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SCHEDULING OF ALUMINUM FORM WORK USING EARNED VALUE MANAGEMENT

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Abstract: In the construction industry, the efficient management of formwork systems is crucial for project success, particularly in high-rise building projects where aluminum formwork is widely used due to its durability, precision, and reusability. Scheduling the activities and usage of aluminum formwork systems poses unique challenges, including the coordination of formwork assembly and disassembly, integration with other construction activities, and management of material logistics. Earned Value Management (EVM) is a project management technique that integrates scope, schedule, and cost variables to assess project performance and progress comprehensively. This paper explores the application of EVM in scheduling aluminum formwork within construction projects, aiming to enhance efficiency, reduce delays, and optimize resource utilization.

Index Terms **- Aluminum formwork, Cost Variances, Earned value management, Project Management, Project Scheduling.**

I. INTRODUCTION

In the dynamic field of construction, the effective management of formwork systems is crucial, particularly in high-rise building projects. Aluminum formwork has emerged as a preferred choice due to its durability, precision, and reusability, which significantly enhance construction efficiency and quality. However, the scheduling of aluminum formwork presents unique challenges, such as coordinating assembly and disassembly, synchronizing with other construction activities.

EVM is a project management technique that quantifies project performance and progress. By calculating key metrics such as Planned Value (PV), Actual Cost (AC), and Earned Value (EV), EVM allows project managers to assess how much work has been accomplished relative to the planned schedule and budget. This method not only aids in tracking progress but also in predicting future performance trends and making decisions.

By integrating EVM into the scheduling of aluminum formwork, construction projects can achieve higher levels of control and precision. This approach not only ensures timely and cost-effective project delivery but also contributes to the broader goal of advancing project management practices in the construction industry.

II. AIM

The aim of this project is to develop an optimized resource scheduling framework for aluminum formwork construction projects. It also aims to demonstrate that integrating EVM into the scheduling of aluminum formwork can significantly enhance project management practices, leading to more successful project outcomes in the construction industry.

III. OBJECTIVES

- Analysis of aluminium formwork Construction.
- Development of on-site scheduling Framework.
- Evaluation of Performance through Earned value management.

IV. ALUMINUM FORMWORK

4.1 General

Formwork refers to the temporary or permanent molds into which concrete is poured to shape the material until it hardens and achieves sufficient strength. It is an essential component in construction in the creation of concrete structures and plays a critical role in ensuring the quality, safety, and efficiency of the construction process.

4.2 History

Aluminum formwork system has been developed by one of the construction company from Europe in the year 1990. As aluminum formwork systems evolved, construction techniques were refined to maximize efficiency and productivity. Engineers and contractors developed standardized procedures for assembly, pouring, and dismantling of formwork, leading to faster construction cycles.

The Company named "MIVAN" from Malaysia first started the manufacturing of such formwork systems. The use of this technology has motivated and empowered the mass construction projects throughout the world. Aluminum formwork provides speed, quality, simplicity and construction which are required for a successful completion of any mass housing project.

4.3. Features of aluminum formwork

Light weight - Aluminum formwork does not depend upon heavy lifting equipment and can be handled by unskilled labour.
Faster construction – It has a seven-day cycle of casting the floor together with all slabs
Simplicity – The forms are simple and no skilled labour required. The stairs also form in place.
Qualitative construction - Concrete surface finishes are good to receive painting directly without plaster.
High Repetitions - Components are durable and can be used more than 250 times without sacrificing the quality or correctness of dimensions and surface
Monolithic – It means the whole structure along with the slab is casted at a single pour.
Economical – The initial cost is high, but considering the repetitions and simplicity it proves to be economical. 20 to 30 percent cost of formwork can be recovered as scrap value.

4.4 Formwork components

Following are the components that are used in the construction of aluminum formwork

1. Wall Components
2. Deck Components
3. Other Components

Wall Components:
Wall Panel – These are the mould for the walls.
Rocker-It is a supporting component of wall.
Kicker-It forms the wall face at the top of the panels and acts as a ledger.
Stub pin and wedge-It helps in joining two wall panels. It helps in joining two joints.
Deck Components:
Deck Panel: It forms the horizontal surface for casting of slabs.
Deck Prop-Support's deck.
Deck Mid–Beam: It supports the middle portion of the beam.
Soffit Length: It provides support to the edge of the deck panels at their perimeter of the room.
Deck Beam Bar -It is the deck for the beam. This component supports the deck and beam.
Other Components:
Internal Soffit Corner: - It is the vertical internal corner between the walls and the beams, slabs, and also the horizontal internal cornice between the walls and the beam slabs and the beam soffit
External Soffit Corner: It is the external corner between the components
External Corner: - It is the external corner of the formwork system
Internal Corner: It connects two pieces of vertical formwork pieces at their exterior intersections
Beam bottom slab panel: it forms the beam bottom of the formwork system.

4.5 Advantages of Aluminum Formwork

- Increased durability.
- The box type structure provides more seismic resistance.
- Higher carpet area
- Smooth finish of aluminium can be seen on walls.
- Uniform quality of construction
- Maintenance is negligible.
- Due to light weight of forms faster construction speed is achieved.
- Less labour is required for carrying formworks.

4.6 Disadvantages of Aluminum Formwork

- Finishing lines are seen on the concrete surfaces.
- It requires proper planning to be cost effective.
- Modifications are not possible as all members are cast in RCC.
- Maintenance and repairs of Concealed services become difficult.

V. EARNED VALUE MANAGEMENT

Earned Value Management (EVM) is a project management methodology that integrates scope, schedule, and cost variables to provide a comprehensive view of project performance. EVM helps project managers assess project progress and performance in a quantifiable manner, enabling decision-making and effective control over project execution.

5.1 Variance:

5.1.1 Direct labour cost variance: This is difference between the standard labour & the actual labour cost for performing the same output.

Direct labour cost variance = Standard labour cost – Actual labour cost

5.1.2 Cost variances: Cost variance is computed by comparing actual performances with budgeted cost of work performed.

Cost of variance = BCWP – ACWP.

- If the cost variance is positive (+ve) then the project has a cost under run i.e. the cost incurred is less than the planned or budget cost.

- If the cost variance is negative (-ve) then there is a cost overrun i.e. the cost incurred is more than the planned or budget cost.
- If the cost variance is 0 then the project is proceeding according to the budgeted cost.

Cost overrun (or under run) = (BCWP – ACWP)/BCWP x 100

5.1.3 Schedule variances: It is computed by comparing budget cost of work perform (BCWP) with the budget cost of work schedule (BCWS)

Schedule variance = BCWP – ACWP.

- If schedule variance is positive (+ve) then the project is ahead of its planned cost i.e. earned value of the work performed is higher than the planned or schedule earned value.
- If schedule variance is negative (-ve) then the project is ahead of its planned cost i.e. earned value of the work performed is less than the planned or schedule earned value
- If schedule variance is 0 then project is proceeding according to the planned schedule. Time overrun & time under run are usually express in term of units of time say month.

VI. METHODOLOGY FOLLOWED IN THE PROJECT

Steps to be followed are as follows -

1. Appropriate Site Selection

2. Collection of Data

3. Analysis of Data in Microsoft Project

4. Preparing of Schedules

5. Creating Reports, Earned value Reports, cost overview reports, milestone reports, cash flow reports.

6. Conclusion

6.1 Aluminum Shuttering 7 days Slab Cycle –

The standard cycle is of 7 days but it may change to 8, 9 or 10+ days according to site conditions, but the activities in it remains same.

Day 1

1. Survey work or marking the grids
2. Form work panel set up work and placing of wall and column reinforcement

Day 2

3. Column and wall panel erection work

Day 3

4. Deck panel work and Internal Checking

Day 4

5. Beam and Slab reinforcement work
6. Leveling work of slab and also external checking

Day 5

7. Electrical conduiting work

Day 6

8. Grid line check and making arrangement for Casting
9. Safety Checking

Day 7

10. Casting

VII. CASE STUDY

- Project Title – K Raheja Vista phase II
- Project Address – Mohamadwadi, Kondhawa, Pune.
- Project Type – Residential Building
- Contractor – Millennium Engineers and Contractors Pvt Ltd.
- MEP Services Contractors – Ram Chaubey
- Architect – A. Arora architects
- Start date of project – 11th December 2023
- End Date of Project – 20th September 2024
- Site Photographs
- The project schedule has been forecasted purely on the basis assumptions of built up area considering as G+7 structure
- It is purely assumed that the project has a total built up area of 500m²/floor. (1 pour area)
- That is 4 flats on each floor.
- This project includes major summary tasks like Concreting, Mechanical - Electrification - Plumbing (MEP), Plaster (Gypsum) 5mm thick coat, Aluminum formwork, etc.

7.1 Calculations:

Table No. 7.1 Quantity and cost for b/up area of 500 Sq.m

Quantity and cost for b/up area of 500 Sq.m						
Sr No.	Item	Approximate quantity PER b/up area		Total	Rate	Amount
		sq.m	unit	qty	Rs.	Rs.
1	Excavation	0.31	cum	155	650	100750
2	RCC for footing	0.046	cum	23	7801	179423
3	RCC for column	0.29	cum	145	14150	2051750
4	RCC for slab and beam	0.7	sqm	350	13000	4550000
5	Gypsum plaster	0.9	sqm	450	387.36	174312
6	External cement plaster	3.2	sqm	1600	236.72	378752

Quantity and cost of excavation, Rcc work for footing, column, slab, beam, gypsum plaster and external cement plaster is as shown in table 7.1

Table No. 7.2 Quantity and cost of concreting for 1st to 7th floor

Quantity and cost of concreting for 1st to 7th floor							
Floor	Item	Approx. qty per b/up area	Surface Area	Height	Volume	Rate	Amount
		sq.m	In sq.m	In Meter	In Cum.	Rs./cum.	Rs.
1	Wall	0.17	85	3	255		
2	Slab	0.7	350	0.15	52.5		
				Total	307.5	6208	19,08,960
				Grand total for 7 floors	**2152.5**	**Rs.1,33,62,720/-**	

In table 7.2, Quantity of concreting for walls and slabs for all floors in total are 2152.5 cum. And rate of concreting is Rs.6208/- per cu.m. Hence, cost of concreting for all floors works out to be Rs. 1,33,62,720/-

Table no. 7.3 Quantity and cost of steel required for parking

Quantity and cost of steel required for parking				
Sr No.	Item	Total (Kg)	Rate in Rs	Amount in Rs.
1	FOOTING	275	70	19,250
2	COLUMN	2400	70	1,68,000
3	BEAM	3500	70	2,45,000
4	SLAB	3750	70	2,62,500
			Total	6,94,750

In table 7.3, Quantity and costing of steel required for parking footing is 275kg, for column is 2400kg, beams is 3500kg, and for slab is 3750kg. Cost of steel is taken as Rs. 70/-kg and total is Rs. 6,94,750/-

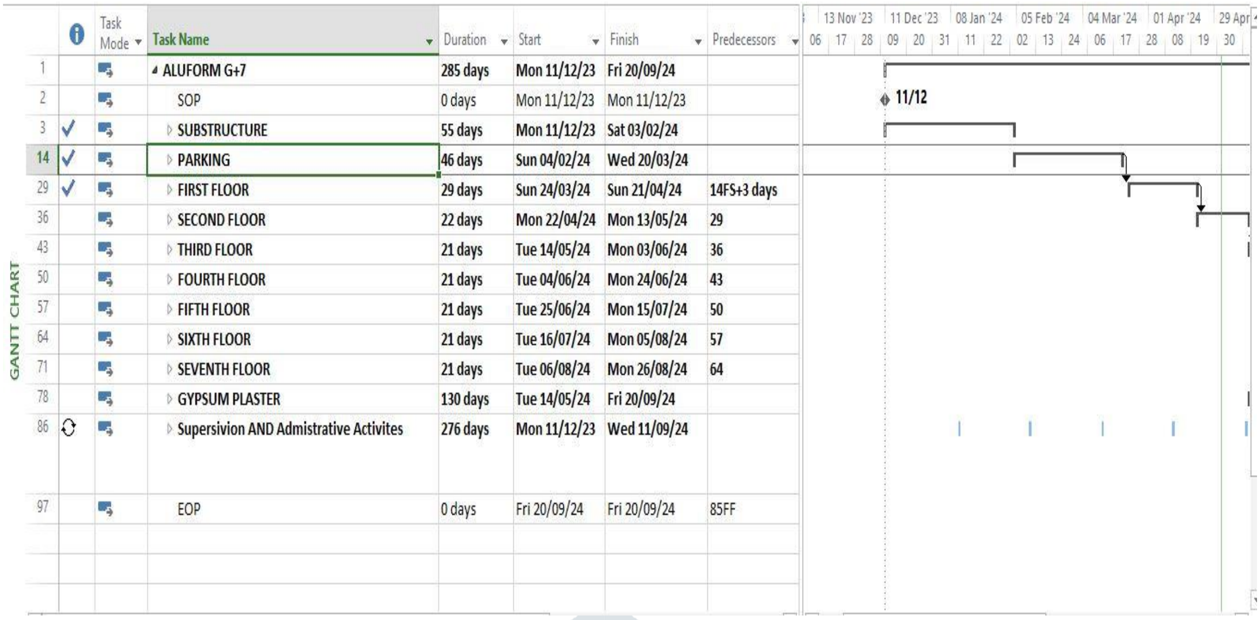
Table no. 7.4 Quantity and cost of aluform work for all floors

Quantity and cost of aluform work for all floors				
Sr No.	Item	Quantity (sqm.)	Rate in Rs.	Total in Rs.
1	Wall	1803	12000	2,16,36,000
2	Slab	500	12000	60,00,000
Grand Total		2303	12000	2,76,36,000

Quantity of slab and walls is worked out to be 500 and 1803 sqm. And rate considered is Rs. 12,000/-per sqm. Hence, cost works out to be Rs. 2, 76, 36, 000/-

VIII. RESULT, DISCUSSION AND MSP INPUTS

Using Microsoft project and on site data received Project Schedules has been prepared and tracked according to the on-site going activities. "**Figure 8.1**" shows the project schedule as in the start and end date of project, duration of project, activities in each task and also resources assigned.



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		ALUFORM G+7	285 days	Mon 11/12/23	Fri 20/09/24	
2		SOP	0 days	Mon 11/12/23	Mon 11/12/23	
3	✓	SUBSTRUCTURE	55 days	Mon 11/12/23	Sat 03/02/24	
14	✓	PARKING	46 days	Sun 04/02/24	Wed 20/03/24	
29	✓	FIRST FLOOR	29 days	Sun 24/03/24	Sun 21/04/24	14FS+3 days
36		SECOND FLOOR	22 days	Mon 22/04/24	Mon 13/05/24	29
43		THIRD FLOOR	21 days	Tue 14/05/24	Mon 03/06/24	36
50		FOURTH FLOOR	21 days	Tue 04/06/24	Mon 24/06/24	43
57		FIFTH FLOOR	21 days	Tue 25/06/24	Mon 15/07/24	50
64		SIXTH FLOOR	21 days	Tue 16/07/24	Mon 05/08/24	57
71		SEVENTH FLOOR	21 days	Tue 06/08/24	Mon 26/08/24	64
78		GYPSUM PLASTER	130 days	Tue 14/05/24	Fri 20/09/24	
86		Supersivion AND Admistrative Activites	276 days	Mon 11/12/23	Wed 11/09/24	
97		EOP	0 days	Fri 20/09/24	Fri 20/09/24	85FF

Figure 8.1 Project schedule

"**Figure 8.2**" shows the project schedule tracking Gantt chart. In this the completed activities are reflected with blue color showing the percentage as how much it is completed and grey color indicates the baseline for it.

Figure 8.2 Project tracking Gantt chart

Earned value reports shows the Actual cost work progress (ACWP)in blue color, scheduled cost work progress (SCWP), Budget cost work schedule (BCWS) and Actual cost work schedule (ACWS) in "**Fig.8.3"**

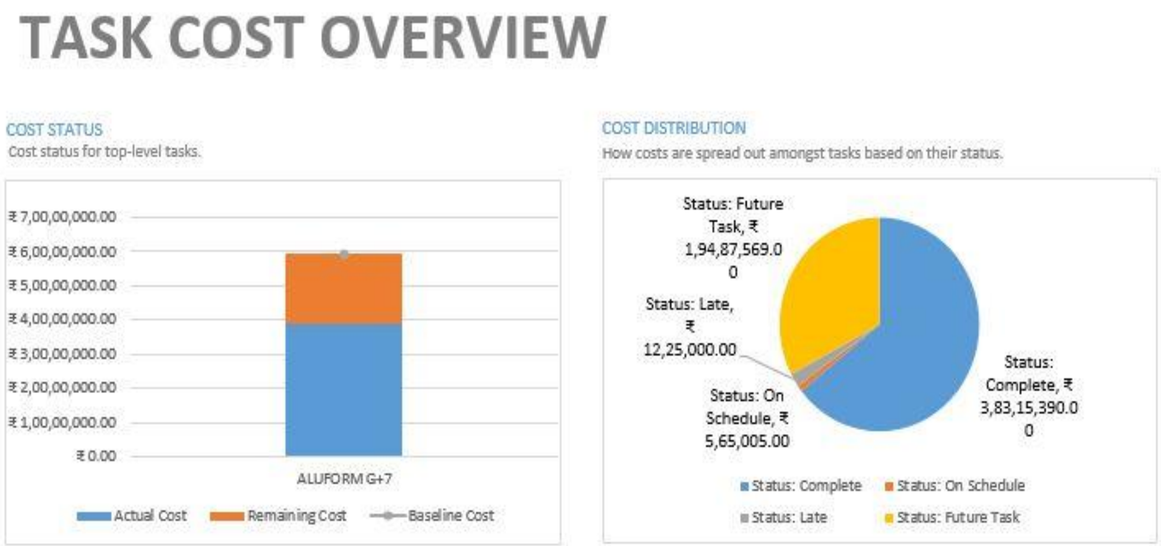
Cost variance (CV) = BCWP – BCWS. The EAC (Estimate at completion) is Rs. 5, 95, 92,964/-, ACWP as Rs. 2,50,000/

GANTT CHART

	Task Name	Planned Value - PV (BCWS)	Earned Value - EV (BCWP)	AC (ACWP)	SV	CV	EAC	BAC	VAC	Ad
1	ALUFORM G+7	₹1,225,000.00	₹0.00	₹250,000.00	-₹1,225,000.00	-₹250,000.00	₹59,592,964.00	₹59,342,964.00	-₹250,000.00	
2	SOP	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
3	SUBSTRUCTURE	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹299,423.00	₹299,423.00	₹0.00	
4	LINE OUT	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
5	EXCAVATION	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹100,750.00	₹100,750.00	₹0.00	
6	PCC	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
7	FOUNDATION	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹198,673.00	₹198,673.00	₹0.00	
8	REINFORCEM	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹19,250.00	₹19,250.00	₹0.00	
9	SHUTTERING	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
10	CONCRETE P(	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹179,423.00	₹179,423.00	₹0.00	
11	DESHUTTERIN	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
12	CURING	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
13	PLINTH	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	
14	PARKING	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹7,656,002.00	₹7,656,002.00	₹0.00	
15	COLUMNS	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹2,219,750.00	₹2,219,750.00	₹0.00	
22	SLAB & BEAM	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹5,057,500.00	₹5,057,500.00	₹0.00	
28	PLASTER	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹378,752.00	₹378,752.00	₹0.00	
29	FIRST FLOOR	₹0.00	₹0.00	₹250,000.00	₹0.00	-₹250,000.00	₹30,359,965.00	₹30,109,965.00	-₹250,000.00	
30	SURVEYING	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	₹0.00	

Figure 8.3 Schedule for cost wise entries showing cost variance

Task cost overview chart reflects the cost status and cost distribution. In which actual cost is indicated in blue color and the remaining cost of project in orange color in bar chart form. The other pie chart shows the cost distribution. It reflects the future task, completed task, on schedule task and also late task. The cost details include the actual cost incurred, the remaining cost, baseline cost and also the variance in cost in "**Fig.8.4**"



COST DETAILS

Cost details for all top-level tasks.

Name	Fixed Cost	Actual Cost	Remaining Cost	Cost	Baseline Cost	Cost Variance
ALUFORM G+7	₹0.00	₹ 38,823,894.50	₹20,769,069.50	₹ 59,592,964 .00	₹59,342,964.00	₹250,000.00

Figure 8.4 Task cost overview

In "**Figure 8.5**" graph shows the activities on horizontal axis and cost incurred on vertical axis. The blue color indicates the baseline cost of that activity, red color indicates the actual cost incurred and green color indicates the variance in cost. It indicates that the activities like foundation, substructure, parking; first floor has been completed. Activities in first floor are also completed with a variance in cost of Rs. 2, 50,000/- which is shown in green color. Second floor is 45% complete.

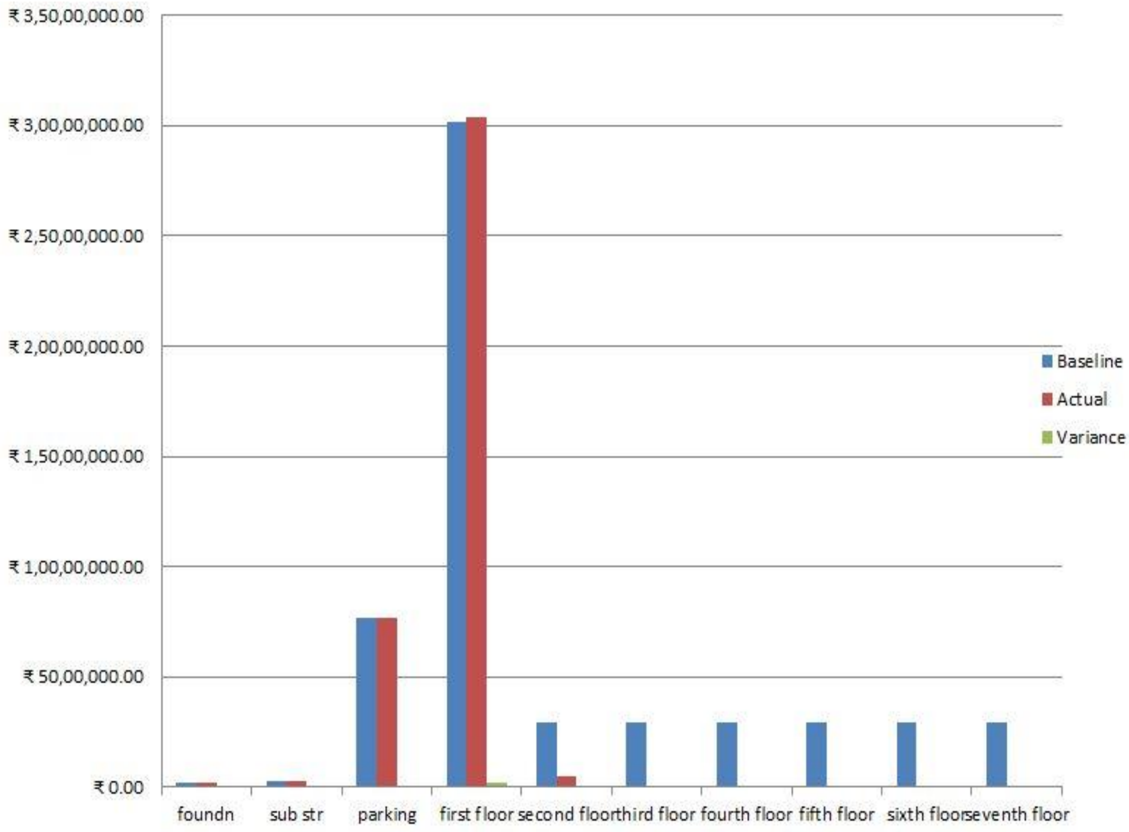


Figure 8.5 Percentage completion graph

IX. CONCLUSION

It can be concluded that Scheduling of formwork is a critical aspect of construction management that can significantly impact overall project cost. Effective formwork scheduling involves careful planning and resource allocation to minimize delays and optimize the use of materials and labor.

Construction by aluminum formwork is cost-effective and efficient for mass housing projects. It's expensive but can save time and cost, as finishing works are skipped which includes plastering, painting in high rise building. Casting in one pour gives strength and durability making it seismic resistance. The formwork can be used more than 200 times in turn saving cost of formwork and time of project. Aluminum formwork can deliver high quality construction at reasonable cost and with speedy construction.

The integration of Earned Value Management (EVM) into the scheduling of aluminum formwork in construction projects offers significant advantages in terms of project control and efficiency. By applying EVM principles, project managers can gain a comprehensive view of project performance, encompassing scope, schedule, and cost dimensions. This approach enables better decision-making, proactive management, and improved resource utilization, ultimately leading to more successful project outcomes.

Efficient scheduling allows for better cash flow management by ensuring that expenditures on formwork materials and labor are spread out in a planned manner. This can improve the overall financial health of the project.

X. ACKNOWLEDGMENT

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