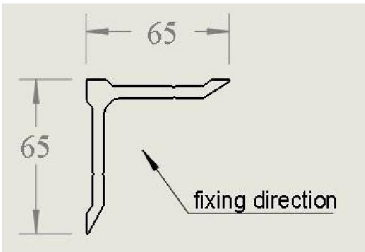


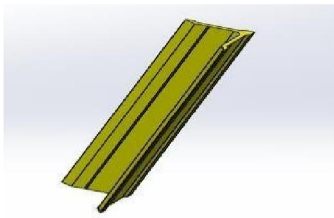


iii) Rocker
Mostly start from floor level.
Rarely start from different level.
Width varies from 50 to 600 mm

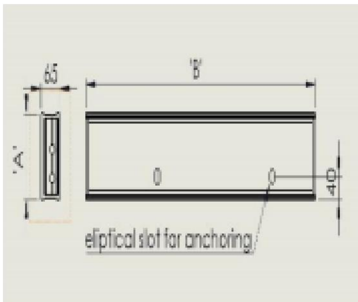


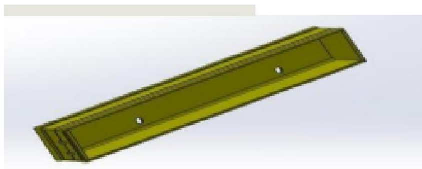
iv) External Corner
65 x 65
Start 50 mm above
from floor level



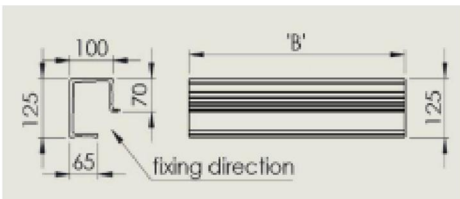


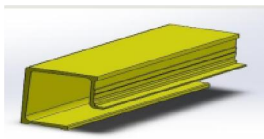
v) Kicker panel
Standard Heights
100 , 125, 150, 175.
Standard lengths
2400 , 2100, 1800.



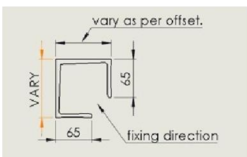


vi) Column Collar
Section 100 x 125 with lip.

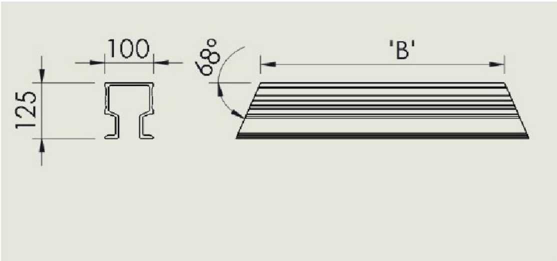


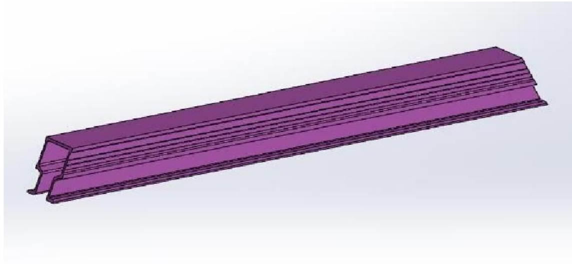


vii) SX Panel
Uses when beam creates Horizontal offset with wall.
Profile Vary as per Offset Condition.

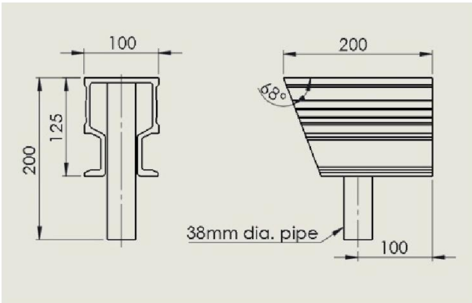


viii) Mid / End Beam (MB / EB)

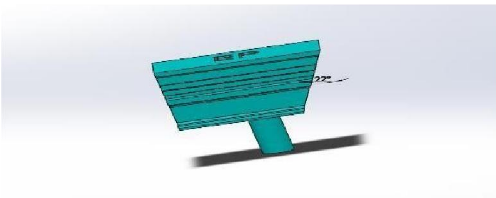




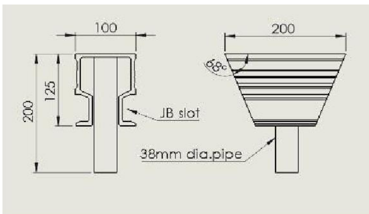
Fix between two DP by joint bar. 68° Inside Cut



Single Prop at Center.
680 Inside Cut.
Standard Length 200 mm.



ix) Deck Prop
Single Prop at centre.
Standard Length
(ALUMINIUM)



2.1) Design Calculations

DESIGN OF WALL PANELS

Pressure from Concrete = 26 kN/m3 Max Pouring Height = 2 m ACI 347 = 57.07 kN/m2 CIRIA Report -108 = 53.51 kN/m2 Max Hydrostatic Pressure shall be at Bottom Portion = 26*2 = 52.00 kN/m2 Design Pressure with F.O.S. =1 = 52.00 kN/m2.

2.1.1) Design of Sheet:

Span-1 Span (1) =0.205m Pour Height = 2 m Density of Concrete = 26 kN/m3 Sheet Thickness = 0.0038 m Stress available in Table 25 of IS 8147- 1976 =143 N/mm² I xx = 4.57267E-09 m4 y = 0.0019 m Pressure on Sheet = 52.0000 kN/m2 B.M. = 52*0.205^2/10 = 0.21853 kN-m Z required = (0.21853*1000000)/143 = 1528.1818 mm3 Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.898 mm SAFE 0.585.

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- Standard Wall Panel Span-2

Span (2) = 0.205 m

Pour Height = 1.775 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y = 0.0019 m. Pressure on Sheet = 46.1500 kN/m2 B.M. = 46.15*0.205^2/10 = 0.193945375 kN-m Z required = (0.193945375*1000000)/143 = 1356.2614 mm3.Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.684 mm SAFE Span-3

Span (3) = 0.205 m.

Pour Height = 1.550 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y = 0.0019 m

Pressure on Sheet = 40.3000 kN/m2.

B.M. = 40.3*0.205^2/10 = 0.16936075 kN-M Z required = (0.16936075*1000000)/143 = 1184.3409 mm3. Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384)*(WL4 /EI) = 1.471 mm SAFE.

Span (4) = 0.230 m

Pour Height = 1.325 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y = 0.0019 m Pressure on Sheet = 34.4500 kN/m2 B.M. = 34.45*0.23^2/10 = 0.1822405 kN-m Z required = (0.1822405*1000000)/143 = 1274.4091 mm3 Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.992 mm SAFE.

Span (5) = 0.23 m

Pour Height = 1.075 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y = 0.0019 m Pressure on Sheet = 27.9500 kN/m2 B.M. = 27.95*0.23^2/12 = 0.123212917 kN-m Z required = (0.123212916666667*1000000)/143 = 861.6288 mm3 Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.616 mm SAFE.

Span (6) = 0.255 m

Pour Height = 0.825 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y = 0.0019 m Pressure on Sheet = 21.4500 kN/m2 B.M. = 21.45*0.255^2/12 = 0.116232188 kN-m Z required = (0.1162321875*1000000)/143 = 812.8125 mm3. Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.874 mm SAFE Span-7 Span (7) = 0.28 m Pour Height = 0.55 m.

Span (7) = 0.28 m

Pour Height = 0.55 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y = 0.0019 m Pressure on Sheet = 14.3000 kN/m2 B.M. = 14.3*0.28^2/12 = 0.093426667 kN-m Z required = (0.0934266666666667*1000000)/143 = 653.3333 mm3 Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.816 mm SAFE.

Span (8,9) = 0.305 m

Pour Height = 0.25 m Density of Concrete = 26 kN/m3

Sheet Thickness = 0.0038 m I xx = 4.57267E-09 m4 y

= 0.0019 m Pressure on Sheet = 6.5000 kN/m2 B.M. = 6.5*0.305^2/12 = 0.050388542 kN-m Z required = (0.0503885416666667*1000000)/143 = 352.3674 mm3 Z available I xx/y = 2406.6667 mm3 SAFE Deflection = (2.5/384) *(WL4 /EI) = 1.162 mm SAFE.

2.1.2) Design of I Stiffener: I Stiffener

Span = 0.586 m Stress available in Table 25 of IS 8147 - 1976 is 143 N/mm² I xx = 50986 mm4 Y = 20 mm Pressure on Member '1' = 1.775*26 = 46 kN/m2 Load = 46.15*(0.225/2+0.225/2) 0.250 = 10.38375 kN/m B.M. = 10.38375*0.586^2/12 = 0.2971 kN-m Z required = 0.29714485125*1000*1000/143 = 2077.9360 mm3 Z available = I / y = 2549.3000 mm3 SAFE Deflection = WL4 /384EI = 0.908 mm SAFE.

2.1.3) Design of Side Frame: Span (Wall tie spacing) = 0.400 m

Stress available in Table 25 of IS 8147 - 1976 is 143 N/mm² I xx = 114427.08 mm4 Y = 32.5 mm Pressure on Member '1' = 1.775*26 = 46 kN/m2 Load = 46.15*0.586/2 = 13.52195 kN/m B.M. = 13.52195*0.4^2/10 0.250 = 0.2164 kN-m Z required = 0.2163512*1000*1000/143 =

1512.9455 mm3 Z available = I / y = 3520.8333 mm3 SAFE Deflection = WL4 /384EI = 0.114 mm SAFE.

III. COMPARISON BETWEEN ALUMINIUM FORMWORK AND CONVENTIONAL FORMWORK:

When comparing aluminium formwork with conventional formwork systems, several factors come into play. Here are the key points to consider in the comparison between aluminium formwork and conventional formwork:

1. Construction Speed: Aluminium formwork allows for faster construction cycles due to its lightweight and modular nature. The assembly and disassembly of aluminium formwork systems are quicker than conventional systems, resulting in shorter project durations.
2. Cost-Effectiveness: Although aluminium formwork may have higher upfront costs, it offers cost savings in the long run. The reusable nature of aluminium formwork reduces material expenses over multiple projects and requires less labour for installation and removal.
3. Sustainability: Aluminium formwork is considered more sustainable than conventional formwork systems. Its reusability minimizes construction waste and reduces the environmental impact associated with using traditional formwork materials, such as timber.
4. Structural Performance: Aluminium formwork provides enhanced structural performance compared to conventional systems. It offers greater strength and stability, ensuring precise and consistent concrete placements, which results in improved structural integrity.
5. Labour Requirements: Aluminium formwork systems require a skilled workforce for efficient assembly and disassembly. However, once the workers become familiar with the system, it can significantly reduce the labour requirements compared to conventional formwork methods.

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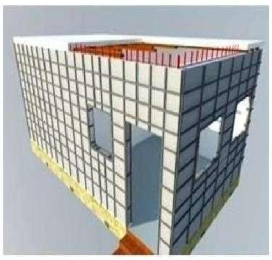
6. Adaptability to Architectural Changes: Aluminium formwork is highly adaptable to accommodate architectural changes during the construction process. Its modular design allows for adjustments, making it easier to incorporate modifications in floor plans, wall configurations, and other design elements.
7. Quality Control: Aluminium formwork offers better quality control due to its precision and consistency. The standardized components ensure accurate dimensions and alignments, resulting in higher quality concrete finishes.
8. Reusability and Maintenance: Aluminium formwork can be reused for multiple projects, reducing the need for continuous investment in formwork materials. Proper maintenance and storage practices can prolong the lifespan of aluminium formwork components, ensuring their durability and reusability.
9. Safety: Aluminium formwork systems incorporate safety features such as guardrails and access platforms to provide a safer working environment. This helps minimize the risk of falls and accidents during construction activities.
10. Durability: Aluminium formwork is known for its durability and resistance to weathering, moisture, and corrosion. In comparison, conventional formwork materials, such as timber, may require more frequent replacements and repairs.

IV. CONCLUSION

The comparison between aluminium formwork and conventional formwork systems reveals several

Aluminium formwork systems p[illegible]precise concrete placements and improved structural integrity. The standardized components of aluminium formwork contribute to better quality control, achieving accurate dimensions and alignments. Moreover, the adaptability of aluminium formwork

Fig: Mock-up of Aluminum Panel



enables easy incorporation of architectural changes during construction. Labour requirements are reduced with aluminium formwork, as workers become familiar with the system, leading to increased efficiency. Safety features, such as guardrails and access platforms, further enhance worker safety on construction sites. The durability of aluminium formwork makes it resistant to weathering, moisture, and corrosion, advantages of using aluminium formwork in high-rise building construction. Aluminium formwork offers resulting in longer lifespan and reduced maintenance faster construction speed, cost-effectiveness, sustainability, enhanced structural performance, adaptability to architectural changes, improved quality control, reduced labour requirements, and better safety measures. The structural design of aluminium formwork, with its lightweight and durable components, allows for efficient assembly and disassembly, resulting in shorter project durations. Although it may entail higher upfront costs, the reusability of aluminium formwork leads to long-term cost savings. Additionally, the sustainability aspect of aluminium formwork reduces construction waste and environmental impact compared to conventional formwork systems. needs compared to conventional formwork materials. Overall, the comparison demonstrates that aluminium formwork provides numerous benefits, making it a favourable choice for high-rise building construction. By embracing aluminium formwork, the construction industry can achieve improved efficiency, costeffectiveness, sustainability, structural performance, and safety, leading to successful and timely project delivery.

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