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The Case Study of Application of Tunnel Formwork for High-rise Building Project

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Abstract: The construction business is become increasingly time-conscious these days. These days, the construction industry places a great deal of importance on time—that is, the project's duration or completion date. Time loss eventually equates to financial loss, hence the adage "Time is money" is coming to pass. Additionally, given the extremely low labour availability of today, industry should shift from being labour-oriented to being machine-oriented. The ideal element where we can switch from labour to machinery is formwork. Formwork is essential to building, both financially and in terms of time. Formwork alone accounts for around 25% of the project's overall cost. We are aware of the difficulties and waste involved with building with traditional formwork systems.

A lot of repetitive tasks are involved in the construction of high-rise buildings, which also have identical floors. Construction costs are significantly impacted by the lengthening of the construction process. Choosing the most effective formwork method will save the most money. 20–25% of the project's overall cost is made up of formwork. With a shorter slab cycle time, the adoption of an improved formwork system helps to save costs. This study compares the aluminium formwork used in the construction of high-rise buildings with the tunnel formwork method. Nothing more than a box-sized steel fabrication, the tunnel shape enables monolithic casting of the structure—that is, the casting of RCC walls and slabs in a single, continuous pour. Hot air blowers that are attached to the formwork system speed up the setting of the concrete

Key Word: - Aluminium Formwork, Tunnel Formwork, Cost Saving, time saving

1. INTRODUCTION

1.1 Explain tunnel Formwork

A single operation can be used to cast both the wall and the slab using a tunnel form, which is a box-sized steel manufactured form. Concrete for walls and slabs can be continuously poured after the reinforcing is in place. The concrete sets more quickly when hot air blowers are deployed, allowing for a 24-hour slab cycle in which

one slab is completed in a single day. It is possible to pour a floor area of 300,400 m^2 every day. Depending on the style of construction, a workforce of 10 workers can cast 12 apartments in a single day. A ten-story structure can be finished in a maximum of 2030 days. The overall weight of a low-rise building, such as one with five stories, can be planned to be 1.10–1.20 tons/m2 less than it would be with a standard method of 1.30 tons/m2. employing precast elements is crucial when employing tunnel formwork since it increases production in a short amount of time, saving both money and time. For projects like apartment buildings, hotels, dorms, jails, and other large-scale symmetrical construction projects, it works especially well for repeating cellular construction. Because tunnel form construction takes less time, it is also utilized in many home developments, particularly those that are earthquake resistant. Custom engineered formwork known as tunnel formwork has replaced traditional steel/plywood shuttering systems. It is a cellular structure's mechanized system. Its foundation consists of two half-shells together to create a room or cell. An apartment is made of multiple cells. Walls and slabs can be cast in a single day using tunnel forms. There are phases to the structure. A portion of the structure will be cast in a single day for each phase. The program and the total floor area that can be poured in a single day dictate the phasing. In the morning, the formwork is prepared for the day's pour. In the afternoon, concrete is poured after the reinforcement and utilities are installed. Concrete for walls and slabs must be poured in a single operation once the reinforcement is installed. The following day, early in the morning, the formwork is removed and set up for the ensuing stages. The following operations make up the on-site 24-hour cycle implementation.

•Removal of the prior day's formwork.

•Formwork placement for the current phase, which includes plumbing, electrical, and mechanical service installation.
Putting in reinforcement in the slabs and walls.

• The heating apparatus and, if required, the concrete. The following components of the system are easy to build and arrange, thanks to their thoughtful design and development:

• An extensive selection of standard-sized components

• All necessary equipment for stability, circulation, and safety is included in basic standard equipment.
• Opposing calliper-device Wall form kits are moved by crane in a single lift.

1.2 Why is Tunnel Formwork is Important?

Formwork is a makeshift framework used to hold up newly mixed concrete until it is strong enough to support its own weight. The formwork is removed once the concrete has set, creating a solid structure that is the desired size and shape. This is a crucial component used in building construction. In the construction industry, using traditional formwork—that is, wooden formwork—was standard procedure for many years. Although the construction industry is in a very different place now, research is still necessary to select the best formwork from a variety of angles. The two most important factors are time and cost, but we also need to pay attention to quality, safety, and the amount of construction waste that is produced. Low waste formwork technologies are used in building these days. Shear/RCC walls, which are thin walls, are gradually replacing the massive columns used in buildings. Thus, it provides a sizable carpet area and eliminates offsets within the structure. Additionally, the level of construction quality is improving. There are already a lot of formwork options on the market, but research is necessary to determine which formwork is ideal for a given kind of structure. High-rise or multi-story structures have become the norm due to population growth and spatial constraints. We must concentrate on elements that give concrete strength in order to make these constructions sound, and formwork is crucial in this regard. Formwork is a makeshift construction, similar to a die or mold, that is used to hold concrete as it is being poured, giving it the proper shape, and providing support until the concrete is strong enough to sustain itself. Aside from its own weight, formwork must be able to support all imposed dead and living loads. The first known instance of a concrete mold is found in the Pantheon, a cathedral that was formerly a Roman temple.

To produce a high-quality concrete finish, formwork needs to be carefully planned, manufactured, and installed. Concrete will not take on the appropriate shape or strength if this is not done correctly. One of the newest formwork methods to reach the Indian building sector is advanced tunnel formwork. It is determined that under Indian conditions, it is appropriate for mass construction. It provides both quality and speed at a pace faster than that of the majority of formwork technologies. When labour is combined with large machinery, such as tower cranes, building can be completed more quickly while maintaining durability and quality control. This lowers the structure's overall time and expense. This essay primarily focuses on sophisticated tunnel formwork systems, including their parts, operating cycle, cost, advantages, and speed and economy-related limits.

2. OBJECTIVE

1. To comprehend tunnel formwork and how it is used.

2. To contrast the traditional formwork method with cost analysis.

3) A discussion and recommendation regarding the efficient use of tunnel formwork for tall buildings.

3. LITRATURE REVIEW

Randolf Miranda, Anand Kodre:- Real estate construction industry has a reputation of not begin very technologically sophisticated, generally lagging in innovation, construction techniques & management. But now a day's lot of research is carried out in this sector, advanced TUNNEL formwork & ALUFORM system are good examples of this innovation. Formwork perform key role in construction. Formwork itself costs around 20-25% of total cost of project. Also it requires minute level planning to achieve quality and economy. Advanced TUNNEL formwork system and ALUFORM system (Similar to MIVAN technology) are used to construct monolithic structures in which slab, beam & walls are casted at one time which acts as RCC load bearing structure. This paper aimed at studying advanced tunnel formwork system in high rise building, to compare this system with Aluform system and to find best formwork in terms of economy and rapid construction.

Bhagirathi Singh Dr. Pankaj Singh:-

Winds of change are blowing across every industry in India but the construction industry is still reluctant to utilize the advanced techniques that can enhance the productivity and efficiency of the construction industry. In recent years construction industry is witnessing increased demand in multistorey construction and repetitive modular structures are becoming an integral part of it. These structures require detailed planning in order to save cost and time. As formwork accounts for about 25 40% of the total project cost and almost 60% of the time in concrete construction, we need to pay attention to the development in formwork techniques and replace conventional formwork with new formwork techniques like tunnel formwork. This paper aims at focusing on the benefits and limitations of tunnel formwork in contrast to conventional formwork thus changing the mindset of local construction industries that are still dependent on conventional formwork techniques.

Deepak Mehra, Dr. Pankaj Singh and Ravindra Gautam,:-

To address the housing and transportation requirements of an exponentially increasing population, Indian construction industry has grown by leaps and bounds. Thus with the globalization of Indian economy & introduction of multinational companies in India for construction activities, it has become imperative to have precise & speedy construction projects. Conventional construction methods are not able to cope with the demand of infrastructural facilities with high degree of quality control & assurance. No doubt, conventional methods prove to be economical, but they fail in providing required number of dwellings in time; hence latest construction technologies by applying fast-track construction is the only remedy left to address this issue. Formwork is an important part of construction and it takes 25-30 % of total cost of construction. Thus with the use of new technologies in formwork, construction permits casting of larger elements in a single pour, which reduces time and labour requirement as compared to conventional methods. Thus, the various new systems have promised to achieve overall economy with faster as well as high quality construction. In this paper, an attempt is made to have a comparative study of established conventional formwork technology with a set of new formwork

techniques, which are currently not used much in Indian construction industry; and hence suggest which method is superior for the construction project under consideration.

Kalbhor Shailesh S, Dr. A. C. Attar :- The high rise building construction consist of number of repetitive activities and also have same identical floors. The increase in duration of construction greatly affects the construction cost. Selection of best formwork system gives best result in cost saving. Formwork consist of 20-25% of total

cost of project. So that used advanced formwork system helps in cost saving as reduction slab cycle time. This study is done for comparative analysis of tunnel formwork system and aluminium formwork used for high rise building construction.

4) CONCEPT AND METHODOLOGY

4.1 The Tunnel Form's Life Cycle

The total structure is divided into a number of roughly identical construction phases and sizes correspond to daily labor to cast concrete in order to optimize the volume of formwork, equipment, and workforce. Reinforcement mesh is used instead of regular steel bars to save time. Formwork for the wall is positioned using kickers, and the wall and slab reinforcement are laid. A crane lifts the two half tunnels that are fastened together to form a single tunnel to the intended place. There are more ties. In order to promote early concrete settling, hot air blowers are installed after the concrete is poured. Thus, the tunnel forms are removed the following day after the concrete reaches striking strength overnight. To be reused, the tunnel forms are cleaned and oiled.

Fig no 3: Working Cycle

4.2 Movement of Forms

The crane may raise the forms using some chains or cable. The load in the lifting rings and chains increases with increasing chain angle. Never allow the chains to form an angle greater than 60º.

4.3 Propping of the Slabs

Even if the setting of concrete is hastened (by heating and/or utilizing the accelerator), the concrete has little time to dry when employing tunnel forms in a 24-hour cycle. Therefore, in order to avoid deflection, some props must be placed as soon as the first tunnel is removed. The concrete strength, the structure's architecture, and the loads placed on the structure determine the location and quantity of props. Usually, one prop is enough for a typical width of tunnel every two meters.

4.4 The major components in Tunnel formwork are as follows:

1) The partial tunnel. When two half tunnels are bolted together, they produce a single unit that functions as a tunnel.

2) The two half tunnels are joined at the back panel to form a single, complete tunnel.

3) Outside Wallform is utilized for platform lifting arrangements as well as formwork arrangement for the end wall.

4) Tunnel panels are moved by means of lifting beams.

5) Tunnel panels are lifted using a lifting device.

6) Roller for tunnel form movement.

7) Kicker Form stabilizes the form and stops cement slurry leaks.

8) Slab Stopend is a marker marking the slab's end.

9) Slab Boxouts are conduit apertures in slabs.

10) A door aperture is called a door boxout.

11) A window opening is called a window boxout.

12) Stripping Platform for simple tunnel form removal following concrete

13. Gable End Frame: This structure serves as a platform for workers to walk about.

14) In order to provide lateral support for the concrete to be poured and to hold the form in place, tie rods and cone sets are driven in before concrete is poured.

15. Tunnel forms are moved from one floor to another using cranes and lifting apparatus.

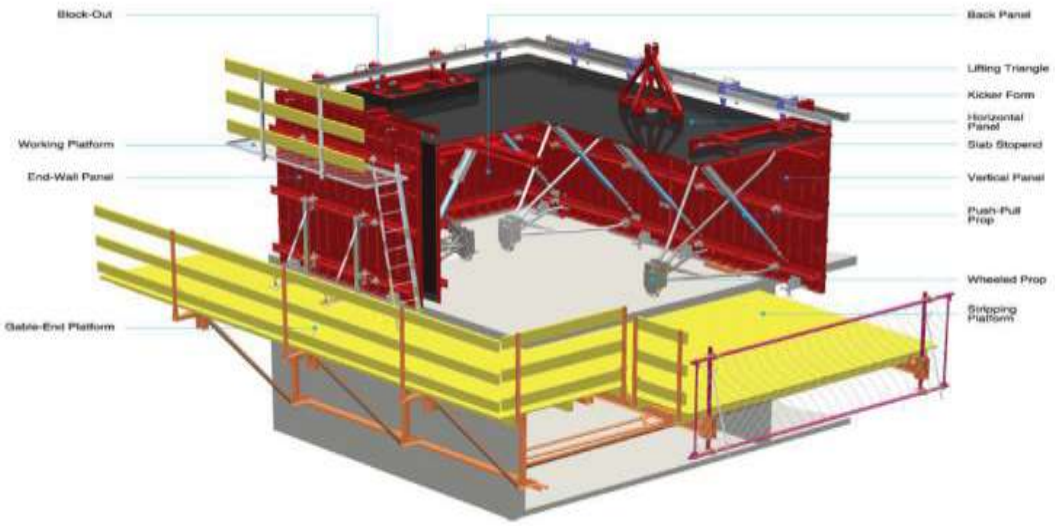

Fig no 2: Components of tunnel formwork

4.5 Consideration of Cost Involvement in Tunnel Form

It goes without saying that the cost of building will increase with the number of floors for all structural systems. Previous research on tunnel formwork has demonstrated that when the number of storeys grows, the unit cost per apartment reduces in buildings with the same wall thickness. The initial cost, the cost of materials or assembly, the cost of reuse, the cost of machinery and operations, and the daily labour expense are the factors that affect cost. Although tunnel formwork has a relatively high initial cost, it is ultimately cost-effective due to its reduced life cycle and potential for form reuse. Reusability lowers the cost of materials, assembly, and erection.

The expense of the finishing procedure is decreased because of the superior finish. Formwork oil (1 litre for 2045 m2 of formwork) is applied on a regular basis to preserve the longevity of the formwork; as such, it is an inexpensive maintenance expense. Crane costs and operating expenses are included in the cost of machinery. Because the task is repetitious and requires specialized labour, the overall building period is shortened, which significantly lowers the daily labour and supervision costs.

4.6 Role of Management

When using tunnel formwork for concreting, coordination is crucial. Design and quality issues are always impacted by financial and scheduling limitations. Management enters the picture in order to achieve design conformance, optimal quality, and cost and time savings.

1) The duty of educating the workers to guarantee efficient performance.

2) Structures should be designed such that the most amount of tunnel may be completed with the assistance of a single tower crane position. To cut down on idle time and transportation time, the crane, precast workshop,

material storage, etc., should be positioned strategically.

3) Thorough planning is necessary. Before the project starts, all of the actions must be scheduled. This will shorten the latency. The ability to anticipate and carry out interdependent tasks in a sequential manner facilitates the provision of space for facilities and ducts.

4) Alternatives should be chosen in advance since tunnels confront more obstacles, particularly when there are very short and very big slab spans. This will facilitate quick building.

5) The entire perimeter platform system of the tunnel form system provides the maximum level of jobsite safety; nonetheless, risk management should not be disregarded.

6) Every sector needs to be involved. For tunnel formwork to be completed on schedule, coordination between the designing, execution, and architectural teams is necessary.

5. CASE STUDY

A) Case Study -01

Name of Organisation:- vascon engineers ltd

Project Name:- Praposed Group Housing Kailash Enclave Sector-18 Lucknow,UP

Location :- Sector-18, Vrindavan Yojna ,Lucknow,UP

Project Cost:- 286Cr

Technical Specification:-

1) Plot Area:- 8Acre

2) Built up Area of project:- 130333Sqm

3)Number of Building:- 10 Building (S+8 Floor) + 1 Club House

4)Number of Flat :- Total 2BHK-688 Nos ,3BHK-576 Nos

5)Type of Formwork Used:- Upto Stilt Floor Conventional Formwork above Aluminium formwork

Name of client: - Uttar Pradesh Avas Evam Vikas Parishad,Lucknow

Architectural Consultant: - Civil Consultant,Lucnkow

Structural Consultant: - Vastech Consultants Pvt ltd,Pune

B) Case Study -02

Name of Organisation:- Rohan Builders Pvt ltd

Project Name:- Rohan Abhilasha Housing Project , Wagholi, Pune

Location :- Lohegaon, Wagholi Rd, Wagholi, Pune, Maharashtra 412207

Technical Specification:-

Plot Area:- 23 Acre

2) Built up Area of project:- 120799 Sqm

3)Number of Building:- 7 Block (U.B+L.B+12 Floor) , Club House

Total Flat:- 2200Nos

4)Type of Formwork Used:- Type of formwork used:

I. Up to 2nd parking level: Conventional formwork

II. 3rd to 14th floor: Tunnel formwork.

Type of Project: - Real Estate

Architectural Consultant: - Mindspace architects, Bangalore.

Structural Consultant: - JW Consultants, Pune.

Contractor hired for tunnel form:- BUYUK ISKENDER, Ankara, Turkey.

6.DATA COLLECTION

A) Data Collection from Case Study-01

1) Concrete: - to employ retarders as an additive to speed up the concrete's setting time. Self-compacting concrete should be utilized in an aluminium formwork system to allow for the free flow of concrete. To allow for easy concrete flow, keep the slump flow of concrete between 550 and 600 mm.

2) Steel: - All walls in the aluminium formwork system are constructed from RCC members; so, RCC walls are composed of steel mesh or steel bars. A steel wall reinforcement is fixed in accordance with the surveyor's point layout and structural drawing. following the installation of the wall and slab shutter reinforcement.

3) Shuttering: to the stilt slab of flooring Aluminium formwork is utilized above stilt floors, and conventional plywood shuttering is used. The aluminium formwork panels are installed in accordance with the surveyor's arrangement and the formwork drawing. Every Aluminium panel has a number marked to ensure that there are no mix-ups after DE shuttering. Following the formwork repropping at the lower floor's DE shuttering.

4)Plumbing and Electrical Fitting: The plumbing system should be kept slack at the wall and slab in accordance with the MEP drawing. For plumbing pipe fitting, the wooden ribs are fastened to an aluminium panel in accordance with the plumbing drawing. Junction boxes and electrical conduits are fixed in accordance with electrical drawings.

5) Brickwork: There are no brickwork walls in aluminium formwork. simply the plumbing shaft's brick wall.

6) Final Work: After the aluminium formwork is DE shuttered, the wall tie hole is filled with GP-2 cement and the below-floor housekeeping is completed. Once the wall tie hole and tie rod have been filled, door and window

shutters should be fastened. Wall putty or gypsum plaster should then be applied to the wall following wall panel joint grinding.

7) Equipment employed: Tower cranes are used to carry steel and shutter materials for the next floor in order to expedite construction.

8) Manpower: Skilled labour is needed for steel reinforcement and aluminium formwork.

9) Work Speed: Compared to conventional formwork, the work speed will be halved.

KAILASH ENCLAVE QUANTITY SUMMARY SHEET - (ATOWER)			
Sly No	**Description**	**Unit**	**BLOCK**
A	**CONCRETE**		
1	PCC Plinth M10	Cum	487
2	Concrete M25	Cum	2285
3	Concrete M25 SCC	Cum	5920
4	Trimix (M25)	Cum	164
			8856
B	**SHUTTERING**		
1	Ply Shuttering	Sqm	12485
2	Alumunium Shuttering	Sqm	64673
C	**STEEL**		
1	Reinforcement Steel	MT	614
2	115 mm Brick Work	Sqm	200

A-BLOCK AREA STATEMENT			
Sl No	**Description**	**Unit**	**Qty**
1	**Plinth Area**	**Sqm**	**1775.00**
2	**Stilt Floor Area**		
	Total Stilt Area	Sqm	1697.00
3	**Typical Floor Area**		
	One Floor Area	Sqm	1686.00
	Eight Floor Area	Sqm	13488.00
4	**Above Terrace Area**	**Sqm**	**287.00**
	Total Builtup Area	**Sqm**	**17158.00**

B) Data Collection From Case Study-02

CONSTRUCTION PERIOD ANALYSIS FOR SHUTTERING WORKS

The availability of labor and supplies on location determines when the work will be finished on schedule. Here, we just take into account Tower A1, the lone tower in A-Block. Using half of a tunnel form set.

Sr. No	Description	Tunnel form	Conventional formwork
1	1st Slab		14days
2	2nd Slab		14days
3	3rd Slab	7days	
4	4th Slab to 15th slab	48 days 4 days each	

Sr.No	Building Name	Items	Unit	Qty
1	A Building	Steel	MT	550
		Shuttering Mockup	Sqm	1550
		Shuttering Quantity	Sqm	22500
		Concrete	Cum	4500

7. DATA ANALYSIS

Based on the project's objectives, questionnaires were created for data gathering. In order to collect data and conduct a survey using questions, two distinct locations were examined.

Rohan Builders India Pvt Ltd. Is using Tunnel Formwork System and

Vascon Engineers Ltd using aluminium system.

Case study Details

Case Study-01	Case Study -02
Vascon Engineers Ltd	Rohan Builders Pvt. Ltd
Kailash Enclave ,Lucknow,UP	Rohan Abhilasha Wagholi, Pune
Residential	Residential
Aluminum Formwork System	Tunnel Formwork System

A] Data Collected from Interview

From Case study 1 Vascon Engineers Ltd:

Sr.No	Parameters	
1	Cost	
	Initial Invesment	High
2	Avg cost/m2	7500-8000/Sqm

3	Labour Cost/m2	170 Sqm
4	Numbers of repetations	100
5	Cycle time	10days
6	Size of panel	450X2050,600X2050 As per Layout
7	Salvage value	50% of cost
8	Deshuttering time	24hrs
9	Manpower requirments	4labour /day/sqm
10	Durability	High
11	Accuracy	+-5-6mm
12	Curing method	Curing compound

B] Data Collected from Interview

From Case study 2 Rohan Builders Pvt Ltd:

Sr.No	**Parameters**	
1	Cost	
	Initial Invesment	High
	Avg cost/m2	22000/Sqm
	Labour Cost/m2	200/Sqm
2	Numbers of repetations	500
3	Cycle time	3Day
4	DE shuttering time	12hr
5	Manpower requirements	50-65Nos /slab area
6	Accuracy	+- 3mm
7	Durability	High
8	Wastage of material	0%
9	Additional Equipment Requirements	Tower Crane, Boom Placer
10	Curing method	Thermal curing
11	Finishing	Paint Finish

General Comparative statement

Sr.No	Description	Tunnel formwork	Aluminium Formwork
1	1 Initial Investment	High	High
2	Avg cost/m2	22000/Sqm	7500-8000Sqm
3	Labour Cost/m2	200/Sqm	170/Sqm
4	Cost As per Repitation	44/Sqm	80/Sqm
5	No of Repetition	500nos	100nos
6	Cycle Time	3days	10days
7	Size of Pannel	Half Pannel 1 to 6m	450X2050
8	Wight of Pannel	3-4 /Mt	8-8.5 kg/Sqm
9	Deshuttering Time	12hr	24hr
10	Additional Equipment Requirements	Tower Crane , Boom Placer	Staff & Material
11	Manpower Requirement	55-60/Slab	4 Labou/day/Sqm
12	Durability	High	High
13	Percentage of Wastage	0	0
14	Accuracy	+- 3mm	+-5-6mm
15	Curing Method	Thermal Curing	Curing Compound
16	Casting System	Monolithic Structure	Monolithic Structure

Initial Investment

Sr.No	Type	Unit	Rate
1	Tunnel Formwork	Sqmt	22000 Rs
2	Aluminum Formwork	Sqmt	8000 Rs

Cost As per Repitation

Sr.No	Type	Unit	Rate
1	Tunnel Formwork	Sqmt	44 Rs
2	Aluminum Formwork	Sqmt	80 Rs

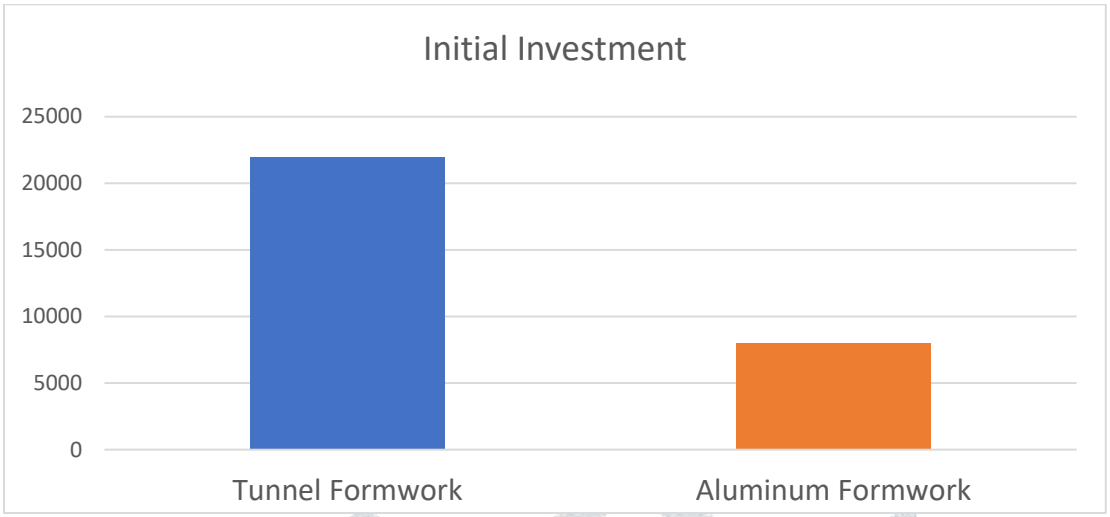

Chart-01 Comparison with initial investment

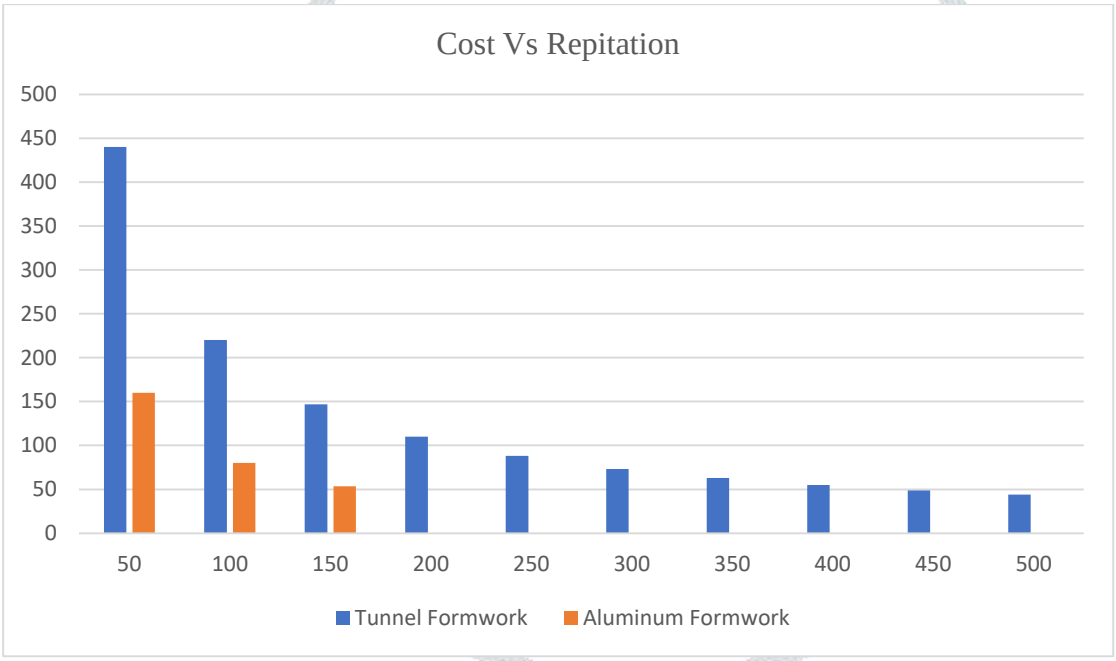

Chart-02 Cost Vs Repitation

8. DISCUSSION & SUGGESTION FOR EFFECTIVE UTILIZATION OF TUNNEL FORMWORK FOR HIGHRISE BUILDING

Economy

The following are the fundamental cost factors for tunnel formwork economy.

1. Cost of material and heavy machinery depreciation

2. The expense of operating machinery.

3. Labor costs per day

4. Costs associated with supervision.

Tunnel formwork becomes more cost-effective in the long run, even though the initial investment in materials and heavy machinery is very high since it reduces slab cycle and increases reuse possibilities for large, multistory buildings. Early returns on investment are possible due to the significantly faster building speed compared to conventional formwork systems and the higher turnover rate in a shorter amount of time. Additionally, low labour and material costs and fewer finishing treatments are needed for objects with high-quality finishes. One of the most important tasks when employing tunnel formwork is installing precast elements. These elements boost productivity and provide an amazing architectural view when they are quickly assembled, saving both time and money.

9.CONCLUSION

The construction sector in India is infamous for its subpar management, bad technology, incorrect building, and delayed project completion. However, a lot of research is done in this field these days; innovative solutions like aluminium formwork systems and sophisticated tunnel formwork are excellent examples. A slab cycle of one day can be achieved with a tunnel formwork system; however, a slab cycle of seven to ten days can be achieved using aluminium formwork. Upon examining these formwork systems, we discovered that the initial expenditure for both systems is greater than that of a conventional formwork system, and that the operational costs of tunnel formwork are higher than those of aluminium formwork.

Compared to aluminium formwork, tunnel formwork has significantly more formwork repetitions—more than 500 compared to 150–200 for aluminium formwork. Tunnel formwork shows to be more time and cost-effective because to the reduction in slab cycle time. Additionally, the quick completion of the project (it was completed in one-third the time compared to the Aluminium Formwork system) resulted in returns on the initial expenditure. Therefore, when looking at things long term, the tunnel formwork system is better than the aluminium formwork system.

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