GC'2017

CACHAN

15 et 16 mars

CONSTRUCTION ET CONCEPTION DE LA TOUR MAHANAKHON À BANGKOK

Kanokpat CHANVAIVIT, Chloé CLAIR (BOUYGUES THAI),

André LY (BOUYGUES INTERNATIONAL BUILDING)

MahaNakhon Tower
Structure design

ANDRE LY (BOUYGUES)

MahaNakhon

Highest building in Bangkok

314m

BOUYGUES-THAI

Warnes Associates

ARUP

BOUYGUES-THAI

Warnes Associates

ARUP

Tower Characteristics

77 Storeys:

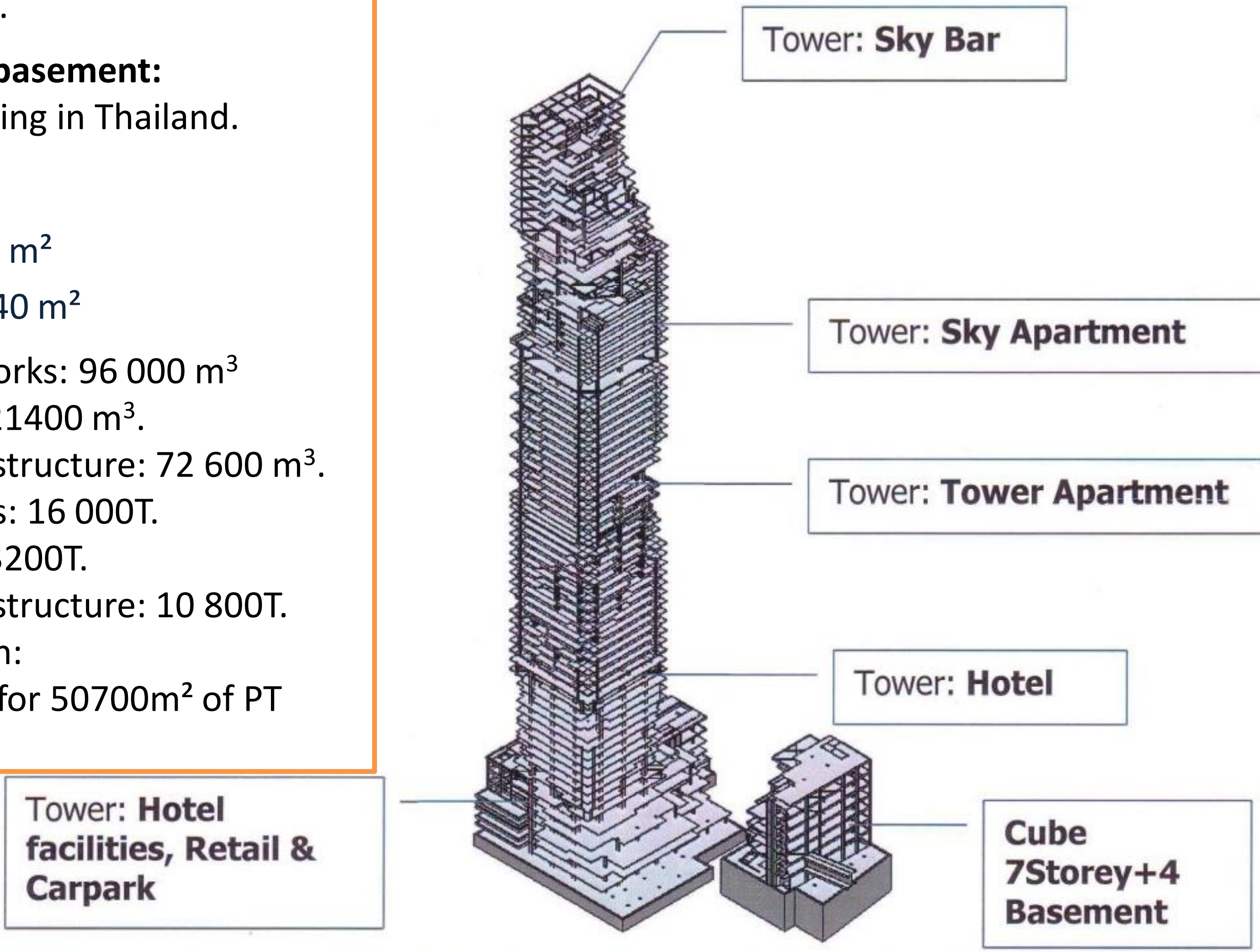
- 76 superstructure levels
- 1 basement.

314 m Height + 5 m basement:

- Tallest building in Thailand.

Quantities:

- Site: 14,500 m^2
- GCA: 140,540 m^2
- Concrete works: 96 000 m^3
  - Raft: 21400 m^3.
  - Superstructure: 72 600 m^3.
- Steel Rebars: 16 000T.
  - Raft: 3200T.
  - Superstructure: 10 800T.
- Post-Tension:
  - 350 T for 50700m^2 of PT slabs.



Conceptual Design:

-**Architect**: Office of Metropolitan Architecture (OMA) / Ole Scheeren.

-**Structure**: ARUP Beijing – CPI

Design Development (Design & Built) Construction Stage:

-**Architect**: Ole Scheeren - Hok Lok Siew.

-**Structure**: Warnes - ARUP Australia - Bouygues Thai - Bouygues Batiment International (BIIN)

-**Peer Review Structure:** Robert Bird (Australia) Aurecon

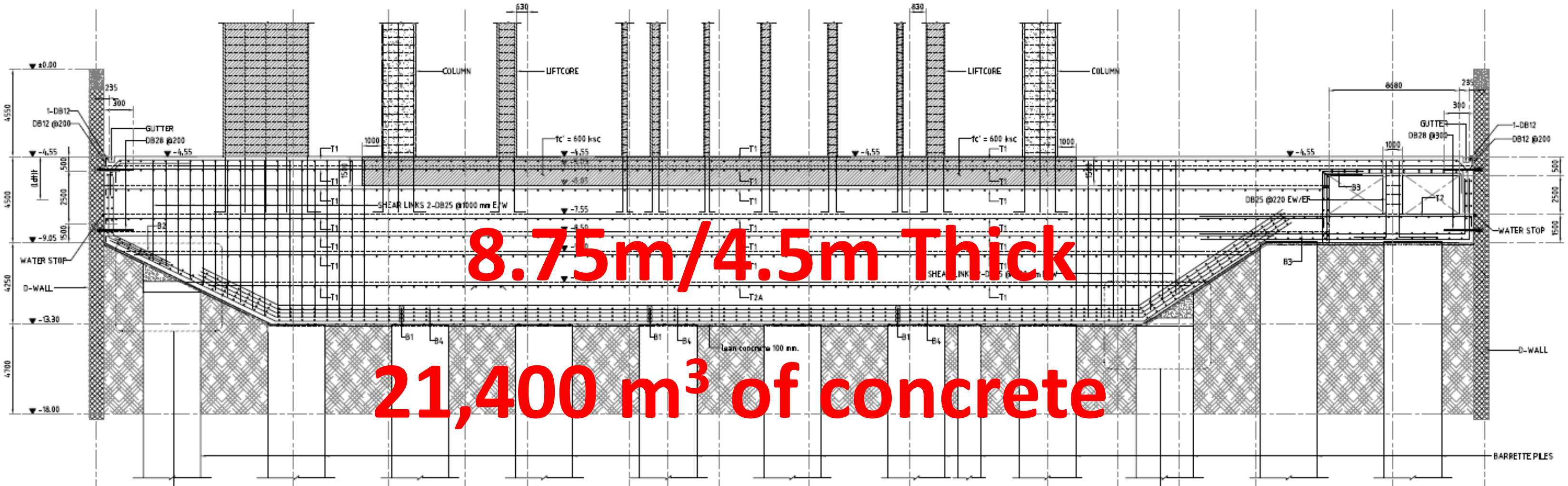
Structural Elements

- Foundation
- Core walls
- Columns
- Outriggers
- Floor slabs

Foundation


113 + 16 = 129 Barrettes 1.2 x 3.0
Tip level at -65m.
113 OF 1200x3000 ORIGINAL BARRETTES
16 OF 1200x3000 ADDITIONAL BARRETTES

Foundation



8.75m/4.5m Thick

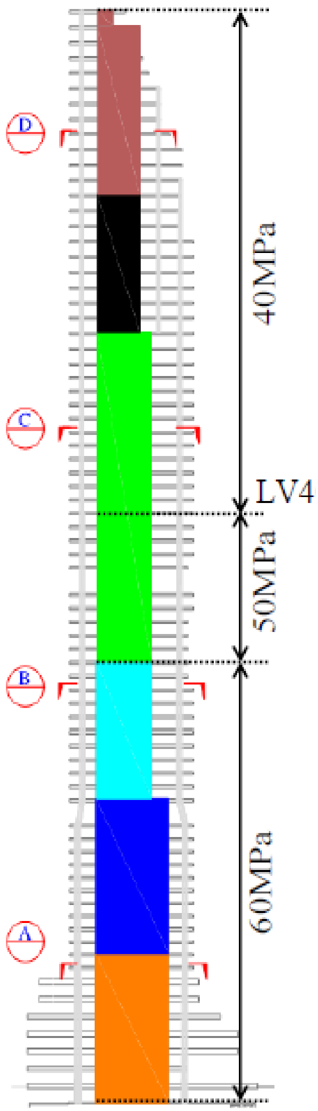
21,400 m^3 of concrete

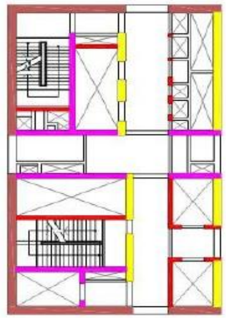
12 concrete pours, over a period of 2 months

3,200 T of steel rebars

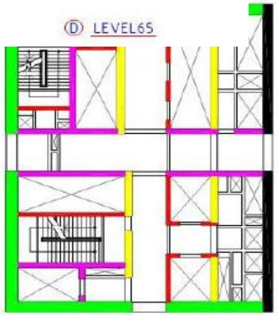
Rebar ratio = 150 kg/m^3

Core walls



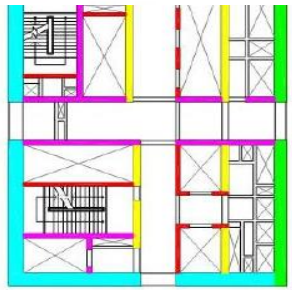


22m x 14m from the L52 to Top.

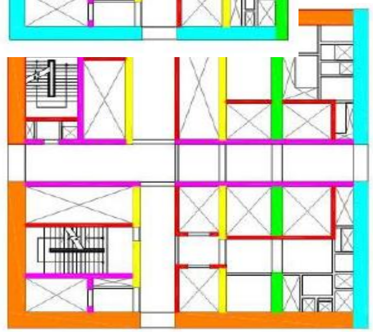


Color Code	Location	Core Wall Width
	BASEMENT 1 - LEVEL 8	1100
	LEVEL 9 - LEVEL 19M	1000
		900
		700
	LEVEL 52 - LEVEL 59	600
	LEVEL 60 - LEVEL 73	500
		400
		300
		200

22m x 17m from the L21 to L52.

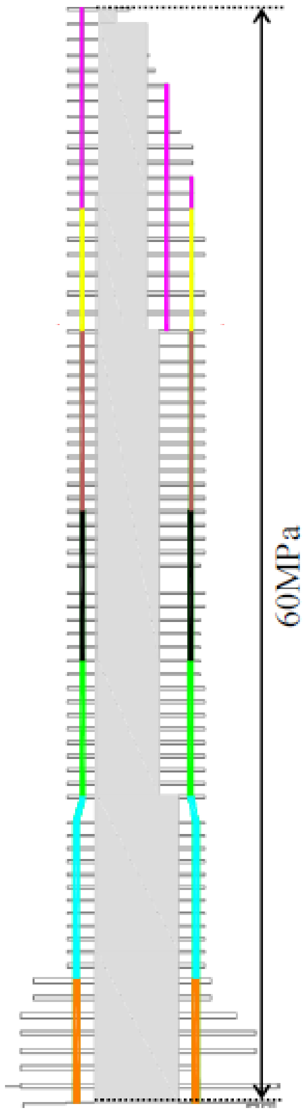


22m x 17m from the L21 to L52.

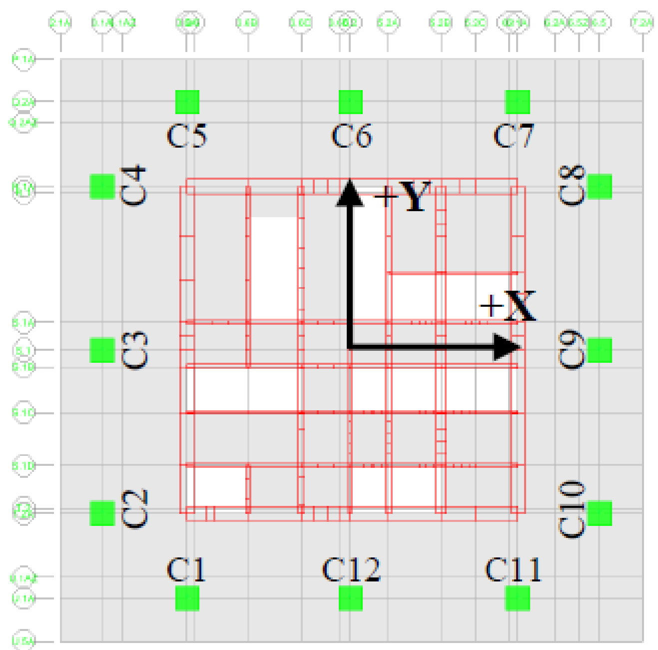


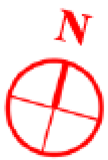
22m x 22m from the B1 to L20.

Columns



Color Code	Location	Column Size
	BASEMENT 1 - LEVEL 7	1800x1800
	LEVEL 8 - LEVEL 19	1600x1600
	LEVEL 20 - LEVEL 29	1400 x1400
	LEVEL 30 - LEVEL 39	1200x1200
	LEVEL 40 - LEVEL 50	1000x1000
	LEVEL 51 - LEVEL 59	900 x900
	LEVEL 60 - ROOF LEVEL 73	800 x800

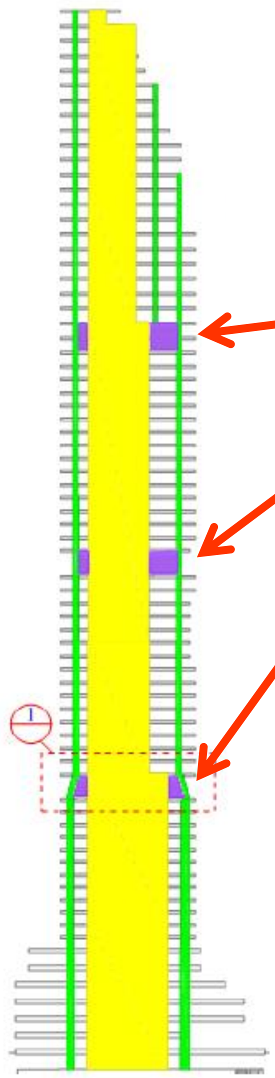




12 Mega-columns around the core

Concrete strength 60 MPa

Outriggers

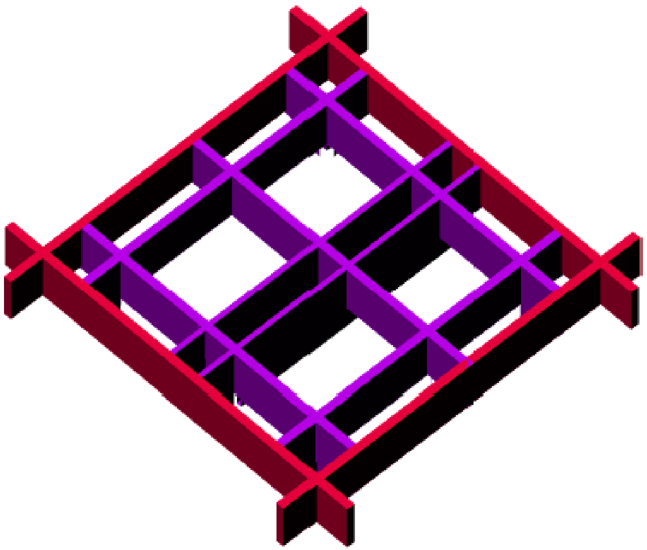


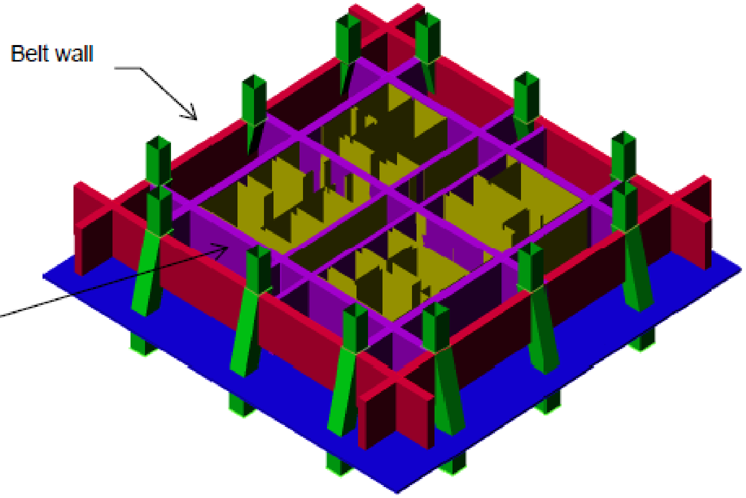
3 LEVELS OF OUTRIGGERS (TECHNICAL LEVELS) :

L51-L52

L35-L36

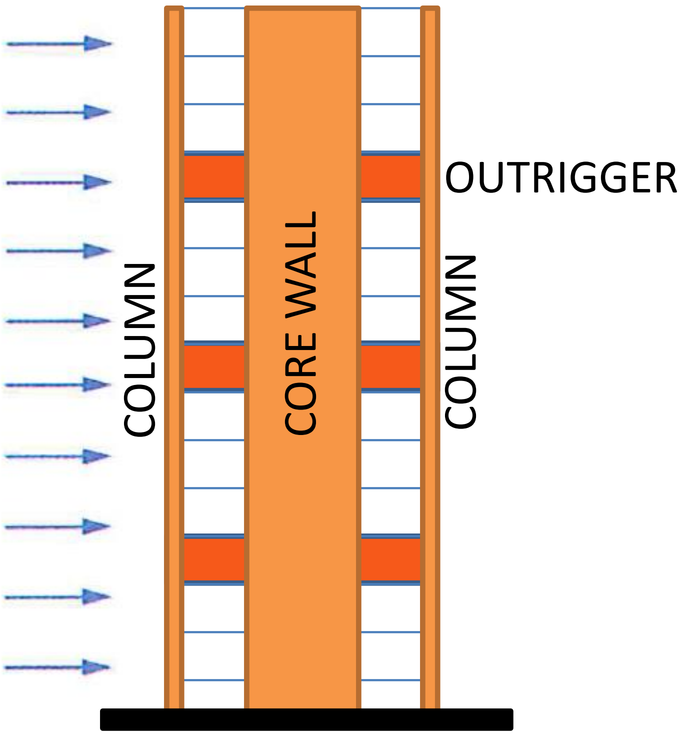
L19-L20

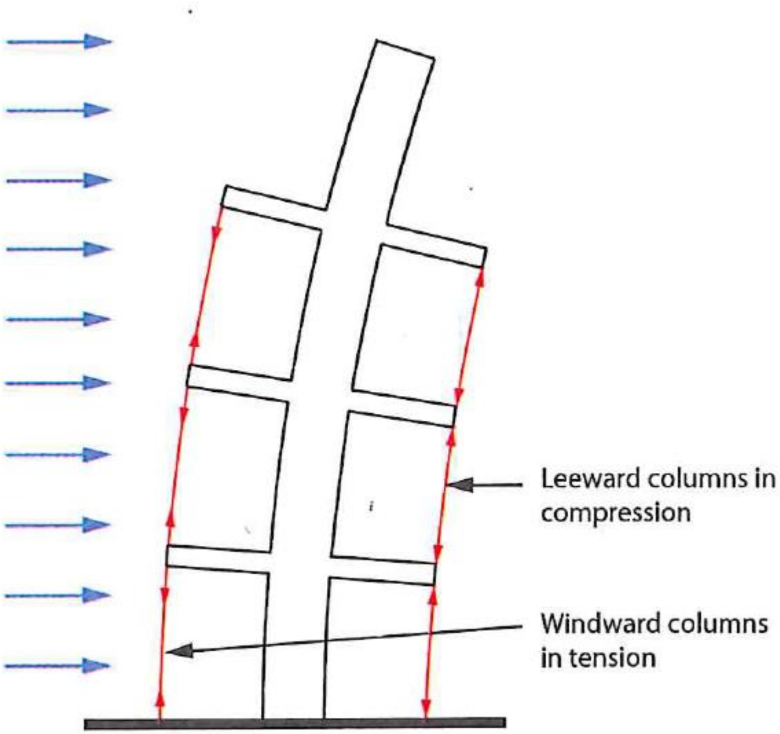




REINFORCED CONCRETE DEEP WALLS; 2 FLOOR HEIGHT (8 m)

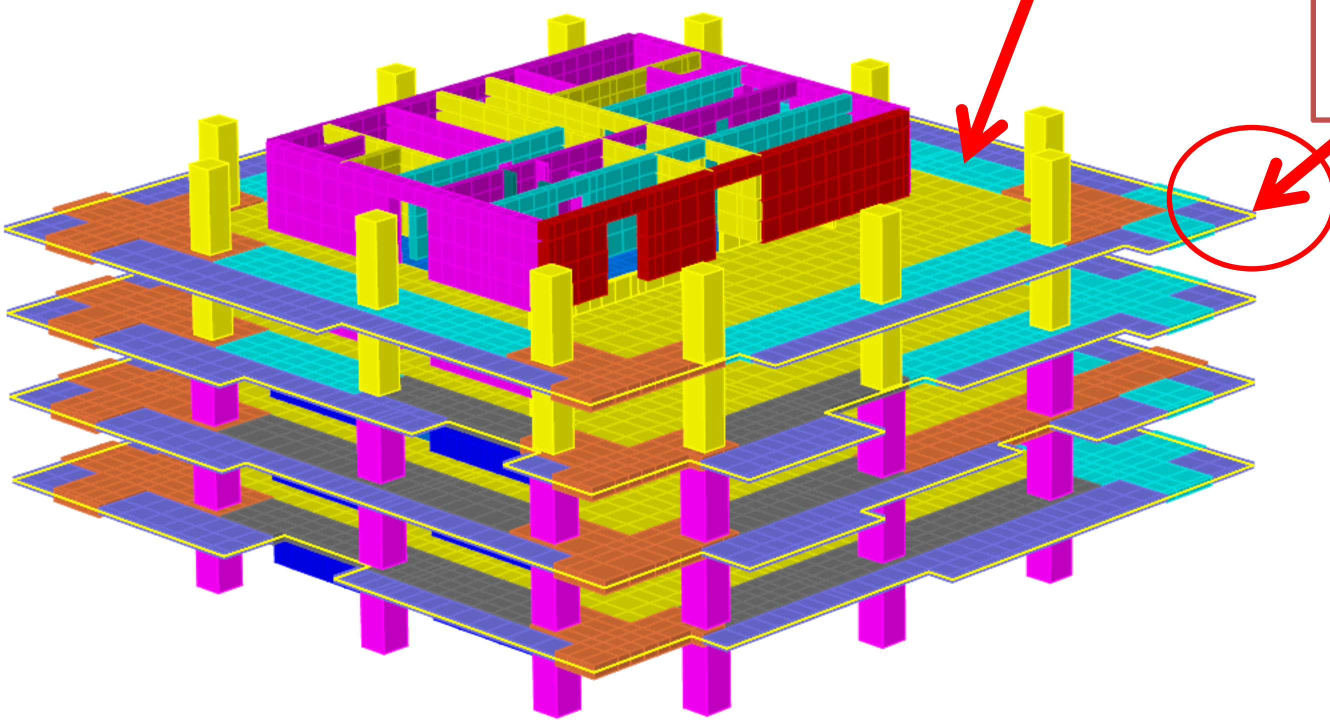
Outriggers





Increase stability under lateral Loads

Slabs



Post-Tension band beams 600mm thick.

8m cantilever slab in the corners

DESIGN CRITERIA

Codes, standards and guidelines

Codes, Standards, Guidelines and Recommendations	
IBC 2006/ ASCE 07-05	Seismic Design
ACI 318-99	Building Code Requirements for RC design and detailing
AISC 2005 & AWS	Design and detailing of structural steel members and joints
ISO137 or ISO-6897	Vibration and human comfort
DPT 1311	Performance of the tower under wind load.
CEB-FIB 90 or equivalent (AS3600)	Relative shortening of vertical components and compensation.
CTBUH 2008	Recommendations for the seismic design of High-rise building: for performance based design/ evaluation of the tower (Appendix B)

Wind approach

Wind Tunnel Test by Dr. Virote Boonyapinyo of Thammasat University (March, 2009) – updated on December 2012 by Pr Nakhorn.	
Wind Design Speed	V = 25.00 m/s @ 10m / 50 years return period V = 20.25 m/s @ 10m / 10 years return period
Damping ratio	ζ = 1.00% for service level (10 year return period) (Arup's advice) ζ = 1.50% for ultimate level (50 year return period) (Arup's advice)
Material properties	Short term material properties for assessing wind acceleration and movement acceptability.
Lateral Performance	Overall Maximum Deflection: H/500 (H = building height) (62cm) under the 10 year wind.
	Interstory drift: h/300 (h = storey height) under the 10 year wind.
	Acceleration: 15 mg under the 10 year wind event (DPT 1311-50 [5]).

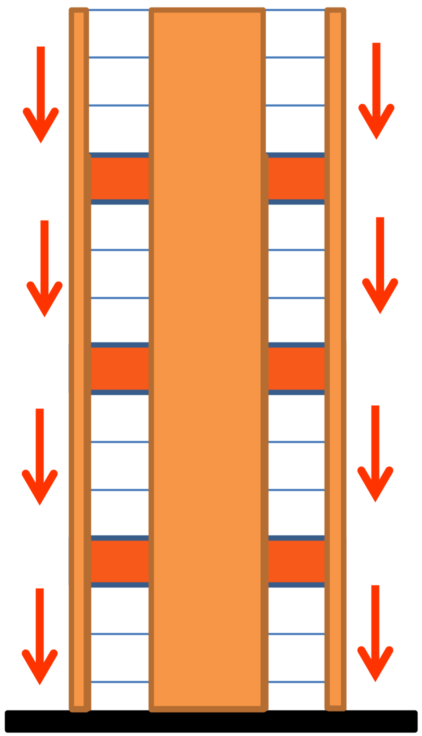
Analysis and Design Software

SOFTWARES	USE
PLAXIS 3D	Soil-Structure Interaction Analysis for Mat Foundation
ETABS V9.7.4 (CSI)	Overall 3D Analysis
ADAPT or CEDRUS	Design of Slab system (RC/PT)
Excel Built-up spreadsheets	Raft design
	Column design
	Beam design
	Shear-wall design
	Coupling-beam design

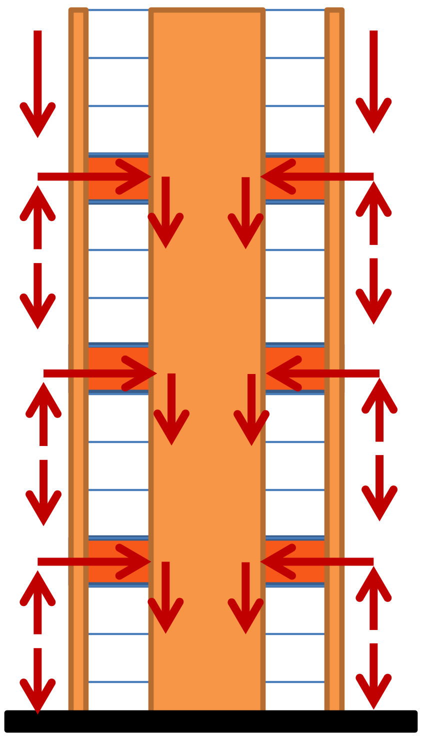
KEY POINTS/CONSTRAINTS

KEY POINTS/CONSTRAINTS

Staged Analysis Model



Stage Analysis Model



Full Model in one go

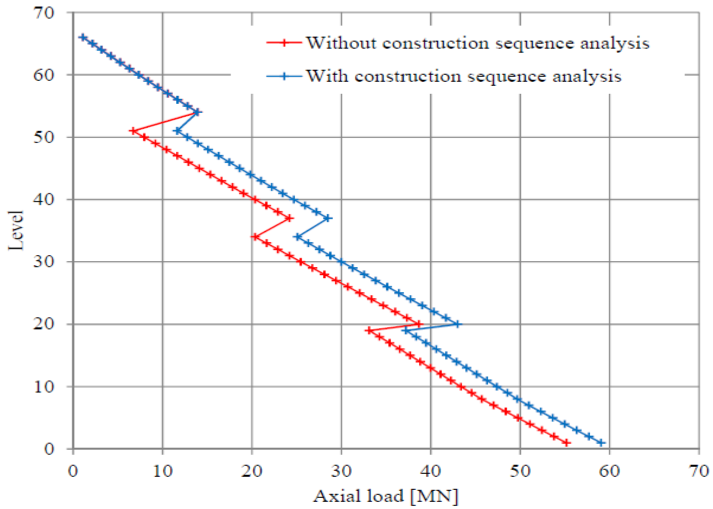


Figure 16 – The effect of a construction sequence analysis on the gravity dead load distribution in column C6.

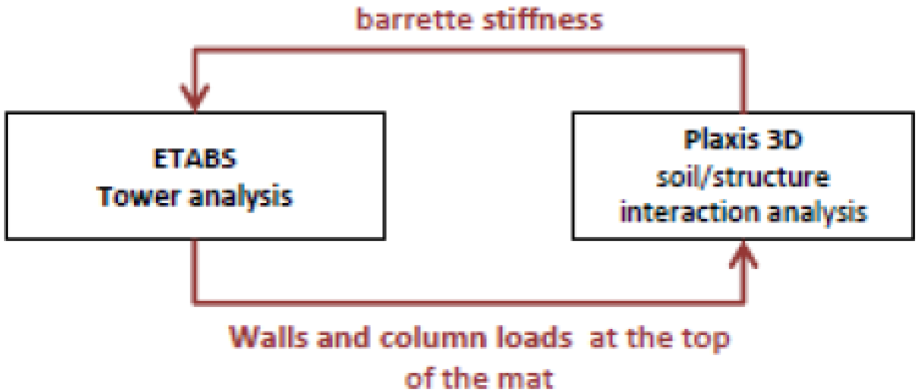
Impact of the stage analysis model = Increase in column loads.

Reduction in core gravity loads.

Reduction in design actions in outriggers.

KEY POINTS/CONSTRAINTS

Soil-Structure Interaction



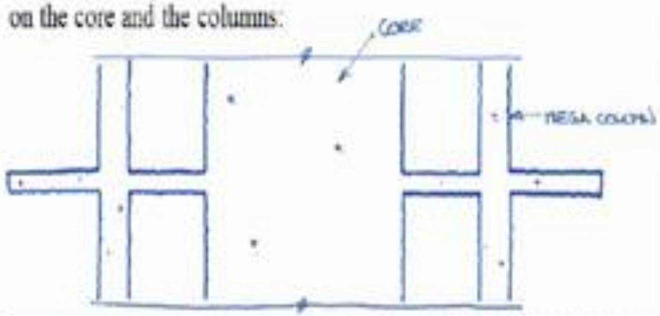
<u>Iteaction process between ETABS and PLAXIS 3D</u>

Convergent criteria is 10% difference on the barrette reaction from the previous iteration.

KEY POINTS/CONSTRAINTS

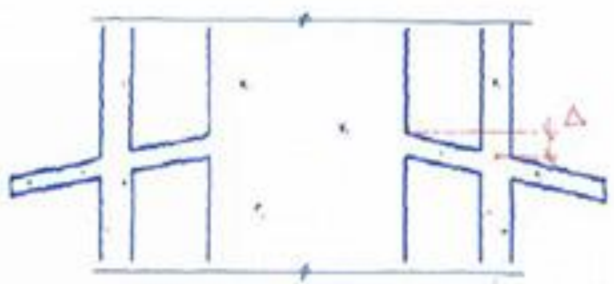
Axial shortening

Ideally, a building would be schemed such that there is little or no differential in the axial stress on the core and the columns:



$$\left(\frac{P}{A}\right)_{core} \sim \left(\frac{P}{A}\right)_{column}$$

However, for this building there is a significant stress differential that will cause the columns to shorten relative to the core:



$$\left(\frac{P}{A}\right)_{core} \ll \left(\frac{P}{A}\right)_{column}$$

KEY POINTS/CONSTRAINTS

Axial shortening

The axial shortening is controlled by:

- The outriggers walls.
- The presets above the floor 52
- The acceptable limit is 15mm

KEY POINTS/CONSTRAINTS

Acceleration: 15mg under wind 10 years

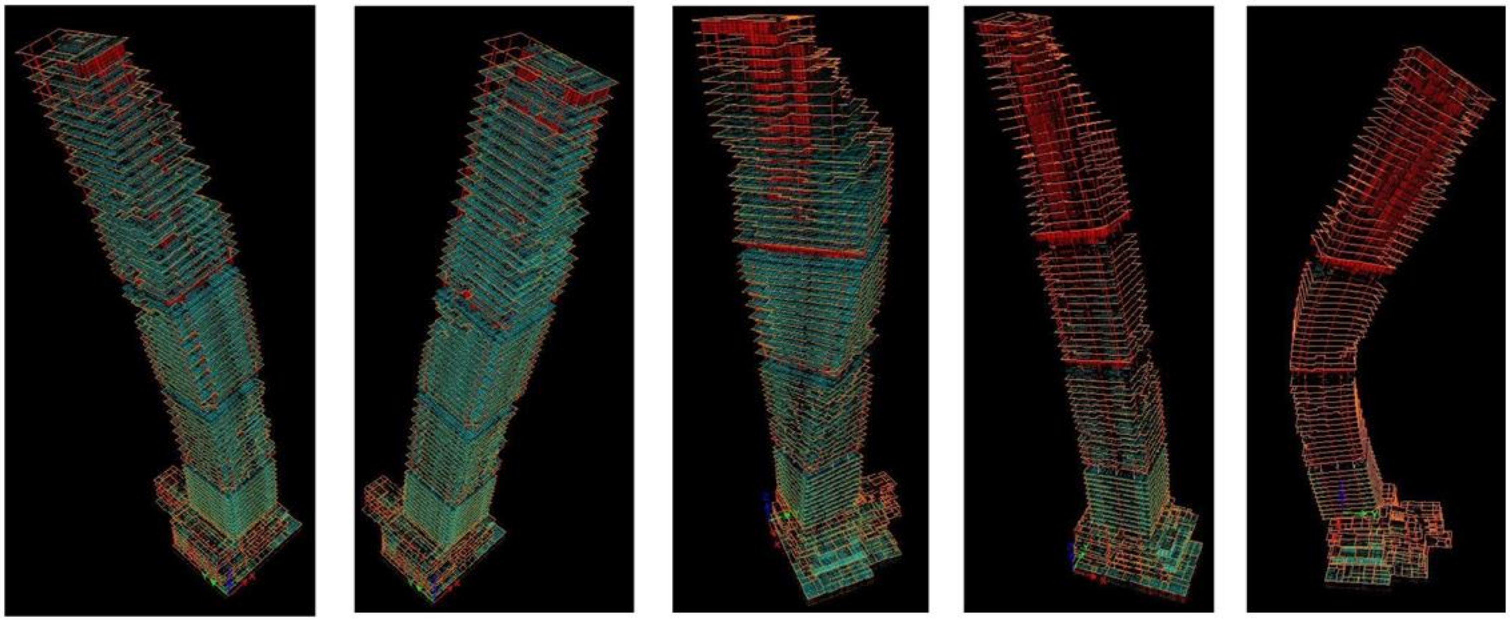
- Impact on the Human comfort.

Lateral Drift: H/500

- Impact on the façade design.
- Impact on the lift design.

KEY POINTS/CONSTRAINTS

Dynamic properties

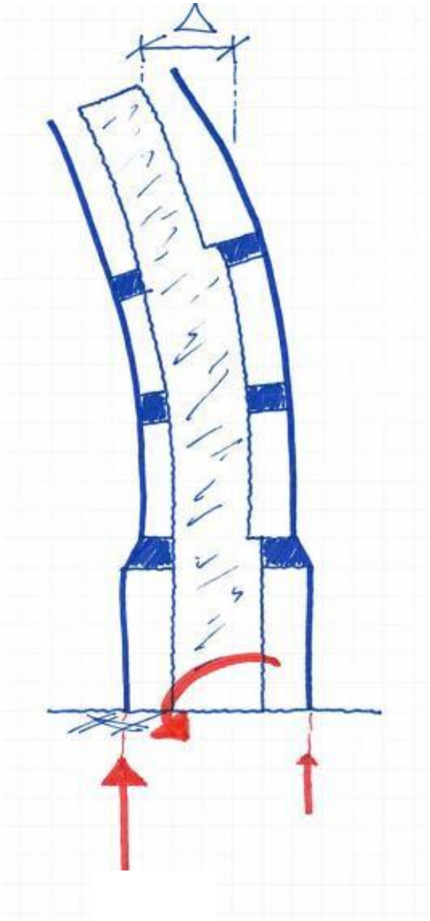


Period:

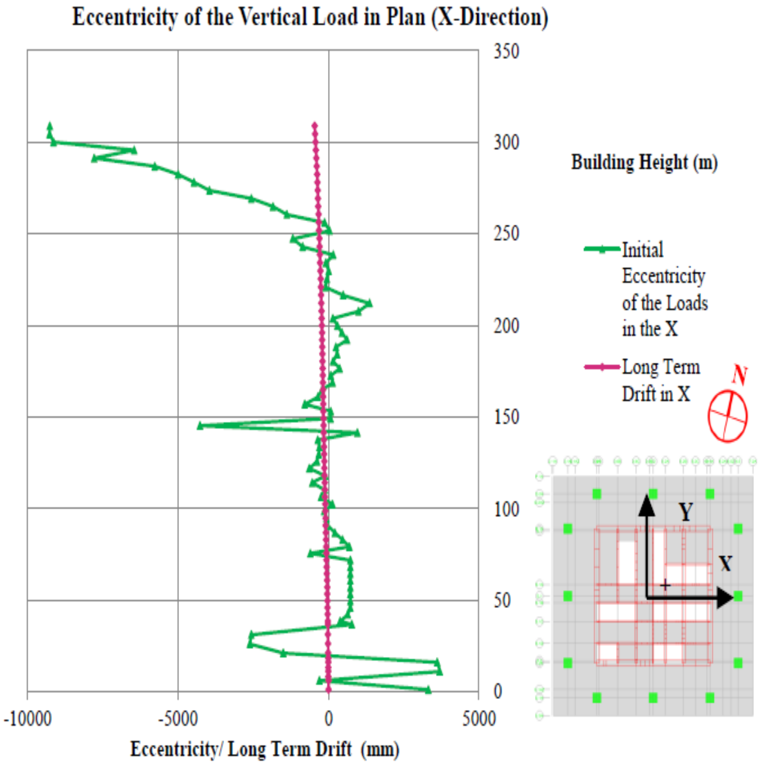
Mode 1: 7.05s | Mode 2: 6.80s | Mode 3: 2.17s | Mode 4: 1.826s | Mode 5: 1.601

KEY POINTS/CONSTRAINTS

Lateral displacement under gravity loads



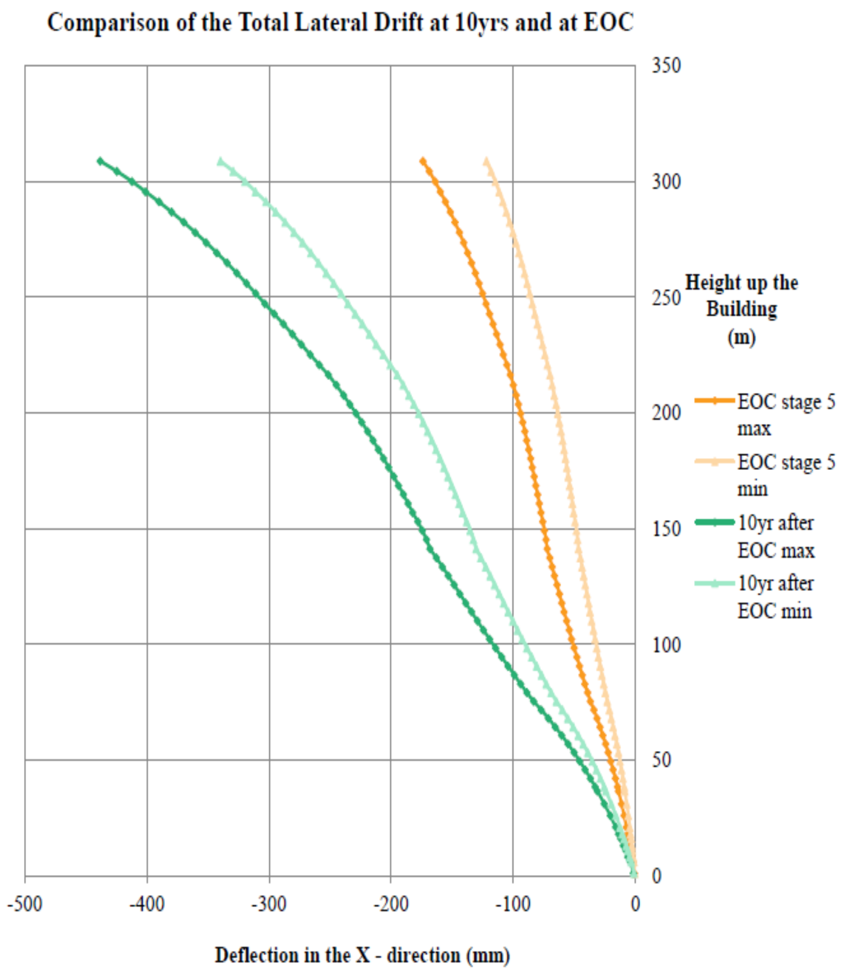
Indicative **long term** deformed shape and load distribution under gravity

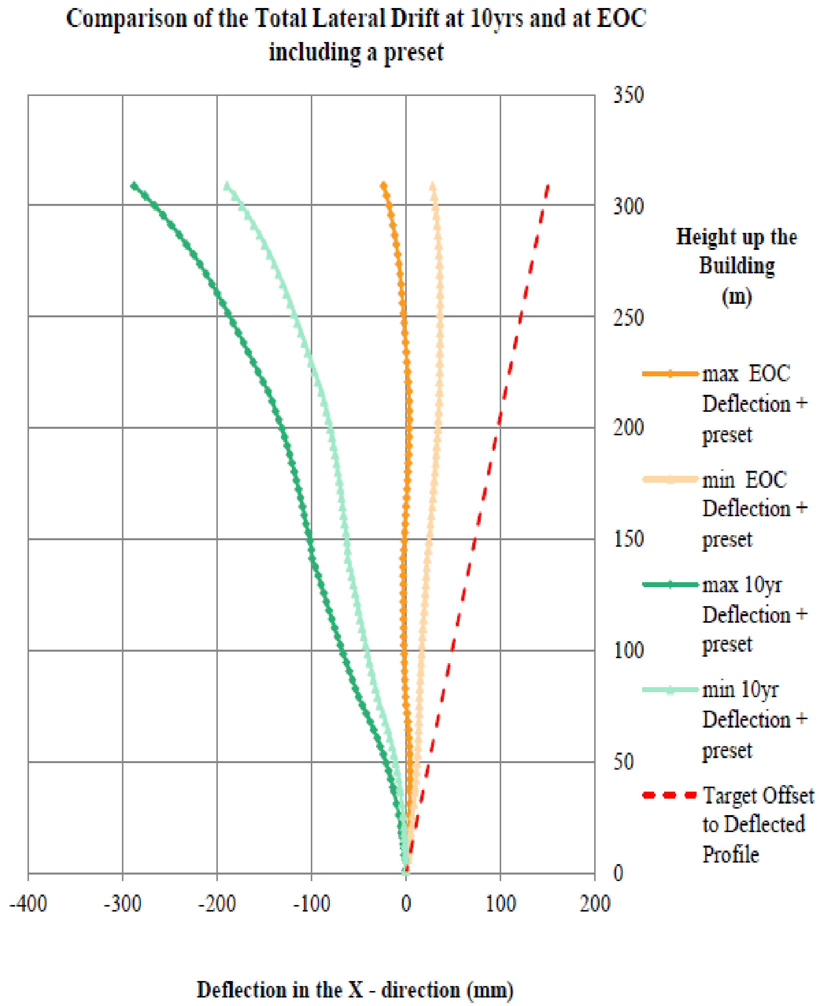


Eccentricity of the vertical loads

KEY POINTS/CONSTRAINTS

Lateral displacement under gravity loads



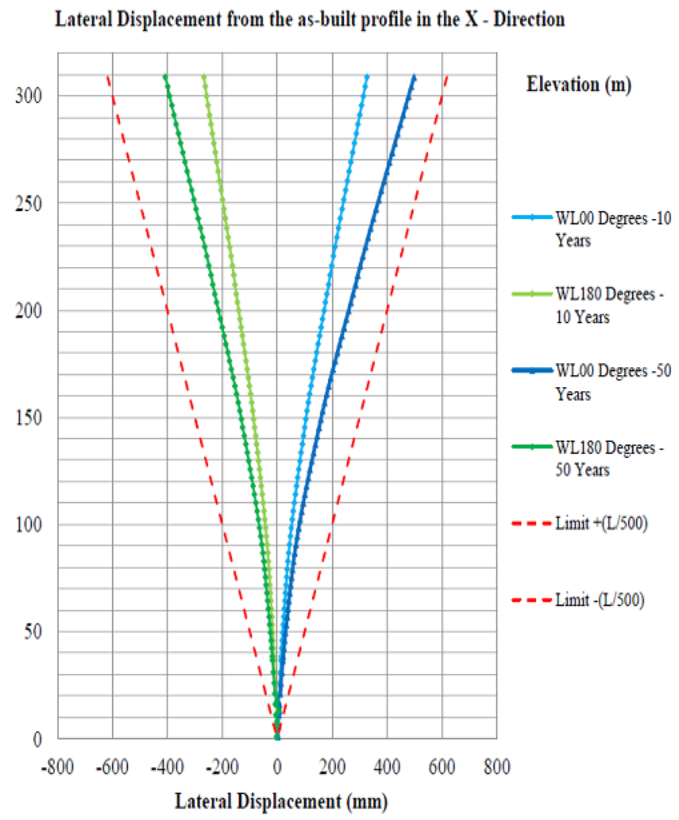


Deflection **Without** preset = **440 mm**

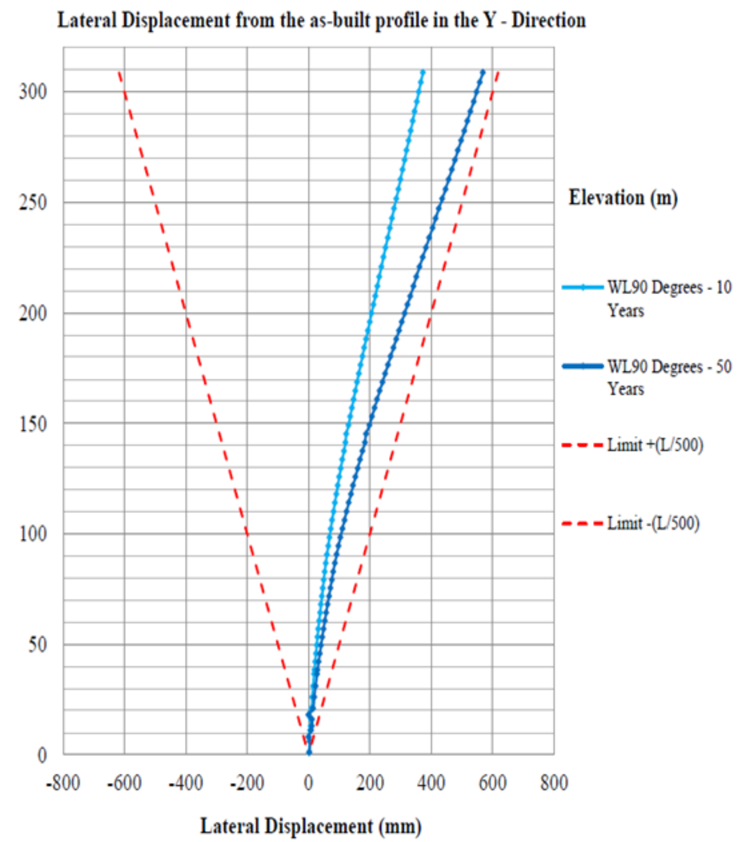
Deflection **With preset** = **280 mm**

KEY POINTS/CONSTRAINTS

Lateral displacement under Wind loads



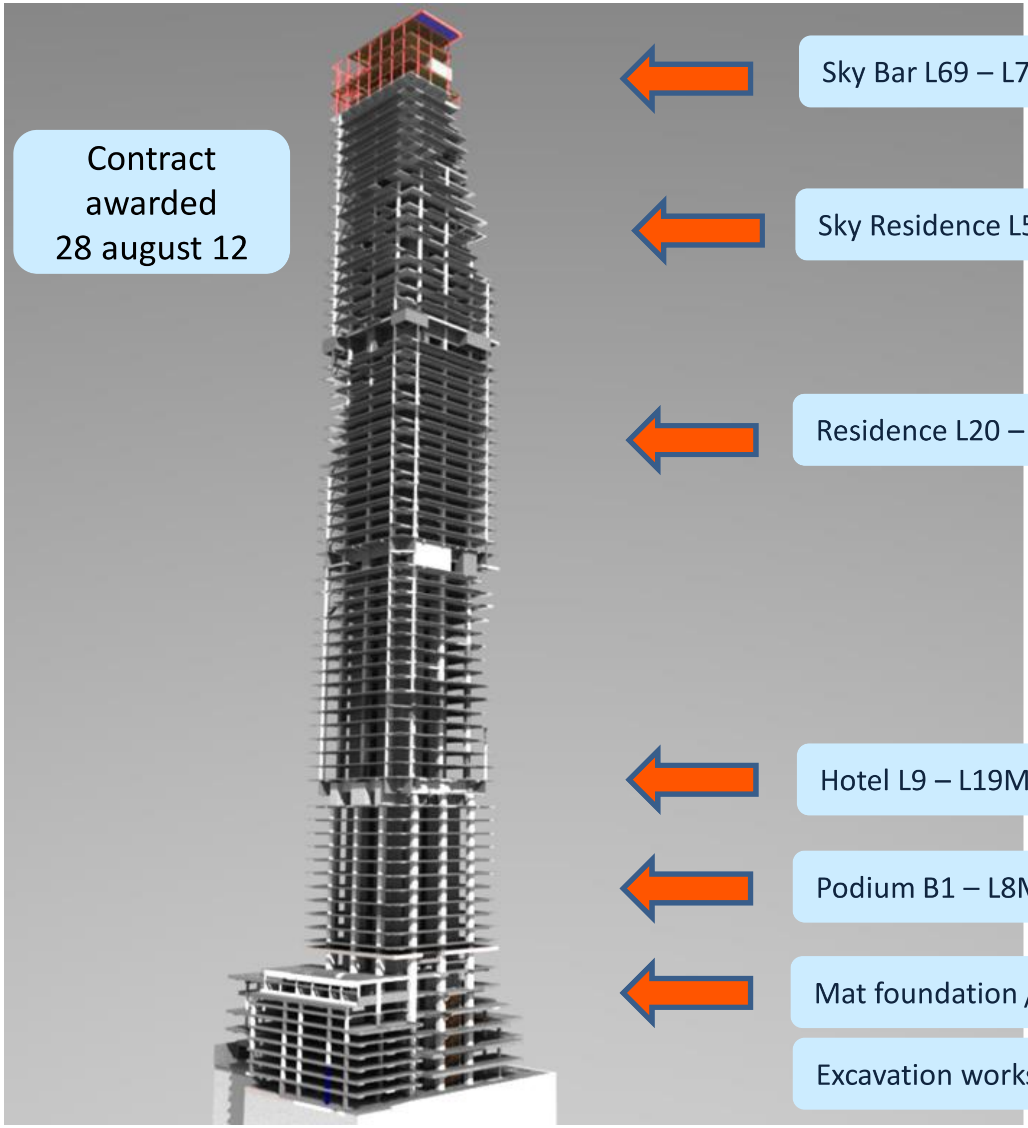
Deflection in X direction ~**340 mm** (Wind 10y)



Deflection in Y direction ~ **340 mm** (Wind 10y)

KEY DATES AND PICTURES

COMPLETION KEY DATES



Sky Bar L69 – L74 / 131 days : 10 October 15

Sky Residence L52 – L68 / 114 days : 01 June 15

Residence L20 – L51M / 227 days : 07 February 15

Hotel L9 – L19M / 114 days : 25 June 14

Podium B1 – L8M / 196 days : 28 February 14

Mat foundation / 95 days : 16 August 13

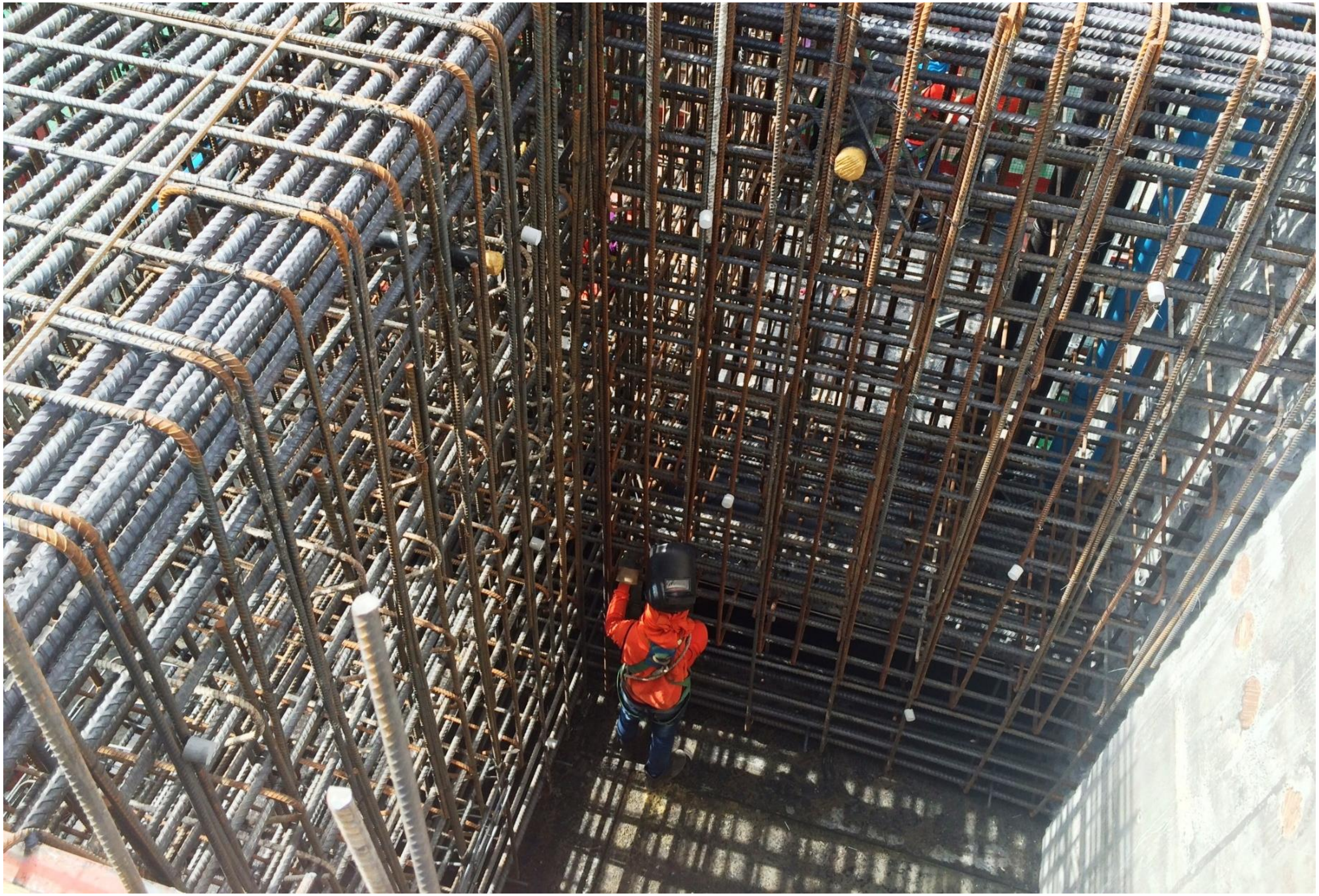
Excavation works / 258 days : 13 May 13

12/2012 – Excavations

06/2013 – raft pouring

10/2013 – Megacolumns and Core

01/2014 – Megacolumns and Core



05/2014 – Outriggers L19

05/2015 – Facade

12/2015 – Top-up

12/2012 – 06/2016

Celebration 08/2016

THANK YOU

BOUYGUES-THAI

Warnes Associates ARUP