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A Case for Tunnel Formwork Rapid Construction Methodology for Urban Housing Demand in Pakistan

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A CASE FOR TUNNEL FORMWORK RAPID CONSTRUCTION METHODOLOGY FOR URBAN HOUSING DEMAND IN PAKISTAN

By

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Abstract :

Urbanization is considered a key factor behind economic advancement of all developed countries, which means well connected, vibrant and livable cities that bring specialized skills together in a dense environment. In the backdrop of rapid urbanization in Pakistan, which according to the World Bank's statistics estimates to approximately 55% of the total population, Pakistan should realize the necessity of investing for managing this ever-increasing urban transition primarily by providing low cost housing in our cities. An explosive population growth coupled with a consistently lack luster public policy mechanism for steady supply of housing units have resulted into a back log of an estimated 10-Million housing units. The current administration has taken an expansive policy initiative for bridging this gap by launching its flagship "NAYA Pakistan Housing Program" which envisions to establish 5-Million housing units across the country during its tenure. However, the existing construction industry in Pakistan which shall be mobilized in view of this policy initiative regarding design considerations, technical solutions, materials, construction and management techniques to deliver on this tall claim needs to be rationally assessed. Keeping in view the urgent requirement of bridging the huge backlog under a fairly speedy schedule this paper exclusively aims at assessment of repetitive modular structures for high rise buildings in particular the Tunnel formwork construction methodology in the context of Pakistan's construction environment and its comparison with the conventional frame structure construction techniques thus underscoring benefits and limitations in terms of cost

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for each technique and subsequently building a case for adoption of the earlier.

Keywords :
Tunnel formwork, Construction Management, Affordable Urban Housing in Pakistan

1. Introduction

Sprawling urban development is an imminent character of cities of developing countries rapidly transitioning from rural to urban based economies. With more people settling into urban centers to work in services and manufacturing sector switching from lower productive agricultural sector the strain on existing infrastructure in these centers cannot be overstated. Pakistan has been witnessing an unprecedented bulge in this fast-increasing populace who have been migrating from rural based economies to urban ones only to be found trapped in an informal service delivery sector. Foremost is the requirement of housing that needs to be proactively taken-up by the policy makers in order to harness the positive of urbanization such as density by focusing on strategies to provide mass multi-storey or medium-rise buildings for accommodating low income settlers. The vision of incumbent government is a step in a right direction by initiating "NAYA Pakistan Housing program", however, the means and tools available in Pakistan's construction industry to deliver on this highly ambitious program needs to be assessed in light of technical considerations and construction techniques applied in recent times to achieve a similar public housing objective.

Repetitive modular structures using specialized formwork techniques such as Tunnel formwork System has ceased to remain a novelty in developed world, however, its application and benefits have remained obscured in the developing world for a long time until very recent. Turkey, India & Malaysia has been using this special construction technique successfully to bridge its public housing demand and so can Pakistan which has an escalating back log of housing units.

2. Objective

The objective of this paper is to provide comparison of tunnel formwork construction with conventional frame structure construction in our local environment to build a case the former for constructing high rise public residential buildings in Pakistan.

A quantitative study of construction cost comparison of the two formwork systems based on real life case studies from project is presented in this paper to achieve this objective.

3. Literature Review

Tunnel form structural systems (i.e. Box systems), with load carrying mechanism having RCC shear walls and slabs are prevailingly used in the construction of multistory residential units. This particular formwork holds superiority over its conventional counterparts in terms of speed, economy and enhanced seismic resistance.

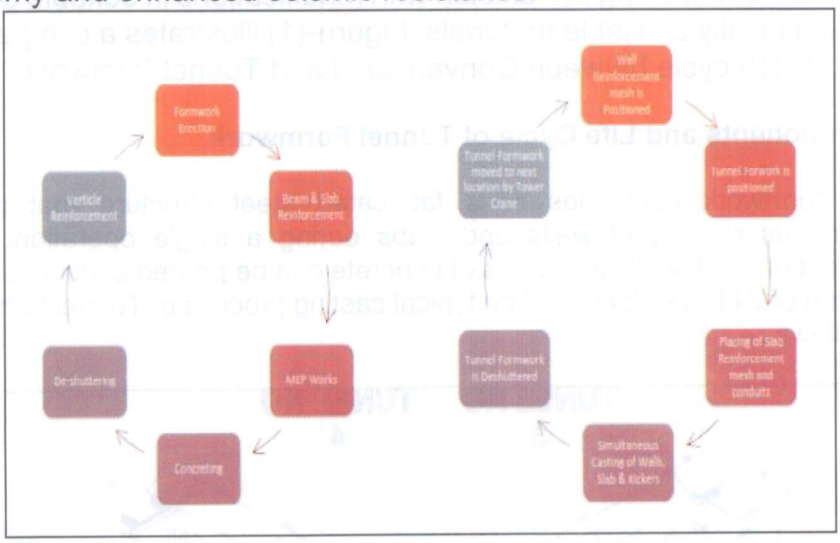


Figure1: Typical slab cycle of Conventional and Tunnel formwork is illustrated (Own Source)

Presently, we don't have qualitative data to suggest the cost and time benefits of using repetitive modular structure technique in Pakistani construction industry, however, voluminous published literature worldwide on the comparison between the two formwork systems nonetheless points to a significant reduction in slab cycle time as compared to conventional methods and thus reduces the overall formwork cost (Aakanksha 2017). The research in this regard concludes that construction quality achieved is enhanced while using repetitive modular formwork technique with less wastage of material registered (Mishra 2014) as well as less manhours consumed as compared to conventional frame structure (Abdul Kadir et al. 2006). Moreover, the composition of Tunnel formwork system consisting of reinforced concrete (RC) shear walls and slabs exhibits superiority over conventional frame structure especially for its usage in high rise

buildings (Kalkan and Yüksel 2008) and in seismic prone areas (Balkaya and Kalkan 2004).

The above said features attributable to this advance form of Tunnel formwork system make its use ideal for addressing the rapid demand of public housing needs. The evaluation carried out by (Tezgelen and Yilmaz Karaman 2014) for assessing user comfort from residents of different social status varying from high income to low income earners residing in tunnel formwork mass housing schemes launched in Turkey provides significant insight in adopting such technique for providing similar low cost housing in Pakistan with modifications in suitable design and using locally available materials. Figure-(1) illustrates a comparison of typical slab cycle between Conventional and Tunnel formwork.

4. Components and Life Cycle of Tunnel Formwork

Tunnel formwork comprises of a fabricated steel structure that allows simultaneous casting of walls and slabs during a single operation. After placement of steel, walls and slabs of concrete can be poured continuously. in a duration of 24 hrs slab cycle. The typical casting process of Tunnel formwork is as follows :

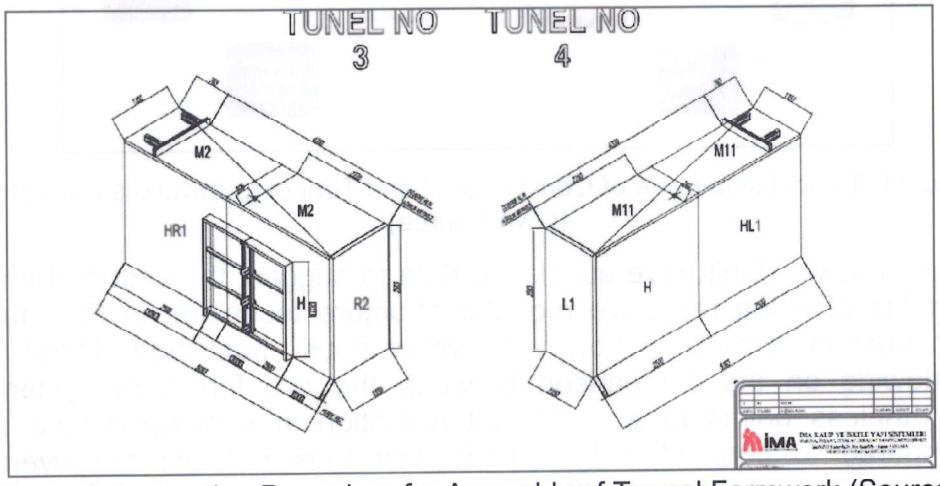


Figure 2: Instruction Procedure for Assembly of Tunnel Formwork (Source IMA Formwork)

- *Step-1:* Reinforcement Mesh of walls is placed with the help of Tower Crane before casting the kickers.
- *Step-2:* Two and a half tunnel panels are shifted in to place with the help of Tower Crane and fixed with bolts and ties.
- *Step-3:* Slab Reinforcement are fixed in place concrete is poured to cast slab & walls.

- Step-4: Using hot air blowers to achieve rapid setting of concrete within a duration of 24hrs.
- *Step-5:* Tunnel formwork is cleaned and oiled for removal and placement at new location.
- *Step-6:* The whole process is repeated for the next slab cycle.

Description of Item of Works	Conventional Frame Structure (PKR / SQFT)	Tunnel Formwork Structure (PKR / SQFT)	Difference % age
	(A)	(B)	C= (B-A) X 100 / A
Concrete	434.88	660.26	52
Shuttering Cost	94.36	150*	59
Reinforcement	678.55	976.86	44
Internal Plaster (Ceiling)	25.42	Not required	N/A
Masonary (Internal Walls)	116.42	Not required	N/A
Masonary (External)	91.16	163.54	79
Internal Plaster (Walls)	179.89	Not Required	N/A
Scaffolding for Internal Walls Plaster	74.17	Not Required	N/A
External Plaster	60.58	47.1	-22
Scaffolding for External Walls Plaster	30.29	14.13	-53
Brick Ballast	11	11	N/A
PCC Floor	100	100	N/A
Exterior Heat Insulation	Not Required	113.04	N/A
Grills and Chowkats	19.05	20.87	10
Total	1,916	2,257	18

Table-1 Item wise per square feet cost comparison of Grey Structure for both Conventional and Tunnel formwork construction techniques (own source)

5. Methodology for Data Analysis

The assessment for a quantitative comparison between the two types of formwork techniques in the context of Pakistan was carried out in this study. Primary basis of this comparison was considered as construction cost of grey structure using the two formwork system since cost is the foremost important aspect in any public sector development project and cost of shuttering attributes to approximately 20% of the cost of concrete works as per the established estimates published by Finance Department Government of Punjab, Pakistan generally adopted on public sector projects. The cost of grey structure comparison was conducted on real time project design data available with the authors at the time of this study for construction of multi-storey building having *G+9* floors at Islamabad using conventional frame structure methodology with a total covered area of *94,600 Sq ft* whereas, a similar multi-storey building model was designed using with the same covered area using Tunnel formwork methodology.

Keeping in view the inherent limitations in comparing the two design models, the per square feet cost of each item of grey structure

construction using both formwork systems were developed and analyzed for a relatively fair comparison as tabulated in Table-1.

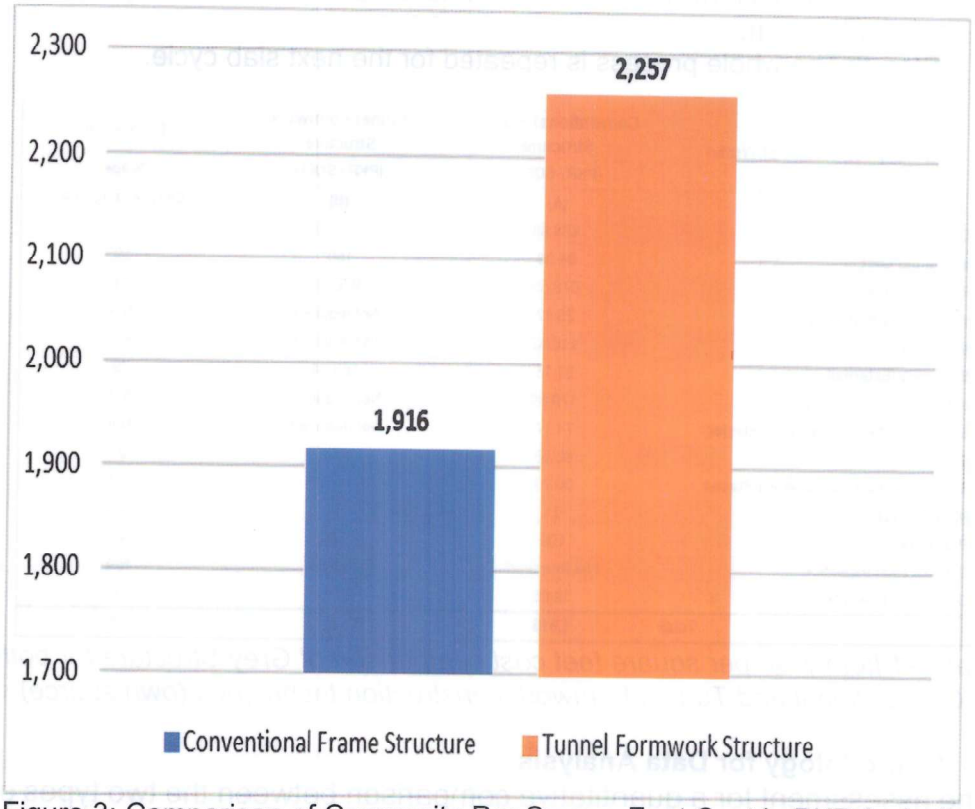


Figure 3: Comparison of Composite Per Square Feet Cost in PKR for both Conventional and Tunnel Formwork construction techniques (Own Source)

5.1. Cost of Conventional Frame Structure

In our analysis the cost of concrete works using conventional frame structure on the basis of Market Rate System published by Finance Department Government of Punjab, Pakistan, has been further sub-divided into concrete and shuttering cost. The composite cost for Conventional Frame Structure was determined to be *PKR 1,916/-* per Sq ft while using thickness of 6 inches Hollow Block Masonry for both external and internal partitioning (1:4 cement sand plaster) excluding scaffolding cost.

5.2. Cost of Tunnel Formwork Structure

In contrast, the per Sq ft cost for Tunnel formwork technique was determined to be *PKR 2,257/-* based on quoted cost of *USD 145 Per Sq m* for importing Tunnel formwork from a foreign vendor. It is noteworthy that the composite cost of shuttering of Tunnel formwork structure i.e. Rs. 150/- per Sq ft (see Table-1) in contrast to the shuttering cost of

conventional formwork structure is approximately 60 % higher than the latter. The significant cost difference is primarily due to the required capital cost of the tunnel formwork shuttering. This cost includes the cost of skilled labor and the cost of Tower crane which will be required to execute construction of Tunnel formwork Structure. Our calculation for computing the composite shuttering cost of Tunnel formwork is based on initial investment cost of PKR. 78 Million to be distributed on 125 repetition uses. The design consideration for estimating the grey structure cost taken are as follows:

i. All internal walls having thickness of 200mm (8 inches) shall be constructed using the tunnel formwork system.
ii. All columns and beams shall be concealed within the above-mentioned design thickness.
iii. No plastering is required on interior walls and ceiling due to superior finish.
iv. Exterior wall shall be constructed by Hollow block masonry with 50 mm extruded polystyrene insulation.
v. Number of usage cycles of tunnel formwork are restricted to 125 as opposed to 500 cycles recommended by foreign vendor.

6. Time Comparison

A comparison of time required for Grey structure works of conventional building projects vs tunnel formwork construction is illustrated as Figure-4. This comparison was based on real time planning data of conventional building and planning data provided by Turkish vendor for conventional building using tunnel formwork construction respectively. Time required for tunnel construction includes considerable margin for delays due to characteristic issues faced by construction industry of Pakistan. This comparison suggests that Grey Structure works of conventional building construction with similar area generally would take four and a half (4.5) extra months than building constructed with Tunnel formwork methodology.

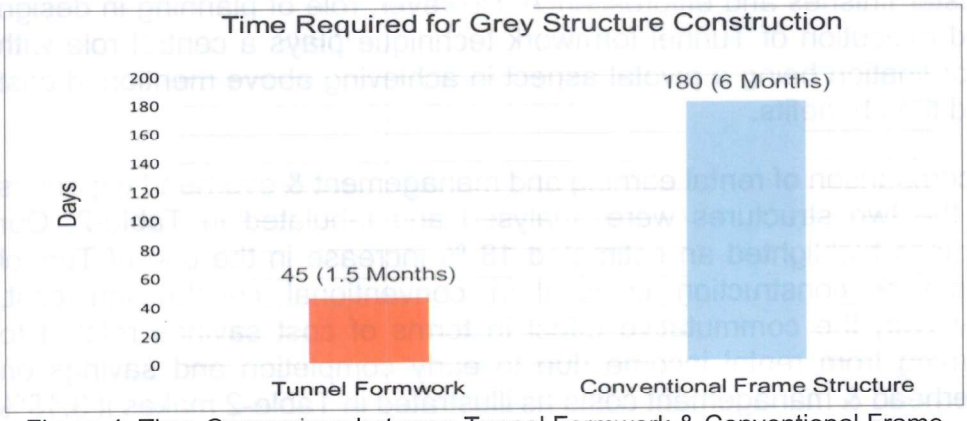


Figure 4: Time Comparison between Tunnel Formwork & Conventional Frame Structure (Own Source)

7. Assessment of Results & Findings

Results of our analysis indicates 50% & 40% increase in cost of concrete and steel works respectively using Tunnel formwork construction technique. This is due to the fact that all vertical support members used in conventional frame structure are replaced by concrete shear walls while using tunnel formwork technique. This cost is significant but can be lowered using slender wall thickness design without compromising on the overall strength of the structure.

The cost of Tunnel formwork exclusively is around PKR 225/- per Sq ft of composite per Sq ft cost of this system (9.6%) which is significantly higher than PKR 89/- per Sq ft of composite per Sq ft cost for conventional frame structure (4.1%). The cost gap can be further reduced, once local manufacturing of tunnel formwork kick starts in Pakistan. The adoption of these technique on industrial scale will also decrease the Labour component of this cost with enhanced skill acquisition in a competitive labour market.

Benefits of Tunnel Formwork Construction

The primary benefit of Tunnel formwork technique holds in its rapid deployment of formwork and slab cycle completion. Simultaneous casting of structural elements i.e., walls, cross-walls & slabs results in a monolithic structure with reduced construction time. The built-in capability of this system to accommodate installation of conduits for mechanical, electrical, gas and water works by overlapping activities with finishing works provides flexibility in schedule, ensures quality and reduces total building time.

Other benefits include elimination of workmanship issues related to plaster finishes and efflorescence. However, role of planning in design and execution of Tunnel formwork technique plays a central role with coordination being a pivotal aspect in achieving above mentioned cost and time benefits.

A comparison of rental earning and management & overhead expenses of the two structures were analysed and tabulated in Table-2. Our findings highlighted an estimated 18 % increase in the use of Tunnel formwork construction costs than conventional construction cost, however, the commutative effect in terms of cost savings related to earning from rental income due to early completion and savings on overhead & management costs as illustrated in Table-2 makes it 3.18% cost effective. Data for rental income used in this based on rental rates

of apartment buildings in Islamabad (zameen.com). Overhead & Management cost are based on real time data collected from apartment building project in Islamabad.

Description of Item of Works	Conventional Frame Structure	Tunnel Formwork Structure	Difference
	(PKR / SQFT)	(PKR / SQFT)	% age
	(A)	(B)	C= (B-A) X 100 / A
Cost of Grey Structure Works	1,916	2,257	18
Earning in Rental Income	-	-270	-
Cost savings on overhead & management	-	-130	-
Total	**1,916**	**1,857**	**-3.18**

Table 2: Cost effectiveness of Tunnel Formwork due to early commissioning of building

8. Conclusion

Pakistan's housing requirements are increasing day by day as more people are migrating from the rural to the urban peripheries. To make this transition sustainable the construction industry as a stakeholder needs to face the challenges of the present age by equipping itself to the tools and technique of this age. The findings of our study highlight an apparent uneconomical solution by replacing the conventional frame system with Tunnel formwork system owing to its reliance on specialized skilled labor and heavy investment in procurement. However, this view is myopic and needs to be viewed in a broader perspective for adopting tunnel formwork system as a permanent feature in addressing the public sector housing demand. The results acquired from this study can be used by project planners for estimating labour input, control costs and project scheduling. Additionally, the findings can be used to determine the most appropriate structural building system for executing a construction project at the conceptual stage by stakeholders.

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