Differential Shortening of Vertical Elements in Concrete Tall Buildings: Creep and Shrinkage Effects

Majid Hashmi.  
ME; PE (USA, MD)  
Managing Director  
KMH Engineering
Future Cities - a 360 degree event on city development

1 Venue, 3 Interconnected Shows
Mumbai | September 19-21
1. Princess tower: Dubai
- Construction completed in 2010.
- Height 415m above Ground.
- 6 Basements + G+ 100 Residential floors
- Guinness book of world records up to 2015- “world’s tallest residential building”.
- Gravity system : composite steel decking
- LLRS : RCC Framed tube system.
- Challenges: To cast 2 slabs per week.
- Accelerations exceeding the limits of 18 milli g.

2. Elite tower : Dubai
- Construction completed 2013.
- Height 381m above ground.
- 4 Basements + G + 86 Residential floors.
- Floor system : Post tensioned slabs
- LLRS : RCC framed tube system.
CONTENTS:
Column shortening
Issues
Creep and shrinkage.
Calculations- Actual measurements on site
Responsibility- Designers
Responsibility- Contractors

KMH ENGINEERING
Column shortening due to Strain

**ELASTIC STRAIN**  due to stress of imposed loads
**CREEP STRAIN**  due to stress of imposed forces
**SHRINKAGE STRAIN**  due to change in concrete volume over time.

Others: (not covered here)
Temperature
Solar gain
Column shortening due to Strain
Column shortening has three components
1. Elastic shortening
2. Creep shortening.
3. Shrinkage shortening.
Elastic shortening

Force applied to the member P
Elastic modulus E
Cross sectional area A
Length of the member L
Creep shortening

Continuous INELASTIC deformation under SUSTAINED loads.

1. Mix design
2. Stress levels.
3. Loading histories.
4. Age of the first loading.
5. Reinforcement ratio.
6. Column to surface area.
7. Ambient humidity.
Shape of shortening curve.

Despite the shortening being cumulative, shortening up the buildings height does not increase linearly.
Princess tower - Dubai Marina - 415m
Settlement of INNER TUBE was more than OUTER TUBE.

The central core was settling more than the perimeter tube. Superelevation was given to inner core. Maximum span was about 10m. Maximum superelevation was about 55mm. Floor decking was installed with a tilt.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Floor</td>
<td>Column Lvl.</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>(+0.003)</td>
<td>(+0.003)</td>
<td>(-0.006)</td>
<td>(+0.006)</td>
</tr>
<tr>
<td>Inner Core Lvl.</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>1.403</td>
<td>(-0.003)</td>
<td>(+0.003)</td>
<td>(-0.006)</td>
<td>(+0.006)</td>
</tr>
<tr>
<td>2nd Floor</td>
<td>Column Lvl.</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>(+0.004)</td>
<td>(+0.004)</td>
<td>(-0.010)</td>
<td>(+0.010)</td>
</tr>
<tr>
<td>Inner Core Lvl.</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>1.720</td>
<td>(+0.004)</td>
<td>(+0.004)</td>
<td>(-0.010)</td>
<td>(+0.010)</td>
</tr>
<tr>
<td>3rd Floor</td>
<td>Column Lvl.</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>(-0.005)</td>
<td>(+0.005)</td>
<td>(-0.009)</td>
<td>(+0.009)</td>
</tr>
<tr>
<td>Inner Core Lvl.</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>38.389</td>
<td>(-0.005)</td>
<td>(+0.005)</td>
<td>(-0.009)</td>
<td>(+0.009)</td>
</tr>
<tr>
<td>4th Floor</td>
<td>Column Lvl.</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>(+0.002)</td>
<td>(+0.002)</td>
<td>(-0.001)</td>
<td>(+0.001)</td>
</tr>
<tr>
<td>Inner Core Lvl.</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>56.630</td>
<td>(+0.002)</td>
<td>(+0.002)</td>
<td>(-0.001)</td>
<td>(+0.001)</td>
</tr>
<tr>
<td>5th Floor</td>
<td>Column Lvl.</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>(+0.003)</td>
<td>(+0.003)</td>
<td>(-0.002)</td>
<td>(+0.002)</td>
</tr>
<tr>
<td>Inner Core Lvl.</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>74.860</td>
<td>(+0.003)</td>
<td>(+0.003)</td>
<td>(-0.002)</td>
<td>(+0.002)</td>
</tr>
</tbody>
</table>

NOTE: ALL MENTIONED LEVELS ARE STRUCTURAL SLAB LEVEL+1.400
Super elevation of the central core

<table>
<thead>
<tr>
<th>FLOOR</th>
<th>DESIGN/CREEP</th>
<th>1st Check</th>
<th>2nd Check</th>
<th>3rd Check</th>
<th>4th Check</th>
<th>5th Check</th>
<th>6th Check</th>
<th>7th Check</th>
<th>Difference b/w Core &amp;Columns</th>
<th>Expected Differential</th>
<th>Consume A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>35th Floor</td>
<td>Column Lvl.</td>
<td>129.630</td>
<td>129.626</td>
<td>129.622</td>
<td>129.617</td>
<td>129.611</td>
<td>129.604</td>
<td>129.594</td>
<td>129.594</td>
<td>(+0.011)</td>
<td>(+0.024)</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td>Inner Core Lvl</td>
<td>129.654</td>
<td>129.645</td>
<td>129.639</td>
<td>129.635</td>
<td>129.628</td>
<td>129.620</td>
<td>129.611</td>
<td>129.605</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40th Floor</td>
<td>Column Lvl.</td>
<td>147.880</td>
<td>147.873</td>
<td>147.867</td>
<td>147.863</td>
<td>147.855</td>
<td>147.845</td>
<td>147.842</td>
<td></td>
<td>(+0.015)</td>
<td>(+0.028)</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td>Inner Core Lvl</td>
<td>147.908</td>
<td>147.896</td>
<td>147.888</td>
<td>147.881</td>
<td>147.870</td>
<td>147.861</td>
<td>147.857</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Super elevation of the outer columns

160m Tall
Armada tower-
Dubai JLT
Differential settlement Minimized.

310m tall building.

In Noida - Under construction
Compensation of differential shortening by tilting of shuttering.

290m tall building.

Worli- Already constructed.

Compensation or super elevation of columns done by tilting the shutter for the slabs. Columns are casted x mm more as per analytical findings.
Reducing the stress in columns, close to the core.

300m tall building.
BYCULLA. Under construction
Significance of finding the actual E value of concrete

Actual E values tested by the labs are used to predict the frequency, which are about +10% compared to code specified values.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Predicted Frequency (Hz)</th>
<th>Measured Frequency (Hz)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.129</td>
<td>0.146</td>
<td>1.13</td>
</tr>
<tr>
<td>2</td>
<td>0.140</td>
<td>0.159</td>
<td>1.13</td>
</tr>
<tr>
<td>3</td>
<td>0.533</td>
<td>0.544</td>
<td>1.02</td>
</tr>
<tr>
<td>4</td>
<td>0.576</td>
<td>0.590</td>
<td>1.02</td>
</tr>
<tr>
<td>5</td>
<td>0.594</td>
<td>0.641</td>
<td>1.08</td>
</tr>
</tbody>
</table>
3. Yaqub tower: Dubai

- Construction completed in 2011.
- Height 328 m above ground.
- **1 Basement + G+ 71** Residential floors.
- Floors: One way and two ways rib slabs.
- LLRS: RCC Tube in tube.
- **Challenges:** RCC Transfer slab at 21st floor.

4. Angsana twin towers: Dubai

- Construction completed 2008.
- Height 220 m above ground.
- **1 Basement + G + 50** Residential floors.
- Floor: RCC flat plate with peripheral beams.
- LLRS: RCC Shear wall frame interactions.
- **Challenges:**
5. MBK tower: Dubai

- Construction completed in 2011.
- Height 200 m above Ground.
- 1 Basement + 59 Residential floors

6. Armada towers: Dubai

Presenter’s Name

- Construction completed 2008.
- Height 180 m above ground.
- 1 Basement + G +44 Residential floors./Offices.
- Challenges: Front cantilevers are gradually increasing up to 11.0m at 22nd floor.
7. Confidential: Mumbai
- Construction restarted in 2017 after 7 years.
- Height 280 m above Ground.
- 1 Basement + 70 Residential floors.
- Challenges: Initially designed for 240m only and constructed up to 120m. NOW ADDED 6 MORE FLOORS.
- RWDI helped in getting the streamlined profile to reduce winds.

8. Supernova: Noida
- Construction started in 2013.
- Height 300 m above ground.
- 3 Basement + G + 80 Mixed use.
- Challenges: RCC outriggers are used to reduce drifts due to wind.
- Dense to very dense silty sand up to 70m below ground. Done iterative PLAXIS analysis with the geotechnical engineers. (Golders and Mr. Jaideep wagh)
THANK YOU

-KMH ENGINEERING