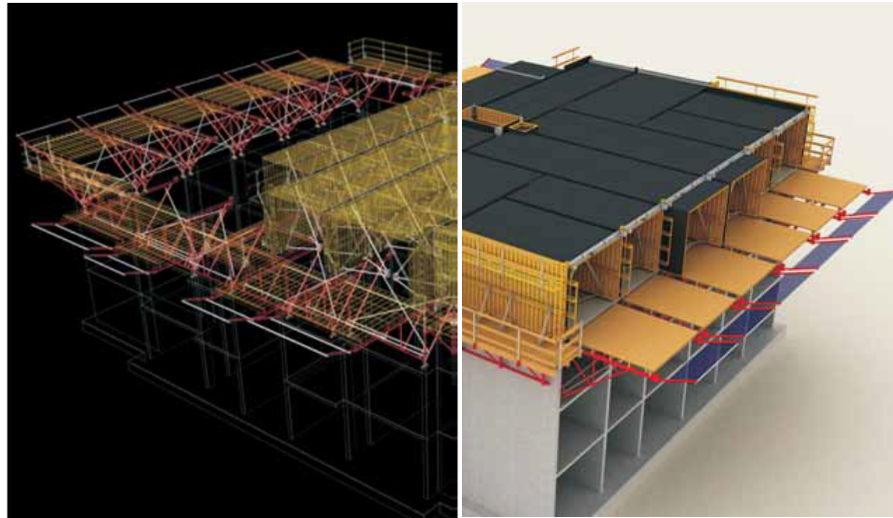


HOUSING FOR ALL CONSTRUCTION TECHNOLOGIES, CHALLENGES

TUNNEL FORM METHOD OF CONSTRUCTION



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22/10/2018

CONTENT

- **Introduction**
- **Various Technologies**
- **Why Tunnel Form Method**
- **Cycle time**
- **Tunnel form Adaptations**
- **Constructability aspects / Prerequisites**
- **FAQs**



Need for Speed

- Projects durations are reduced
 - Focus on Shell & Core
 - Mechanization & Degree of Mechanization
-
- Conventional Methods are Labour intensive
 - Huge Shortage of Labour & Sharp decline in skilled force availability
 - Labour-unskilled, migratory, traditional and family oriented
 - Teams becoming smaller

Construction Techniques

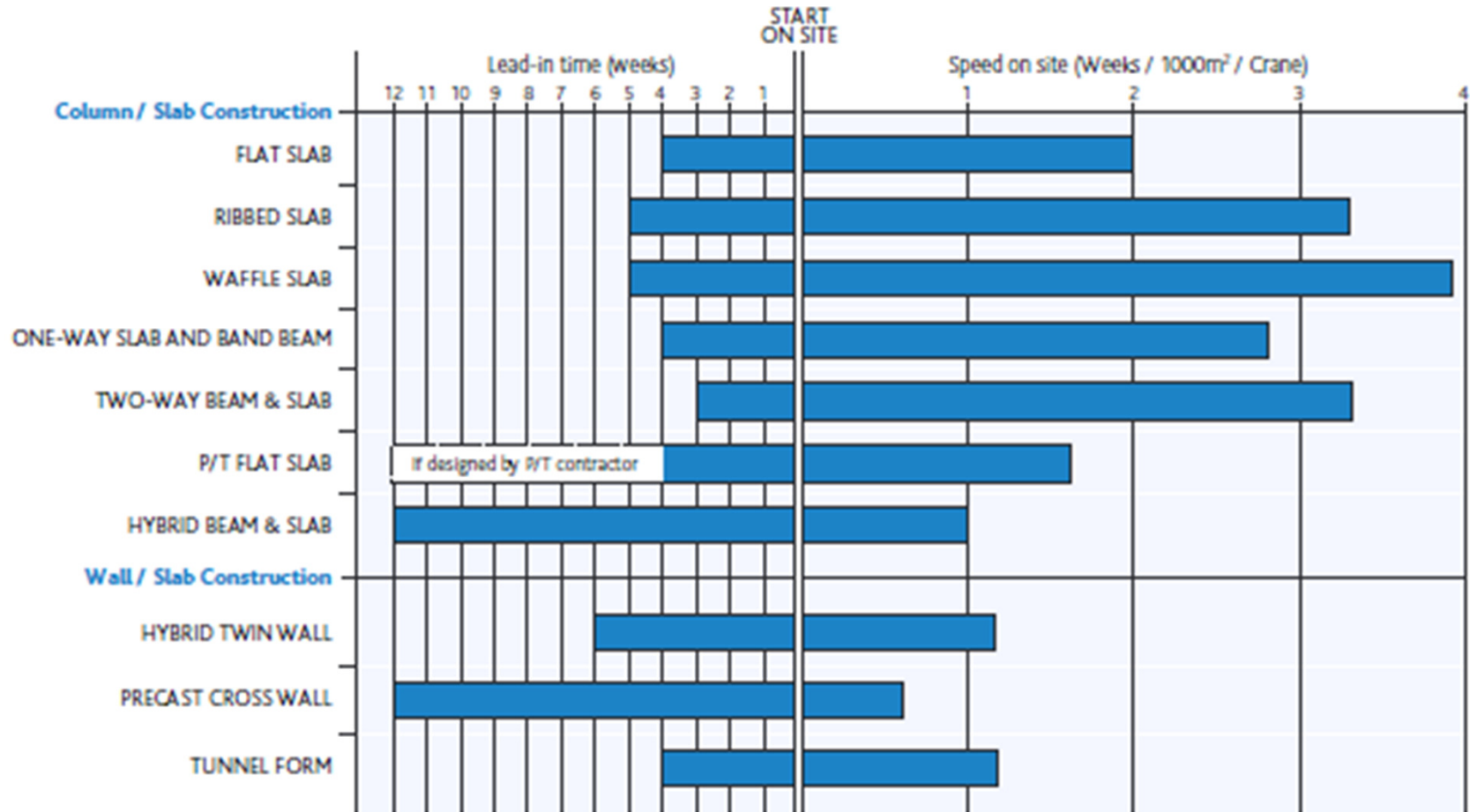
- Lightguage Steel construction, Prefab
- Structural Steel frame & Composite deck
- Precast (frames / wall) construction
- Tunnel form construction
- Hybrid/Composite construction

MINIMIZING WASTE FROM CONSTRUCTION IN THE DESIGN

- Dimensional coordination and standardization
- Modular Design
- Minimizing Temporary/enabling works
- Avoid Late design modifications
- Detailing in Design

By combining different construction techniques in various degree and scheduling their activities sequencing at the planning stage, an optimal construction cycle and floor cycle can be achieved for the project while meeting specific requirements on time, cost and quality.

LEAD IN TIMES AND SPEED OF CONSTRUCTION



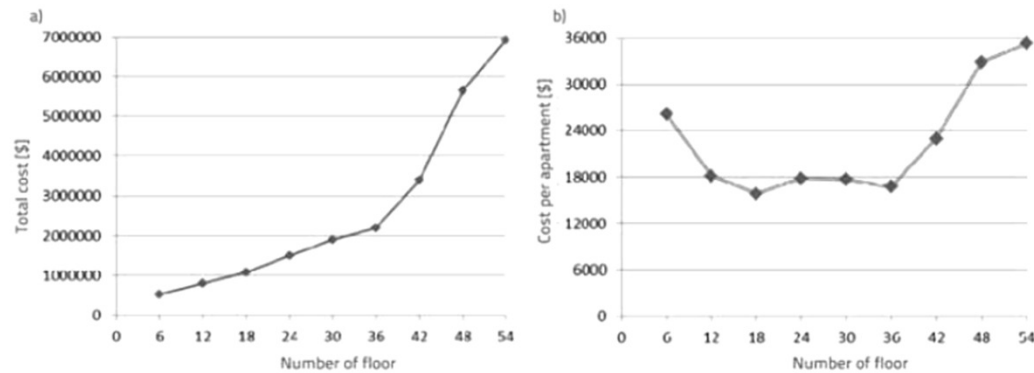
The diagram shows approximate lead-in times and construction speeds for each of type of construction detailed in this publication. Times and speeds are typical but will vary, depending on availability of contractors and materials and site constraints.

Table 1. Shear wall thicknesses

Number of floors	6	12	18	24	30	36	42	48	54
Shear wall thickness [cm]	15	15	20	20	20	20	40	70	80

Table 2. Distribution of floors in the models

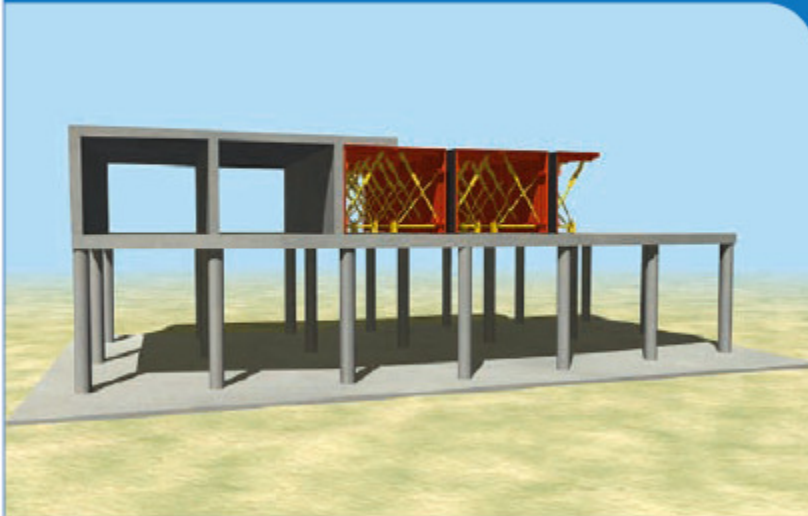
Number of floors	6	12	18	24	30	36	42	48	54
Basement	1	1	1	2	2	2	3	3	3
Structural height [m]	16.80	33.60	50.40	67.20	84.00	100.80	117.60	134.40	151.20
Installation story	0	0	0	1	1	2	2	3	3
Typical floor	5	11	17	21	27	32	37	42	48
Flat	20	44	68	84	108	128	148	168	192



Variation of cost with respect to the number of floors: a) total costs; b) unit cost per apartment

Table 3. The cost of components as related to the total construction cost

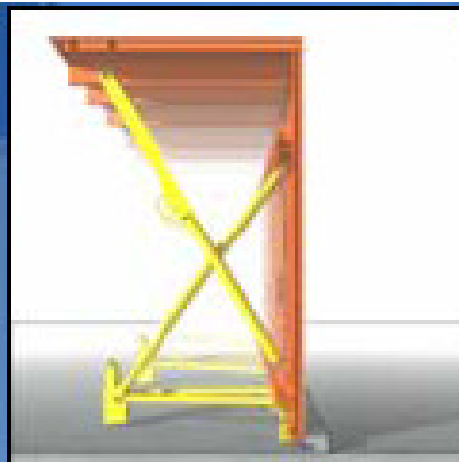
Day two of a three day cycle for the floor plate. The tunnels are struck, moved and poured in a daily cycle. Note: The walls can be used to span between column supports on a lower level.



Benefits:

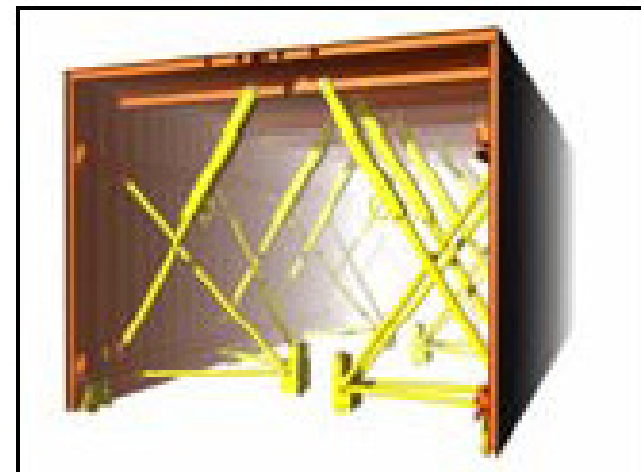
- ✓ Cost
- ✓ Speed
- ✓ Accuracy for prefabricated elements
- ✓ Sound control
- ✓ Fire resistance
- ✓ Robustness
- ✓ Thermal mass
- ✓ Durable finishes
- ✓ Safety
- ✓ Reduced risk
- ✓ Minimal deliveries



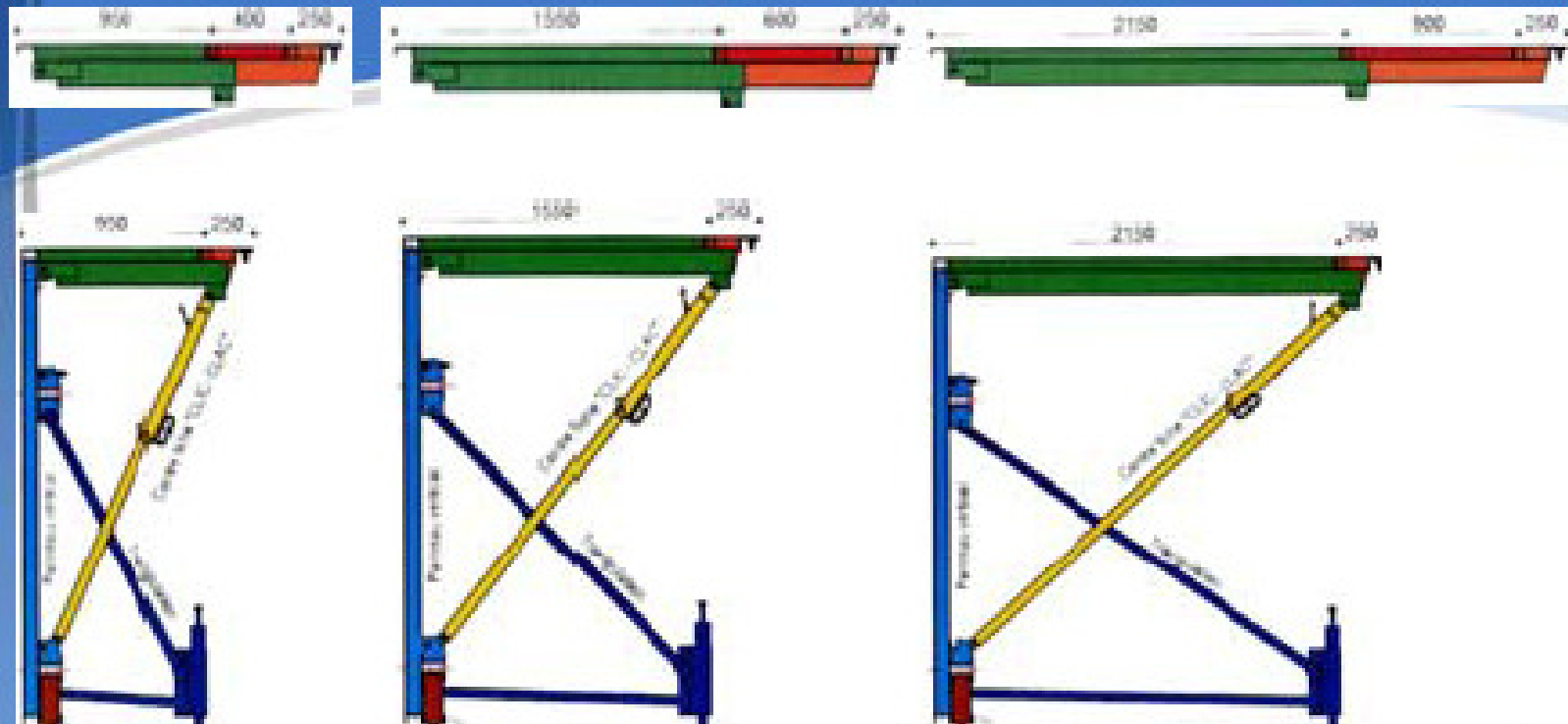


- Half Tunnel
- Manufactured entirely from steel (4mm thick panels)
- Consistently high quality concrete surfaces

- 2 Half Tunnels = Room Tunnel
- Typical spans of 2.4m to 6.6m
- Up to 11m with Tableforms



Tunnel Forms



• Small Sized

• 1,200 - 1,600mm

• Medium Sized

• 1,800 - 2,400mm

• Large Sized

• 2,400 - 3,300mm



Lifting Triangle

Maintains stability of formwork during lift







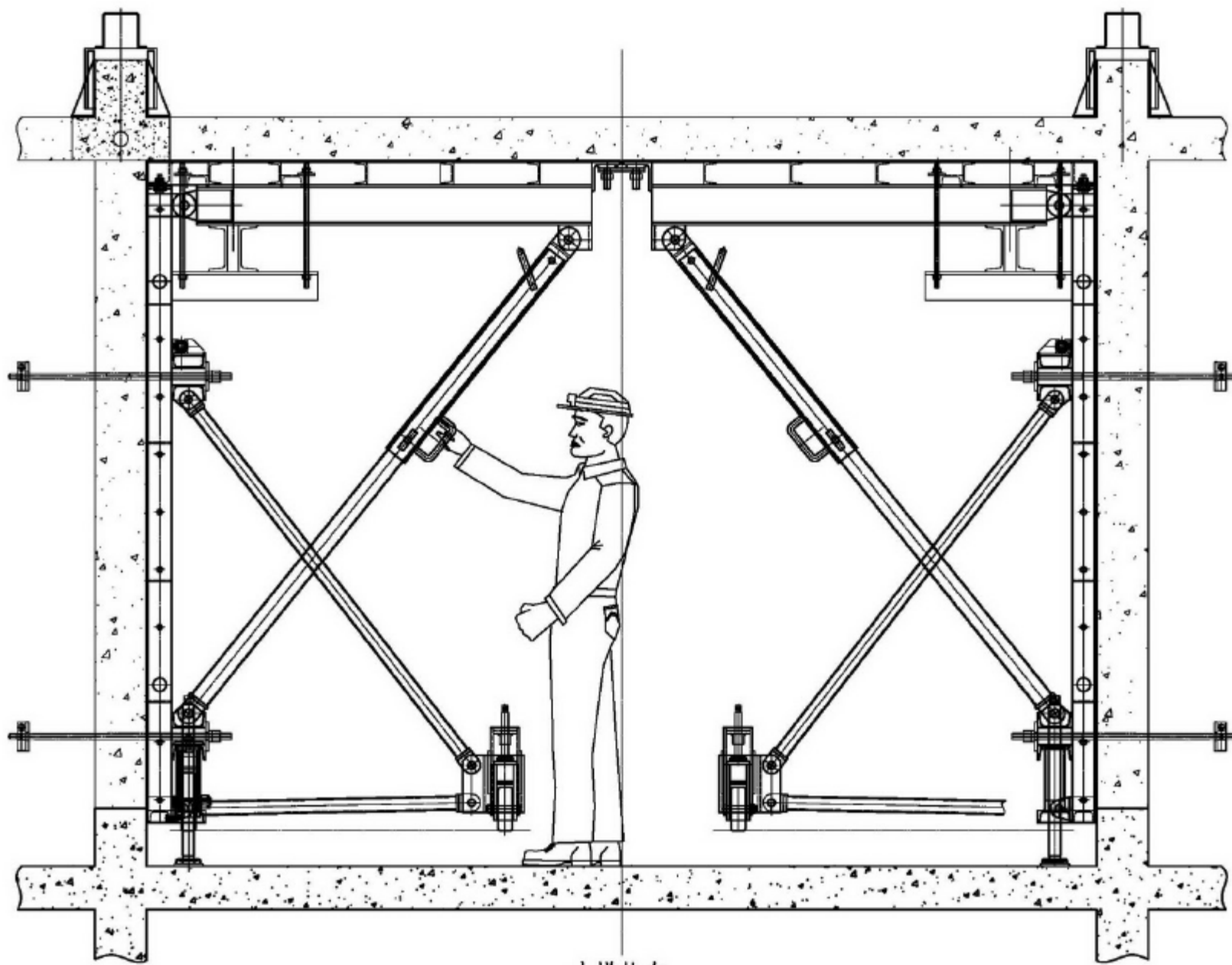
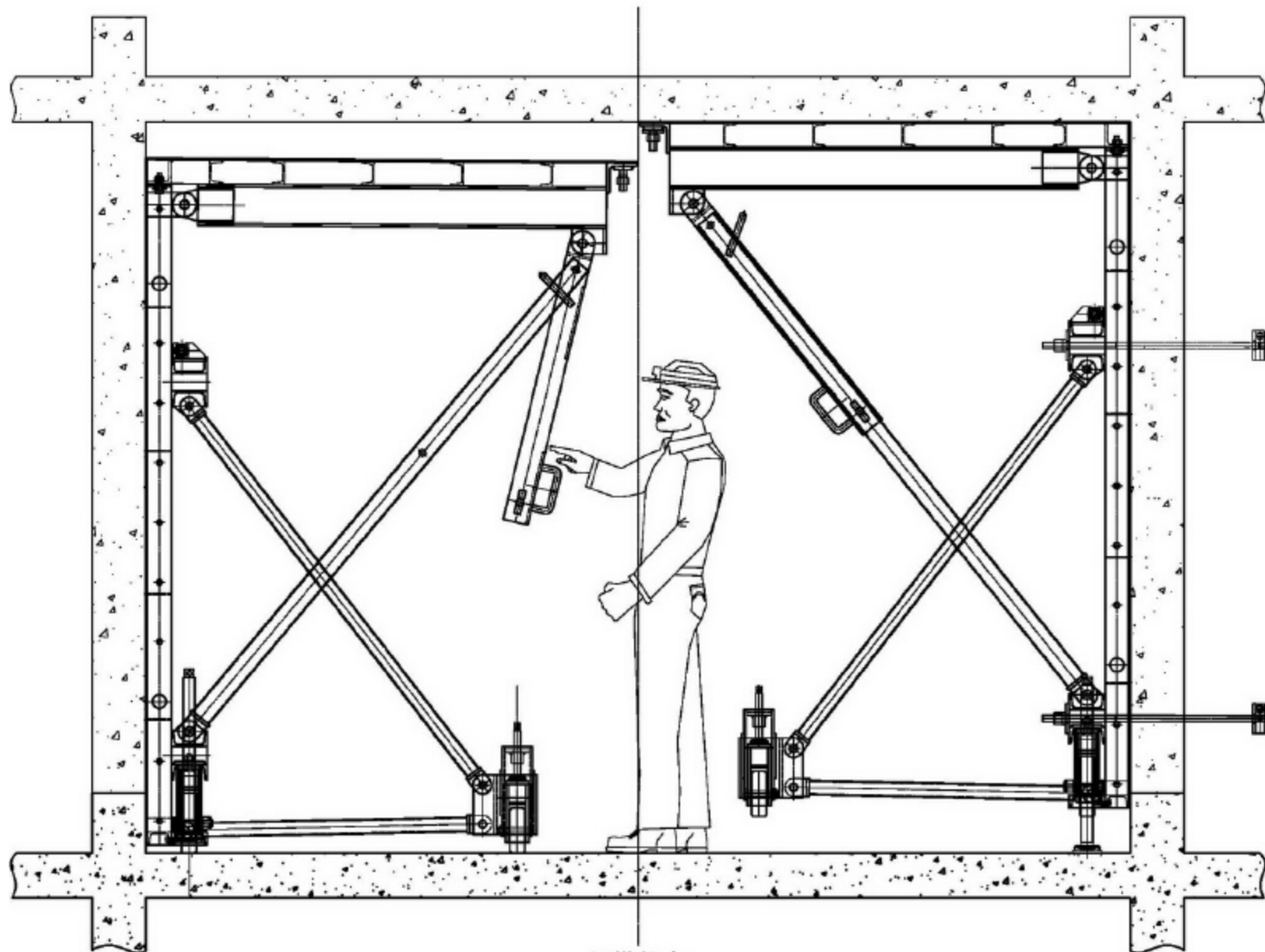
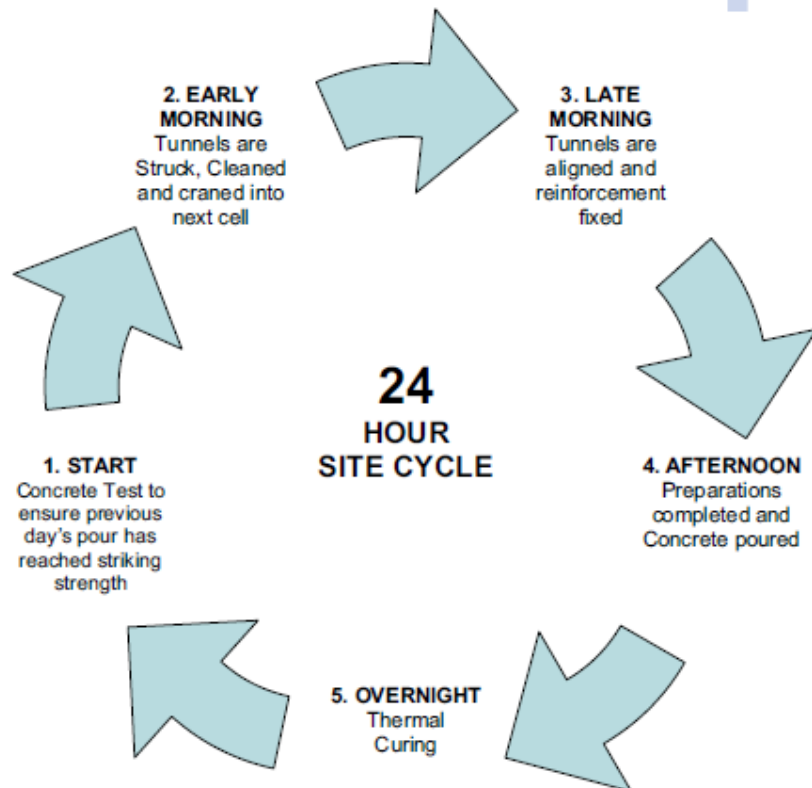


FIGURE 1

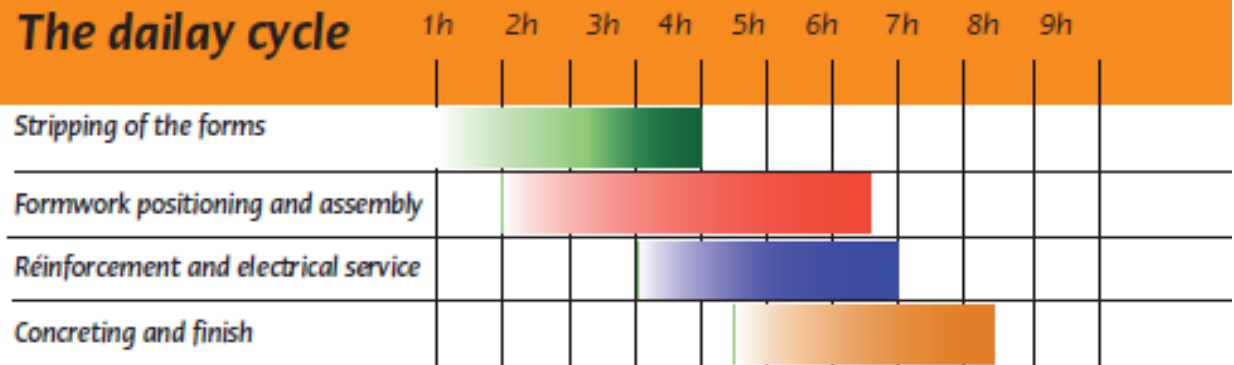




THE 24 HOUR SITE CYCLE



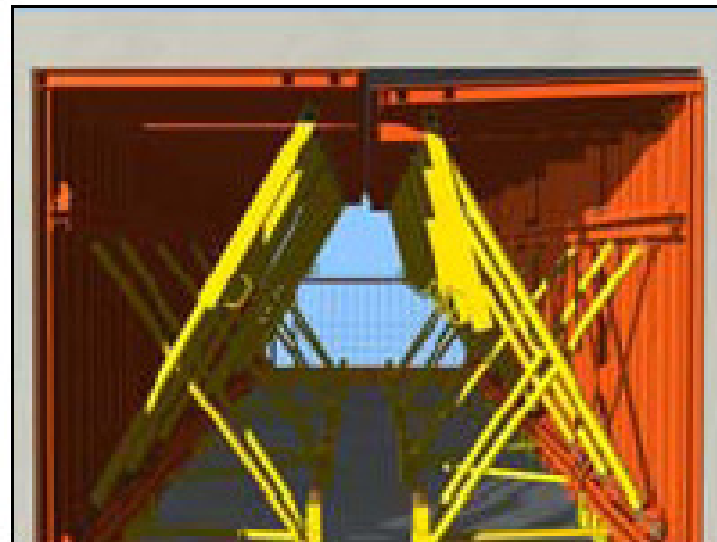
The daily cycle



The 24 Hour Cycle

07:00

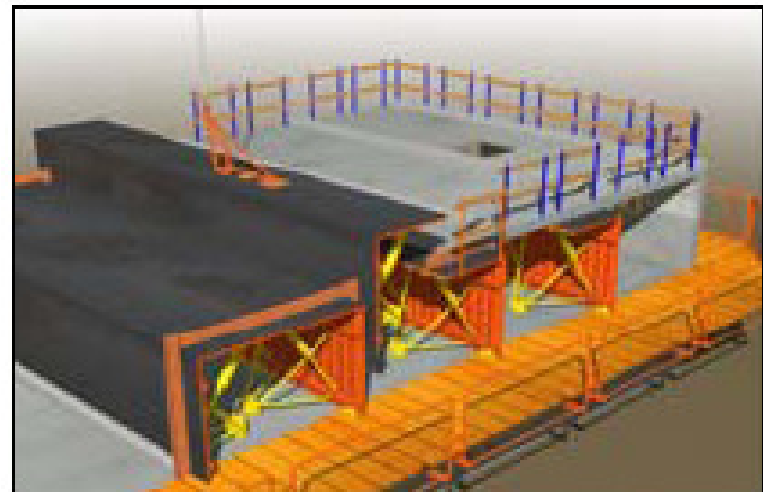
- Concrete cube test completed by Engineer
- Striking of Tunnelforms can begin



The 24 Hour Cycle

07:30

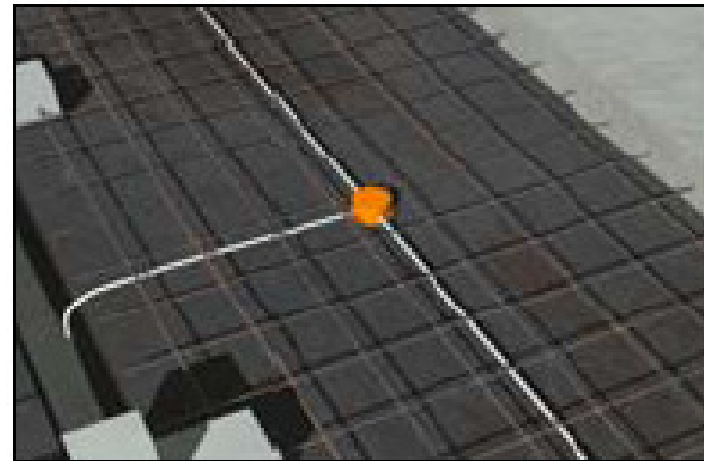
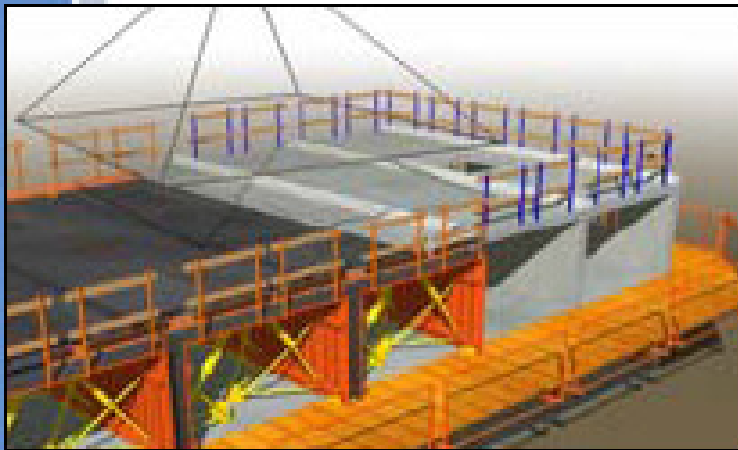
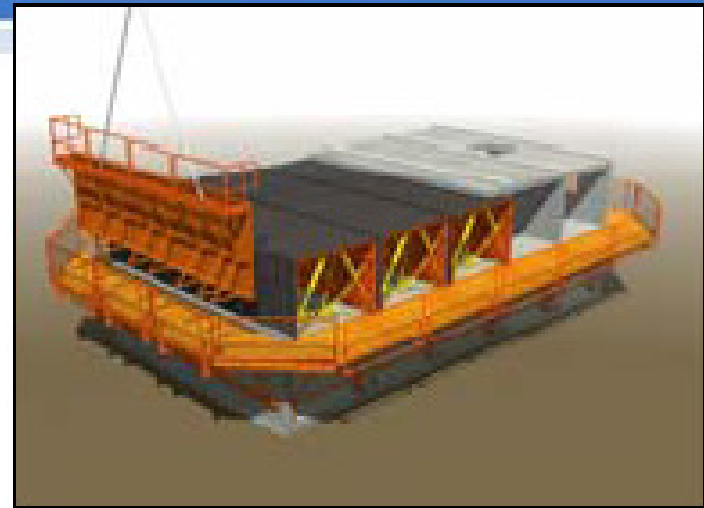
- 1st Half Tunnelform is removed
- Cleaned, oiled and repositioned
- Wall reinforcement placed in advance
- Services are placed within the walls



The 24 Hour Cycle

11:00

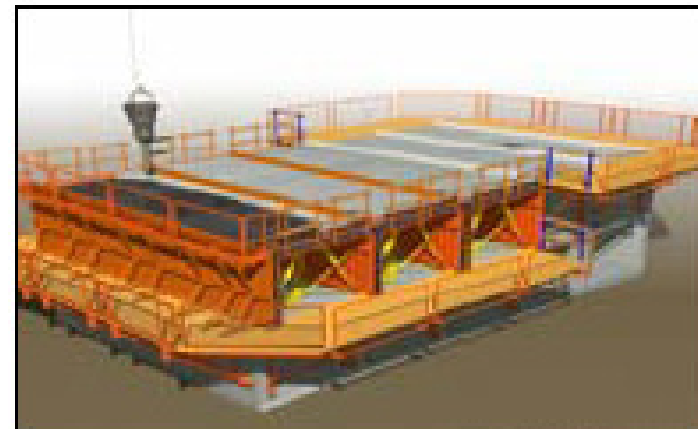
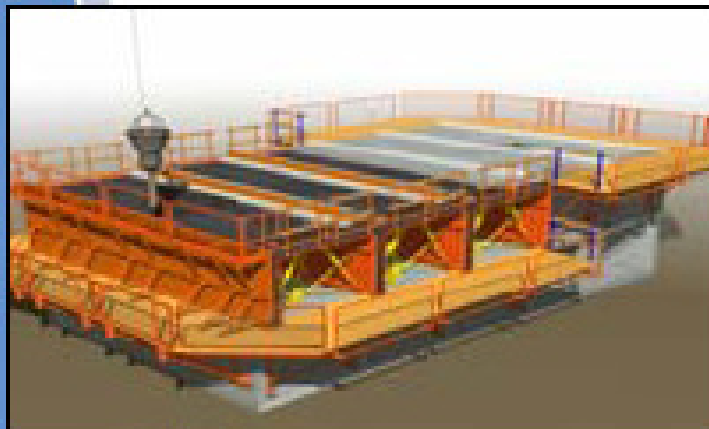
- Final packages are lifted into position
- Once 2 half tunnels are in place then reinforcement can be placed on deck
- Conduits are placed for services as required



The 24 Hour Cycle

14:30

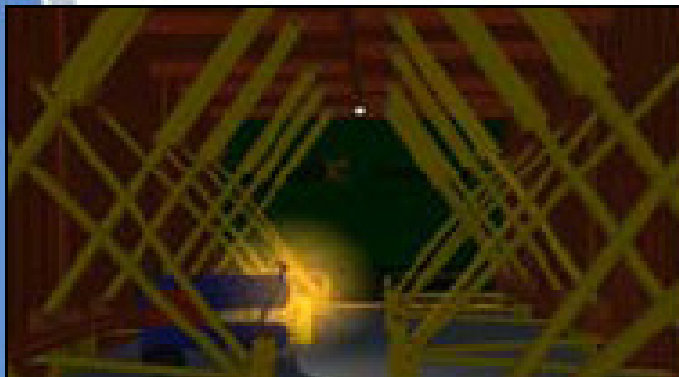
- Concrete pouring can be commenced
- Walls followed by slabs (2 to 3 hours)
- Vibrators are used to ensure a high quality finish unless self compacting concrete is used



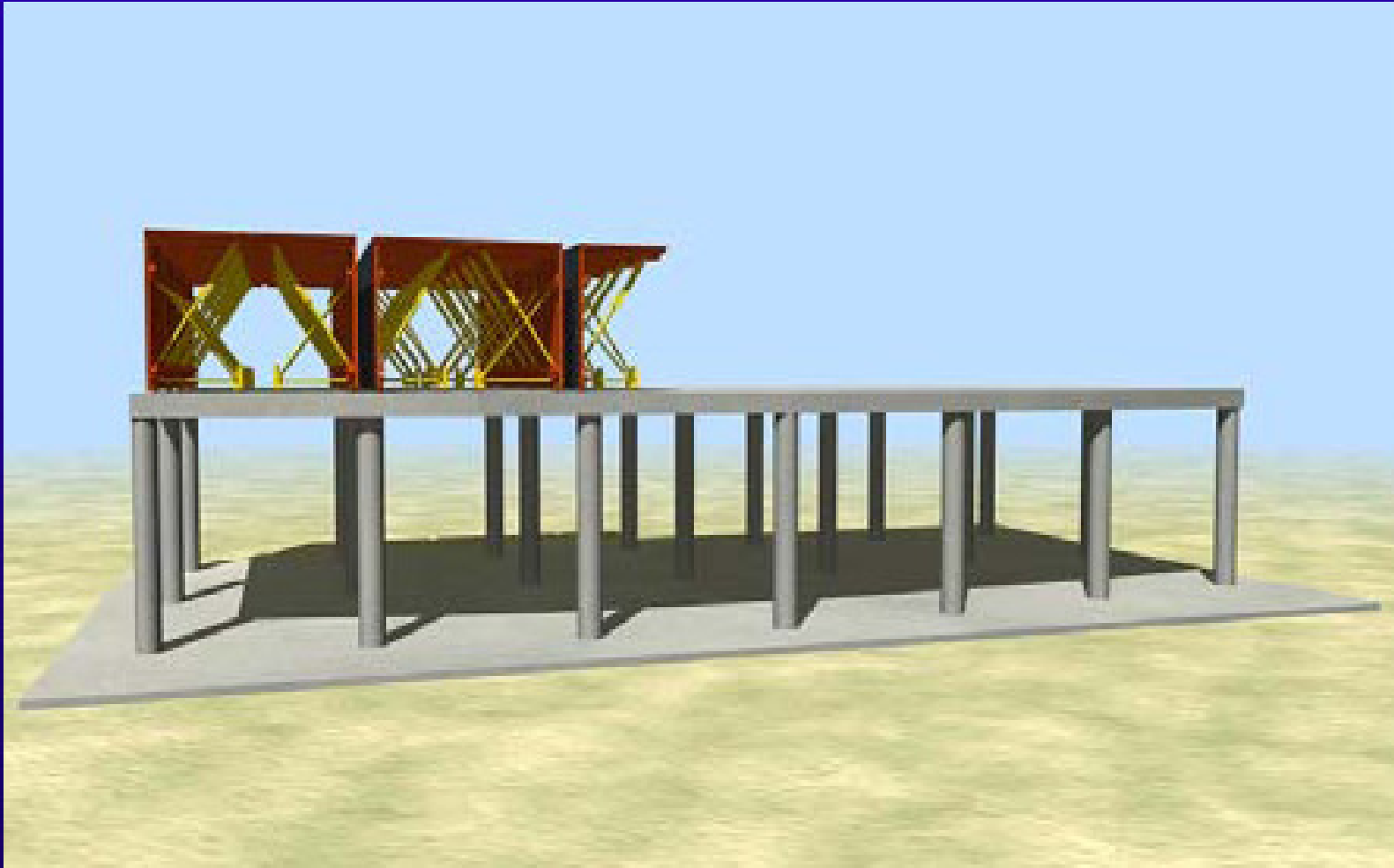
The 24 Hour Cycle

17:00

- Curtains are closed and space heaters inserted
- Heating of the Tunnelforms helps to accelerate the curing process.
- The exercise is repeated the following day...

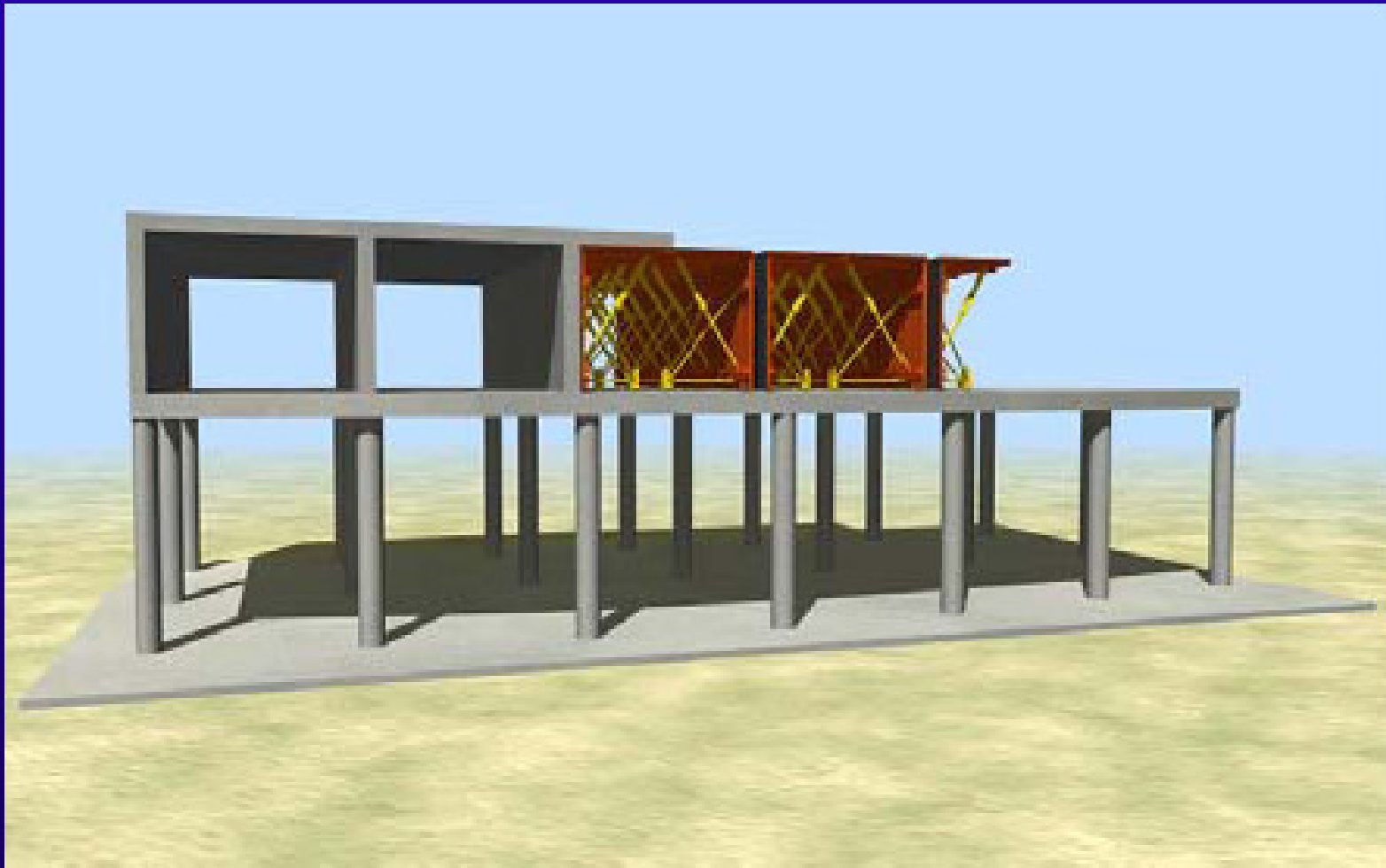


day 1



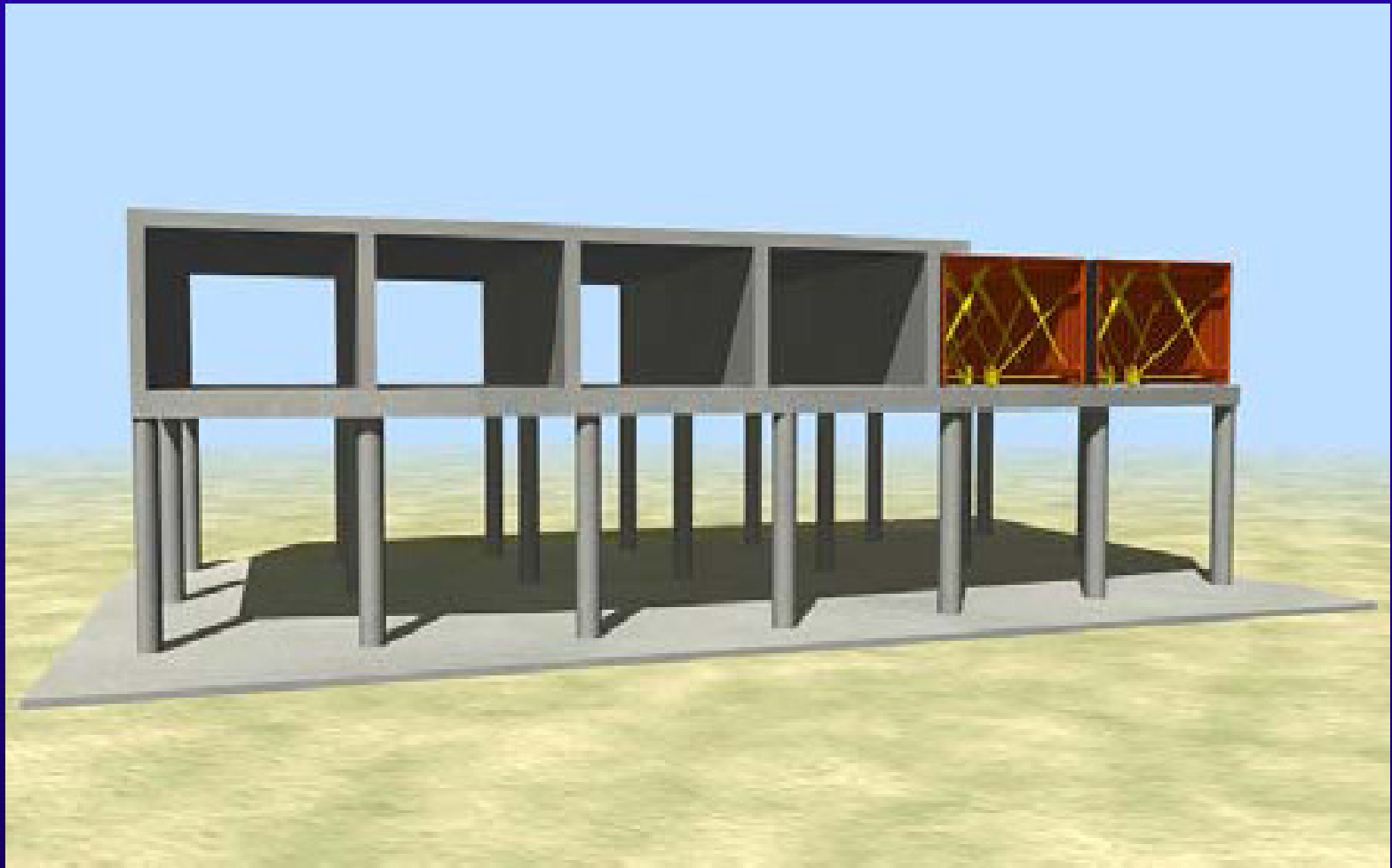
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day 2



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day 3



22/10/2018



Figure 6: Selected Elevation Configuration-3



Figure 10: A Typical Tunnel Form Building Nearing Completion
(Note Masonry Façade Elements)

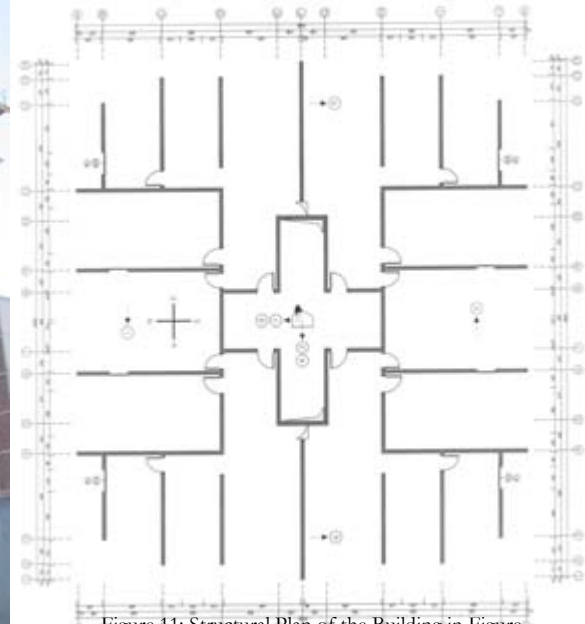
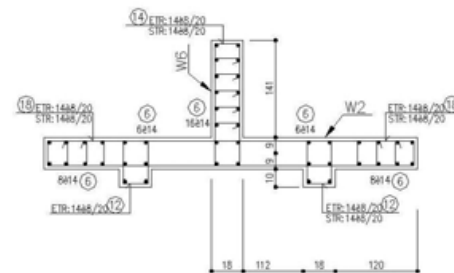
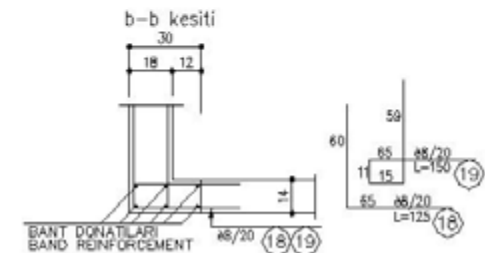
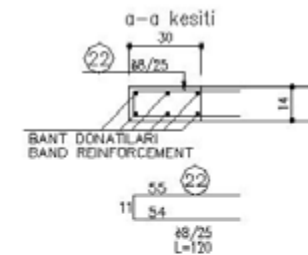
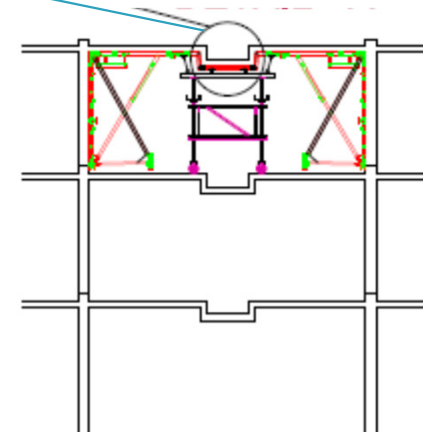
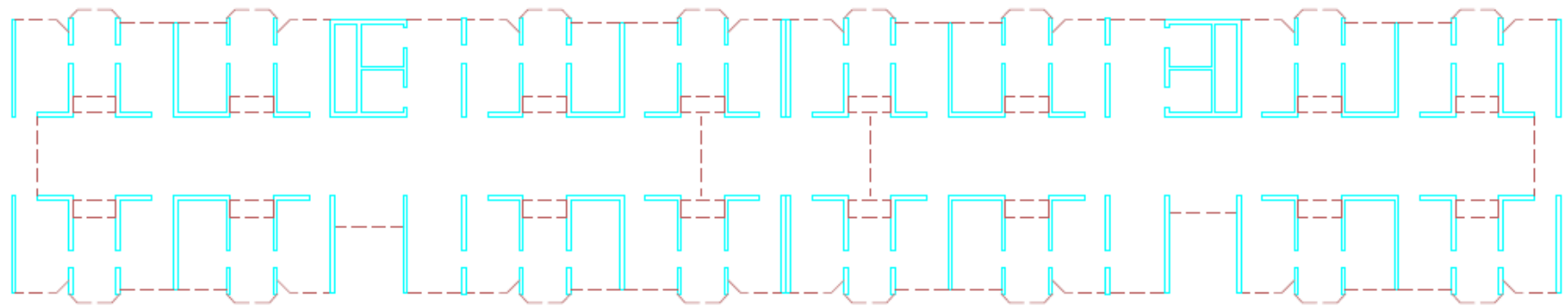
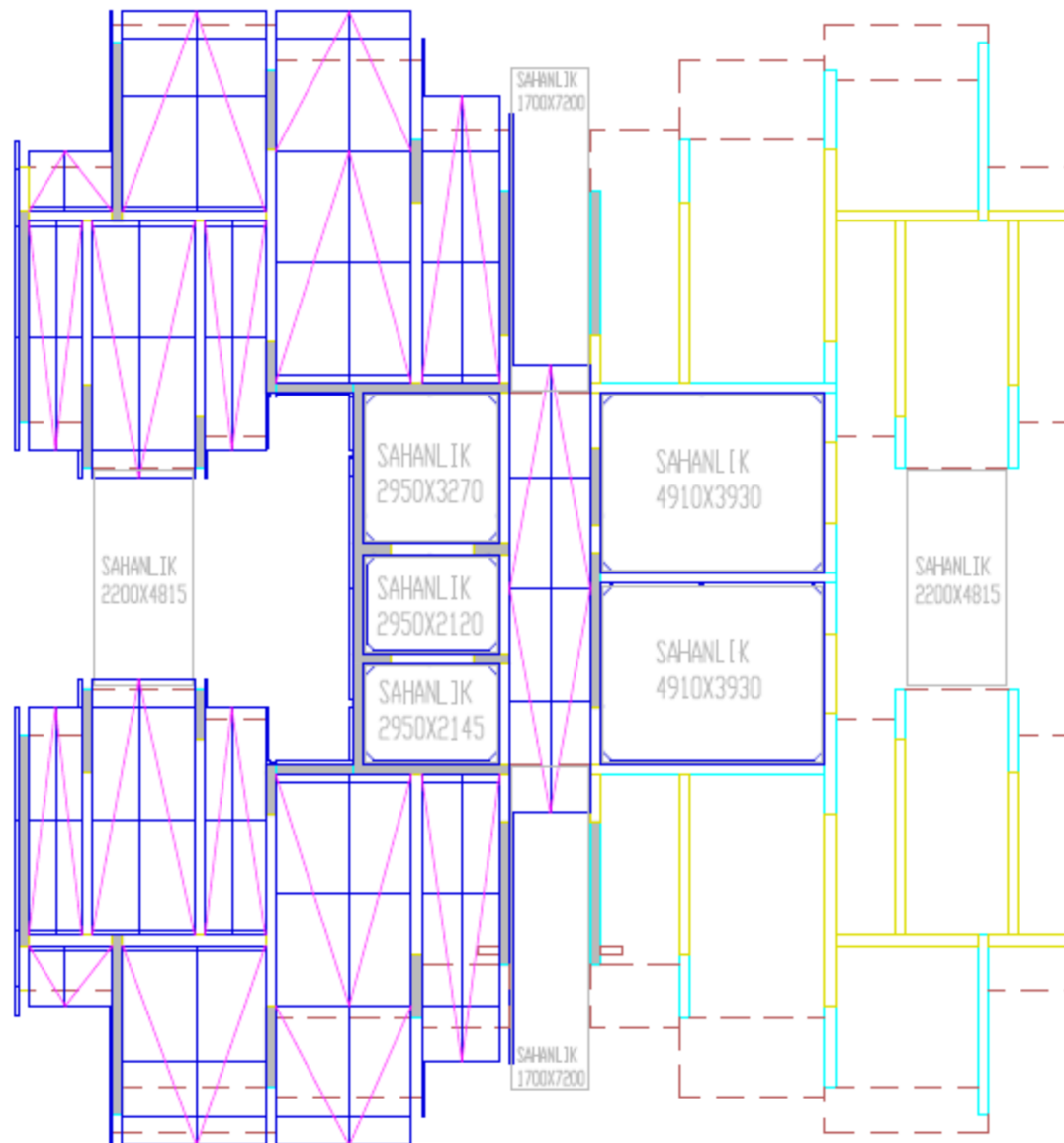
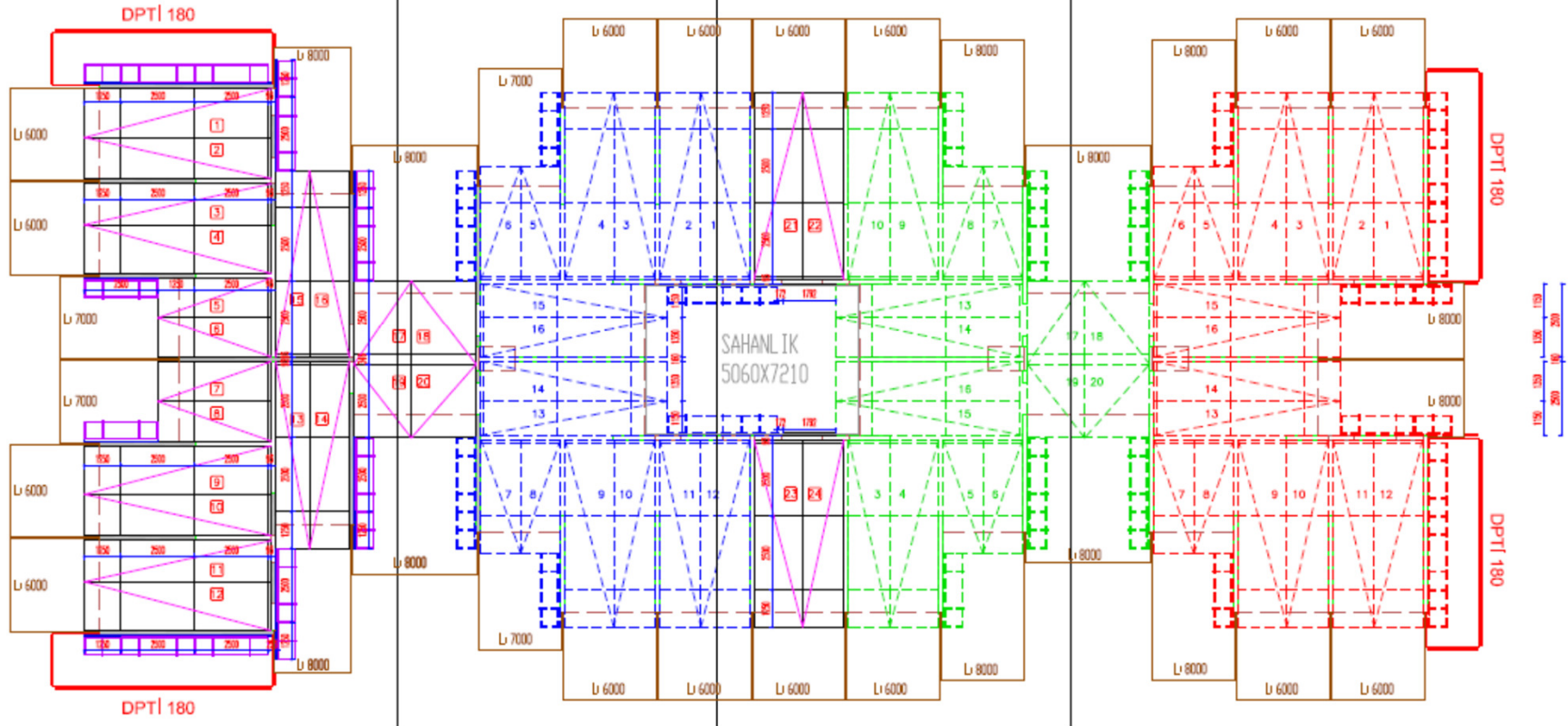


Figure 11: Structural Plan of the Building in Figure 10 (Building Footprint Measures 25x27 m, and Its











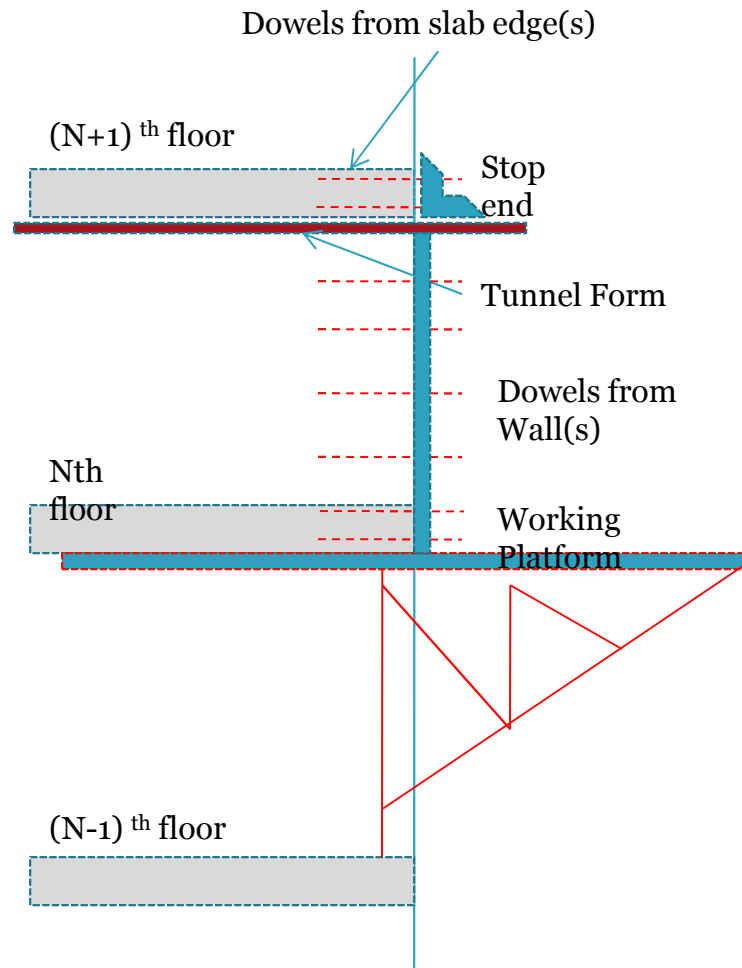


Guide lines for planning of buildings using Tunnel form/Room forms/ Apartment forms

1. Rule-1: 3 side walls & slab as one room; 4th side (generally façade) is left out for removal of formwork.
2. Layout should be such that tunnel forms/room forms can be retrieved from all four side of the building. Preferably from the entire periphery in any of the orthogonal directions.
3. Width of tunnel/internal dimensions of rooms to be in multiples of 50mm preferably and there should be 2 to 3 different widths or combinations, while proportioning the room layouts for economy.
4. Preferable room span from 2.4m to 6.0m (width of room[s]). Larger widths can be accommodated with a table form between two Inverted 'L' forms called half tunnels.
5. Length of tunnel form/room size can be in multiples of 625mm for economy. Otherwise can be made to suit.
6. Building plan should be symmetrical as far as possible either in one or both directions.
7. Load carrying walls must be in same plane (one above the other)
8. Internal beams with end column: Will be treated as wall with reservations/block out forms.
9. A minimum separation distance of 6m for detached buildings. Generally the maximum size of tunnel form +2m required. Typically 10m from neighboring building as a best practice. But, specific details can be worked out.
10. Preferably NO sunken areas. Bottom flush with tile drop. If present, to be cast separately (parallel activity: 1 floor below).
11. Sunken areas in kitchen to be adjusted in flooring & Toilets areas to be under slung.
12. Typical story height ranges from 2.7 to 3.1m.
13. Typical structural walls density is 4%. Ranging from 2 to 6% but can go up to 10% for high rise depending on thickness. Both principle directions generally have same density of walls.
14. Façade may be masonry with textured finish, stone cladding, precast panels or light weight panels with partial/full glazing.

Sr. No	Description(FAQs)	Explanation
1	To prepare shell drawings/ adaptation plans, what details are required to be indicated in architectural as well as structural drawings.	Tunnel form is the only formwork system that comes before the architect is involved. For large mass construction the architect needs to know the principles of tunnel form in order to maximize the great range of flexible designs available with planning.
2	The overall dimensional tolerances, vertical and horizontal faces.	Horizontal levels can be as low as $L/2500$ when tunnel form is systematic and verticality in general a 60 m high building can be accurate to 1-2 cms.
3	The activity location and skill-wise deployment of manpower with computation of productivity	A 320m ² floor area (approx. 1200m ² of tunnel form) completed in one days would require a team of 28-32 workers eg 12 form workers 12 steel workers 1 formwork oiler, 2 crane operator and 4 electricians.
4	Can you provide engineering support to work out the logistics at site?	Yes may be offered, as a separate package
5	Can we have sunk slab, lofts in kitchen. How the provision of toilet sunk slab is done.	May be done with large block outs (with 1 day Lag) but impractical and time consuming. Generally a 5cm screed fill in concrete/cement is used to give necessary gradients for bathrooms etc.
6	What is weight of system, what crane capacity is needed?	A minimum 8MTCrane is required . Per m ² the weight is around 85kg ² per m ² for each m ² of concrete surface without scaffolding and platforms. With scaffolding and platforms the weight is around 100-110kgs per m ² depending upon the project.
7	Is there any saving in steel by using this system?	Yes. As wire mesh is used the saving may be between 10-20% depending upon the project. However this has to come from Structural design & detailing.

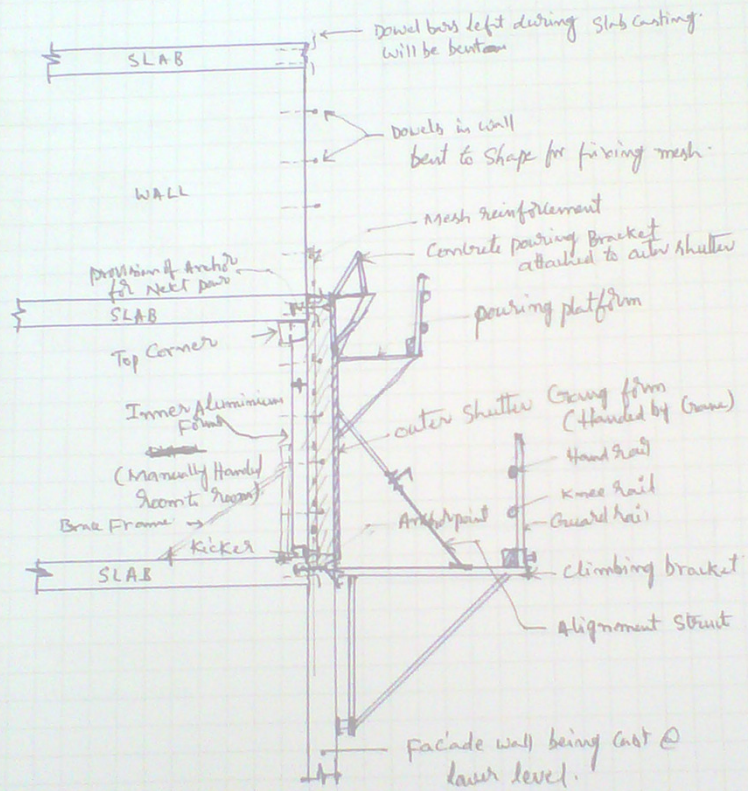
Sr. No	Description(FAQs)	Explanation
8	How cleaning has to be done, after De-shuttering.	Cleaned with a brush and water and re-oiled between each application/floor. Oiled and stored between projects
9	Whether concrete is free flow and self-compacting?	free flow, mid range water reducers present.
10	what will be thickness of these shear walls, external as well as internal.	150mm-250mm depending on the project as per structural design. Tunnel form as a mould don't have any limitation as such.
11	Can we get form finish after de-shuttering?- To avoid plaster	YES. In fact less joint lines and tie holes in this system
12	What is the stripping time, how to support once De-shuttering is done.	Stripping time can be as small as 8 hours when the concrete has reached 40% or as per the requirement. Back propping is done for every 2.5m ² -3m ² of slab as the half tunnels are removed
13	Is tunnel form for Low cost housing or affordable mass housing only?	Need not have to be. Most of the High end luxury projects in turkey done with tunnel form. It is a matter of planning and adaptation.
14		



- Stop end will have provision to take out the dowel bars which will be fixed to tunnel form
- Rebar will be projecting 300mm or as per design from edge of the slab cast
- Dowels will be bent (top bars upwards & bottom bars downwards) and the mesh reinforcement of Façade wall be connected between the dowels
- Façade wall casting will follow 4 floors below the slab being cast

Typ. detail of Facade wall in-situ casting.

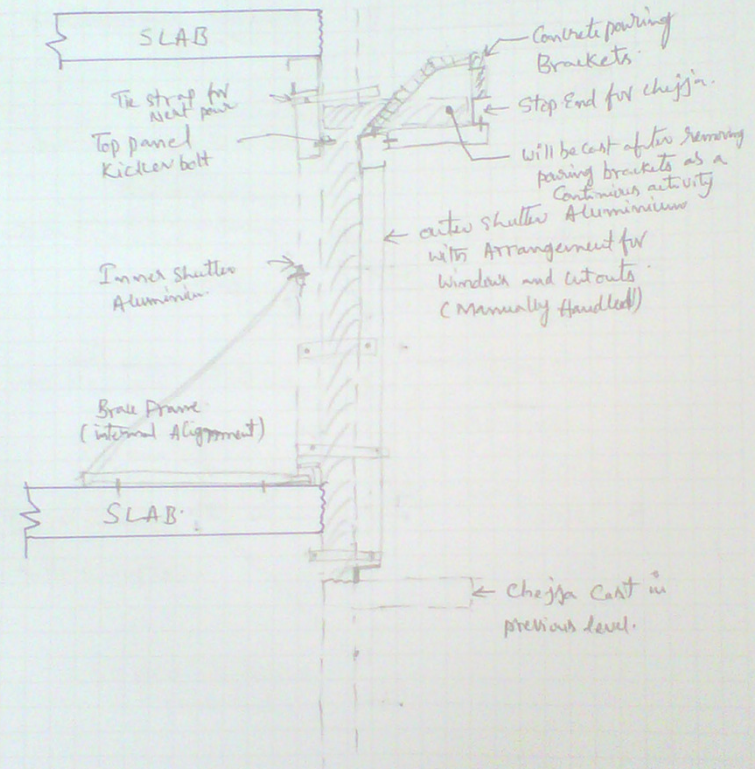
(Straight portions, Ex: Utility Areas with openings & straight walls)



NTS

So Scaffolding adjusted in flooring for deck Areas & utility Areas.

Typ. detail for window & chajja Areas.



Tie patti holes will be filled from outside with Grout later on before painting as a predecessor.



THANK YOU