Design and Techniques for Safety in High Rise Buildings - Focus on Temp. Structures - Formwork

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Contents of my presentation

- Why ‘Temporary structures’ do not deserve ‘temporary’ treatment? The status of formwork in the country and failures in temporary structures
- Solutions available in context of high rise buildings
  - Climbing formwork for wall
  - Slab formwork- Mivan, Doka, and PERI
  - Flying formwork such as: Table Formwork, Tunnel Formwork, Column Mounted Shoring System, and Gang Form
  - Avoiding failures in multistoreyed building construction
Why ‘Temporary Structures’ do not deserve ‘temporary’ treatment?

- ‘Temporary’ gives a feeling as if it is something not that important
- But is it the case-
- In RCC Construction, Temporary structures say formwork
  - Quality, Economy, Safety
  - Consumes about 40-50% of the total cost and about 60-70% of the time
  - Major investment required

Thus ‘TEMPORARY’ is really not ‘Temporary’
Common defects due to poor formwork quality

1. Honey comb

Formwork needs to be designed & built accurately so that the desired size, shape position, correct location, quality and finish of acceptable quality of the cast concrete are attained.
Quality

- Common defects due to poor formwork quality
  2. Poor Construction Joint / Offsets in Concrete Joint
Quality

- Common defects due to poor formwork quality

3. Plywood Grains Stuck on the Concrete Surface

![Image of plywood grains on concrete surface]

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Safety

- In Building Construction
  - 60% Failure due to Formwork Collapse, Shoring Collapse, Inadequate Shoring & Lateral Bracing
  - 8% due to premature removal of shore.
  - 18% Failure is due to faulty materials.

Thus Formwork needs to be built adequately so that it is capable of supporting all dead & live loads without danger to workmen and to the concrete surface.
Collapse of one floor leading to another
View of the bent shoring (due to excess load)
View of the portion of the slab which failed due to concrete overloading
Another view of the portion of the slab which failed due to concrete overloading (note the buckled props)
Another view of the portion of the slab which failed due to concrete overloading
View of portion of slab and beam formwork which collapsed
Another view of portion of slab and beam formwork which collapsed
Wall Formwork

Fig. __ Traveling Climbing Formwork System
Fig._L&T-Doka Wall Formwork with Traveling Climbing System in Use for the Construction of LNG Tank for M/s Punj Lloyd Ltd. Site at Dabhol (Diameter of the Tank 80 m, Shutter Panel Size 4m x 3.8m, Height of Tank = 40m.)
L&T WALL FORMWORK WITH TRAVELING CLIMBING SYSTEM IN USE FOR THE CONSTRUCTION OF LNG TANK

FOR M/S. PUNJ LLOYD LTD., SITE AT DABHOL. (DIAMETER OF THE TANK 80M, SHUTTER PANEL SIZE 4M x 3.8M, HEIGHT OF TANK 40M)
In CB 240 system, the formwork is mounted on a carriage and can be moved around 750 mm. In CB 160 system, the formwork is simply tilted backward when striking.
CB System being transported through crane

In both the systems, the formwork is moved to the next pour together with the scaffold in one crane lift.
RCS formwork

formwork is supported on a mobile carriage which can be retracted up to a distance of 900 mm. System can be climbed either with the crane or lifted by means of mobile hydraulic climbing devices. In this system a component called climbing shoe guides the climbing rail to the next casting segment. The climbing pawl engages automatically and secures the complete unit after lifting for 500 mm.
The system is useful in all the regular climbing applications.

This system has climbing mechanism with a lifting power of 100 kN, which raises the climbing unit to the next pour without the need for intermediate anchors.
Slab and Beam by L&T formwork

- Modular, easy to erect and dismantle.
- Durable, faster construction.
- Better site and store-yard management
- L&T ‘Doka flex’ for casting waffle slab

‘L&T Doka’ at RCC slab casting

‘Doka Flex’ for Waffle slab at Bangalore

Source: L&T
Gridflex Aluminum Grid Slab by PERI

Skydeck aluminum panels

Detail view of Skydeck panel slab formwork

Source: PERI
Multiflex Girder Slab by PERI

Multiflex girder slab

Detail view of Multiflex girder formwork

Source: PERI
MIVAN formwork is the lightweight panel made of extruded aluminum rail section and welded to aluminum sheet.

- Good stiffness to weight ratio and ensures minimal deflection.
Beam & Slab system by MIVAN

- The system is simple, flexible and cost-effective.
- Factory made, highly précised aluminum sections
- Possible reuse could be even up to 250.
- Delivers total quality work increases concrete durability.
- 4 to 5 day cycle for floor-to-floor construction- Profitable.

MIVAN wall junction

Details of formwork junction
Construction steps for MIVAN

- **Step 1**: Setting out and survey; adjustment if any and Timber stay fixing along the setting out line

- **Step 2**: Vertical rebar fixing and first stage mechanical and electrical works.
Construction steps for MIVAN

- **Step 3: Wall, column, and beam formwork erection**
Construction steps for MIVAN

- **Step 4: Deck / soffit formwork erection**
Construction steps for MIVAN

- Step 5: Slab rebar and 2nd phase of M&E works
Construction steps for MIVAN

- **Step 6: Sunken portion formwork fixing, spacer and vertical soldier fixing**
  The formwork for sunken portion is fixed besides fixing of spacer and vertical soldier. The vertical soldier is used to maintain the verticality of beam side by using tie rod and wing nuts. Spacing of the vertical soldier is approximately 1000 mm. The same slot can be used for fixing walkway brackets.

- **Step 7: Vertical and horizontal alignment and Checking**
  The vertical and horizontal alignments are checked.
Construction steps for MIVAN

- Step 8: Concrete pouring and compaction

- Step 9: Striking of wall formwork
Flying formwork

- The flying form is a system of formwork which is assembled into form units usually at ground and is located to form concrete elements at the site location. The form units are further relocated at new location with virtually no disassembly of parts to form concrete elements.

- The flying forms are more common in high rise buildings for rapid cycle construction where in large repetitions are possible and thus justifying their relatively high initial cost of fabrication.
Flying formwork

- In case of flying formwork all the members are assembled together to allow lifting of the whole system in one piece which is in contrast of hand set forms.

- A typical flying formwork consists of sheathing member (mostly plywood), trusses or shores, wooden beams as stringers and joists.

- Joists are timber or aluminium beams connected in most cases to deep trusses.
Step-1

- Forms are preassembled at ground level
- Entire assembly is lifted and placed on existing floor or at desired level by crane and hoist line.
Step-2

- Form assembly is then moved and placed into exact position by movable dollies.
Flying Formwork Cycle

**Step-3**

- Form assembly is adjusted to correct height and attached firmly with other modules.
- Reinforcement steel is fixed and electrical, mechanical and plumbing work is done.
Step-4

- Form assembly support systems are lowered to bring the form down.
- This process is done by the hydraulic jacks placed under the formwork.
Step-5

• Then the form assembly is moved to the edge of the support system by dollies.
• Special attention on its movement has to be given.
Step-6

- Form assembly tilts when about half of assembly is out of the floor slab.
- Again the formwork is hoisted to the upper level for the next cast.
Table Forms

- Another variant of flying form.
- Capable of providing very high speed of construction.
- Used primarily for multi-storey building (such as residential flats, hotels, hostels, offices and commercial buildings) construction works with regular plan layouts and long repetitive structures.
Table formwork being flown to its new location
Table formwork

Table formwork being positioned
Transportation arrangement for table formwork
Table form in practice

Extensive use of Table form at Oberoi Mall Project Site Mumbai (Courtesy L&T)
Table module being shifted
to new location (Note the props in folded position)
Table module being transported using crane (note the lifting fork)
Table form being shifted on trolley to the desired location
PERI Table Formwork

- Peri offers modular tables which are pre assembled for immediate use.
- The modules are available in four standard sizes which allow optimal adjustment to the building. The sizes are:
  - Table Module VT 200/215 x 400
  - Table Module VT 250/265 x 400
  - Table Module VT 200/215 x 500
  - Table Module VT 250/265 x 500
Peri Uniportal Table form
Table swivel head

Table swivel head used in props
Skytable form - PERI

Skytable form (see the trusses)
Tunnel form

- Fixed bracing.
- Need to dismantle into smaller modules before reuse.
Tunnel form

- Wall and ceilings are cast together.
Tunnel formwork system
Construction steps - Tunnel form

Construction of starter wall for the tunnel formwork system
Construction steps-Tunnel form...contd.

Placement of tunnel form in progress
Construction steps - Tunnel form...contd.

Tunnel form (window)
Construction steps - Tunnel form... contd.

Heating equipment in position for the tunnel form work
Column Mounted Shoring System

Column mounted shoring system (Courtesy Formwork–Shoreall available at http://www.formwork-exchange.com)
Column Mounted Shoring System

Column mounted shoring system (Courtesy Formwork–Shoreall available at http://www.formwork-exchange.com)
Column Mounted Shoring System
Issues in Multistoreyed Building Construction

Shoring explained

Installing shores for Slab 1
Casting Slab 1
Installing shores for Slab 2
Casting Slab 2
Installing shores for Slab 3
Casting Slab 3
Removing shores under Slab 1 and installing shores for Slab 4
Casting Slab 4

The process is repeated similarly for higher floors
Shoring and reshoring explained

- Installing shores for Slab 1
- Casting Slab 1
- Installing shores for Slab 2
- Casting Slab 2
- Reshoring under Slab 1 and installing shores for Slab 3
- Casting Slab 3
- Removing reshore under Slab 1, reshoring under Slab 2 and installing shores for Slab 4
- Reshoring under Slab 2 and casting Slab 4

The process is repeated similarly for higher floors.
Preshoring explained

(a) Freshly cast floor
(b) Partially cured concrete
(c) Deflected shape
(d) Deflected shape
Backshores

- Backshores are shores placed snugly under a stripped concrete slab or structural member after the original forms and shores have been removed from a small area without allowing the slab to deflect or support its own weight or existing construction loads from above.
Assumptions made in the simplified analysis

- Shores and reshores are infinitely stiff relative to the slabs.
- Slabs interconnected by shores therefore all deflect equally when a new load is added, and carry a share of the added load in proportion to their relative stiffnesses.
- Slabs have equal stiffness and added loads are shared equally by the interconnected slabs.
- Ground level floor or other base support is rigid.

Computation of loads on slabs and shores
Two levels of shores and one level of reshore - Summary

live load, and self weight of formwork, shores, and reshores considered
Computation of strength of concrete slab at a given point of time

- The available strength depends mainly on the concrete age, the type of cement, and the construction temperature.

- The 28-day design ultimate load carrying capacity of the slabs can be computed as:
  \[ U_{28} = \gamma_1 \times D.L. + \gamma_2 \times L.L. \]

- The strength at day \( x \) is computed by:

ACI suggested values of \( \gamma_1 \) and \( \gamma_2 \) are 1.4 and 1.7 respectively.

IS: 456–2000 suggested values of \( \gamma_1 \) and \( \gamma_2 \) are equal to 1.5.
### Strength Calculation 1

\[ f_{ct} = \frac{t}{(a + b \cdot t)} f_{ck} \]

Source: ACI209R-92

Where,

- \( f_{ct} \) is compressive strength at time \( t \) (days elapsed) after casting
- \( f_{ck} \) is 28-day characteristic compressive strength of concrete
- \( a, b \) are constants depending on the type of cement and curing method

<table>
<thead>
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<th>Type of Curing</th>
<th>Type of Cement</th>
<th>( a )</th>
<th>( b )</th>
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</thead>
<tbody>
<tr>
<td>Moist Curing</td>
<td>Type I</td>
<td>4.0</td>
<td>0.85</td>
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<tr>
<td></td>
<td>Type III</td>
<td>2.3</td>
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<tr>
<td>Steam Curing</td>
<td>Type I</td>
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<tr>
<td></td>
<td>Type III</td>
<td>0.7</td>
<td>0.98</td>
</tr>
</tbody>
</table>
Solution steps

- **Step 1**: Load distribution for two levels of shores and one level of reshores
- **Step 2**: Allowable loads on the slabs
- **Step 3**: Comparison between the values obtained in step 1 and step 2
Comparing allowable v estimated load

- The allowable load is compared with the expected load coming on the slabs for a particular construction method and it should be made sure that the latter is always less than the former.

- In case the allowable load is exceeded, suitable adjustments can be made. For example, changes can be made in the following parameters:
  - the construction cycle,
  - the period for shore and reshore removal,
  - number of levels of shores and reshores etc.
Other books by the author

Construction Project Management
Theory and Practice

Determinants of Construction Project Success in India

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