

Comparative Study And Analysis Between Tunnel Formwork And Conventional Formwork System

Aditya S. Lahare

Post Graduate Student, Construction and Management,
NDMVPKBT COE, Pune, Maharashtra, India

Abstract: India is developing country and it is in the process of going to more interconnected world. Now day's duration, quality and cost are the main factors considered in construction; also as per current situation for more accuracy in work, industry should move from labour oriented to machine oriented. Recently lot of research is carried out in this sector, Tunnel formwork is a latest example of this modernization. Formwork selection is a main part in construction. Around 20-25% of construction cost is invested in formwork. To achieve quality and cost construction planning, material availability, customer requirements, limiting conditions are important. Advanced Tunnel formwork system is a highly systematic, earthquake resistant technique that produces monolithic structure 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 Conventional system and to find best formwork in terms of economy and rapid construction.

Keywords: Tunnel Formwork, Conventional System, Slab Cycle Time, Productivity, Cost.

I. INTRODUCTION

Formwork includes the actual material contact with concrete known as form face and all the necessary associated supporting structure. Formwork should be capable of carrying all dead load and live loads on it. A detail construction planning is pre-requisite element to ensure the project in completing on time, planning and meeting the budget, quality, safe and environmental requirements. A well-organized and modern formwork requires less manpower and keeps costs in control. But substantially the client is a challenge and takes time.

Formwork planning is done as follows

STAGE 1: The necessary information and limiting conditions must be collected and defined. When projects of similar nature are executed, a checklist can be of immense help in obtaining information required to prepare a complete scheme.

STAGE 2: The formwork system to be used can be selected. In addition to cost of the materials, the choice of the system will be influenced by the experience of the planner and of the team, which has to set up the formwork on the site, and

by the project archive. A database / project archive that captures the experience gathered over the years can aid in cost effective system selection.

STAGE 3: This involves all engineering design tasks. This part of the process is most time consuming. It is important to be able to allow for changes arising at later phases of the project. The emphasis should be on maximum reuse of materials available and procuring minimum materials Just-In-Time.

II. OBJECTIVE

Objective of study is to study tunnel formwork systems & after to compare with Conventional system on basis on

- ✓ Alternatives to reduce Slab cycle time
- ✓ Productivity Analysis.
- ✓ Cost Analysis.

And hence to suggest best formwork system for high rise building.

III. FORMWORK

There are various types of formwork used in India. Several systems are adopted at different places in the world; eventually the systems which are reasonably economical and easy for operation with skilled labour are useful in India. Certain systems are in trend and more contractors are trying to bring in new technologies. Following are the types of formwork.

A. CONVENTIONAL FORMWORK

This is the oldest type of formwork used in the construction industry. This type uses timber, bamboo, masonry and carpentry in the construction. This type is very much suitable for small houses with two to three storeys and still they are in use for so many constructions.

B. MODERN CONVENTIONAL FORMWORK

In modern conventional formwork more advanced material is used and they can reuse several times. The differences of both types are that steel props and various types of jacks (U jack, T jack) are used instead of timber supports and ply wood sheets are used instead of timber planks on slab decks. eg. Cast in situ method of construction.

C. SEMI-SYSTEM FORMWORK

This type is much more advanced than the modern conventional type. In this type there are pre-fabricated formwork items such as pre-fabricated formworks for slab panels and supports and ply wood should be used additionally for slab deck, beams and columns for the surface. There are other forms of semi system formwork such as table forms, flying forms etc. DOKA is the most famous brand for this type of formwork and some people know about this type only as "DOKA formwork". These types of formworks can be categorized under the Composite Construction method.

D. MODERN FORMWORK

System formwork has prefabricated modular components with casting panels. The system formwork is fabricated as it suits the required shape. The biggest advantage of this type is the speedy and quality construction. But the high initial cost is the main disadvantage and hence it is not economical to use in low-rise buildings. But this is the most economical form of formwork type to be used in high-rise building construction when it is having few typical storeys. eg. Mivan, Tunnel formwork

E. TUNNEL FORMWORK

The tunnel formwork is a room sized structural steel fabricated form which is used to cast the shear walls and floor slabs of a building as a monolithic structure in a continuous pour. The forms are then heated using hot air blowers for accelerated curing of the concrete for particular area. This is

the most cost-effective when the structure consists of large number of identical units.

The sequence of construction comprises placing of reinforcement, electrical and sanitary conduits along with the tunnel forms. Concrete is then poured and the open side of the forms is covered and hot air blowers placed inside. The forms are removed the next day and placed on the next site using cranes. The optimum use of tunnel form is in multiunit shear wall structure with identical floor layout at each level.



Figure 1: Tunnel formwork

F. TUNNEL FORMWORK CONSTRUCTION METHOD

a. TYPE & DESIGN OF THE STRUCTURE

The structure is designed as a portal frame having monolithic casting of the wall, slab and columns. The beams are eliminated and columns are in built with the wall.

b. FOUNDATION

The foundations are completed with the conventional method and dowels are left out for column and wall reinforcement. The wall reinforcement is tied in position along with the electrical conduits and reservations for the plumbing fixtures before placing the tunnel forms in position.

c. TUNNEL FORM WORK FOR WALL AND SLAB

The tunnel form is placed in position with the help of a tower crane to half shells which are placed together to form a room or a cell, while several shells are making an apartment. After placing two tunnel forms together, the level can be adjusted with the help of its leg jacks and wheel strut. The soffit level can be adjusted with the inclined prop. The two adjoining room tunnel forms are tied together with the help of tie rods. To fix the tie rods, a spacer cone is provided between the vertical panel of two tunnels & the tie bolt pass through this cone. At the gable end of the building gable end frame is erected to support the outer wall to form strong back. The global end frame is specially designed frame to support end form & it can be installed within no time. For sidewalks & to facilitate stripping, stripping platforms are erected. The typical arrangement is given in the sketch.



Figure 2: Tunnel form work for wall and slab

d. SCAFFOLDING

For scaffolding & dismantling of the tunnel forms specially designed stripping platforms are used. This provides a readymade truss made with steel tube & having wooden scantling at top. Each bracket is composed of upper horizontal steel I beam of 120mm at least 6 meter long onto which three 60mm dia tubes are welded to form a triangular shape. These trusses are arranged in the consoles between two successive slabs, already poured. This arrangement is very easy to install. The scaffolding arrangement requires no welding etc. & can be easily erected with tower cranes. The scaffolding for slab area of 100 Sq. m can easily be completed within 2 hours. The same scaffolding can be erected to next floor very easily with the help of crane.

e. REINFORCEMENT, PLUMBING RESERVATIONS & ELECTRICAL CONDUITS

The placing of the wall reinforcement leads the tunnel form work erection by one phase. To save the time reinforcement network are used in place of normal steel bars. Readymade prefabricated reinforcement mesh is used for slab & wall reinforcement. These meshes are available in different sizes & are cut in sizes as per drawing & placed in position with the help of cranes. This arrangement saves a lot of time in cutting, fabricating & placing the reinforcement. After placing the tunnels in position, reinforcement is placed in position. In accordance with the design, steel block outs may be installed on the form work panels to form the plumbing openings. Similarly the electrical conduits may be laid on the slab & in the wall before the concrete.

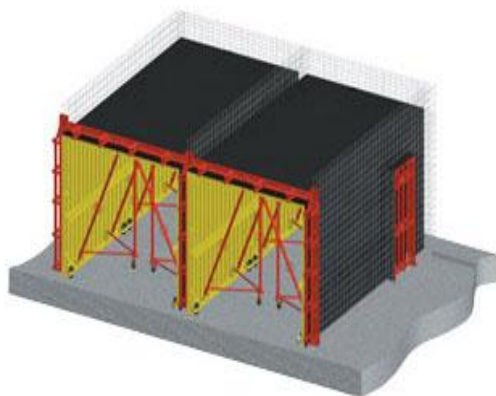


Figure 3: Reinforcement, plumbing reservations & electrical conduits

f. CONCRETING & HEAT CURING

After the completion of the formwork, concrete is poured. The grade of the concrete depends on the design. Normally concrete with 12 to 15mm slumps is used for walls & 7 to 9mm for the slab. After completion of the concrete the tunnels are closed with protective curtains to assist the curing process. Sealing the ends of the curing tunnel and heating the enclosed space from inside with the help of burners & LPG are used to heat the concrete. The slab is covered from top with an insulating material to prevent the heat loss. This process shall continue till the concrete attains the desired strength. However care is to be taken to prevent concrete from burning. The studies show that the concrete attains maximum strength in 12 hours, when heated up to 54 degree C. Care must be taken that the internal temperature of the concrete should not exceed 80 degree C. The rate of the temperature rise should be limited to 20 degree C. /Hours. Before any heat is applied, minimum procuring period of 2 hours is recommended. This process normally takes 6 to 12 hours depending on the weather conditions.

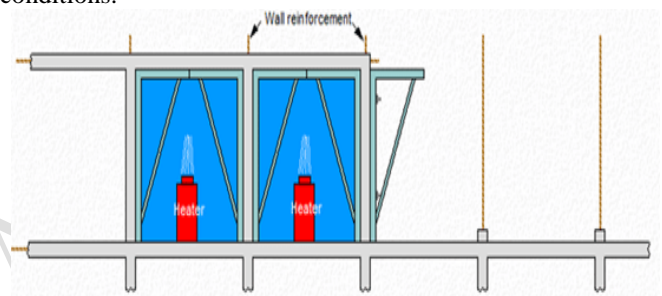


Figure 4: Concreting & heat curing

g. QUALITY CONTROL OF THE CONCRETE

Concrete cubes are taken at the time of the concreting as per the normal procedure. To confirm that the strength required for striking has been achieved, cubes should be cured under the insulation on the upper central area of the slab and then tested before the form is struck. The cubes should follow the same temperature history of the concrete in the slab as closely as possible, if they are to reflect the maturity of the slab. If the strength of the cube is around 65 to 70% of the designed strength, the stripping process may start.

h. STRIPPING OF THE FORMWORK

The next morning tunnels are ready for opening after testing of the cubes. The opening procedure is also very easy & can be solved very fast. In fact the opening of the tunnel on one floor & its mounting on the other floor can go on simultaneously. It saves lot of time. For this purpose all the insulating materials are removed, tie rod & nuts are removed and placed on horizontal walling. After opening of all ties, the leg jacks are lifted first and then a slight deformation is given to the half tunnel form by shortening the inclined struts. The half tunnel array will drop down automatically to the floor. After this the forms are manually rolled out onto the stripping platform and the lifting triangle is attached by securing the wing nut of the triangle. Then the form are placed to next

location. All spacer cones are removed from the wall by means of a punch.



Figure 5: Stripping Of Formwork

IV. CASE STUDY

Sr. No.	Details	Case study I	Case study II
1	Name of firm	Rohan Builders India Pvt. Ltd, Pune	A V Bhat builder, Pune
2	Name of project	Rohan Abhilasha Wagholi, Pune	Ecstasy, Hingane, Pune
3	Type of project	Residential	Residential
4	Type of system used	TUNNEL formwork	Conventional system
5	Area for data collection	Wing A6 of 'A' block	Ecstasy
6	Consultant hired for system	MESA Imalat, Hi Tek Insat	Navate Architect, JW consultant
7	Slab Area	13568 sq. meter	3345sq. m.

Table 1: Table summarizing case studies

V. DATA COLLECTION

Data collected from both site is as below:

- ✓ Plan, Section of building
- ✓ Survey report
- ✓ Quantity estimates of material (Steel, Concrete & formwork)
- ✓ Formwork technical manuals & user guide.
- ✓ On site actual data collection.

VI. DATA ANALYSIS FROM STUDY

From bar chart prepared based on data collected there are 3 possible alternatives where we can reduce time in each slab cycle.

- ✓ Concreting operations.
- ✓ Crane operation.
- ✓ By increasing quantity of formwork.
- ✓ Increase in labour productivity.

ALTERNATIVE 1: REDUCING TIME IN CONCRETING OPERATIONS

Average rate of concreting operation with transit mixer is 15 m³ per hour. This quantity can be increased by supplying concrete direct from batching plant to concreting area. Average distance of pipeline is 105 meter from batching plant to concreting area. This alternative is not possible due to following reasons.

- ✓ Due to added hyper plasticizers setting time of concrete is reduced as per demand of site engineers to achieve slab cycle of 4 days.
- ✓ Due to longer pipeline (about 110 meter) chances of setting of concrete in pipeline itself leads to choke up problem with concrete pump.
- ✓ Also direct supply of concrete from batching plant to concreting area leads to segregation of concrete due to difference between batching plant output and concrete pump capacity.
- ✓ These problems can be overcome by using 2 transit mixers for concreting activity.

ALTERNATIVE 2: REDUCING TIME IN CRANE OPERATION

Second alternative available is reducing time by optimizing tower crane operations. From bar chart drawn it is clear that tower crane remain idle for 2 hours every day. This time can be used for activities in next day, but as all activities are to be carried out in continuous manner we cannot reduce time by using tower crane for next day activity. However we can use this time to carry out other works such as moving material to store, moving material from store to required position etc.

ALTERNATIVE 3: INCREASE QUANTITY OF SHUTTERS

- ✓ At present 50 % of quantity per floor is being used Increasing quantum of shutters can be one of the alternative but it leads to subsequent increase in heavy machinery, highly skilled labour and initial investment.
- ✓ tunnel formwork if used 100% quantum of slab, as it involve heavy investment in procurement, heavy machineries, specialized expert labour it becomes uneconomical. In case project involves more than 20 storied building over large area, total economics may change considerably. However this aspect will require further study to arrive at conclusion.

ALTERNATIVE 4: INCREASE IN LABOUR PRODUCTIVITY

At present stage Tunnel formwork technology is relatively new to Indian construction industry. As there is huge difference between productivity of hired highly skilled labours and Indian labours, at present stage there are chances of delay in slab cycle. As time passes proper training and adapting technology leads to increase in productivity of Indian workers, which may reduce slab cycle time.

CYCLE TIME ANALYSIS (TUNNEL FORMWORK)

For cycle time analysis of tunnel formwork, slab cycle of both systems is studied and based on average cycle time of both systems i.e. 4days slab cycle of tunnel formwork and 20 days slab cycle of conventional system study is done.

Following chart is prepared by combining average slab cycle of slab and tower crane data collected from site.

Area considerations

- ✓ Formwork available: Formwork available (1500 m²)
- ✓ Concrete area of building A6-I for slab & wall (Tunnel formwork area required):1480 m²
- ✓ Slab area per floor of building A6 part I : 550 m²

Time considerations

- ✓ Time required taking out “one half tunnel”, moving to desired location and fixing to location is 8 minutes.
- ✓ Time required unfixing “wooden platform”, and moving it to desired location and then fixing is 20 minutes.
- ✓ Time required to move and fix “wall/ slab box out” is 6 min.

PRODUCTIVITY ANALYSIS

A production rate is defined as the number of units of work produced by a person in a specified time. Production rates may also specify the time in man-hours or man-days required to produce a specified number of units of work. The time that a labour will consume in performing a unit of work varies between labours and between projects and with climatic conditions, job supervision, complexities of the operation and other factors. Productivity is one of the factors in time & cost calculations. More is the productivity less will be time required for activities and hence cost. Work done in one day (in m²) Total man hours

COST ANALYSIS

Sr. No	Building	Details	Amount (Rs)
1	A1	Steel	9050040
		Shuttering	8874450
		Concrete	5092500
		Labour	8644800
2	A6	Steel	17080515
		Shuttering	16701300
		Concrete	9582500
		Labour	16281600
3	A4	Steel	11427795
		Shuttering	11198700
		Concrete	6425000
		Labour	10909200
		Total turnover	131268400

Table 2: Table showing turnover for A1, A6 & A4 building (Constructed by using 1 set of tunnel formwork)

Sr. No	Description	Quantity	Unit	Rate (Rs/ Unit)	Amount (Rs)
1	RCC work				
A	Footing, Plinth beam (M25)	250	Cu. Meter	4300	1075000
B	1st to 3rd floor (M30)	950.72		4500	4278240
C	4th to 7th floor (M30)	950.72		4500	4278240
D	Terrace floor	179.32		4025	721763
	Total concrete (M20, M25, M30)	2330.76	RS		10353243
2	Reinforcement (3% wastage)				
A	1st to 14 th floor	469	MT	46000	21574000
B	Terrace floor	11		46000	506000
C	Binding wire	11.21		50000	556050
	Total reinforcement		RS		22636050
3	Conventional material				
	Ply	1100	no	1200	1320000
	Ballies	2000	no	200	400000
	Wooden planks	500	Sq. Meter	1500	750000
	Total material		RS		2470000
4	Labour				
	Fitter	3345	Sq. Meter	32	107040
	Shuttering labour	3345	Sq. Meter	40	133800
	Concreting labour	2330	Cu. Meter	225	524250
	Total Labour		RS		765090
	Total amount		RS		36224383

Table 3: Table showing part BOQ of RCC work slabs for Residential building Ecstasia site

VII. CONCLUSION

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 is good examples of this innovation.

- ✓ We can achieve 1-3 days slab cycle by TUNNEL formwork system, where as we also can use Conventional formwork we can achieve slab cycle of 21 days.
- ✓ Considering Indian conditions tunnel formwork if used 100% quantum of slab, as it involve heavy investment in procurement, heavy machineries, specialized expert labour it becomes uneconomical. In case project involves more than 20 storied building over large area, total economics may change considerably.
- ✓ Also after studying and comparing both the systems it can be concluded that, though initial investment and per day operational cost in Tunnel formwork is more than Conventional system, due to more reuses and reduced slab cycle time Tunnel formwork works out ultimately economical.
- ✓ Returns from initial investment regained due rapid completion of project Hence in long term consideration Tunnel formwork system is beneficial than that of Conventional formwork system.

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