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Application of Advanced formwork system for High rise buildings in Chennai, India

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Abstract - *Various different advanced self-climbing construction systems have been developed and used worldwide. In recent times due to growing population and space constrains there is a need for tall high rise buildings. Throughout India there are various high rise residential developments. Some of these developments use advanced formwork systems like self-climbing formwork. But in Chennai it is not widely used but aluminum form work system is used. The aim of the study is to study, analyze and understand the application of self-climbing formwork in high rise building projects. As a part of the study various case studies of the self-climbing form works used in India are explored and we attempt to conceptually implement the self-climbing formwork in a project in Chennai and analyze the differences.*

Key Words: **Self-climbing formwork, advanced formworks, jump formworks**

1. INTRODUCTION

Various high rise residential projects from Mumbai is studied and analyzed as the part of the study with respect to time, cost and quality. Later suitable proposal is identified in Chennai to apply the findings of the case study where SPR High living in Chennai is identified as the site since it is the 1st tallest building in Chennai. It is constructed using MIVAN formwork. For this site we try to apply self-climbing form work and analyze the differences, results between two formwork systems and understand the viability of the advanced self-climbing form work systems in Chennai. From the study it is identified that when the combination of advanced formworks system used for (Walls & slabs) and self-climbing formwork used for (Core wall) total cost is 10.794 % higher compared with aluminum formwork.

2. METHODOLOGY

- Literature study about self-climbing formwork
- Case studies
- Comparative analysis
- Identification of suitable construction system
- Proposal site identification
- Proposed Formwork Cost
- Proposed Construction scheduling
- Comparative Analysis
- Findings
- Conclusion

3. SCF – SELF CLIMBING FORMWORK

Self-climbing formwork system have been widely used in Indian metropolitan cities like Delhi, Mumbai, Kolkata and Chennai for High rise residential apartment. It is a special formwork for tall concrete structures. It is an effective solution for repetitive construction. SCF is a crane independent formwork system which is widely used in Skyscrapers, Bridge Pylons, Airport Control Towers, High Rise Buildings, Elevator Shafts, and Silos. Its components include Platforms for concrete workers, Wall formwork, Lifting beam, Suspension platforms. This formwork also provides working platforms for construction crews. It also provide additional spaces for equipment and safety / weather protection screens. It also enables very large concrete structures to be constructed in one single pour thus creating seamless structures with enhanced strength and visual appearance, as well as reducing construction times and material costs significantly.

4. PROCESS OF SELF CLIMBING FORMWORK

1. Setting up the self-climb form work system
2. Placing steel reinforcement
3. Pouring Concrete
4. Formwork Stripping
5. Formwork shifting to upper level
6. At end of all floors construction Removal formwork using tower crane

5. COMPONENTS

1. Suspension platforms
2. Wall formwork material and pieces
3. Anchor system

4. Climbing brackets

6. ADVANTAGES

1. By using self-climbing form work we can get High-quality surface finishes
2. This formwork has faster construction speed
3. It requires less labour to set up the formwork
4. It can sustain high wind since it has wind ties for support
5. There is high safety for labour during the setting and removal process
6. It is Easy to clean and reuse with little waste generated compared to traditional systems
7. Customization is possible for any type of complex wall geometries
8. This Crane independent construction only requires crane during dismantling

7. DISADVANTAGES

1. Very high initial investments required for self-climbing formworks system
2. Requires only skilled / highly skilled labours
3. Dimensional Accuracy can go low in certain conditions

8. CASE STUDIES

1. High Rise SKY Towers
2. Omkar 1973
3. Lodha Park (Kiara Block)
4. Lodha Park (ALLURA)
5. World One
6. Palais Royale
7. CTRL S Data Center

8.1. HIGH RISE SKY TOWERS

Sky towers project has 4 residential high rise buildings situated in Mumbai. This project is around 20 acres and has built up area of around 8 million Sq.F. the height of towers range from 257m+ to 300m+.the construction schedule targeted was 10 days slab cycle and for residential floors its 7 days.to achieve this 7 days cycle automatic climbing formwork system was used for core walls. Guided climbing system for external wall was followed. Light weight panel formwork for columns, generic panel slab formwork system, and concrete placing booms, tower cranes with high capacity and high performance concrete was used. Core structure preceding construction method is followed using ACS automatic climbing system. The formwork systems used in this project are Automatic climbing platform SCP – 400 is used in sky tower and SKE - 100 / 50 (DOKA) is used in sky forest and sky suite

Construction sequence: Core wall and stair case wall >> flat slab

8.2. OMKAR 1973

OMKAR 1973 towers has around 400 sky bungalows, sizes varying from 2,500 sq. ft. to 18,200 sq. ft. area. It has height of 267 meters and an area of around 5,000,000 sq. ft. The project consists of 3 skyscrapers which are namely towers A, B, and C, all are 73 stories tall. All these towers has 3 floors underground for parking. The Platform SCP is used for core structure and column. It has space for all the site equipment, and is enclosed on all sides, weather-shielded. The core structure has a 7 days jump cycle and the column has 4 days jump cycle. Dokadek 30, Protection screen Xclimb 60, Large-area formwork Top 50 are the other advanced formworks and safety screens used in this project.

Construction sequence: Core wall and stair case wall >> columns >> flat slab

Conceptual Baseline formwork cost		
Sl.No	Formwork location	cost
1	(self-climbing) 2 ' thick structural core wall	₹ 4,92,25,500
2	(self-climbing) 1' thick lift core and stair case	₹ 9,02,52,000
3	(self-climbing) columns	₹ 4,10,67,000
4	roof slab	₹ 2,44,94,040
	total	₹ 18,05,44,500

Table -1: OMKAR 1973 Conceptual Baseline formwork cost

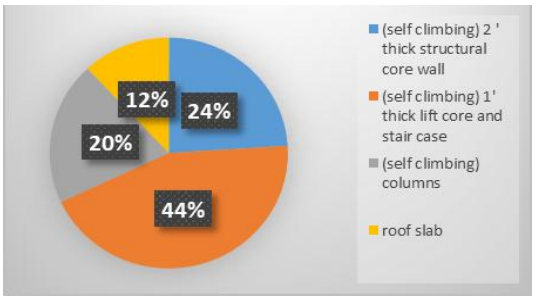

Chart -1: Pie chart formwork cost

8.3. LODHA PARK (KIARA BLOCK)

LODHA - The Park TOWER – 5 is a residential high rise project located in Mumbai, the client is Lodha developer limited company started on July 2015 and was expected to be finished in 44 months. Its tender cost is around 371, 16, 92,726 Rs. The project has a total built-up of 1,03,769 Sq. M. Tower 5 is divided into 5 elements 1.Core wall (1); 2.Core wall (2); 3.Lift lobby; 4.Staircase; 5.Wing slab. In the construction of core wall is done using PERI Vario Automatic climbing system formwork and the wind slab, lift lobby and staircase is construction using kumkang kind aluminum formwork. Construction sequence: Core wall 1 >> core wall 2 >> lift lobby >> wing slab

Conceptual Baseline Core Wall-2 cost				
Criteria	Quantity	Unit	Cost per Sq.M	Scaffolding cost
Panel Formwork	675.58	m2	25,000	1,68,89,500
Climbing formwork	639.84	m2	90,000	5,75,85,600
Aluminum	35.74	m2	8,000	2,85,920
total				7,46,71,000

Table -2: Lodha park (kiara Block) Conceptual Baseline formwork cost

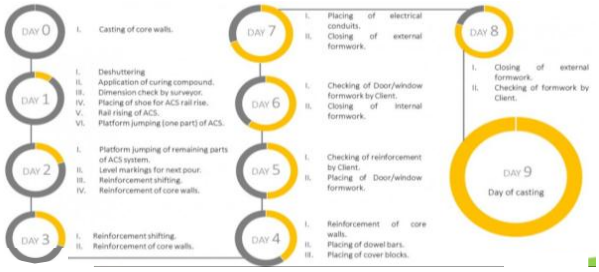

Figure -1: Lodha Park Floor cycle

8.4. LODHA PARK (ALLURA)

The Park by Lodha (ALLURA), located in Pandurang Budhkar Marg, Worli, and Mumbai is around a 7-acre private park in the 17-acre master planned urban oasis. The project time line is 2013 -2021. This building is 268m height. The entire core structure is divided in two parts i.e. inner core and external core. The main contractor for the project is simplex. Main challenge in the project was Irregular huge architectural core, High Safety standards in windy coastal region, higher safety measures to ensure effective outcome from working people. Hydraulic climbing system was found to be suitable solution in this project. This system also ensures anti-fall protection hence better work environment with low man-power requirement. LIWA panel formwork is also used which a crane free manual installation for wall and column formwork is adding with the crane free time from ACS system.

8.5. WORLD ONE

World One is a 280.2 m (919 Ft) tall skyscraper which has 76 floor located in Mumbai, India. In 2022, it was considered tallest completed building in India. It is located in 7.1-hectare (17.5-acre) site of the defunct Shrinivas Mill. The site also has two other parts: World View and World Crest. Developer of this project is the Lodha Group. Construction on World One began in 2011. By December 2014, about 75% of civil construction on the project had been completed. Estimated construction cost was around ₹26,566,282,284 Cr. Project time line: May 7th 2011 – 2020. Core Preceding Construction Method - The building is constructed in two stages the central core first and the surrounding buildings in the next stage.

Conceptual baseline Formwork cost		
Sl.No	Location	formwork cost per Sq.F
1	Lift core wall formwork	₹ 10,54,06,200
2	Column formwork cost	₹ 6,05,34,000
3	Roof Slab formwork	₹ 1,54,58,400
	total	₹ 18,13,98,600

Table 3 -: World one (kiara Block) Conceptual Baseline formwork cost

8.6. PALAIS ROYALE

Palais Royale is a residential supertall skyscraper project in Worli, Mumbai, India. At 320 meters (1,050 Ft), it is the tallest building and third tallest structure in India. Construction began in 2008 still under construction.The project's progress has been stalled due to multiple public interest litigation lawsuits filed by NGOs Janhit Manch and UHRF, Delhi. These litigations were disposed of by the Supreme Court of India in October 2019.On completion, the building would have 120 apartments ranging in size between 740 and 1,300 square meters. To deliver the works on time, two MEVA automated climbing (MAC) systems in parallel to pour the lift and staircase shafts. The MAC provides complete protection for the workers. Alufix wall formwork, was used both on the site to form walls up to heights of 3m, and as part of the climbing systems. Every day, slabs of different sizes were poured immediately below the core, using the Meva Dec slab system. The slab formwork was set by hand with just a small team of workers, saving time.

8.7. DATA CENTER PROJECT

A Data centre project in Ambattur uses crane assisted climbing formwork system.The site area is around 3.98 Acres. Total construction area for the project is around

8, 47,786 Sq.F.This building is constructed by composite construction using steel structure, R.C.C and blockworks. The climbing form works system is used for shear walls and lift core walls due to rapid construction cycle. The formwork is crane guided climbing system which used crane for shifting to upper levels. RMD KWIK rapid climb formwork systems is used in this project. This system comprises of working platform, formwork and ladder components. Tower crane is required for initial setup of the system, lifting and dismantling of the formwork system. SPEED - Climbing bracket connects to wall with recoverable anchor screw - no lost parts. Reduced crane time in moving forms. Platform and formwork are crane handled in one single operation. Speeds up concrete cycle, reducing program time on multi-floor builds. Eliminates the need to lay down form for cleaning and enables cores to be constructed in advance. SAFETY - Self-contained working levels for economical core forming. No tripping hazard on working platform - the decking boards are at the same level as the top of the climbing bracket. Corner platforms neatly abut one another.

8.7. CASE STUDY INFERENCE

For the case studies we can understand that the self climbing formworks are used in combination with other panel formwork system and protection screens. Self climbing formwork when used with the combination of aluminium formwork can be economical. The self climbing formwork is mostly used in the construction of lift cores. The construction is done in two or more phases and the lift core is constructed first this is called core structure preceeding construction method. The planning of the building significantly affects the form work cost so proper preplanning in required. Form work cost of Walls with more Length, thickness and distance between each other is economical compared to that of walls with lesser distance between each other.

9.PROPOSAL SITE

Proposed High-living District is a residential complex consisting of three residential skyscrapers in the neighborhood of in Chennai, India. which is the tallest residential building in Chennai. Tower B is selected for application of self climbing form work. The project has 75 floors. at site they have used S type aluminum formwork with an average of 12 days / floor construction cycle. In the proposal we are going to use self climbing formwork for core structure, advanced panel formwork for walls and slabs, steel safety protection screen.

Sl.No	Criteria	Area in Sq.M
1	Plinth area (1 floor)	1197.4
2	Built up area (1 floor)	996.4
3	Carpet area(1 floor)	836
4	Plinth area for 75 floors	89,805

Table 4 -: Proposed tower B Area

9.1 cost assumptions

Cost assumptions	Cost per Sq.M	Cost per Sq.F
Aluminum formwork		
MIVAN - aluminum formwork	8,750	813
Nylon safety net	350	33
Advanced formwork and protection screen		
Self-climbing form work	95,000	11,148
Safety protection screen	14,500	1,347
Advanced panel formwork For Wall	25,000	2,323
Advanced panel formwork For slabs	15,000	1,394

Table 5 -: Cost assumptions data for aluminum and advanced formwork system

This data is based on values collected from various industry professionals and from case studies. These values may vary based on location. This data is for Chennai and may subject to change based on the manufactures and models.

9.2 R.C.C COST

Sl. No	Description of the item	Unit	Qty.	Rate	total
1	STEEL REINFORCEMENT				
1.1	core wall	Kg	8054	₹ 90	₹ 7,22,050
1.2	Interior and exterior walls	Kg	64119	₹ 90	₹ 57,48,309
1.3	roof slab and balconies	Kg	23501	₹ 90	₹ 21,06,824
2	CONCRETE WORKS				

2.1	core wall	Cu.M	54	₹ 10,222	₹ 5,51,972
2.2	Interior and exterior walls	Cu.M	430	₹ 10,222	₹ 43,94,300
2.3	roof slab and balconies	Cu.M	176	₹ 10,222	₹ 18,00,041
3	CENTERING AND SHUTTERING				
3.1	core wall	Sq.M	777	₹ 670	₹ 5,20,240
3.2	Interior and exterior walls	Sq.M	3587	₹ 670	₹ 24,01,897
3.3	roof slab and balconies	Sq.M	1179	₹ 670	₹ 7,89,115
A	TOTAL COST				₹ 1,90,34,748

Table 6 -: Steel, Concrete and Shuttering cost.

9.3 ALUMINUM FORM WORK - SITE

At site the S-Type aluminum form work is done and for site safety nylon safety nets are used

Sl.No	Description of the item	Unit	Qty.	Rate	total
1	ALUMINIUM FORM WORK				
1.1	core wall	Sq.M	777	₹ 457	₹ 3,54,972
1.2	Interior and exterior walls	Sq.M	3587	₹ 457	₹ 16,38,872
1.3	roof slab and balconies	Sq.M	1179	₹ 457	₹ 5,38,432
2	ALUMINIUM SHEET				
2.1	core wall	Sq.M	777	₹ 8,500	₹ 66,04,500
2.2	Interior and exterior walls	Sq.M	3587	₹ 8,500	₹ 3,04,92,308
2.3	roof slab and balconies	Sq.M	1179	₹ 8,500	₹ 1,00,17,894
3	NYLON SAFETY NET				
3.1	Providing nylon safety net	Sq.M	1269	₹ 350	₹ 4,44,036
B	TOTAL FORMWORK & SAFETY NET COST FOR ONE FLOOR				₹ 5,00,91,014
4	1% LIFTING CHARGES				
4.1	MATERIAL AND LIFTING CHARGES FOR 1 - 5 FLOORS				₹ 9,51,73,742
4.2	FORMWORK LIFTING CHARGES FOR 1 - 5 FLOORS				₹ 5,00,91,014
4.3	MATERIAL AND LIFTING CHARGES FOR 6 - 75 FLOORS				₹ 1,91,63,48,748
4.4	FORMWORK LIFTING CHARGES FOR 6 - 75 FLOORS				₹ 5,04,29,798
C	(R.C.C COST + ALUMINUM FORMWORK + LIFTING) TOTAL				₹ 2,11,20,43,303

Table 7 -: Aluminum formwork and safety net cost.

9.4. ADVANCED FORMWORK - PROPOSAL

For proposal we use combinations of Hi-end advanced formwork systems and

1. Self climbing form work for core walls,
2. wall & slab panel formwork.
3. Steel protection screen for safety

5	ADVANCED FORMWORK FORM WORK				
Sl.No	Description of the item	Unit	Qty.	Rate	total
A	SELF CLIMBING FORMWORK SYSTEM				
5.1	core wall	Sq.M	777	₹ 95,000	₹ 7,38,15,000
B	PANEL FORMWORK SYSTEM				
5.2	Interior and exterior walls	Sq.M	3587	₹ 15,000	₹ 5,38,09,954
5.3	roof slab and balconies	Sq.M	1179	₹ 15,000	₹ 1,76,78,637
6	SAFETY PROTECTION SCREEN				
6.1	steel safety protection screen	Sq.M	1269	₹ 14,500	₹ 1,83,95,764
B	TOTAL FORMWORK				₹ 16,36,99,355
8	1% LIFTING CHARGES				

8.1	MATERIAL AND LIFTING CHARGES FOR 1 - 5 FLOORS	₹ 9,51,73,742
8.2	FORMWORK LIFTING CHARGES FOR 1 - 5 FLOORS	₹ 16,36,99,355
8.3	MATERIAL AND LIFTING CHARGES FOR 6 - 75 FLOORS	₹ 1,91,63,48,748
8.4	FORMWORK LIFTING CHARGES FOR 6 - 75 FLOORS	₹ 16,48,06,514
9	(R.C.C COST + ADVANCED FORMWORK + LIFTING) TOTAL	₹ 2,34,00,28,360

Table 7 -: Aluminum formwork and safety net cost.

9.5 BASELINE COST DIFFERENCE FOR 1 FLOOR

The increase percentage is 164 % higher than the aluminum formwork when compared with advanced formwork system

Sl.No	Description	Aluminium form work	Advanced formwork	Cost Increase
1	Staircase and lift core	₹ 87,53,726	₹ 7,56,09,253	₹ 6,68,55,528
2	Interior and exterior wall	₹ 4,46,75,685	₹ 6,63,54,460	₹ 2,16,78,775
3	Roof slab and balconies	₹ 1,52,52,307	₹ 2,23,74,618	₹ 71,22,310
4	safety	₹ 4,44,036	₹ 1,83,95,764	₹ 1,79,51,728
5	total	₹ 6,91,25,754	₹ 18,27,34,095	₹ 11,36,08,341

Table 8 -: Baseline Cost difference for 1 floor (R.C.C and Formwork)

9.6 TOTAL COST DIFFERENCE

The increase percentage is 10.7945 % higher than the aluminium form work in case we use the combination of Hi-end advanced formwork system and protection screen.

Sl.No	FORMWORK TYPE	COST
1	ALUMINIUM FORMWORK	Approx...₹ 2,11 Cr
2	ADVANCED FORMWORK	Approx...₹ 2,34 Cr
3	INCREASE	₹ 22,79,85,057

Table 9 -: Total cost difference or (R.C.C, Formwork and lifting charges)

9.7. CONSTRUCTION SCHEDULE ALUMINUM FORMWORK (12 DAYS / FLOOR CYCLE)

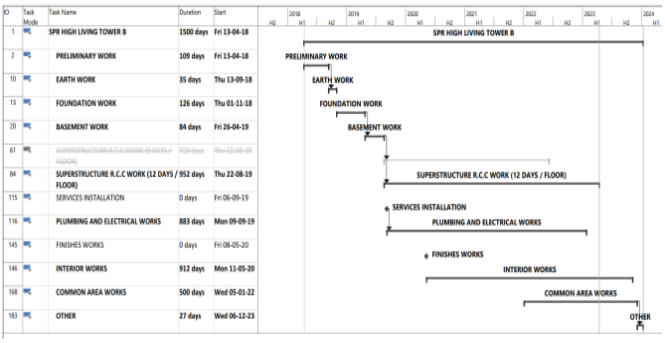

Figure -2: Schedule for Aluminum formwork (12 days / floor cycle)

9.8 CONSTRUCTION SCHEDULE ADVANCED FORMWORK (9 DAYS / FLOOR CYCLE)

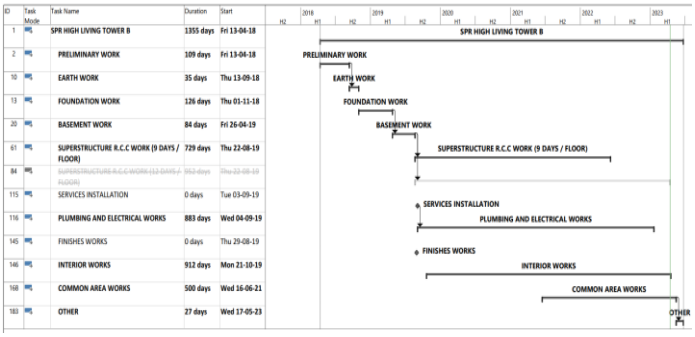

Figure -3: Schedule for Advanced formwork (9 days / floor cycle)

9.9. TIME DIFFERENCE

The duration difference is around 7 months in super structure construction.

SUPERSTRUCTURE				
SL.NO	FORMWORK TYPE	DAYS	MONTHS	YEAR
1	ALUMINIUM FORMWORK	952	32	2.6
2	ADVANCED FORMWORK	729	24	2.0
3	DURATION DIFFERENCE	223	7	0.6

Table 10 -: Duration difference

9.10. COMPARISON TABLE

SI.NO	DESCRIPTION	ALUMINIUM FORMWORK	ADVANCED FORMWORK
1	Construction cycle	12 days	9 days
2	Formwork combination	Wall and slab- S type - monolithic Aluminum Formwork Protection – nylon Safety net	Wall – RCS (Rail Climbing Formwork) Slab – Advanced form work Protection - protection screen
3	Dimensional variations	Nil	Nil
4	Finish quality	Finishing Lines will be visible	High Quality finish
5	Initial investments	High	Very high
6	No. of labors	High Nos required	High Nos required
7	Skilled Labor	Skilled/unskilled	Highly Skilled/unskilled
8	Tower crane	Not required	Required for installing and dismantling
9	Safety during execution	Moderate safety	Very safe
10	Waste production	medium	Zero
11	Complexity of tools	Available on demand	Training & proper monitoring required
12	Repetitions	200-250 times	120 times
13	Scrap Value	30%	40 – 50 %
14	Repair cost	repair is impossible after the deformation	Can be repaired (30-35 % of the total cost)

Table 9 -: Comparative table (Aluminum formwork & advanced formwork)

10. FINDINGS

The cost differences is 10.7945 % higher by using combination of advanced form work system and protection screens compared to MIVAN form work system. The duration of construction is also affected significantly in the superstructure by saving 7 months. The self-climbing formwork is only suitable for sites and cities with limited space constraints and for site where the safety and quality is the highest priority however cost is compromised. Self-climbing formwork is also suitable for projects where the speed, safety and quality of construction is the first priority.

11. CONCLUSION

From the study it is clear from the study that the self-climbing formwork is expensive but by proper planning and using the self-climbing form work with other economical form works cost can be significantly reduced. From this study we could get an overall understanding of the self-climbing formwork used in various high-rise construction projects in India. This proposal study is done for exploring the possibility of incorporating self-climbing formwork in Chennai. It shows how the self-climbing formwork even though expensive can save time considerably with good quality and safety aspects. Self-climbing formwork can be ideal for densely populated locations there is space constrains.

12. RECOMMENDATIONS

Proper Planning and designing is crucial for cutting cost by using advanced formwork system the Formwork cost is usually high for walls and spaces which has shorter length and distance between each other. Advanced formwork system is very efficient for Hi- End residential studio apartments or commercial skyscraper projects with more number of cores and for tall rapid construction projects. By using combination of self-climbing formwork for core and aluminum formwork for walls and slabs instead of panel formwork system cost can be efficiently reduced. Self-climbing formwork can help in fast paced construction projects. Since it has shorter construction cycle.

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