midas Gen Advanced Webinar on

Construction Stage Analysis with Special Emphasis on Column Shortening

Webinar Objective
Construction Stage Analysis
Column Shortening
Procedure for Construction Stage Analysis
Useful Features for Construction Stage Analysis
Project Applications
Live Demonstration
Why midas Gen
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Objective

1. Introduction to Construction Stage (CS) Analysis.

2. Introduction to Column Shortening.

3. Discussion of Features available in midas Gen for CS Analysis.

4. Live demonstration of performing CS analysis on a 40 Storey RC Building and interpretation of Column Shortening results.

5. At the conclusion of the webinar, familiar with construction stage analysis, column shortening phenomenon and midas Gen applicability to those issues.
Construction Stage Analysis

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**Why Construction Stage (CS) Analysis**

1. General analysis is performed under the assumption that all loads are simultaneously applied to a completed structure.
2. This assumption is not valid in a real construction sequence because building is constructed floor by floor and dead load acts sequentially.

![Construction Stage Analysis Diagram]

- **Completed Structure**
  - Self weight of slab
  - Other Dead Loads (Part ions, Finishes)
  - Earthquake

- **Construction Sequence**
  - Dead Load + Live Load
  - Wind Loads
  - LL, WL, EQ Acts
Conventional analysis Vs CS Analysis

Case 1 – Conventional Analysis

Case 2 – CS Analysis
Conventional analysis Vs CS Analysis

Case 1 – Conventional Analysis

Case 2 – CS Analysis
Where CS Analysis is Required?

Long Span Trusses

Long Span Slabs, Beams constructed in multiple stages

Prestressed concrete Structures

CS analysis should be performed for all structures where there is a change in Support Conditions, Loading and varying material properties (Concrete).
Column Shortening

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Column Shortening

**Elastic Shortening**

Decrease in the length under imposed load which is linearly proportional to load.

\[
E = \frac{\sigma}{\varepsilon}
\]

\[
\Delta L = \frac{PL}{A E}
\]

Young’s Modulus is strictly applicable only to the Linear Categories.

**Inelastic Shortening (Concrete Structures)**

Creep Shortening.
Shrinkage Shortening.
Column Shortening

With increased height of structures the effect of column shortening (Elastic & Inelastic) take on added significance and need special consideration in design and construction.

Elastic Shortening of 80 Storey Steel Structure ~ 180 mm to 255 mm.

Elastic Shortening of 80 Storey Concrete Structure ~ 65 mm.

Total Shortening of 80 Storey Concrete Structure ~ 180 to 230 mm.

Inelastic Shortening ~ 1 to 3 times Elastic shortening.
Effects of Column Shortening

- **Absolute shortening is rarely of practical interest.**

- **Differential shortening between adjacent vertical elements is the most important factor for engineer.**

- **Axial Shortening of vertical elements will not effect those elements very much, horizontal elements like beams and slabs and non structural elements are affected.**
Effects of Column Shortening

**Structural Effects**

- Slabs may not be truly horizontal after some time.
- Beams could be subjected to higher bending moments.
- Load transfer.

**Non Structural Effects**

- Cracks in Partition Walls.
- Cracks in Staircases
- Deformation of Cladding.
- Mechanical Equipment.
- Architectural Finishes.
- Built in Furnishings.

These non structural elements are not intended to carry vertical loads and are therefore not subjected to shortening.
Effects of Column Shortening

- Deformation and breakage of Facades, windows & Parapet walls...
- Deformation of Vertical Piping System
- Reverse Inclination of Drainage Piping System
- Deformation and breakage of internal partitions
Movements related to construction sequence

- **Pre-slab installation shortenings**
  - Shortenings taking place up to the time of slab installation

- **Post-slab installation shortenings**
  - Shortenings taking place after the time of slab installation

① : Compensation
② : Design Level
③: Pre-slab Installation shortening
④: Post-slab Installation shortening
Procedure for Accounting Column Shortening

1. **Analytical Measurement**
   - Using Software or Manually (Manual calculation is almost impossible)
   - Reflection of physical properties in calculation from material experiment:
     - Young’s Modulus, Poisson’s Ratio, Mean Compressive strength, Volume to Surface ratio, Shapes, sizes etc.
   - Reflection of effects of Climate on shortening:
     - Average Temperature, RH etc.
   - Construction Sequence:
     - Stage duration, Additional Steps, Member Age, Load activation age, Boundary activation age etc.
   - Reflection of the above effects on site master-schedule.

2. **Experimental Measurement**
   - Installation of sensors or gages in members for determining the actual shortening.
   - Understanding and noting the following:
     - Curing procedure / Temperature,
     - Actual Shortening,
     - Change in Ambient Temperature (Important),
     - Actual Humidity,
     - Deviation from Defined Construction Stages,

3. **Field Measurements**
   - Manipulation of factors in analytical Calculation, Re-Analysis...

Method has Limitation
Compensation at Site

Elapse of Time

Δ1 1st correction

Δ2 2nd correction

Core Wall

Column

Core Wall

Column
Procedure for Construction Stage Analysis
Performing CS Analysis in midas Gen

1. Define materials, sections
2. Assign Elements, Boundaries, & Loads to the groups
3. Define Time Dependent Materials
4. Enter the Construction Stage Analysis Data
5. Perform Analysis
6. Check results for each Construction Stage
7. Check Column Shortening

- Creep & Shrinkage
- Compressive strength
- Specify the duration of CS
- Activate/Deactivate element groups / boundary groups / load groups
Time Dependant Material Properties

Creep and Shrinkage

Compressive Strength
Construction Stage Analysis Data

**Procedure For CS Analysis**

**Construction Stage Duration**

0 day 10 day 20 day 30 day 40 day

- **First Step**
  - Activation or Deactivation of element, boundary, and load

- **Additional Step**
  - Activation or Deactivation of load with time span from the stage start

- **Last Step**
  - Activation or Deactivation of element, boundary, and load
Procedure For CS Analysis

Check results for each Construction Stage

- Analysis results can be checked for each construction stage.
- Absolute minimum or maximum results of envelope can be also checked among entire construction stages.
- Results for creep and shrinkage effect are provided.
Procedure For CS Analysis

Column Shortening Graph

- Post-slab installation shortening (Subsequent Slab)
- Pre-slab installation shortening (Up to slab)
- Total Shortening (Pre-Slab + Post-Slab)
Useful Features for Construction Stage Analysis

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Building Model Generation Wizard

- The wizard readily allows us to define the timing of elements created and loadings applied in the construction stages during the erection of a building.
- You may find it more convenient to first click the [Automatic Generation] button to define the basic construction stages and modify them as necessary.
**Construction Stage Analysis for Composite Members**

- Define an analytical model for each construction stage by assigning activated or inactivated sections corresponding to each construction stage of a composite section.
- By using Composite Section for Construction Stage, we can consider the construction sequence with creep and shrinkage effect.
Material Stiffness Changes for Cracked Sections

- Specific stiffness of specific member types may be reduced such as the case where the flexural stiffness of lintel beams and walls may require reduction to reflect cracked sections of concrete.
- Section stiffness scale factors can be included in boundary groups for construction stage analysis. The scale factors are also applied to composite sections for construction stages.
Spring Supports for Soil Interaction

- **Point Spring Support** (Linear, Comp.-only, Tens.-only, and Multi-linear type)
- **Surface Spring Support** (Nodal Spring, and Distributed Spring)
- Springs can be activated / deactivated during construction stage analysis.

![Nonlinear point spring support](image)

- [Pile Spring Support]
- [Surface Spring Support]
- Nodal Spring and Distributed Spring
**Tendon Loss**

- Pre-stress load can be considered in construction stage analysis.
- Tendon primary / secondary forces are provided with pre-stress loss graph.
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Burj Khalifa (Dubai, UAE)

**Overview**

- **Height**: 705 m
- **No. of floors**: 160
- **Location**: Dubai, United Arab Emirates
- **Function / Usage**: Office Building & Residential Building
- **Designer**: Adrian D. Smith
- **Architect**: Skidmore, Owings & Merrill
- **General Contractor**: Samsung Development
### SK S-Trenue (Seoul, Korea)

<table>
<thead>
<tr>
<th>Overview</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>39,600 m²</td>
</tr>
<tr>
<td>No. of floors</td>
<td>36</td>
</tr>
<tr>
<td>Location</td>
<td>Seoul, Korea</td>
</tr>
<tr>
<td>Function / Usage</td>
<td>Office Building</td>
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<tr>
<td>Structure Type</td>
<td>Composite Structure</td>
</tr>
<tr>
<td>Foundation Type</td>
<td>Mat Foundation</td>
</tr>
<tr>
<td>Lateral load resisting system</td>
<td>RC Core + Steel + RC Composite Frame</td>
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</table>
# Keangnam Hanoi Landmark Tower (Hanoi, Vietnam)

<table>
<thead>
<tr>
<th>Overview</th>
<th>Details</th>
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<tbody>
<tr>
<td>Height</td>
<td>345m</td>
</tr>
<tr>
<td>No. of floors</td>
<td>70 fl., 49 fl.</td>
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<tr>
<td>Location</td>
<td>Hanoi, Vietnam</td>
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<tr>
<td>Function / Usage</td>
<td>Hotel, Office, and Residential building</td>
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<td>Structure Type</td>
<td>Reinforced Concrete Structure</td>
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<tr>
<td>Architect</td>
<td>Heerim, Samoo, Aum &amp; Lee, Hellmuth Obata + Kassabaum</td>
</tr>
<tr>
<td>Contractor</td>
<td>Keangnam</td>
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</tbody>
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Live Demonstration

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Structural Plan

Storey's: 40
Storey Height: 3.15 m
Total Height: 126.85 m

Typical Floor Plan
### Material and Sectional Properties

<table>
<thead>
<tr>
<th>Level</th>
<th>$f_{ck}$</th>
<th>Size</th>
<th>Wall Thk.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; to 10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>50</td>
<td>1200 x 1200</td>
<td>900 x 900</td>
</tr>
<tr>
<td>11&lt;sup&gt;th&lt;/sup&gt; to 20&lt;sup&gt;th&lt;/sup&gt;</td>
<td>40</td>
<td>1000 x 1000</td>
<td>800 x 800</td>
</tr>
<tr>
<td>21&lt;sup&gt;st&lt;/sup&gt; to 30&lt;sup&gt;th&lt;/sup&gt;</td>
<td>35</td>
<td>800 x 800</td>
<td>700 x 700</td>
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<tr>
<td>31&lt;sup&gt;st&lt;/sup&gt; to 40&lt;sup&gt;th&lt;/sup&gt;</td>
<td>30</td>
<td>600 x 600</td>
<td>600 x 600</td>
</tr>
<tr>
<td>Girder</td>
<td>30</td>
<td></td>
<td>900 x 600</td>
</tr>
<tr>
<td>Link Beam</td>
<td>30</td>
<td></td>
<td>700 x 500</td>
</tr>
</tbody>
</table>
Construction Schedule

Partition Load: 5 weeks after first slab casting.
Finish Load: 5 Weeks after Partition Wall Construction.
Steps

**Time Dependant Material Properties**
- Define Creep and Shrinkage Properties.
- Define time Dependant Material Properties.
- Define Time Dependant Material Link.
- Change Element Dependant Material Property

**Define Construction Stage**
- Define Construction stages using Building Wizard for CS analysis
- Create LL group and add LL to LL group.
- Define CS for LL

**Perform Analysis**

**Results**
- BMD’s and SFD’s for different CS.
- Deformations for different CS.
- Column Shortening Graph.
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Easy and accurate modeling using CAD interface and intuitive usage

- Structure Wizards
- Various Material Properties
- Section Property Calculator for irregular shape sections

Fast generation of various load type and international code

- Easy assignment of floor loads
- Static wind and seismic load for international standard
- Various type of display for checking entered loads

Fast and reliable analysis results from the latest analysis algorithm

- Linear static analysis
- Response spectrum analysis
- Heat transfer analysis
- High-end analysis such as construction stage analysis and nonlinear analysis

Intuitive graphical results and various reports

- Precise display of member force diagram
- Intuitive result display using arrows and contour
- Excel compatible table results

Automatic member verification function and steel optimal design

- International design code for steel, SRC, RC structures
- Automatic calculation of design force and strength
- Graphical and detailed design report