DESAIN STRUKTUR TAHAN GEMPA PADA BANGUNAN TINGGI DAN BENTANG LEBAR

Kasus: Signature Tower Jakarta

Sugeng Wijanto, Ph.D., IP-U

27 Oktober 2017

List of Contents:

Why Build Tall?

Engineering in Tall Building

The limits of Materials

Structural Systems and Advance Solutions

Foundation and Basement Wall

Loadings: Designing for Wind

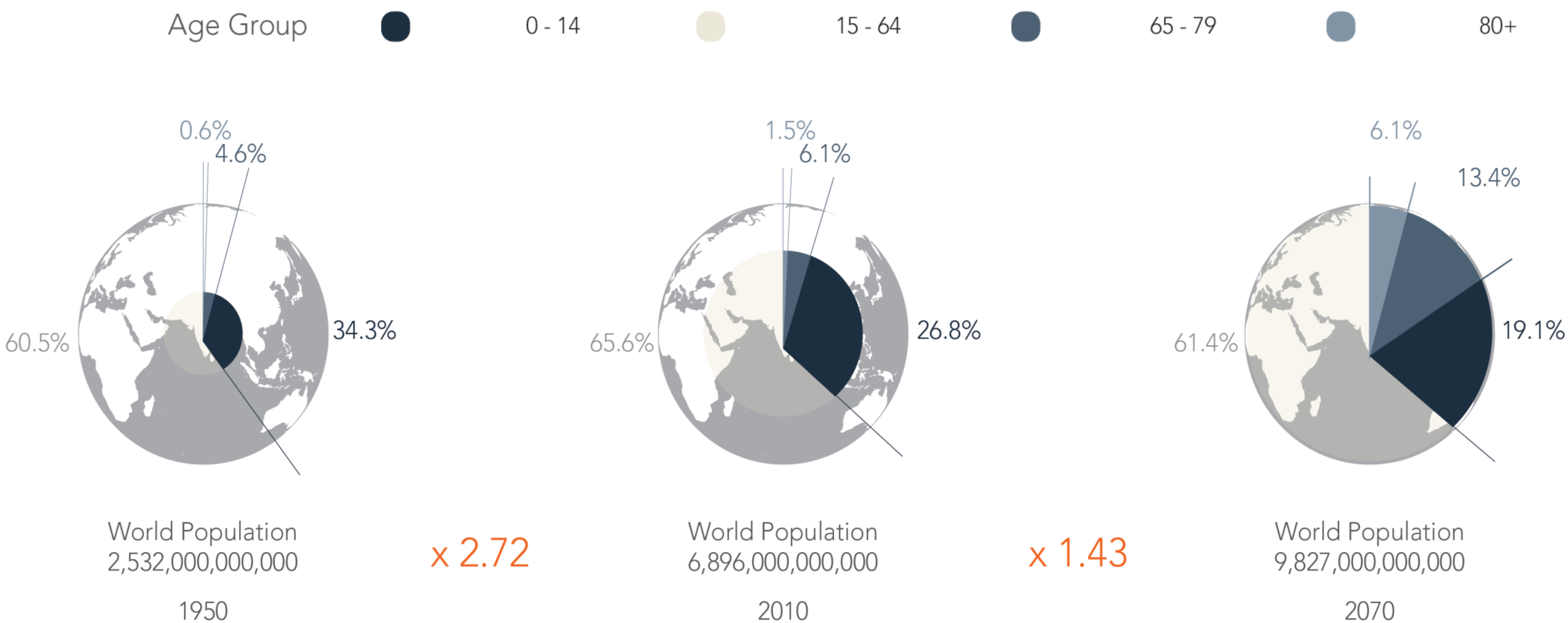
Designing for Seismic

Case Studies

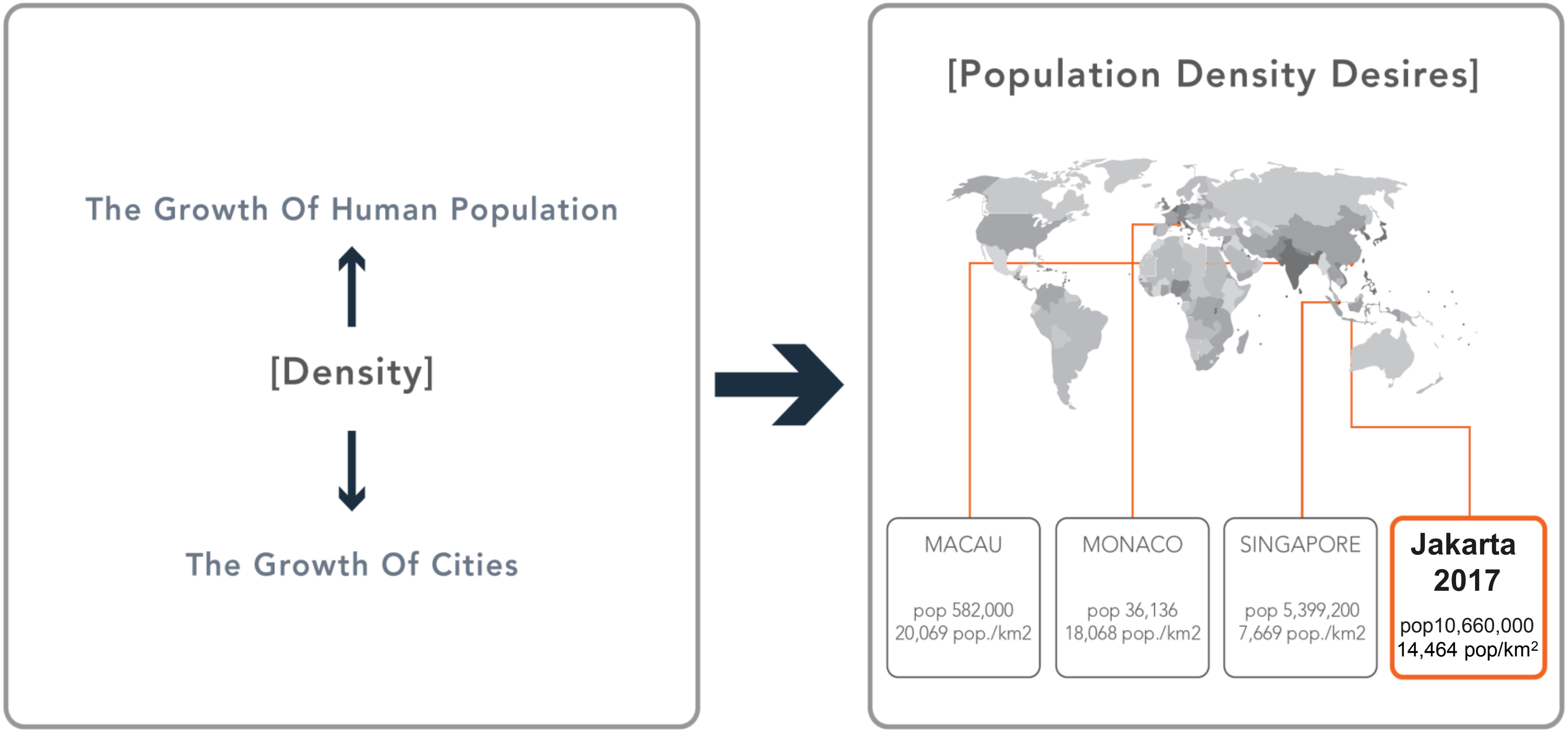
The Future of Tall Building in Indonesia : Signature Tower

Why Build Tall?

THE EVOLUTION OF WORLD POPULATION



THE BEGINNING OF HYPER-DENSE URBANISM



A variety of factors causing people to migrate from rural to urban areas.

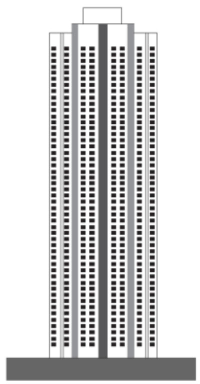
A United Nations study found that half of all humanity lived in urban areas in 2008.

By 2050 the study estimated a full 70% of the world's population will be city residents……

The Heights – Anatomy of a skyscrapers, Ascher, K. 2013

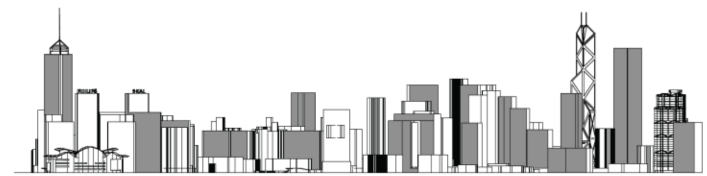
HYPER-DENSE URBANISM

[The Birth of Skyscrapers]



Sustaining the Growth

[Hyper-dense Living Metropolises]



City of Super Intensive Environment

Modern society spends an estimated 90% of its time inside, a far cry from early civilizations whose livelihoods were tied closely to the outdoors……..

Modern skyscrapers are effectively small cities

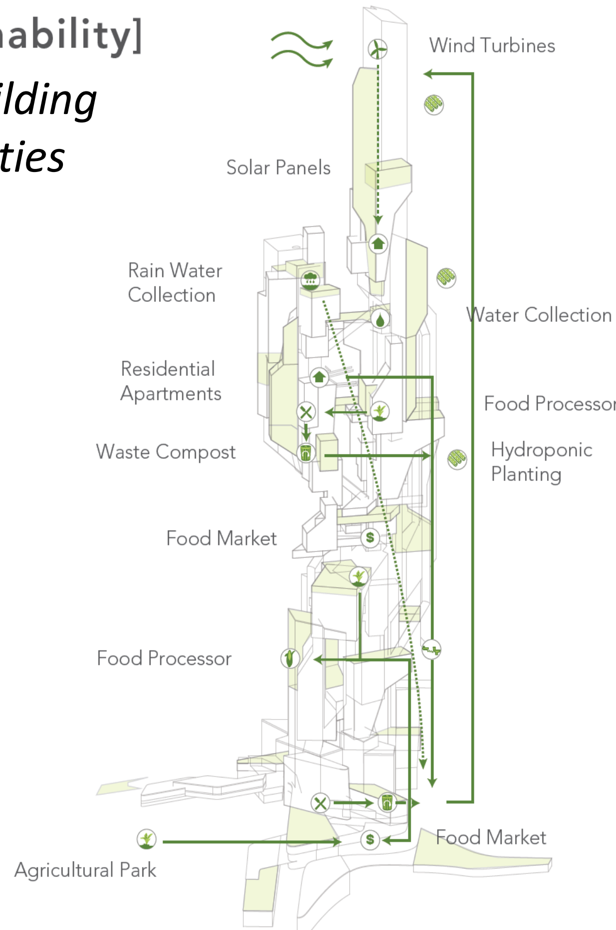
The Heights – Anatomy of a skyscrapers, Ascher, K. 2013

Re-Thinking the Vertical City

[Self-Sustainability]

Green Building

Small Cities

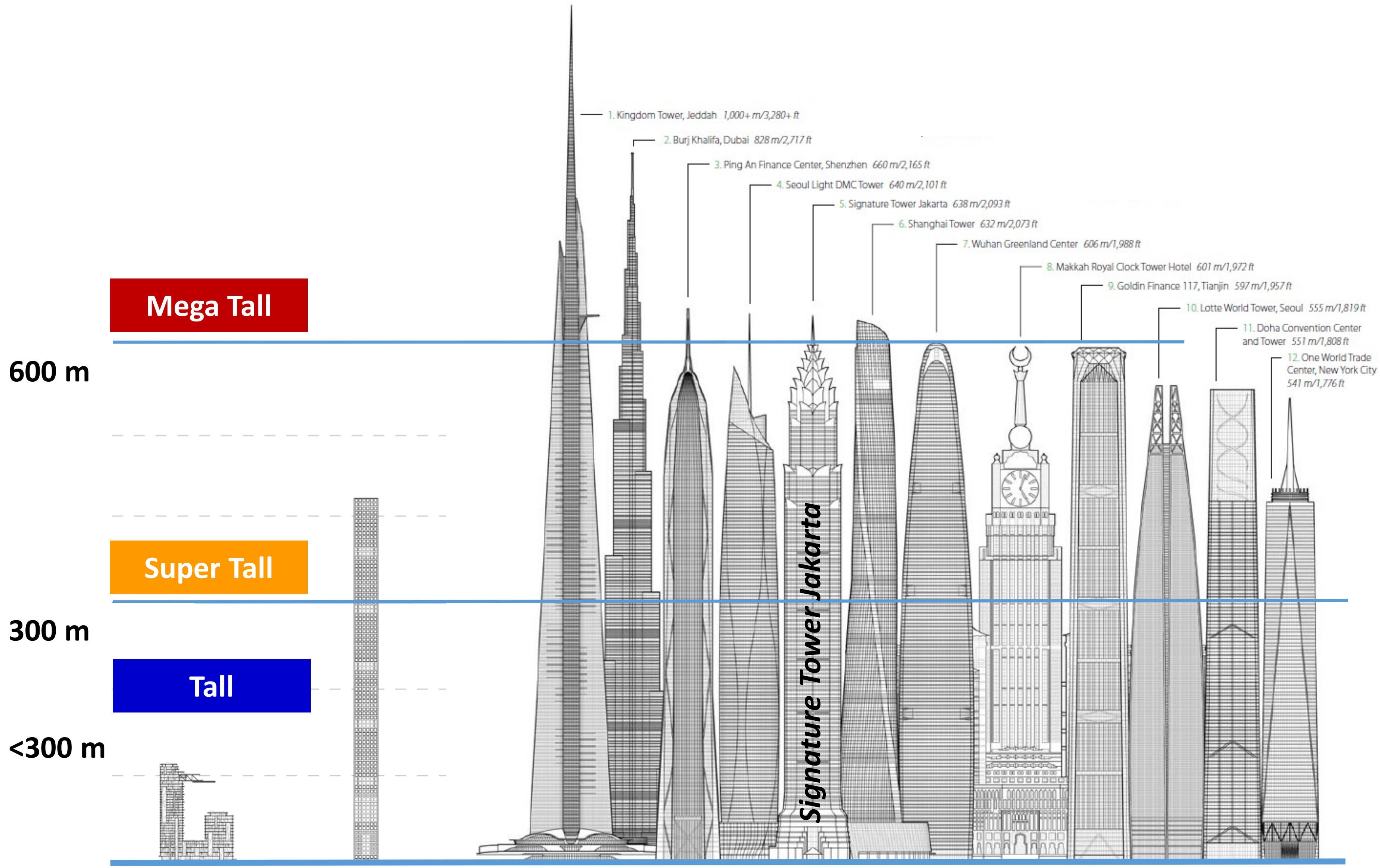


Aesthetics, Symbolism and Status in the 21st Century……..

UP- A Regeneration of the Vertical Dystopia Re-Thinking the Vertical City, Sean Wijanto, 2013


Vertical City

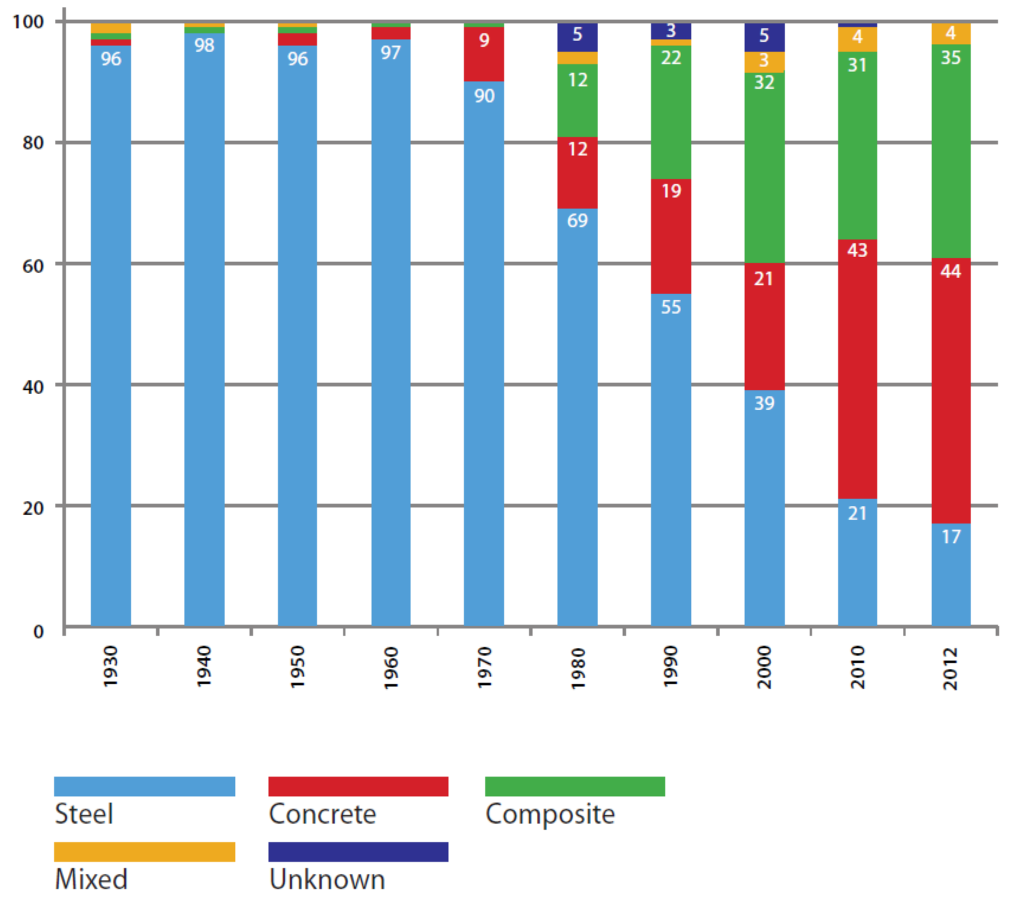
Describe Skyscrapers (CTBUH)



Tall, Super-Tall and Mega-Tall Buildings

The Limit of Materials:

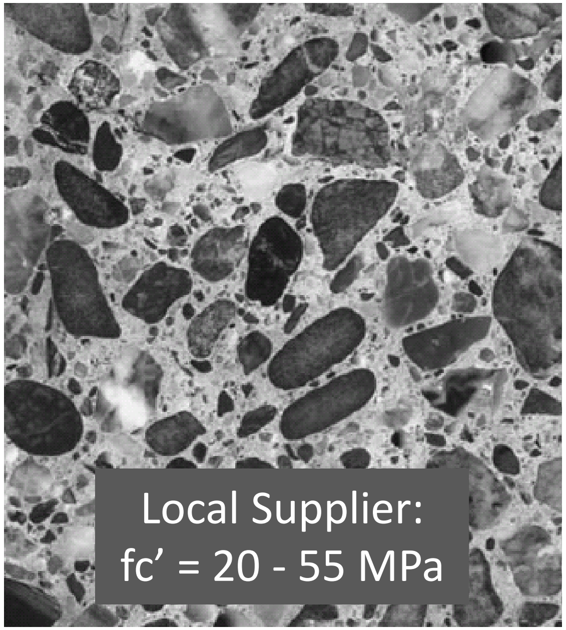
- *Concrete*
- *Reinforcing bar*
- *Strands*
- *Structural Steel*



0.7 100 tallest buildings by structural material, 1930–2012 (data as of January 2013)
Graphic: © CTBUH

What Is Concrete :

A mixture of Cement, Water, Aggregate (fine and coarse) and Admixtures



<u>Three</u> main factors that dictate the design of concrete mixes : - Economic viability

- Usability of the fresh concrete

- Strength and durability of the hardened concrete

Concrete Admixtures:

Liquid admixtures from left to right: anti-washout admixture, shrinkage reducer, water reducer, foaming agent, corrosion inhibitor, and air-entraining admixture (courtesy of Portland Cement Association).

There are Three main types of chemical admixture :

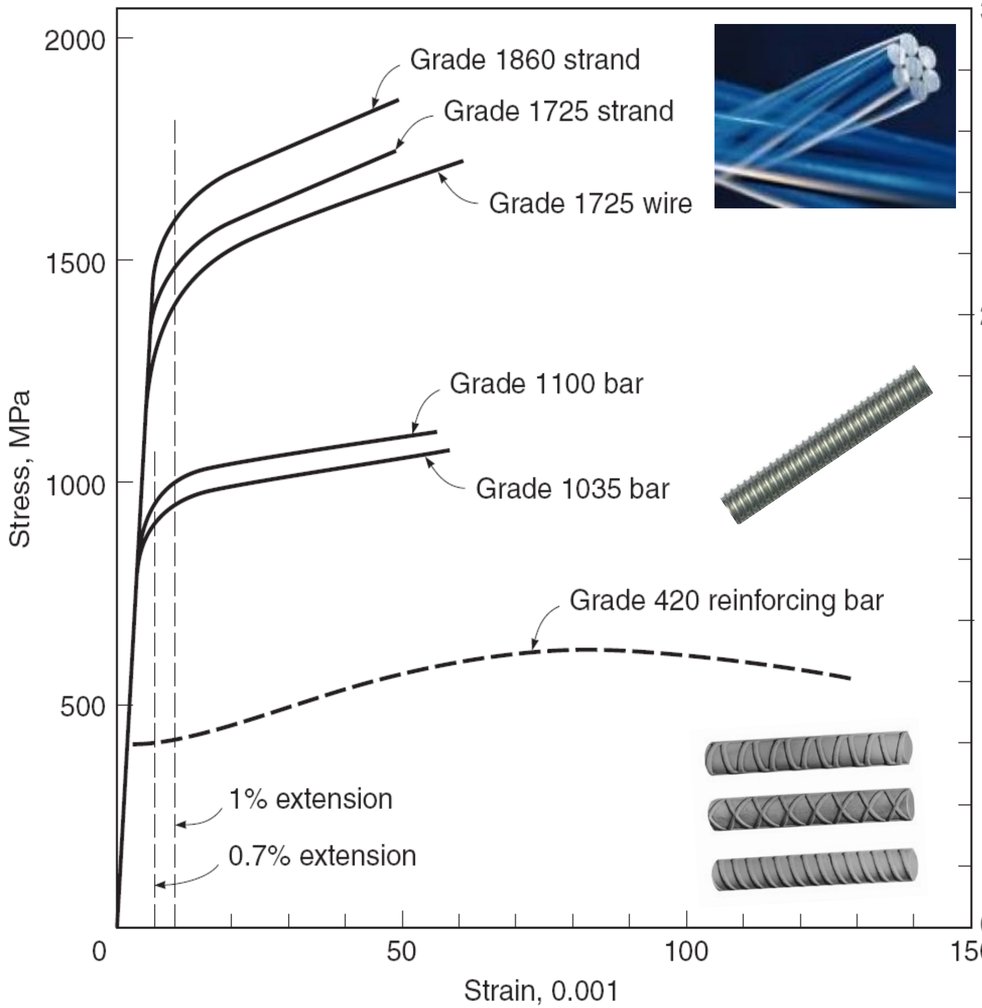
- *Air entraining agents*
- *Set controlling admixtures*
- *Plasticizers*

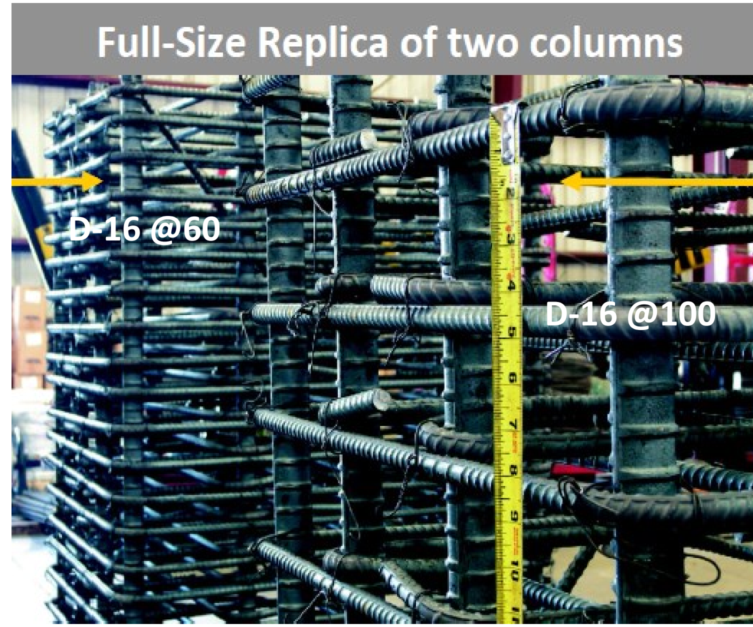
Floating Concrete Dry Dock

Using High strength concrete

- Concrete Grade: 70 MPa
- Use SCC Type

High Strength of Steel Rebar and Strand



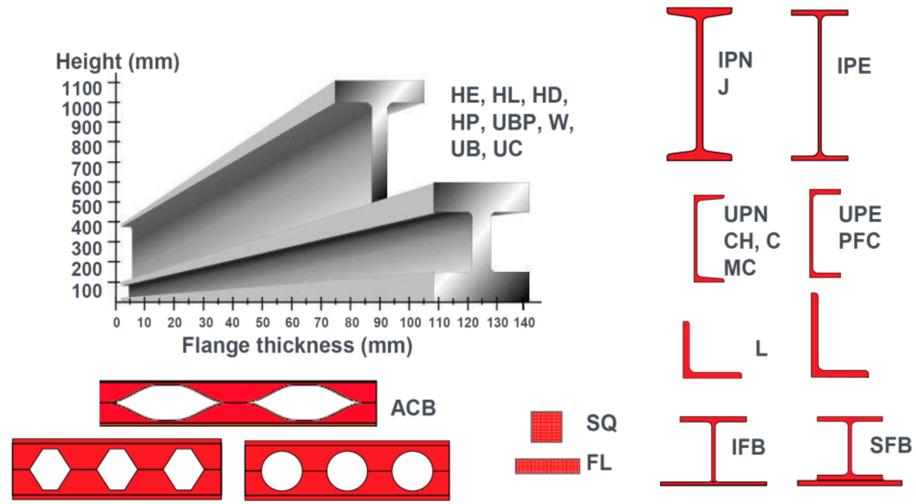


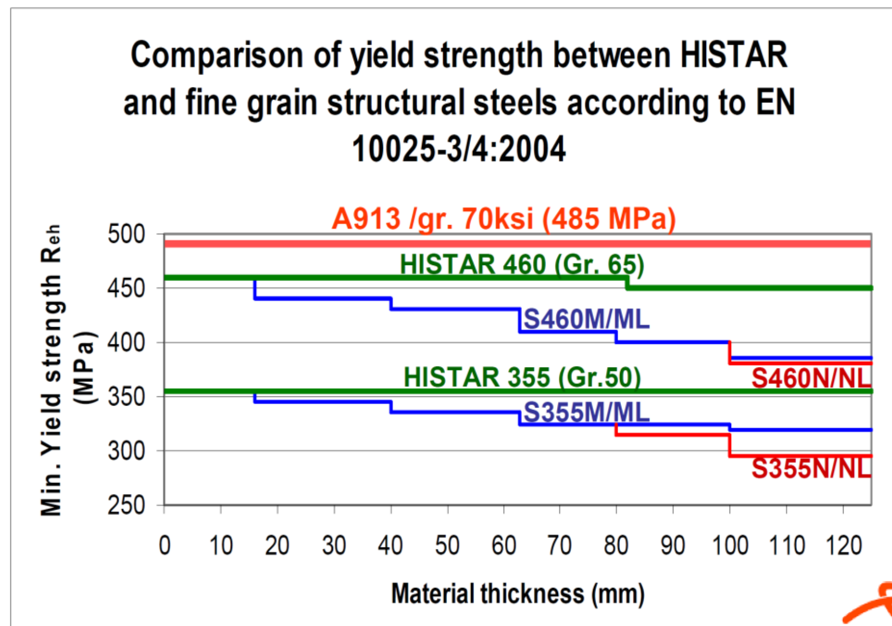
High strength Rebar 690 MPa

- ✓ Reducing Steel and Concrete Volumes
- ✓ Improving Concrete Pouring Efficiencies
- ✓ Lowering Rebar Placing Costs
- ✓ Reducing Placing Time
- ✓ Lowering Cage Weights
- ✓ Saving on Couplers
- ✓ Improving Jobsite Transit, Storage and Logistics

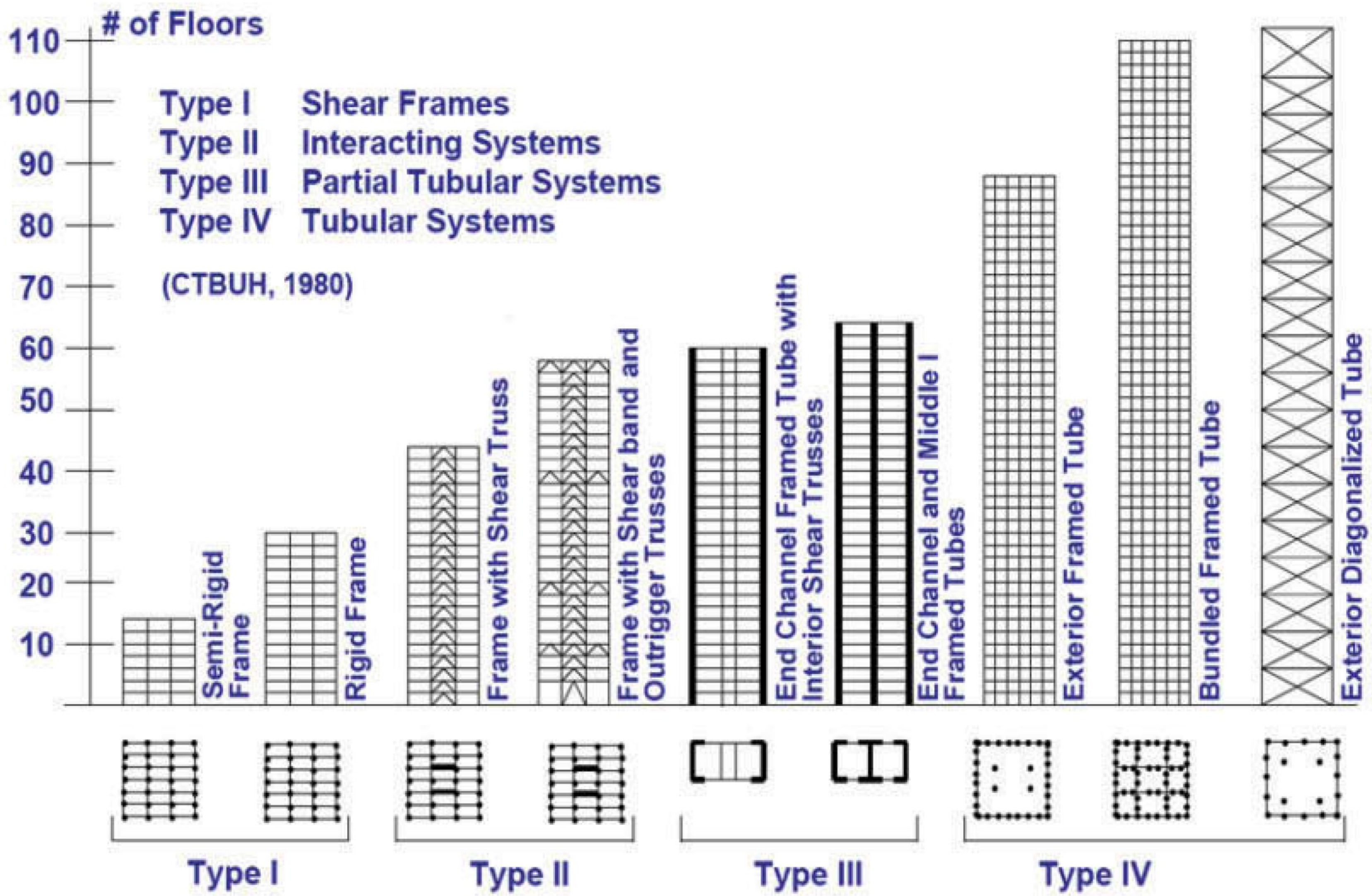
Structural Steel Grades and Dimension

. Fixing of mega columns on site. (Source: Ping An)



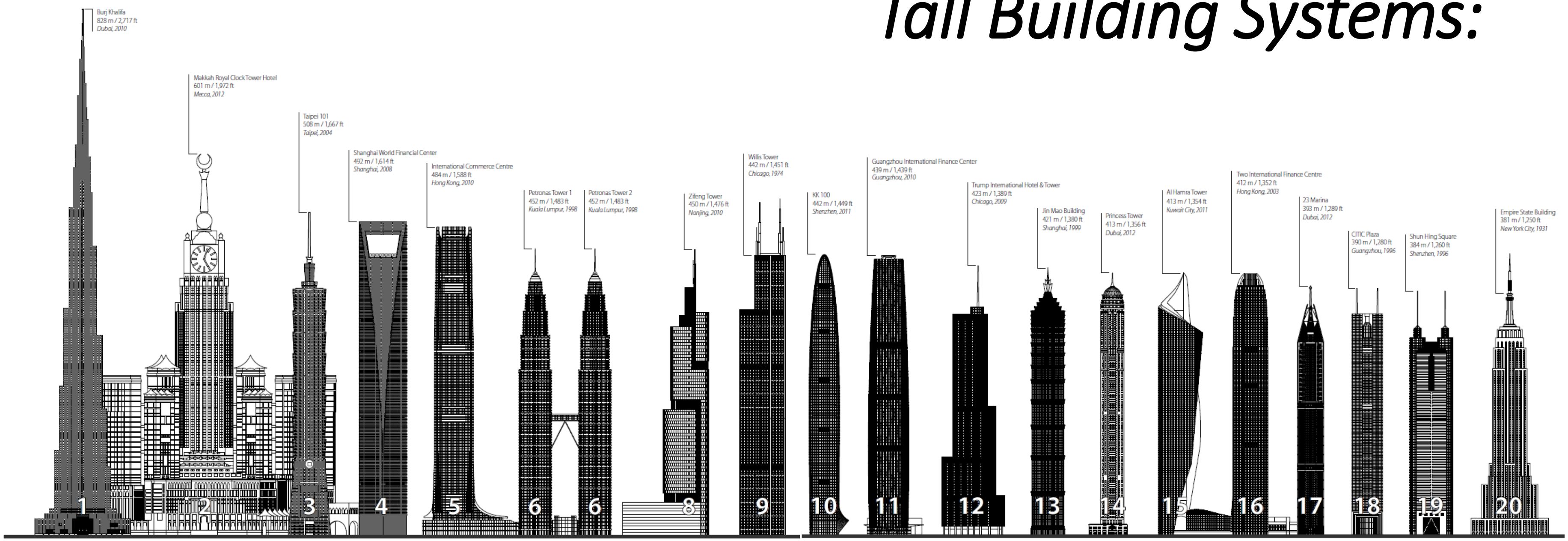


Structural Systems and Advance Solutions



16.9 General limits of structural systems
Graphic: CTBUH

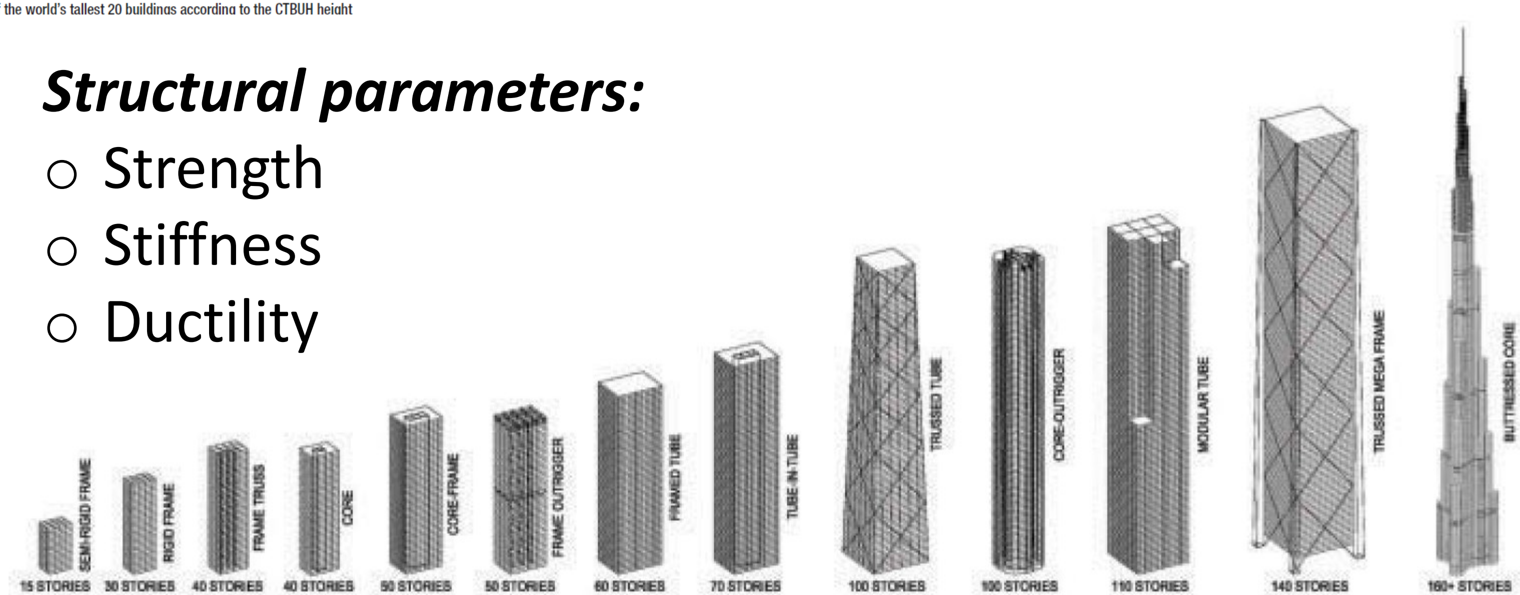
Tall Building Systems:



0.2 Diagram of the world's tallest 20 buildings according to the CTBUH height

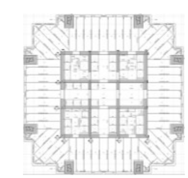
Structural parameters:

- Strength
- Stiffness
- Ductility

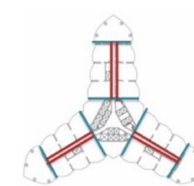


17.5 Tall building systems

Graphic: Skidmore, Owings & Merrill LLP



Mega Structure Columns

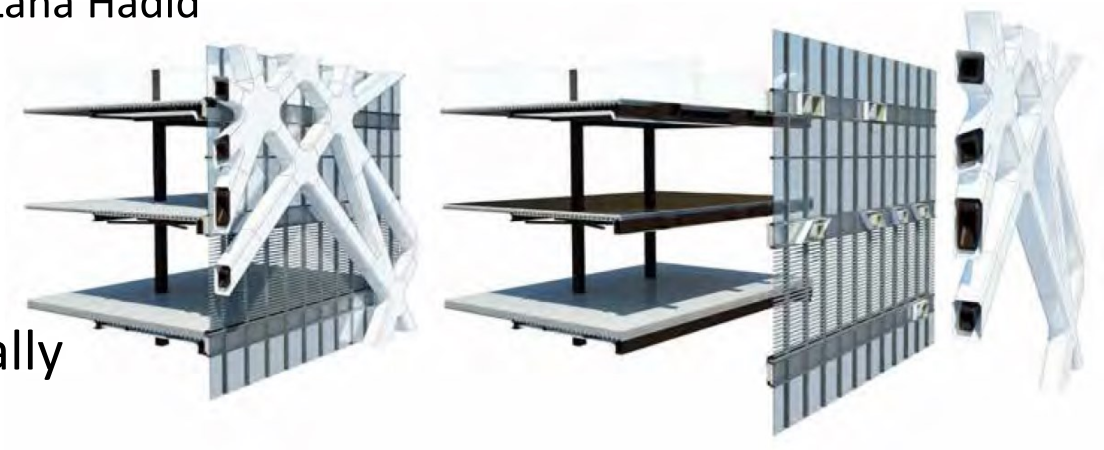


Buttressed Core

The Tall Buildings Reference Book, Edited by Parker, D. and Wood, A. CTBUH. 2013

Façade as Structural Elements

Fifth Hotel City of Dreams, Macau
Architect: Zaha Hadid

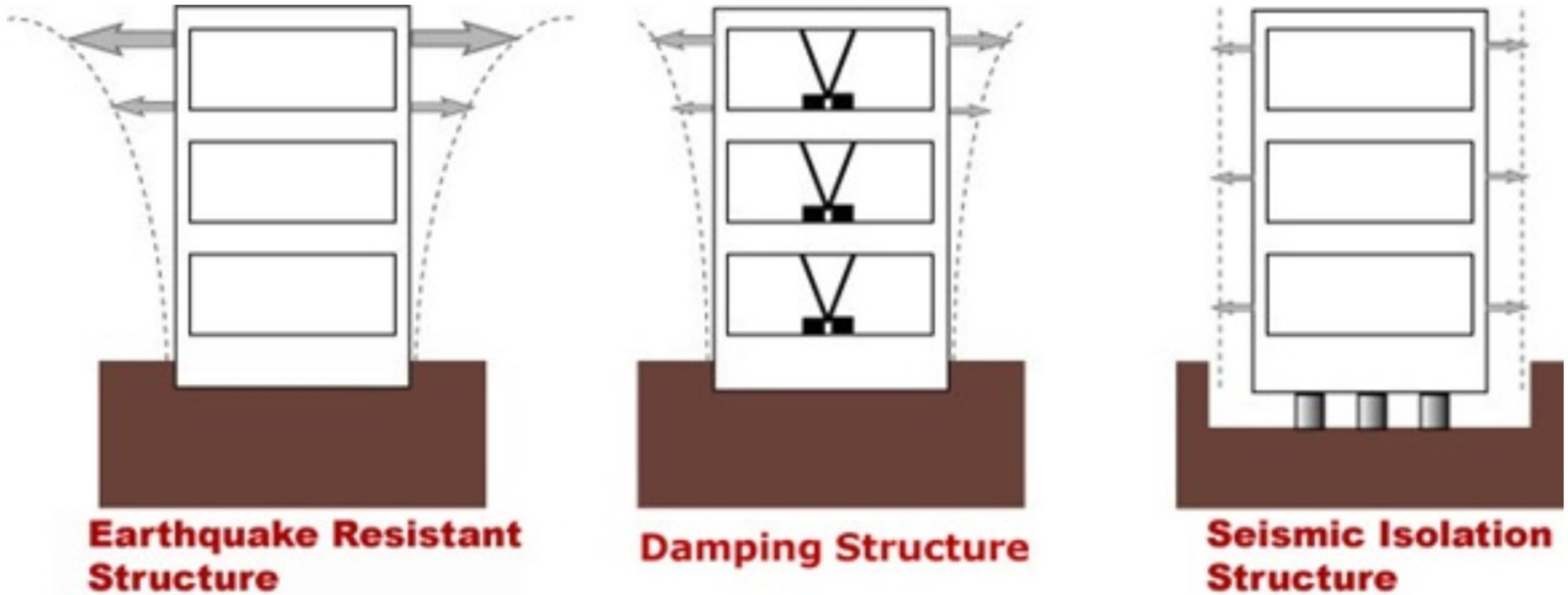


Structural Parameters:

- All nodes need to be horizontally aligned to floor edge beam
- All stubs horizontal and perpendicular to the glazing reference surface
- All members need to be planar and single curved
- BIM Tool is mandatory

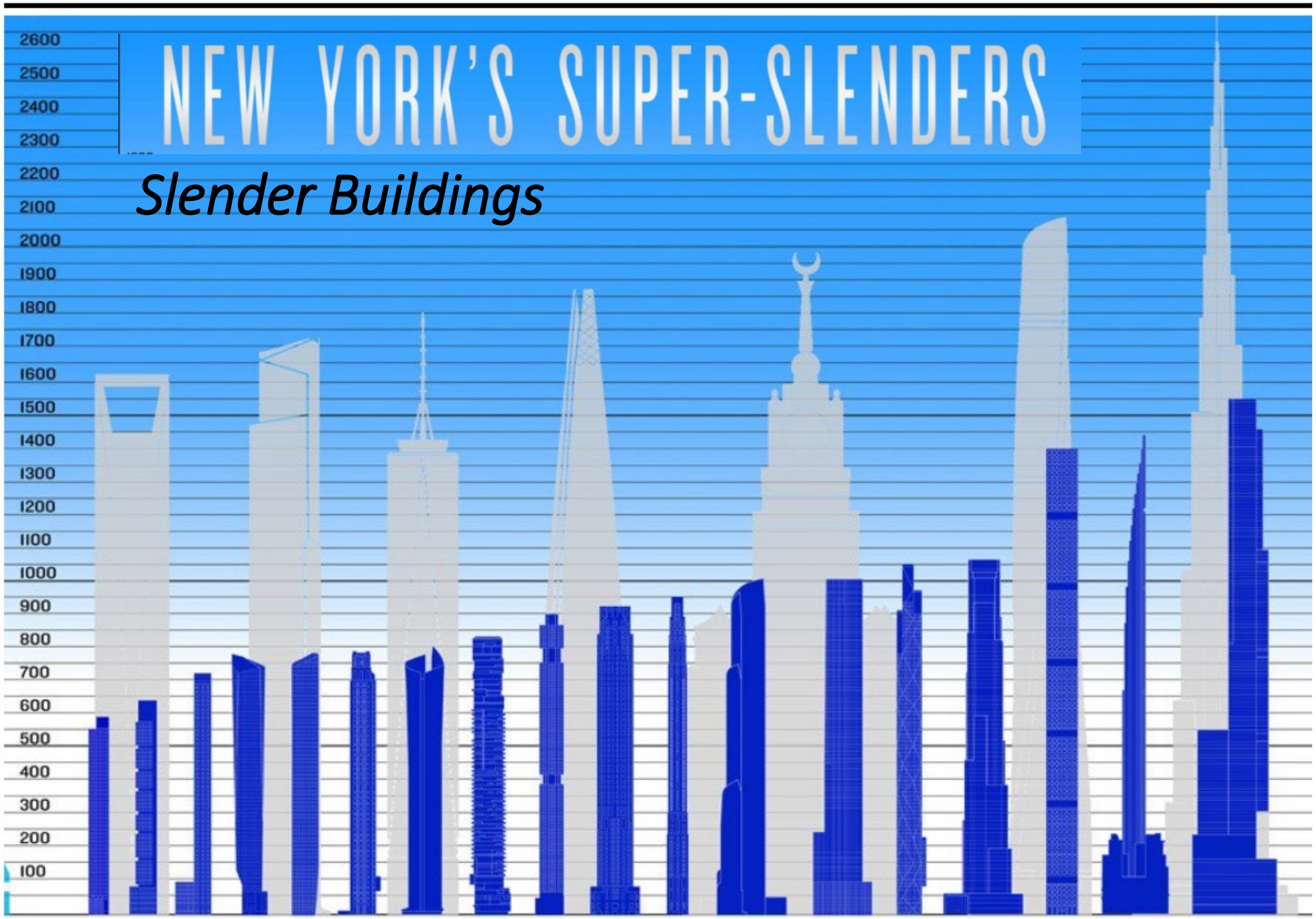
Structural Systems and Advance Solutions

Seismic Isolation



The buildings with damping structure or seismic isolation structure are more secure against earthquake compared to general anti-seismic structure

Slender Tall Building Systems:



The Skyscraper Museum has compared New York's "super-slender" towers to the world's tallest buildings

Many of these measure well over 1,000 feet (305 metres), and some have ratios of base-width to height as extreme as 1:23.

Innovation at Slender Tall Buildings:

Using TMD will reduce building acceleration and improve the serviceability of the tower

Willis, C., Singularly Slender: Sky Living in New York, Hong Kong and Elsewhere, CTBUH 2016

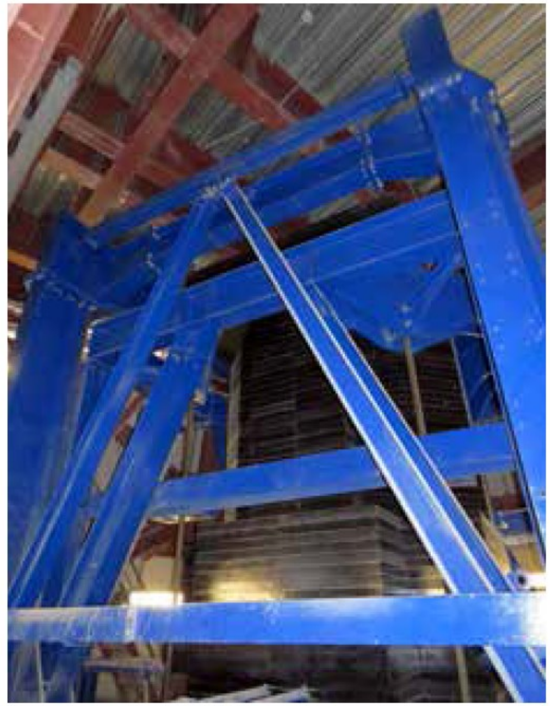


Figure 12. Tuned mass damper (Source: Heerim Architects & Planners)

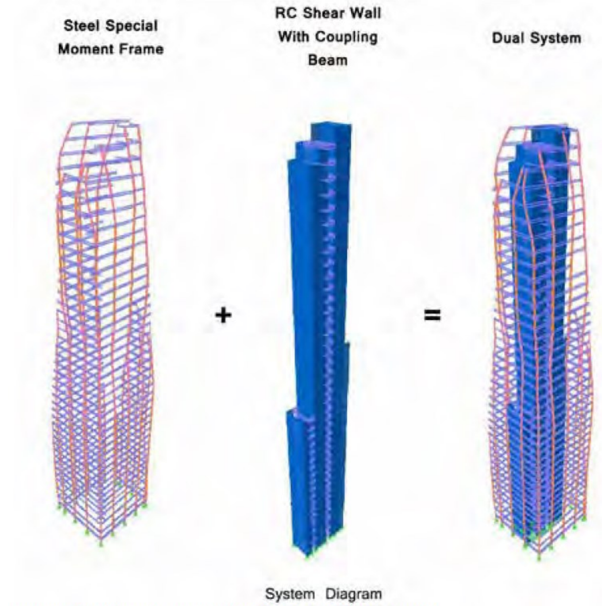
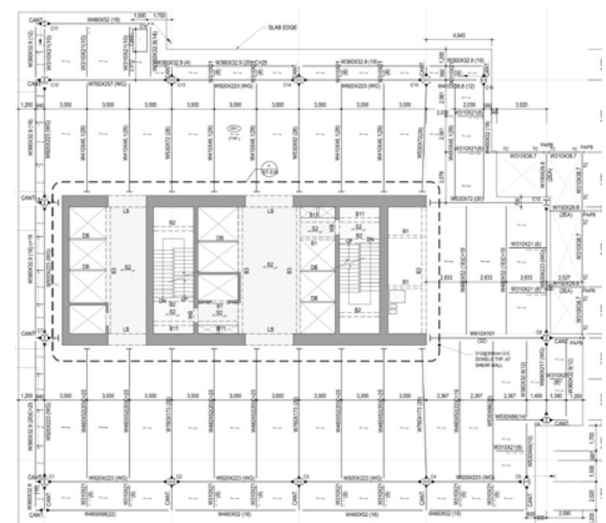


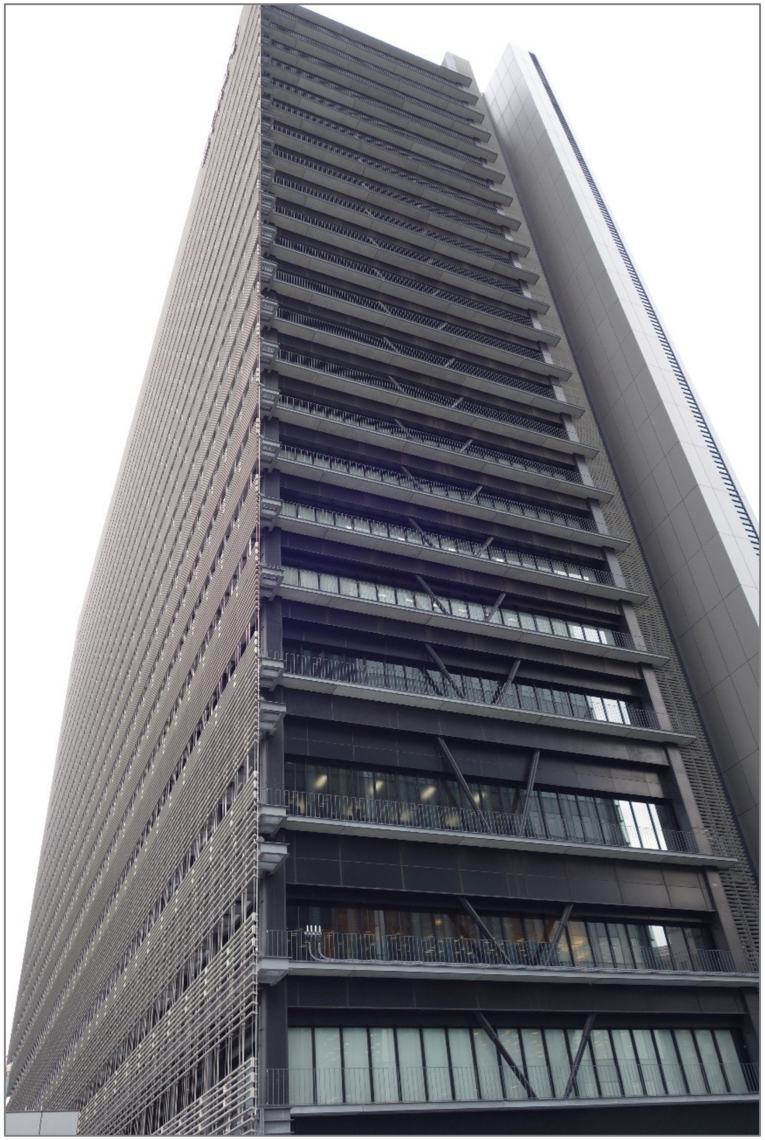
Figure 9. SOCAR Tower lateral resisting system (Source: Thornton Tomasetti, Inc.)



The ***SOCAR*** office tower in Baku, the capital city of Azerbaijan, located in the seismically active. It is a 38-storey with 2 basement levels. Using TMD reduce building acceleration and improve the serviceability of the tower.

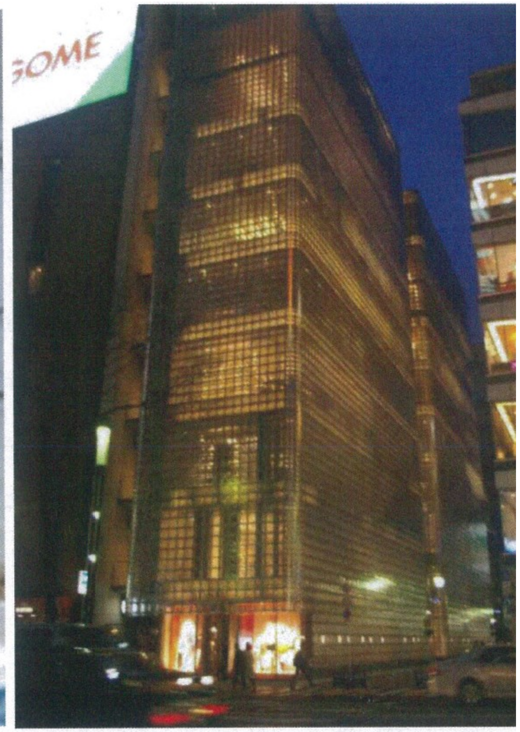
Hybrid structure: RC-core wall with steel floor framing and columns.

Choi H.S., et al, 2016, Structural Challenges with the SOCAR Tower in Baku, a New Megacity in the Caspian Region , CTBUH 2016



SONY Headquarters (2011) – Shinagawa
Dampers used in brace configuration in short direction for both wind and EQ protection

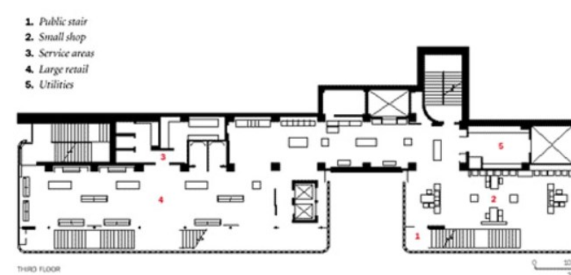
Yozemi Tower Obelisk (2008) – Shinjuku
Dampers used in brace configuration coupling two large “mega” walls in short direction for both wind and EQ protection



Gojū-no-tō (five-storied pagoda)

Maison Hermès Ginza, designed by Renzo Piano, a single signature building (12-storey) in the heart of Ginza. The slender site measures just 12 m x 45 m.

Building design built based on ***a traditional Japanese Pagoda***, with structure only at exterior. Massive dampers used in stepping column configuration for this skinny building protecting the structure from extreme earthquakes



Foundation and Basement Wall

Bored piles are used most often for high rise buildings with some advantages:

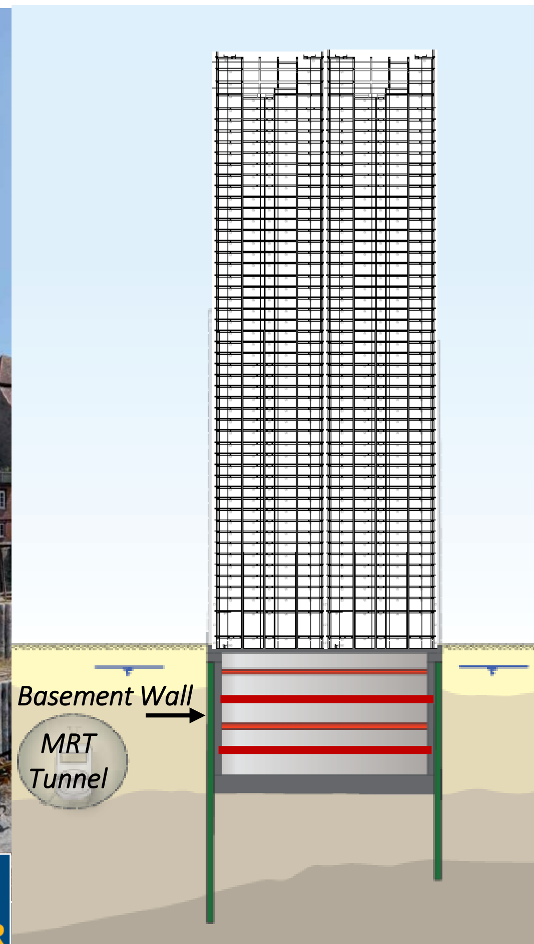
- Large carrying capacity based on end bearing and also side friction
- Constructability in almost any site type
- Concrete is cheapest material
- Flexible diameter up to 3800 mm

Another Foundation types:

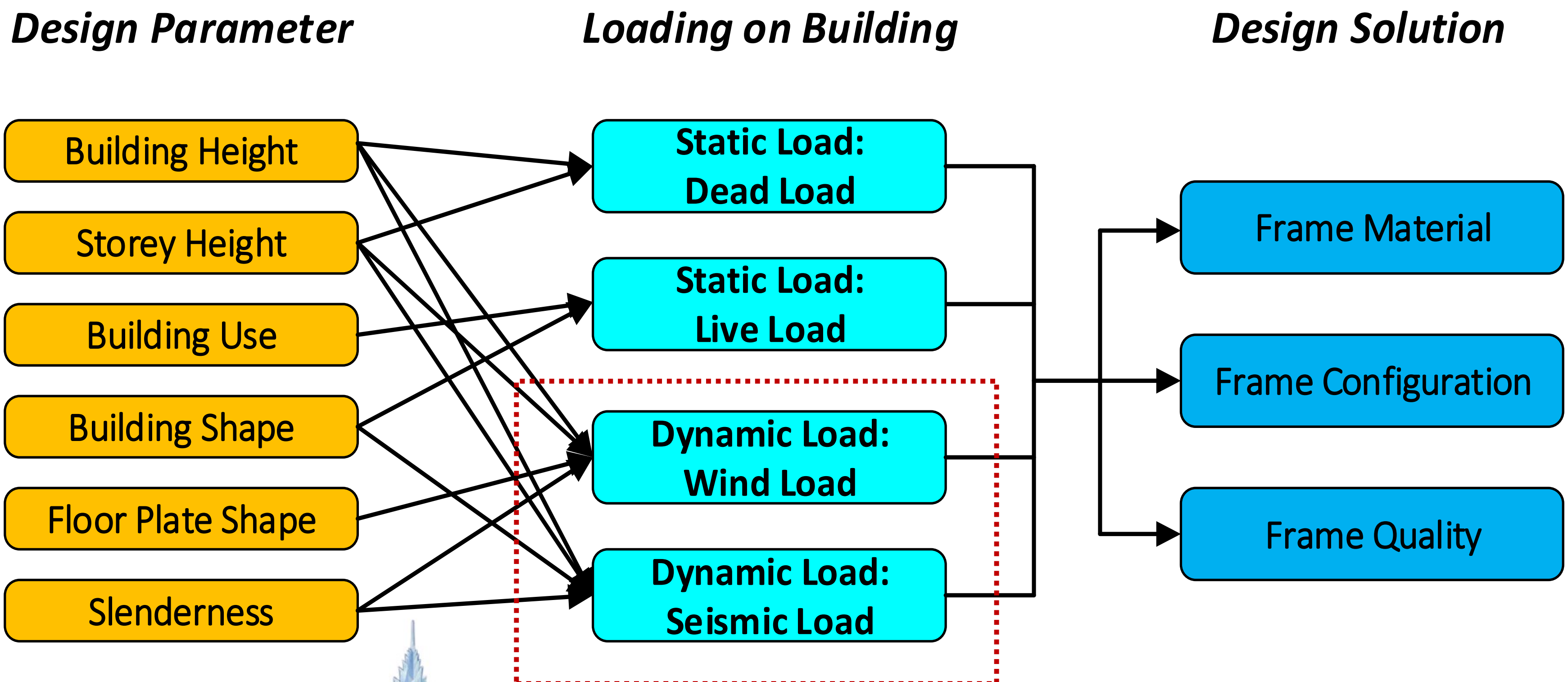
Bored pile type with rectangular shape is called ***Barrettes***; driven piles, a mat foundation alone or even footing which is depend on the soil properties below the tower

Basement Wall

Diaphragm Wall, **Secant Piles**, **Contiguous Bored Piles** or **Soldier Piles** are used for deep basement excavations

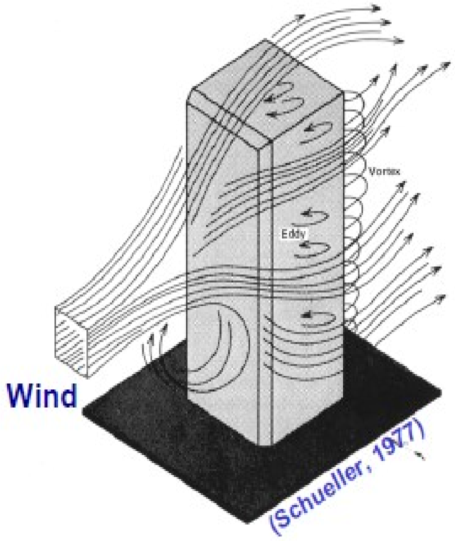


Loadings:



Inter-connection within Tall Buildings
(source: Arcadis)

Designing for Wind

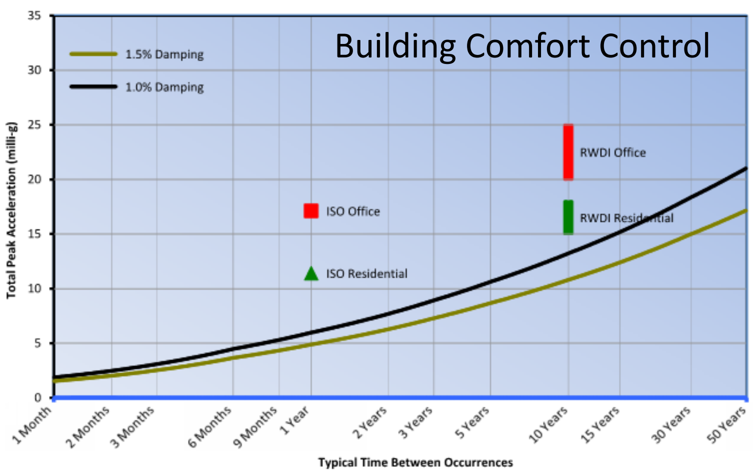


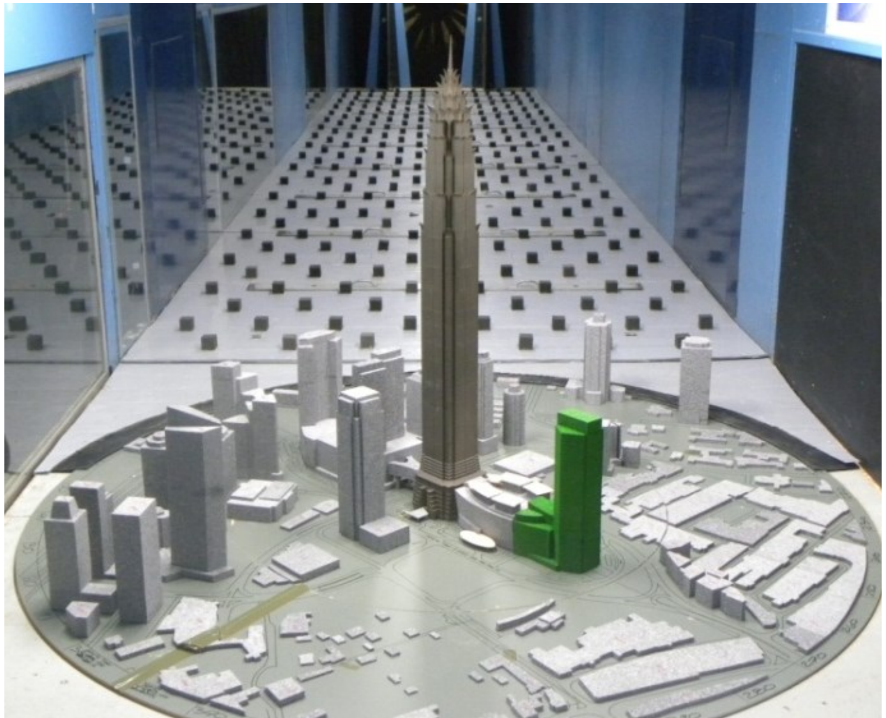
Code Based Design

- Basic Wind Speed ~ 32 m/s
- 3 sec gust speed at 10 m above ground
- Surface Roughness Category B-C-D
- Importance Factor, I = 1-1.15

Wind Tunnel Test

- Force-Balance Model
- Building Comfort Study

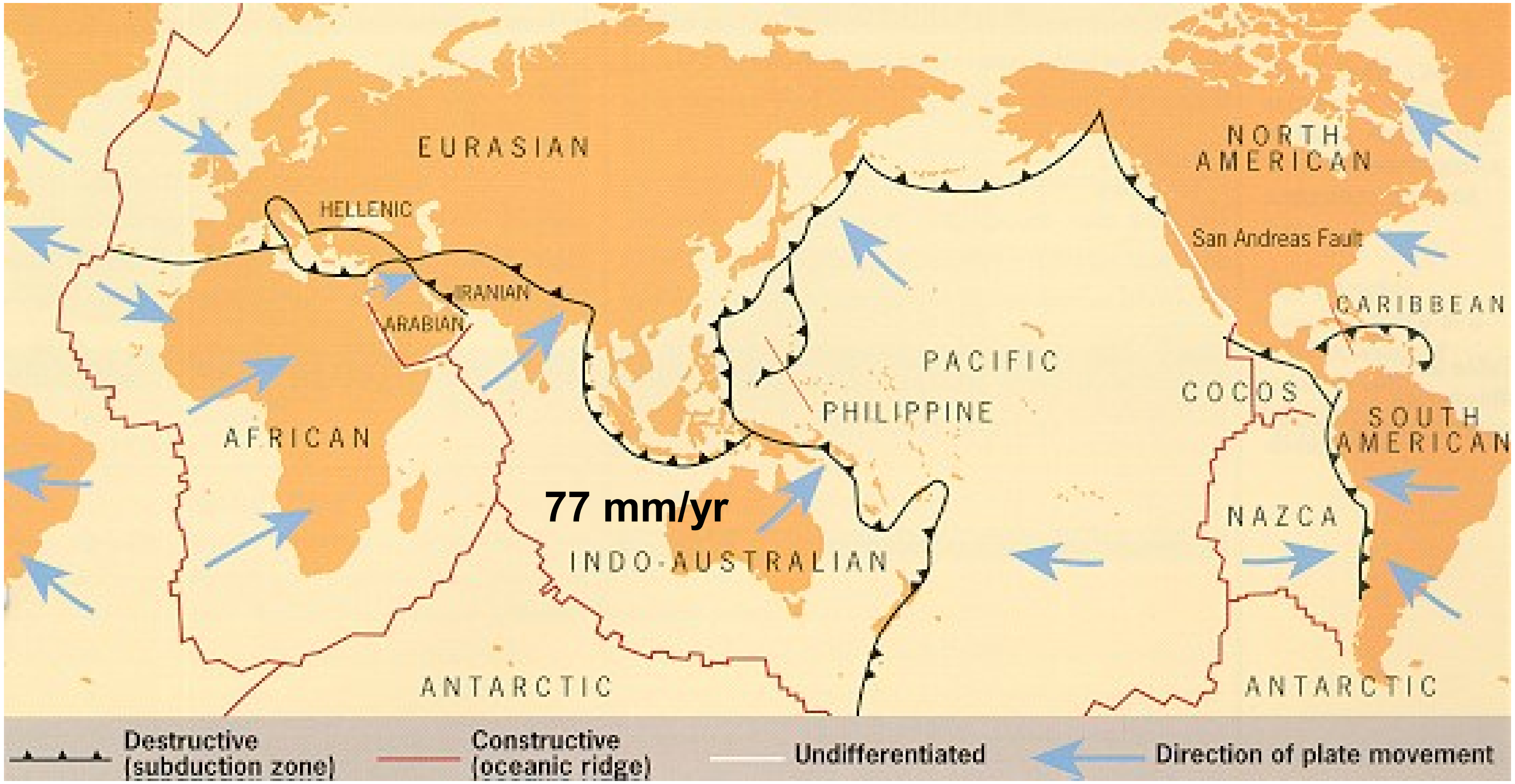


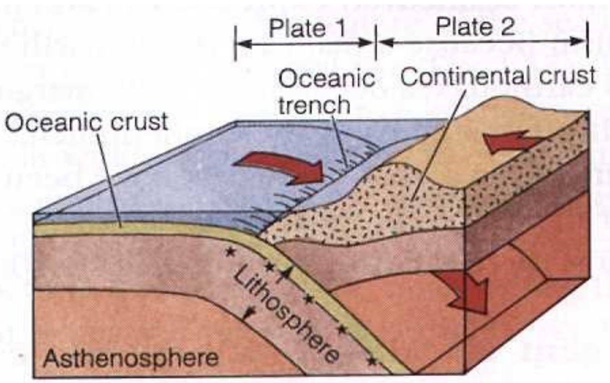


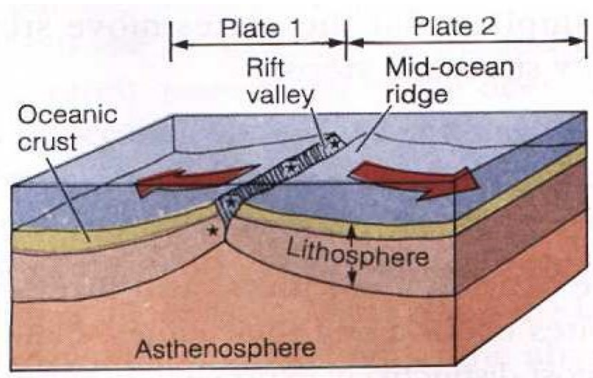
RWDI-laboratory

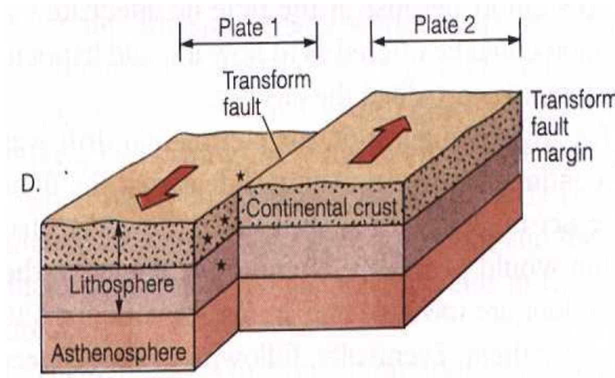
Designing for Seismic

Major World Tectonic Plates and Their Movements



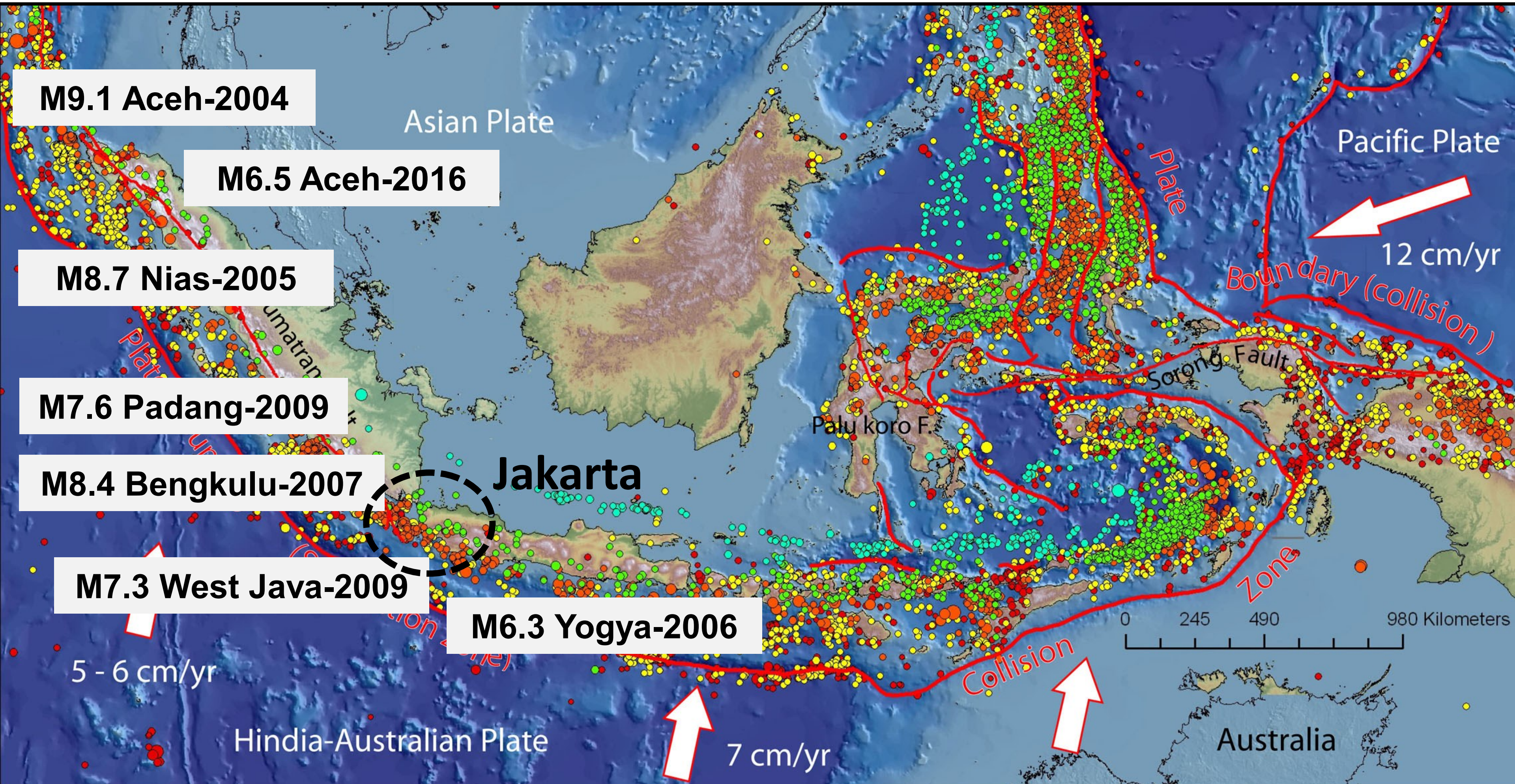






Designing for Seismic

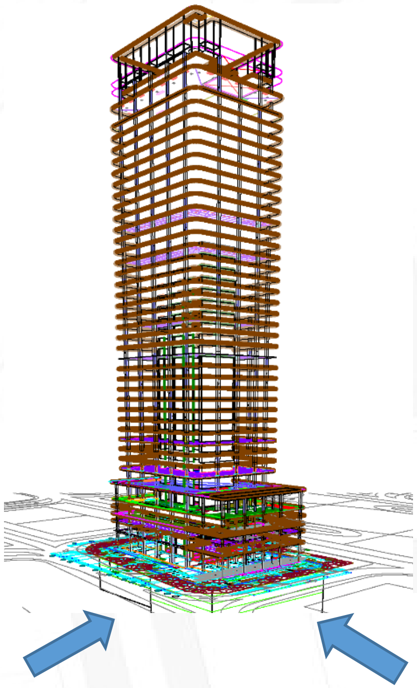
Recent Earthquake Happens in Indonesia since 1964:

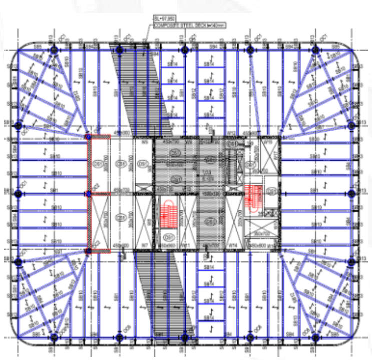


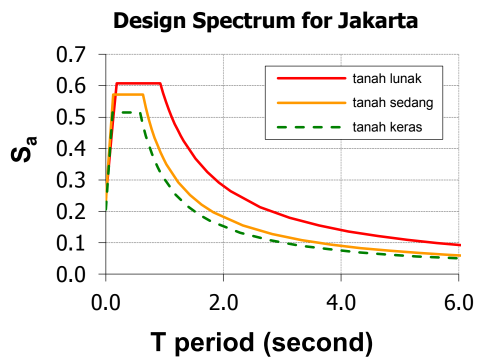
Earthquake data: Engdahl 1964 - 2005

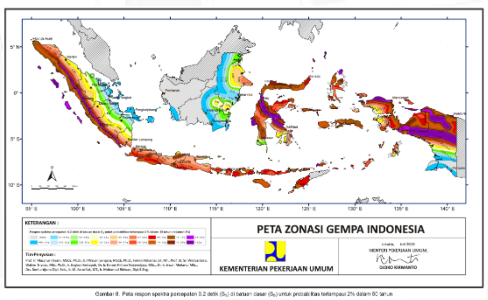
(Courtesy from D.H. Natawidjaja)

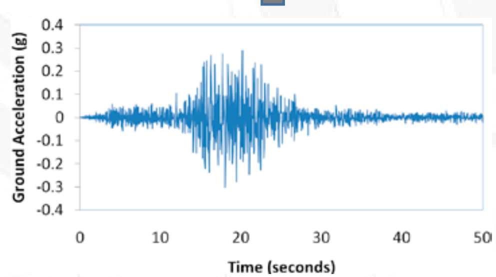
Method of Analysis (Code Based)

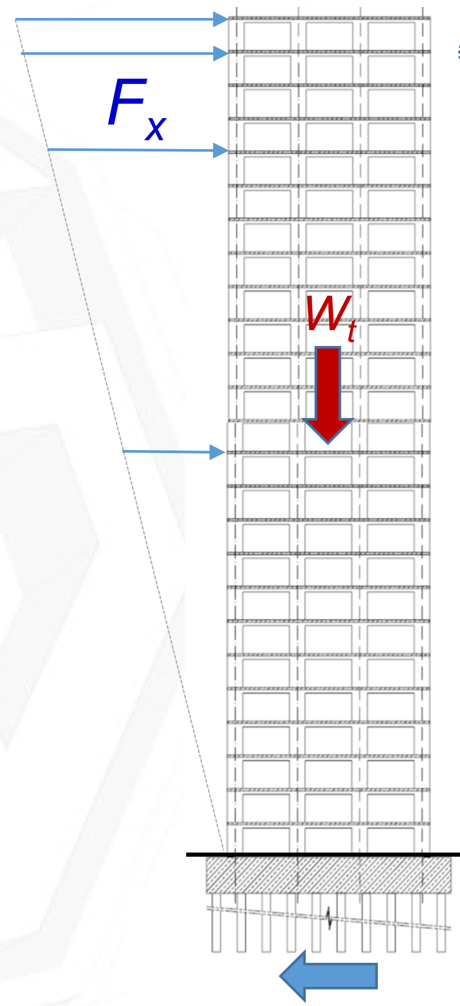


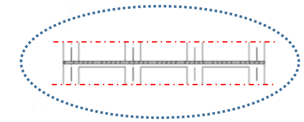












Floor Mass

m = DL+LL_R

$W = m \times g$

Check

$T \geq C_u.T_a$

$C_S = S_D/(R/I_e)$

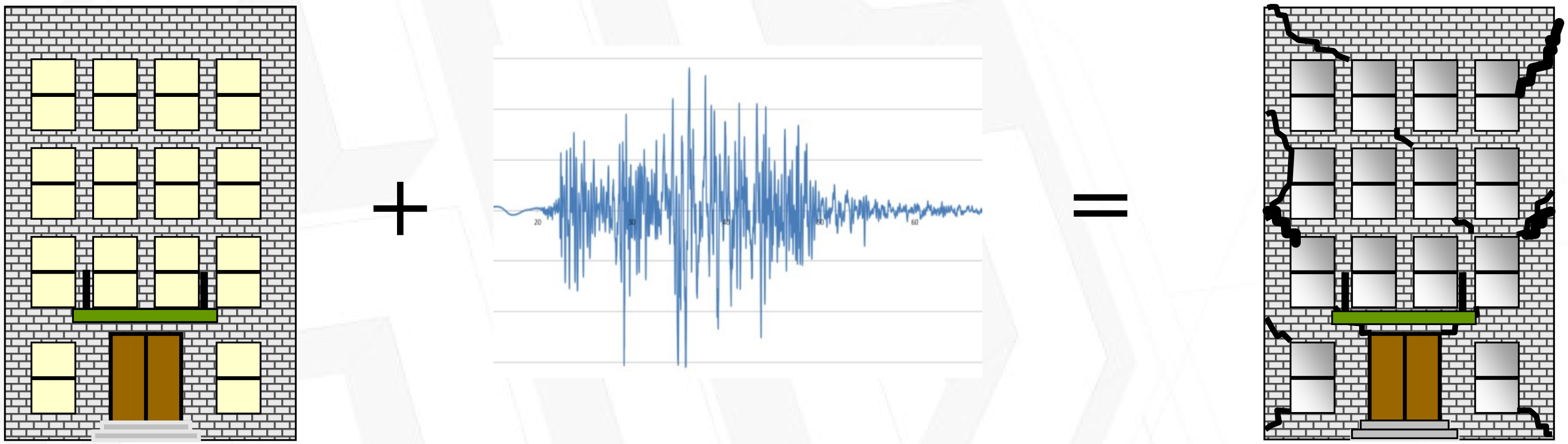
$C_S \geq C_{S\text{-}min}$

$V_b = C_S \times W_t$

Make It Simple Step .....

Method of Analysis (Advance Analysis)

Performance Objectives



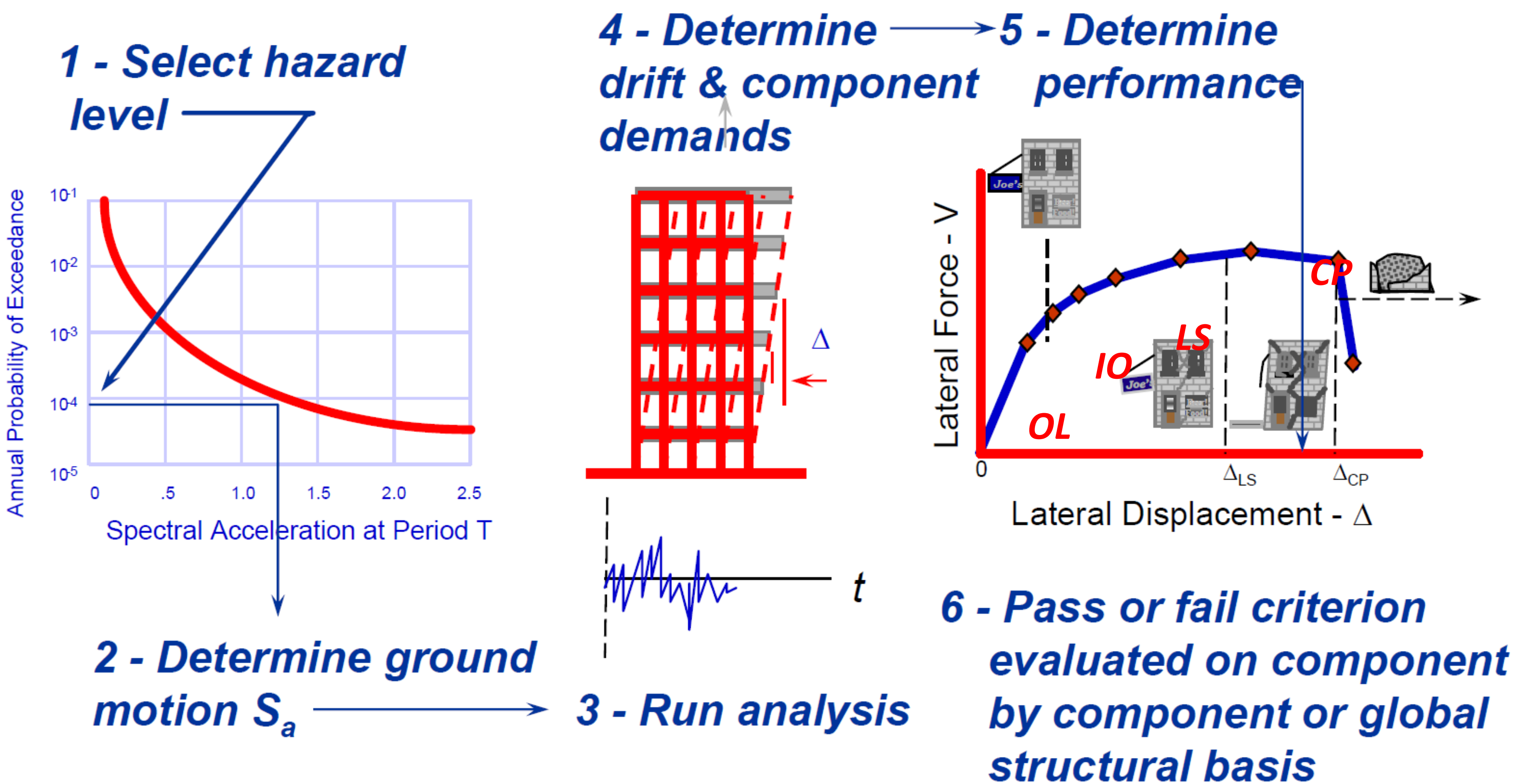
Ground Motion
x% - 50 years

Performance
Level

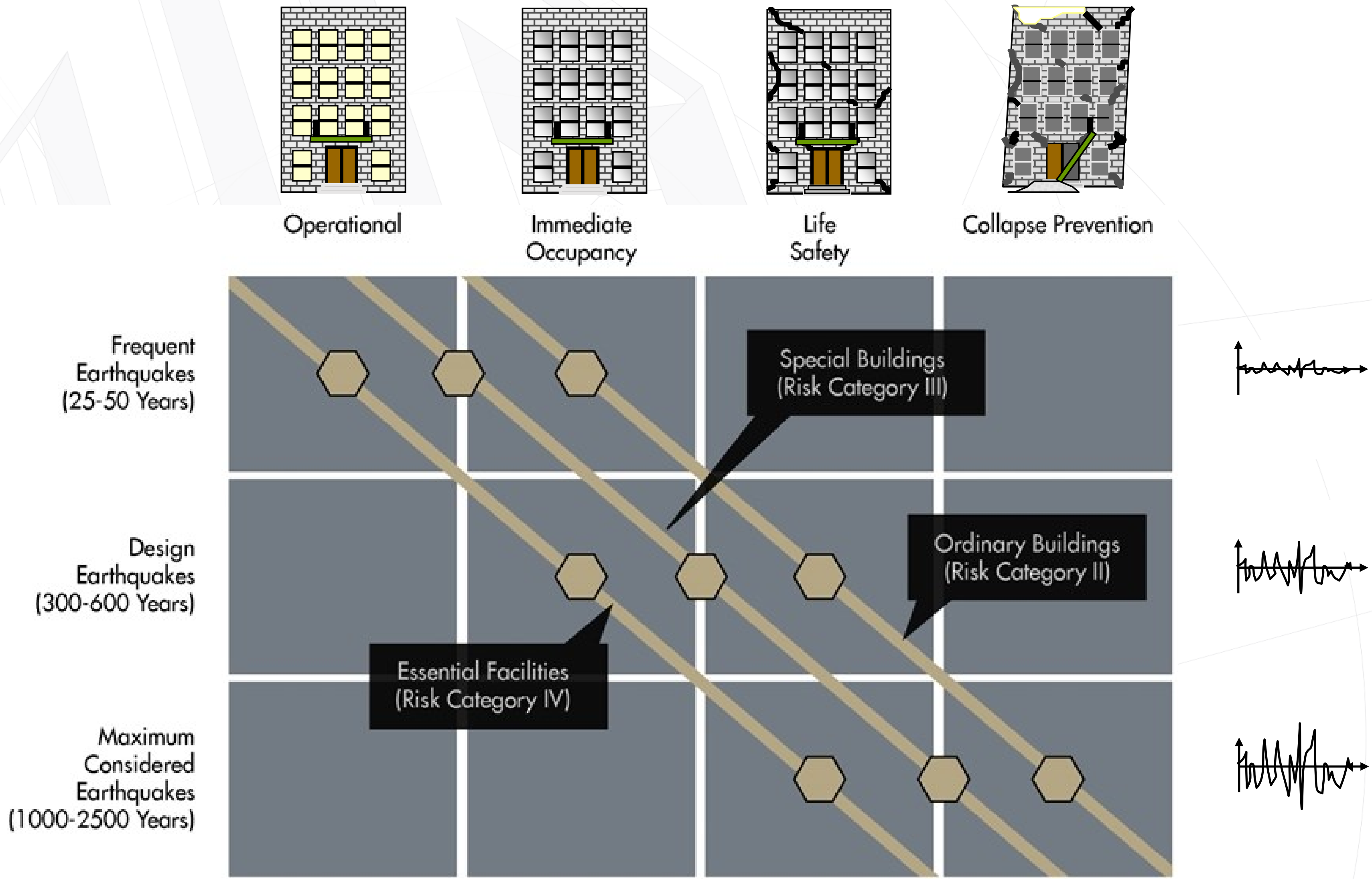
Design Hazard (earthquake ground shaking)

Acceptable Performance Level (maximum acceptable damage, given that shaking occurs)

Performance Based Seismic Engineering (PBSE) Evaluation Approach



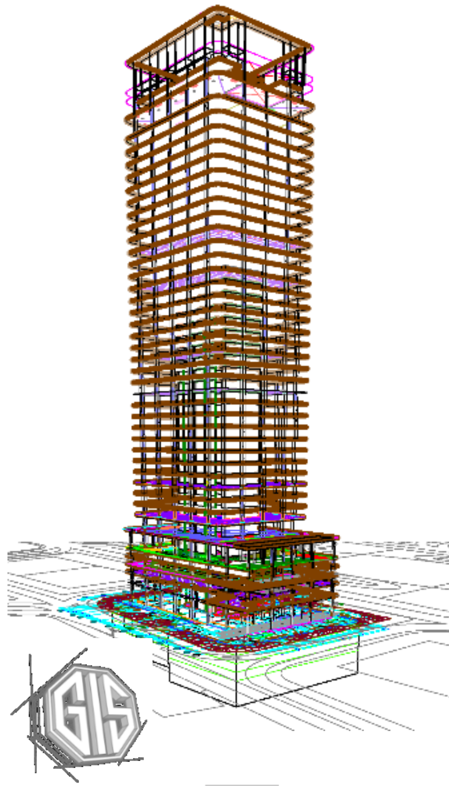
Building Performance Level Matrix

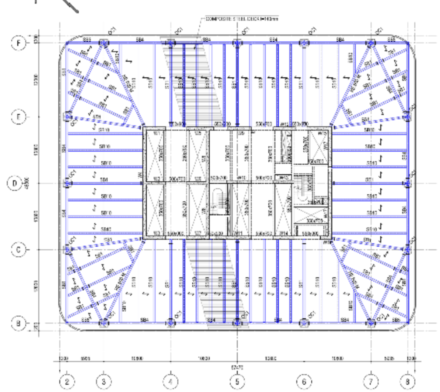


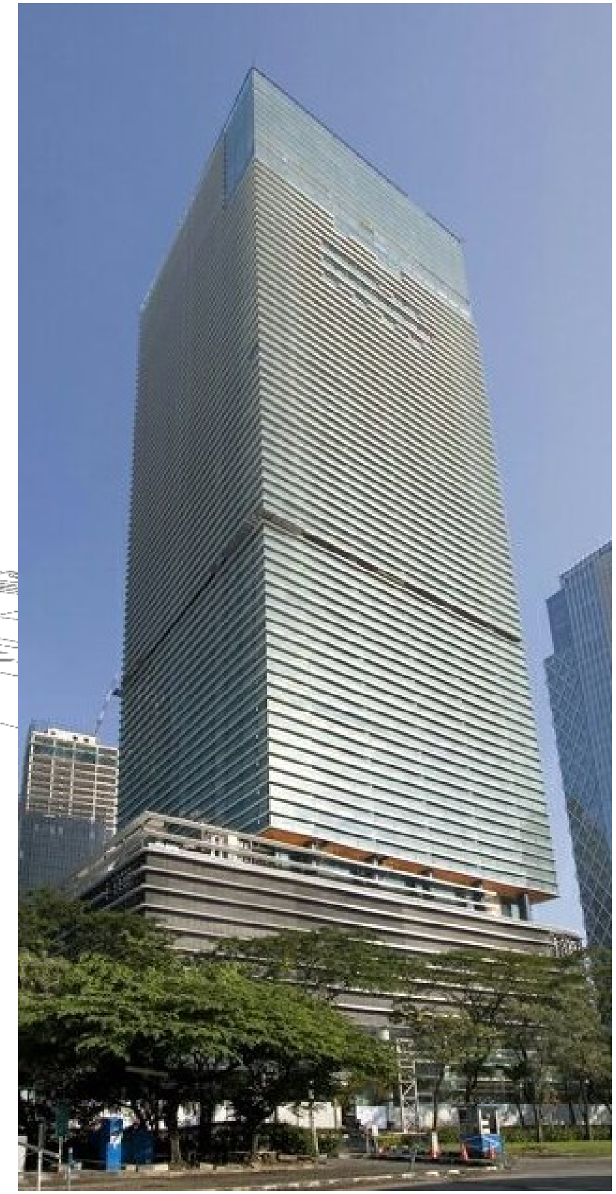
SCBD-Lot 10 Office Building - Jakarta

This office building is located at one of the most prestigious business district in Jakarta. It consists of 40 storeys (excluding its two MEP floors) making a total height of 210.5 metres above the ground floor. Including its six-level basement, the total gross floor area of this building is more than 150,000 m².

Reinforced concrete bored piles and diaphragm walls around its perimeters were used as elements of the foundation and retaining system. The upper-structure of the building is in form of a dual system, which consists of reinforced concrete core walls and steel composite perimeter frames. The columns are concrete filled circular steel tubes. This type of structural system was proofed as able to speed up the construction time significantly and provide additional free space for the tenants, when compared to buildings with ordinary reinforced concrete structures.







Hybrid Structure

RC Core Wall, Steel Composite Beam and Column

Higher Performance Building Level - for MCE_R

Shanghai Tower *(Mega Tall Project)*:

Figure 3.1. With the outer skin removed, the regular circular floor plates are revealed. (Source: Gensler)
图3.1. 将外层表皮剥离后，可以看到每层平面都呈现规则的图形。（来源: Gensler)

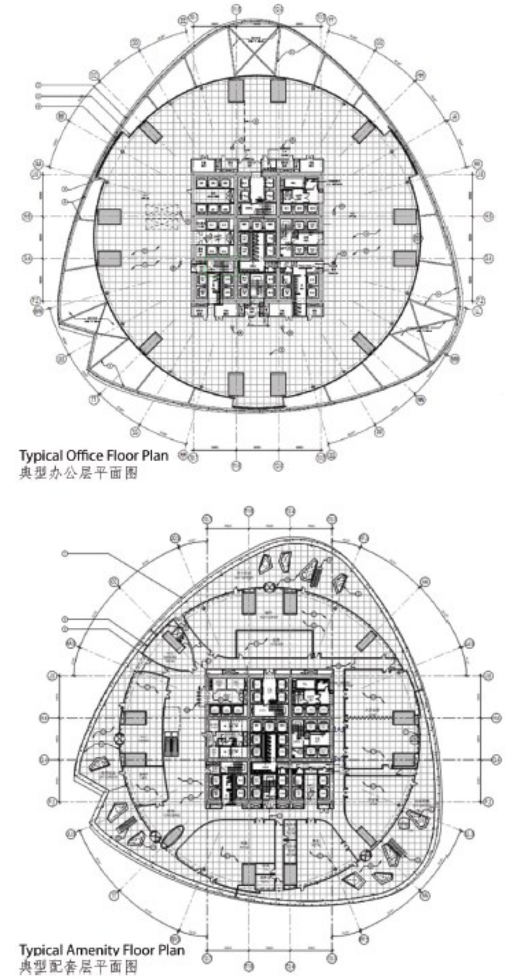


Figure 3.2. Shanghai Tower Typical Floor Plans (Source: Gensler)
图3.2 上海中心大厦标准层平面图 (来源: Gensler)

Height:*

Architectural: 632 meters (2,073 feet)
To Tip: 632 meters (2,073 feet)
To Occupied Floor: 561 meters (1,841 feet)

**See CTBUH Height Criteria on page 133*

Floors Above Ground: 128
Floors Below Ground: 5
Area: 420,000 m² (4,520,842 ft²)
Use: Hotel/Office
Structural Material: Composite

Shanghai Tower *(Under Construction)*:

30 May 2011

Shanghai Tower (Under Construction):

Figure 5.13. View of Shanghai Tower early in its construction in urban context (Source: Gensler)
图5.13. 从城市角度看上海中心大厦施工图景 (来源: 上海建工集团)

Figure 5.7. Unsupported circular foundation pit of 121 meters' diameter (Source: Shanghai Construction Group)

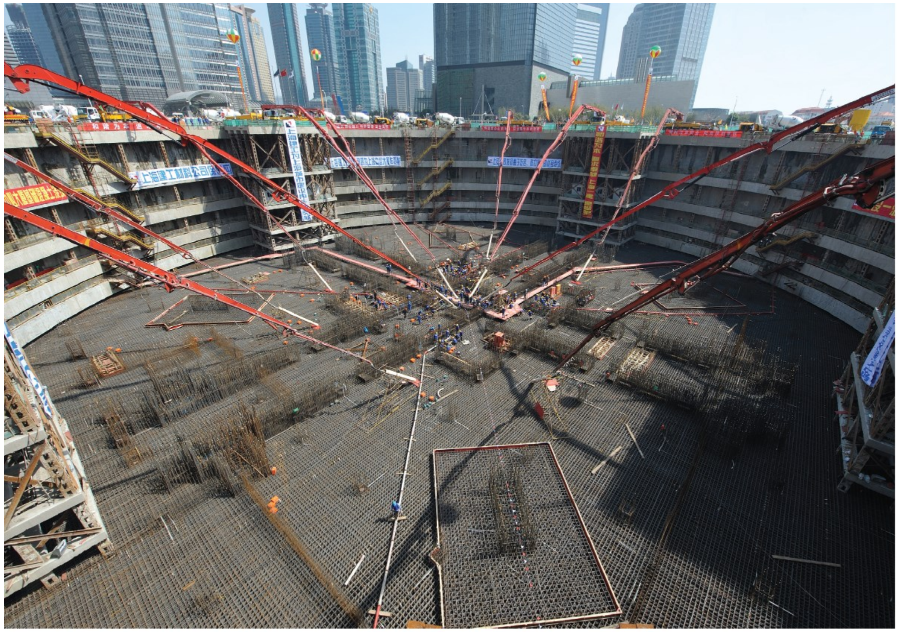
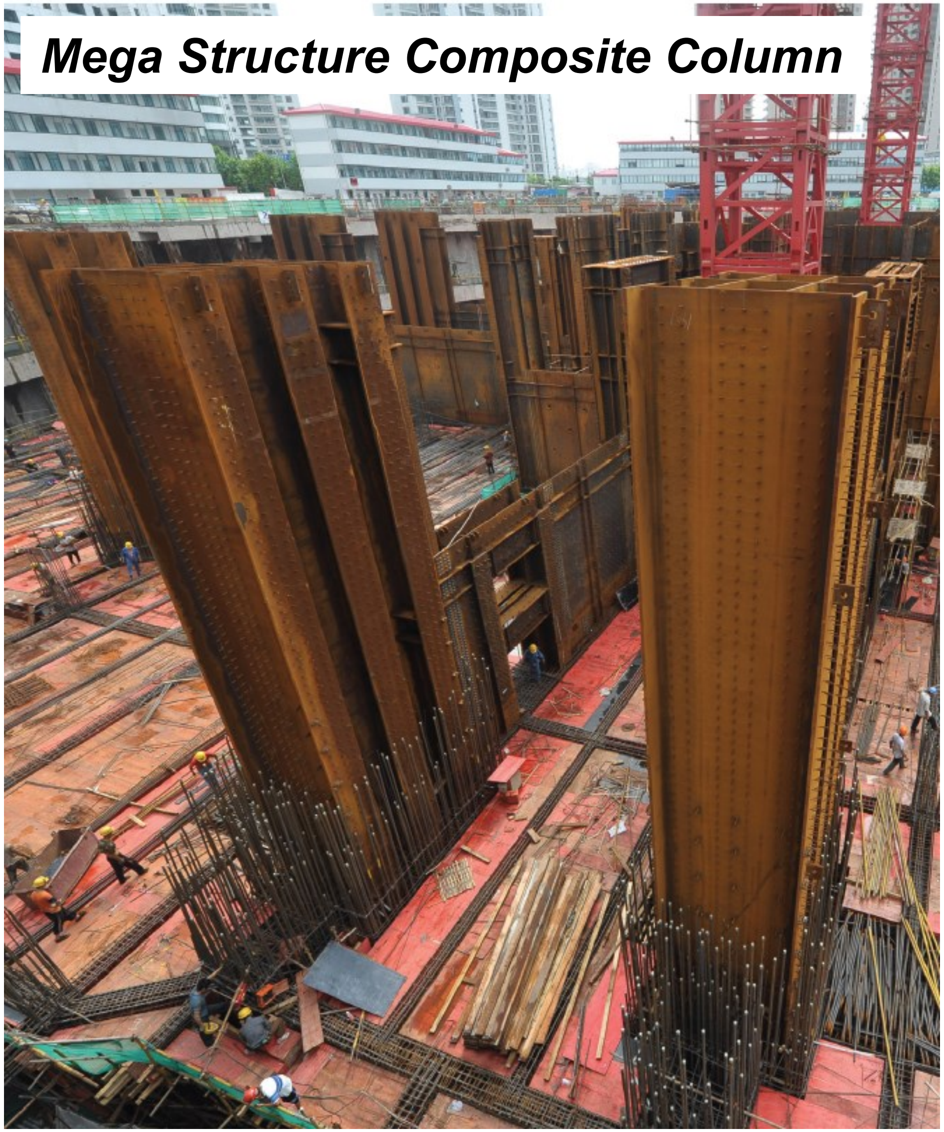


Figure 5.8. Concrete casting for the base slab of tower (Source: Shanghai Construction Group)

Shanghai Tower *(Under Construction)*:

Figure 5.11. Four heavy cranes arranged in the way of out-door hanging (Source: Shanghai Construction Group)



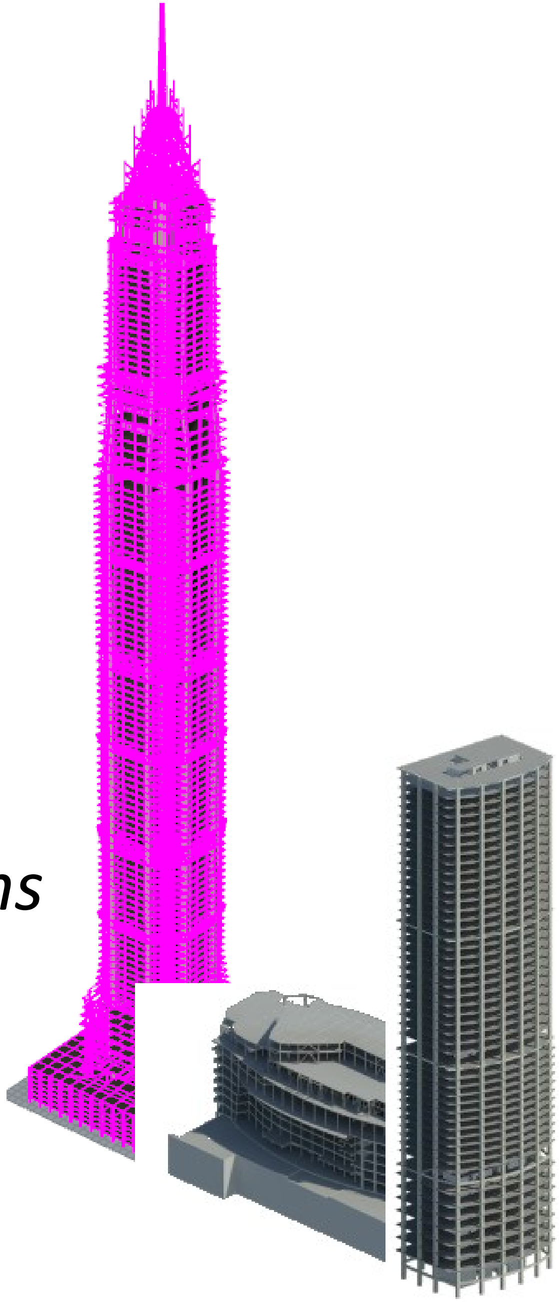
Case Study:

Signature Tower Jakarta

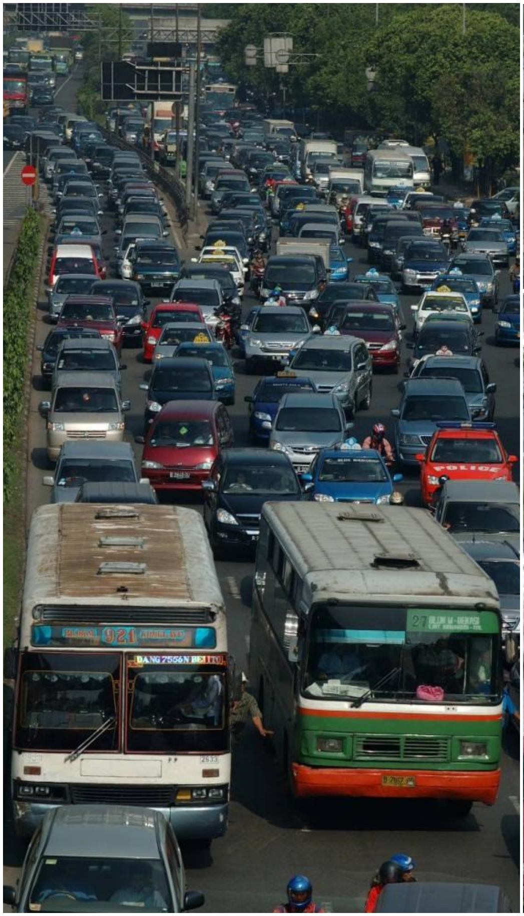
SIGNATURE TOWER

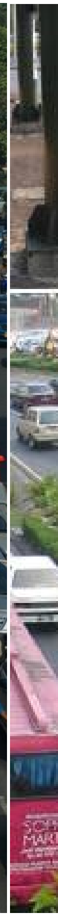
Content:

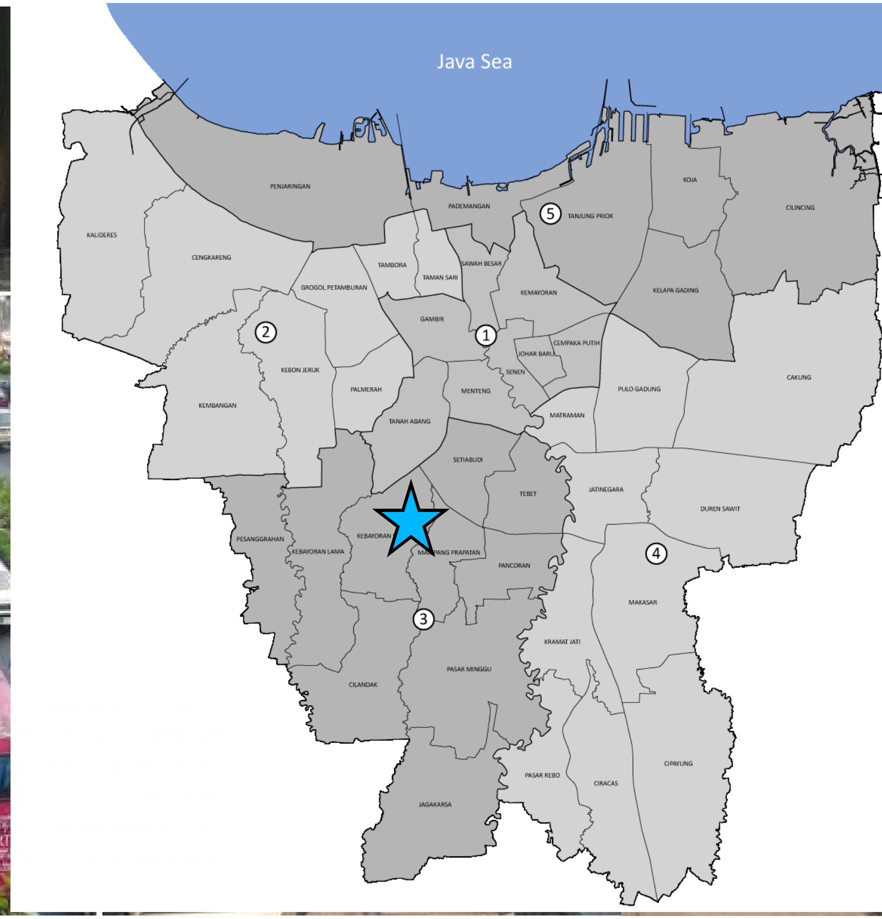
- Overview
- Design Team
- Project Description
- Structural Design Criteria
- Method of Analysis
- *Viscous Elastic Coupling Link Beams (Alternative Option)*
- Long Span – Steel Structure



Overview






Java Sea
PENJARINGAN
PADEMANGAN
TANJUNG PRIOK
KOJA
CILINCING
KALIDERES
CENGKARENG
TAMBORA
TAMAN SARI
SAWAH BESAR
KEMAYORAN
KELAPA GADING
GROGOL PETAMBURAN
GAMBIR
CEMPAKA PUTIH
JOHAR BARU
SENEN
KEBON JERUK
PALMERAH
MENTENG
PULO GADUNG
CAKUNG
KEMBANGAN
TANAH ABANG
MATRAMAN
SETIABUDI
TEBET
JATINEGARA
DUREN SAWIT
PESANGGRAHAN
KEBAYORAN LAMA
KEBAYORAN
PANG PRAPATAN
PANCORAN
MAKASAR
KRAMAT JATI
PASAR MINGGU
CILANDAK
JAGAKARSA
PASAR REBO
CIRACAS
CIPAYUNG
1
2
3
4
5

The population of Jabodetabek is broken down as follows:

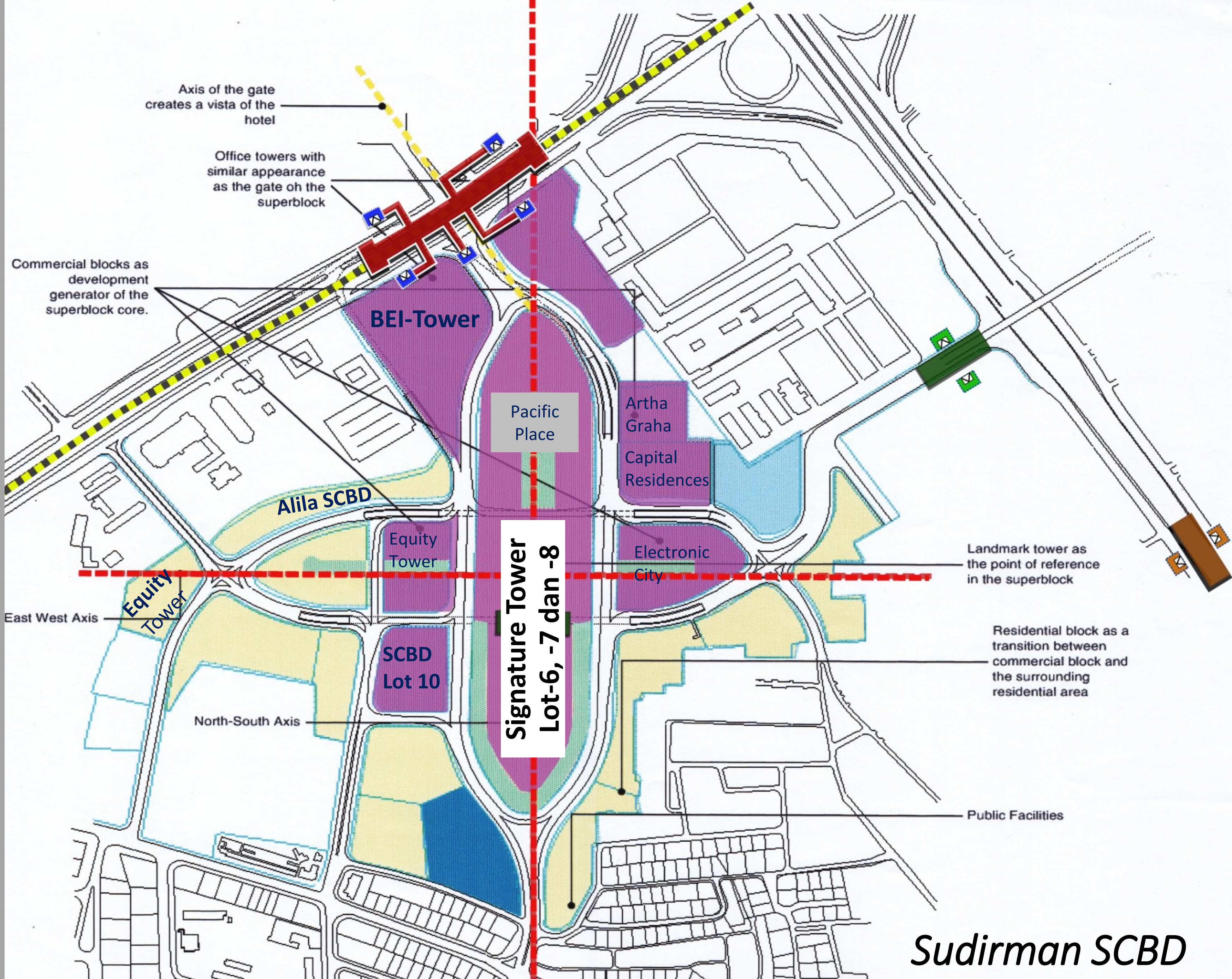
Jakarta (9.59 million); Bogor Regency (4.76 million); Tangerang Regency (2.84 million); Bekasi Regency (2.63 million); Bekasi Municipality (2.38 million); Tangerang Municipality (1.80 million); Depok Municipality (1.75 million); South Tangerang Municipality (1.30 million); Bogor Municipality (950,000)

http://worldpopulationreview.com/world-cities/jakarta-population/
October 2017

The development of Jakarta in the past 40 years has tended to be horizontal and sprawling into rural areas. The need to have higher density development is crucial. The burden of the city's infrastructure is enormous, with traffic congestion, waste and water management. More concentrated and higher density development will partly resolve the city's problems.

The Signature Tower Complex is planned to accommodate those needs. It is strategically located in the central business district of Jakarta, SCBD. The location is accessible by multi-modes of transportation. It is also adjacent to two of the planned MRT stations. The area has become one of the best developments in Jakarta…..

LANDUSE & MOVEMENT



Design Team

> International Consultants

Concept Architect : Smallwood, Reynolds, Stewart, Stewart and Associates Inc.
Structural Engineer : **Thornton Tomasetti, Inc.**
Geotechnical Engineer : Langan International
MEP and Fire Safety Engineer : Beca Engineering NZ Ltd.
Wind Engineering Consultant : Rowan Williams Davies & Irwin Inc.
Façade Consultant : Arup Singapore Pte. Ltd.

> Local Consultants

Architect of Records : P.T. Pandega Desain Weharima (PDW)
Structural Engineer : **P.T. Gistama Intisemesta**
MEP Engineer : P.T. Hantaran Prima Mandiri
Quantity Surveyor : P.T. Arcadis Indonesia

Project Description:

(Courtesy SRSA)

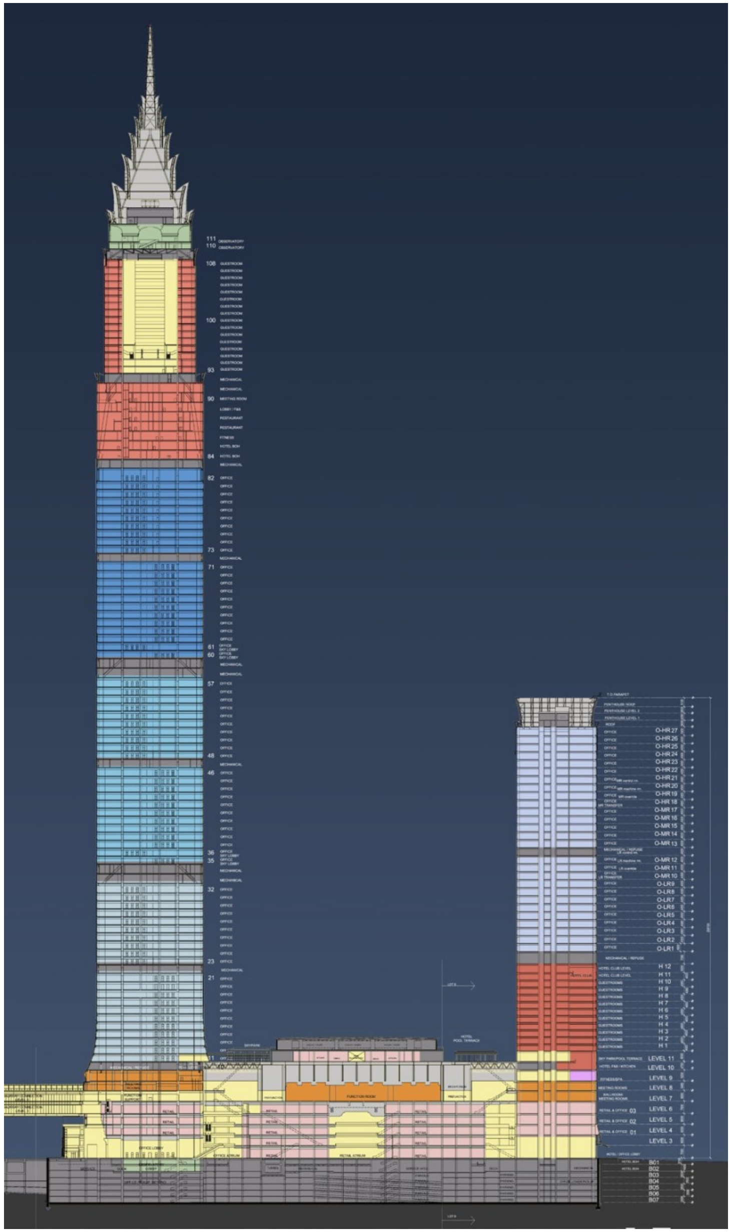
111-storey Signature Tower: three zones of office, hotel and observation level.

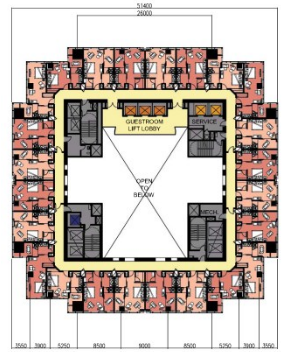
Podium level: retail, convention and entertainment (12 stories)

Lot-8 Tower (52-storey) : hotel and office

Below are ***7 floors of basement***, which are used mainly for mechanical room, back of house and parking space.

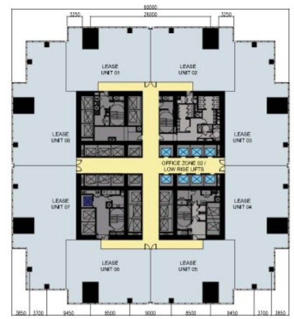
Building Section



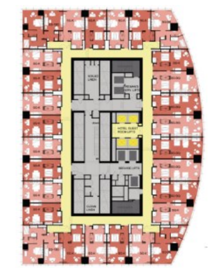


Typical hotel floor plans (L93-L108)

Typical office floor plans



Typical office floor plans



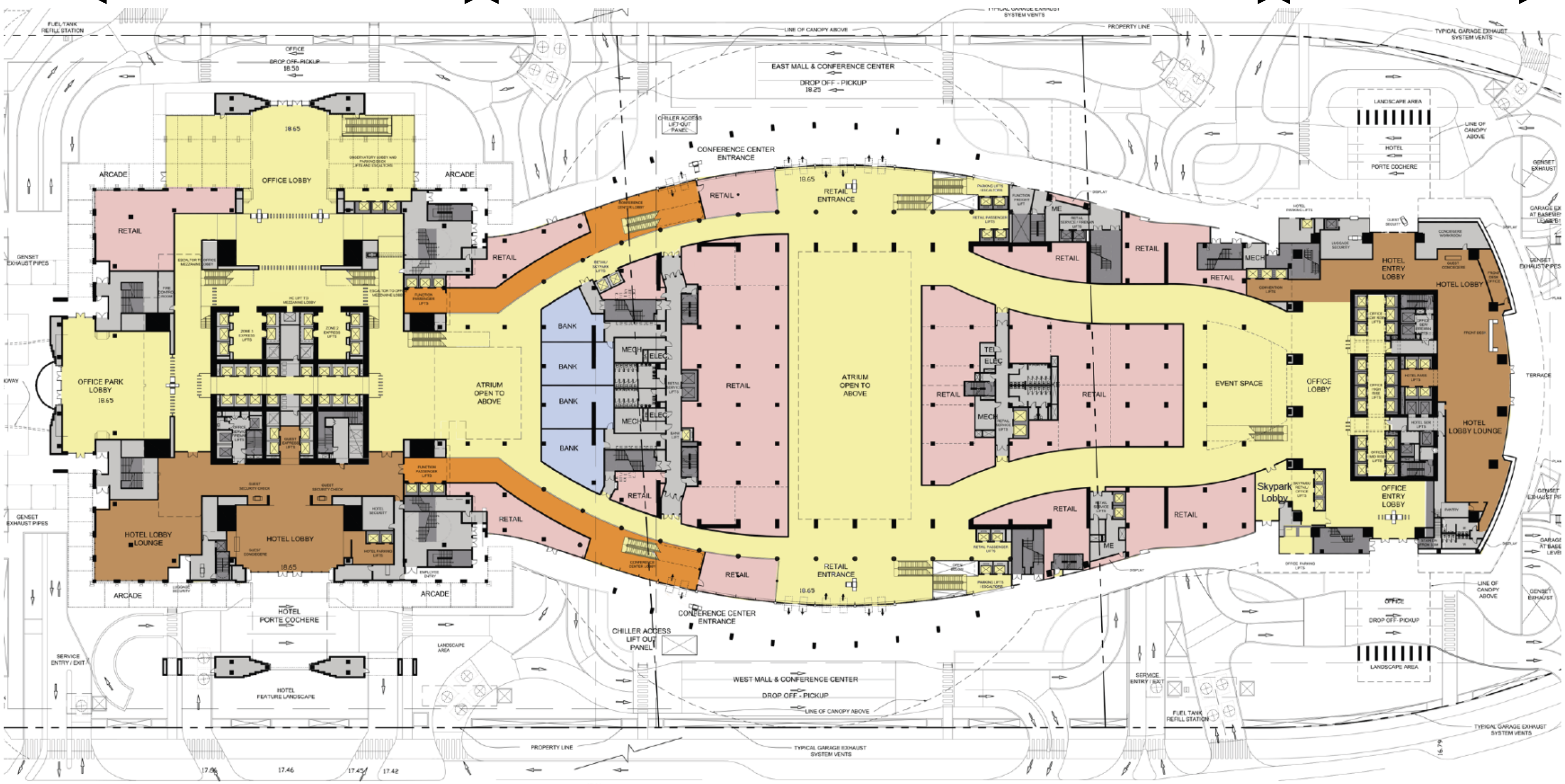
Typical hotel floor plans

Tenth Floor Plan (Sky Roof Plan) - Level 12

Architectural Floor Plans of Lot 6-7-8

Ground Floor Plan - Level 1

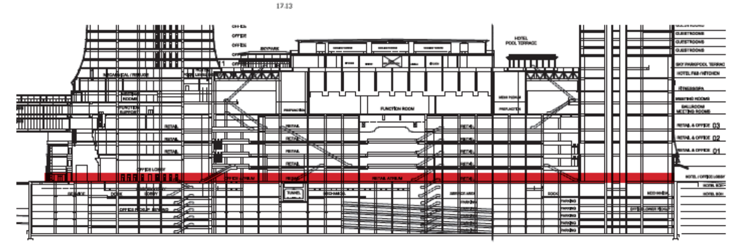
Signature Tower | **Podium – Mall/Retail** | **Hotel & Office**



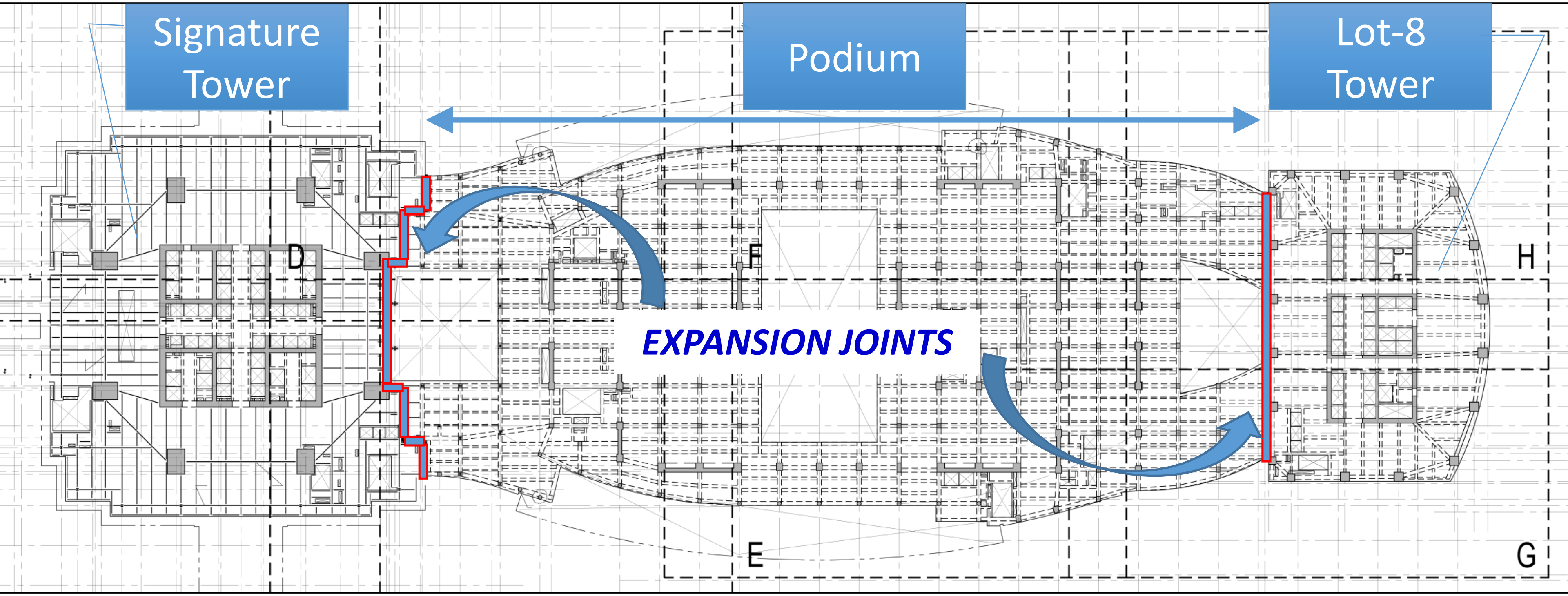
RETAIL	CIRCULATION
CONFERENCE	SERVICE / SUPPORT
HOTEL	PUBLIC LIFTS
OFFICE	SERVICE LIFTS

N

0 400



Structural Expansion Joints



Each structures have different structural behaviors, so **structural expansion joints** are an effective way to separate the structures to avoid the structural interference between dissimilar structures.

Expansion joints were placed between both towers and the above-ground podium.

Structural Materials

- Most of lateral system is controlled by ***strength***
- High strength materials used in design

Concrete:

Tower bored piles	***: 50 MPa***
Mat Foundation	***: 60 MPa***
Super Column	***: 80 MPa***
Wall	***: 70 - 85 MPa***

Structural Steel:

Truss	***: 520 MPa***

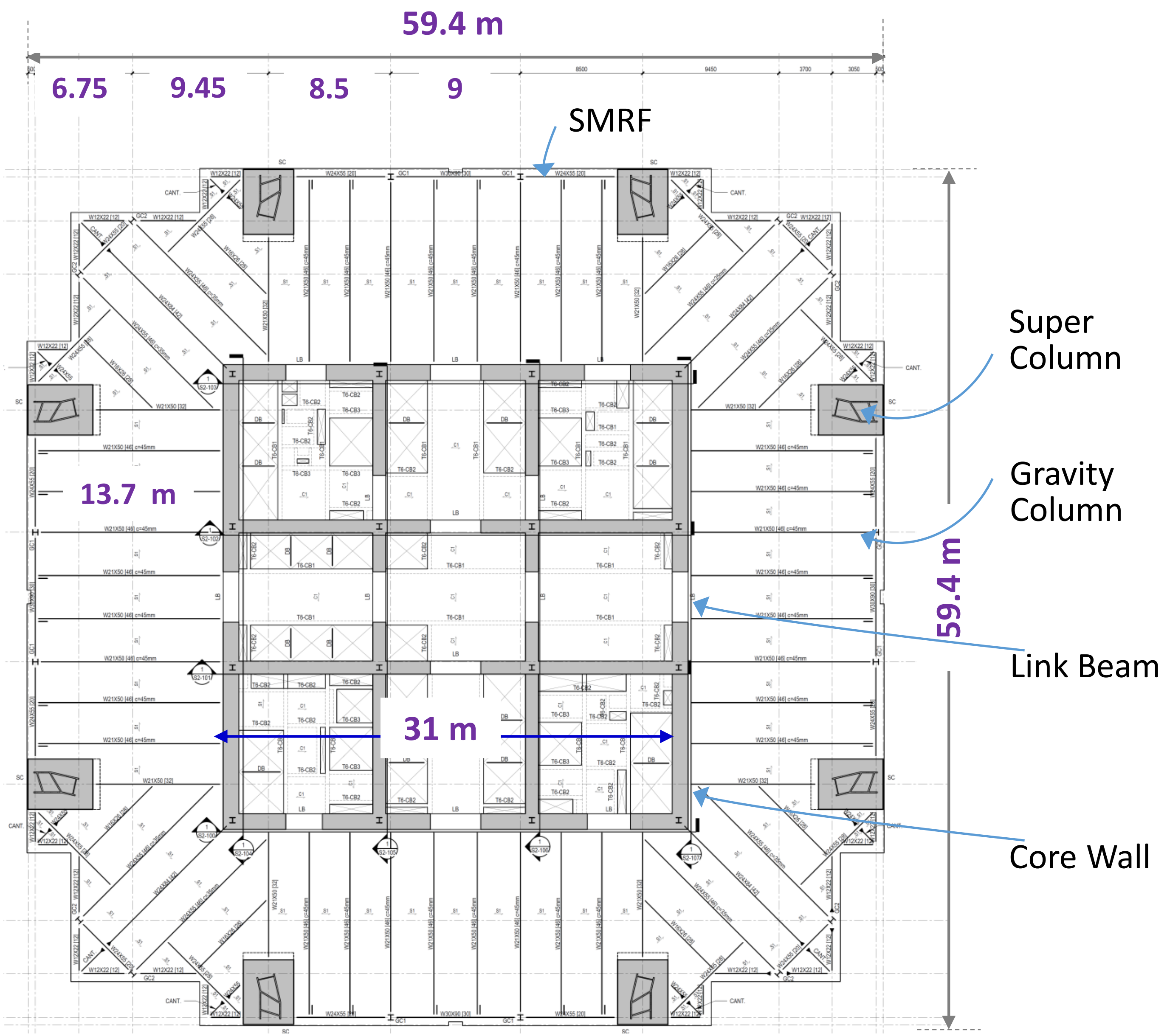
Rebar :

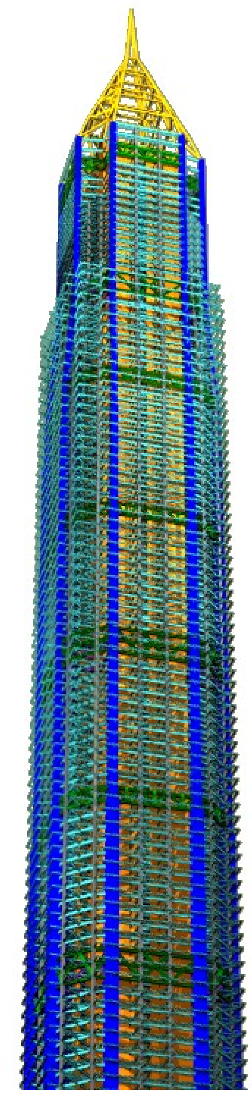
Deformed steel bar	: 400 – 500 MPa

Structural Design Criteria

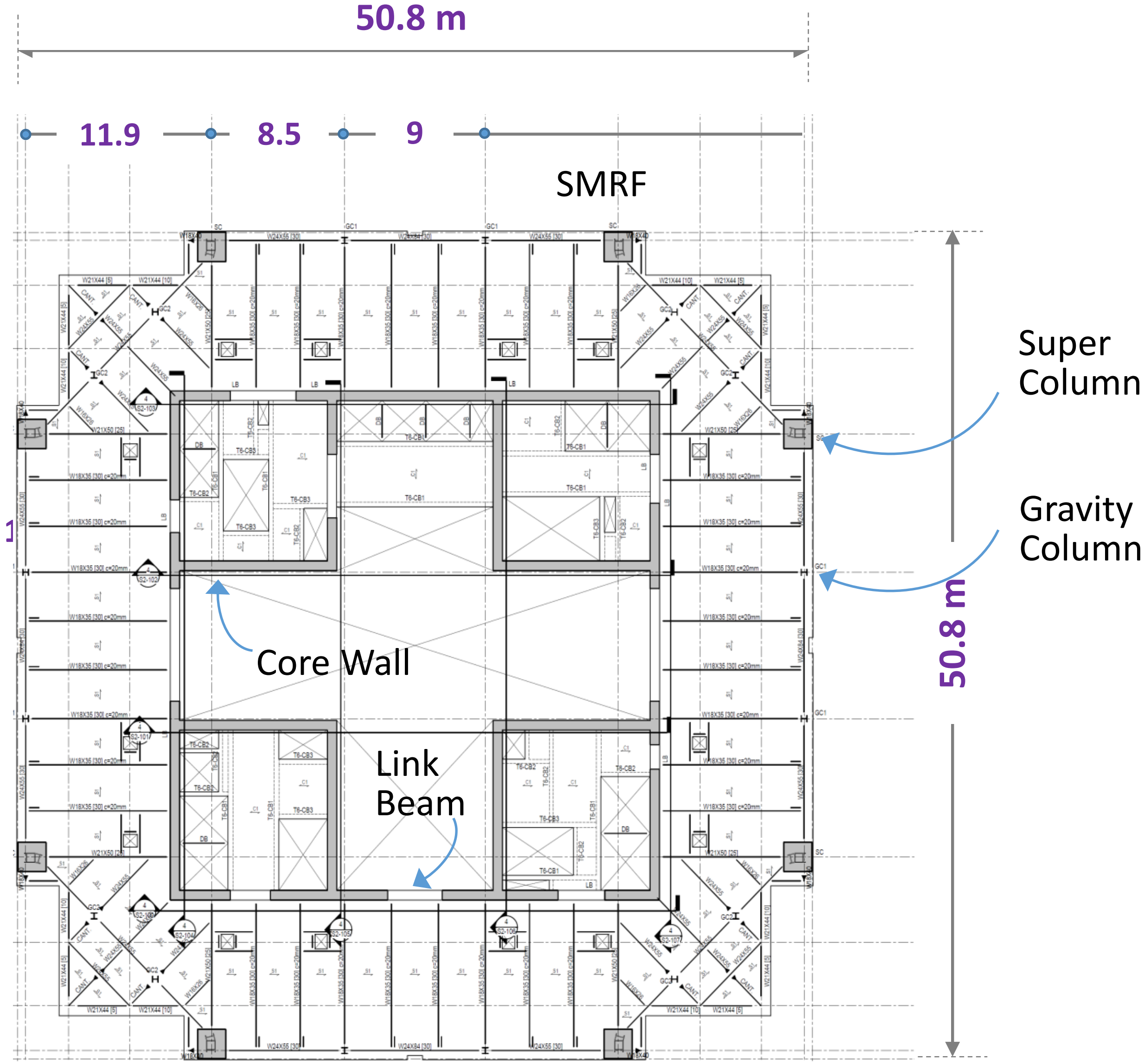
- Location : Jakarta, Indonesia
- Moderate seismic zone
- 638 m to top of spire (above ground)
- 525.8 m to top of roof (above ground)
- Slender Tower (H/B = 8.7) with some architectural setbacks at its corners
- 7 basement levels

Typical Office Floor Plan

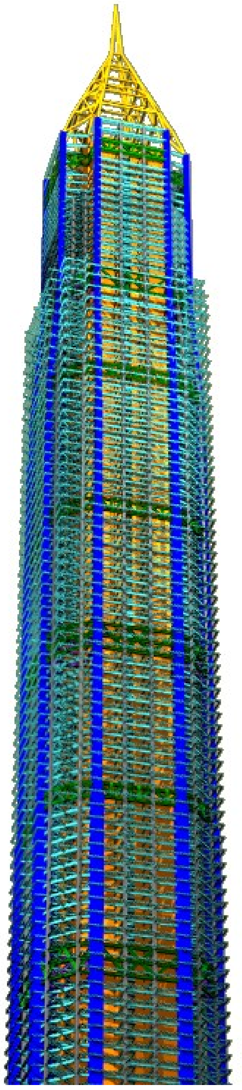




Typical Hotel Floor Plan



(Level 93-108)



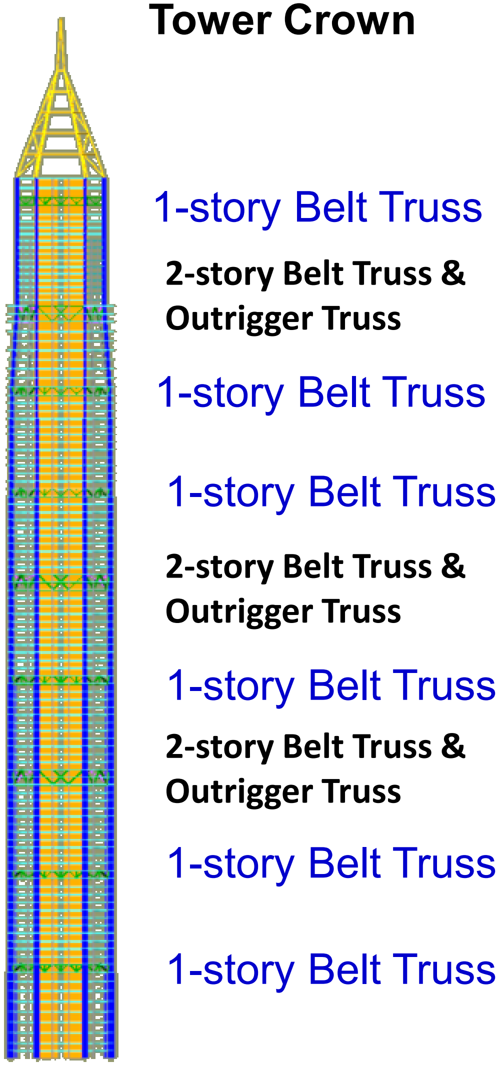
Structural System

Lateral Resisting System

“Core-Outriggers-Mega Frame” System

- ***Primary Lateral System*:**
  - Composite Core Wall
    - Steel plates
    - Built-up steel section
  - SRC Super Columns
    - Built-up steel section
  - Steel Outrigger Trusses

- ***Secondary Lateral System*:**
  Exterior Mega Frame
  - Steel Belt Trusses
  - Steel Floor Trusses
  - SRC Super Columns

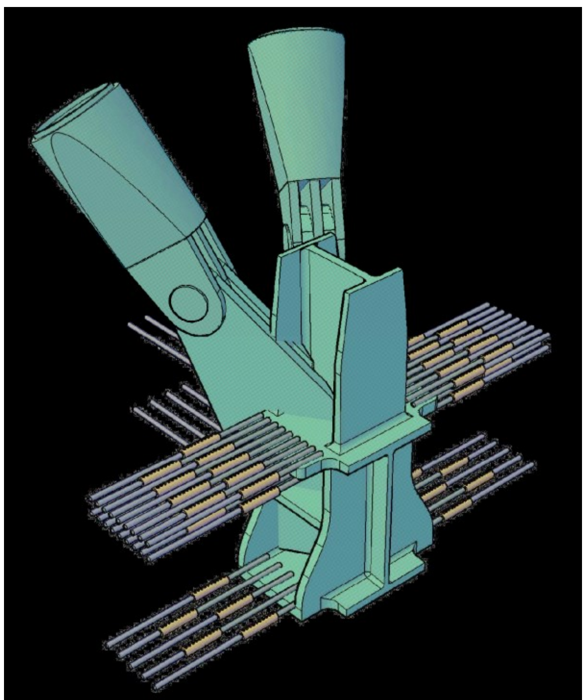


Structural System

- **Super Column**

  Benefit of SRC

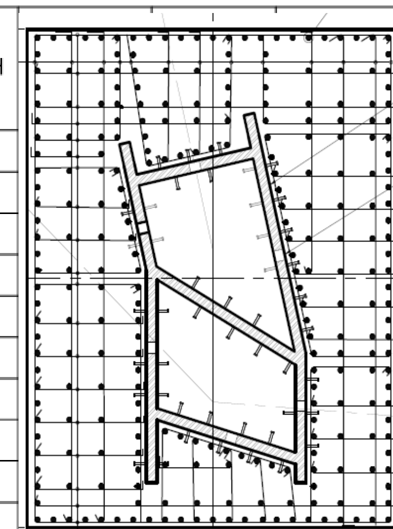
  - Reduce column size
  - Improve ductility



Use BIM as a Tool

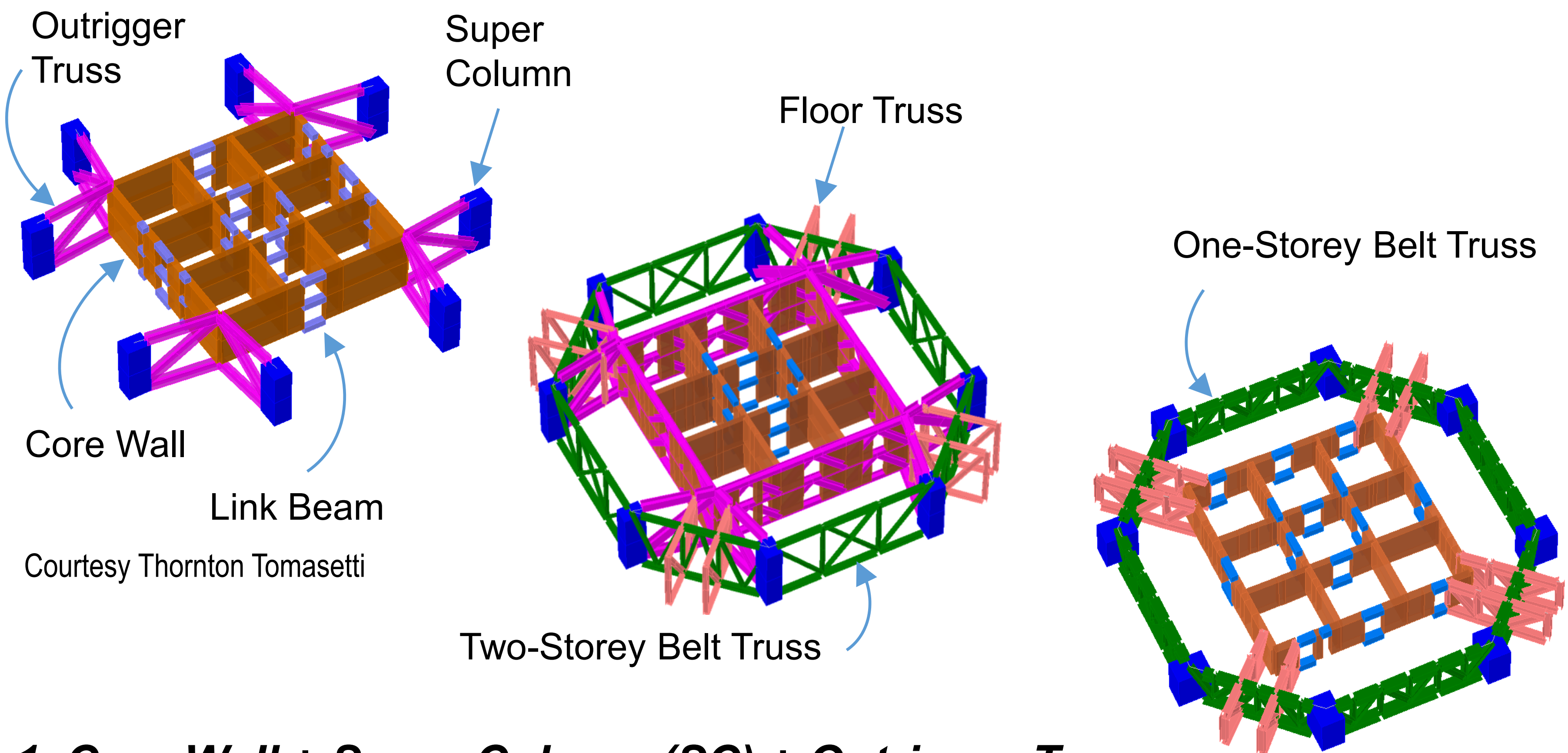
SUPER COLUMN SCHEDULE

LOCATION	EFFECTIVE COL. WIDTH (MM)	EFFECTIVE COL. DEPTH (MM)	CONC. STRENGTH (MPA)
B6 - B1	3500	5000	80
L1 - L10	3500	5000	80
L11 - L22	3500	5000	80
L23 - L34	3500	4500	80
L35 - L47	3500	4500	80
L48 - L59	2500	3300	80
L60 - L72	2200	3000	80
L73 - L83	2000	2600	80
L84 - L92	1800	1800	80
L93 - L109	1500	1500	80



Structural System

Lateral Resisting System

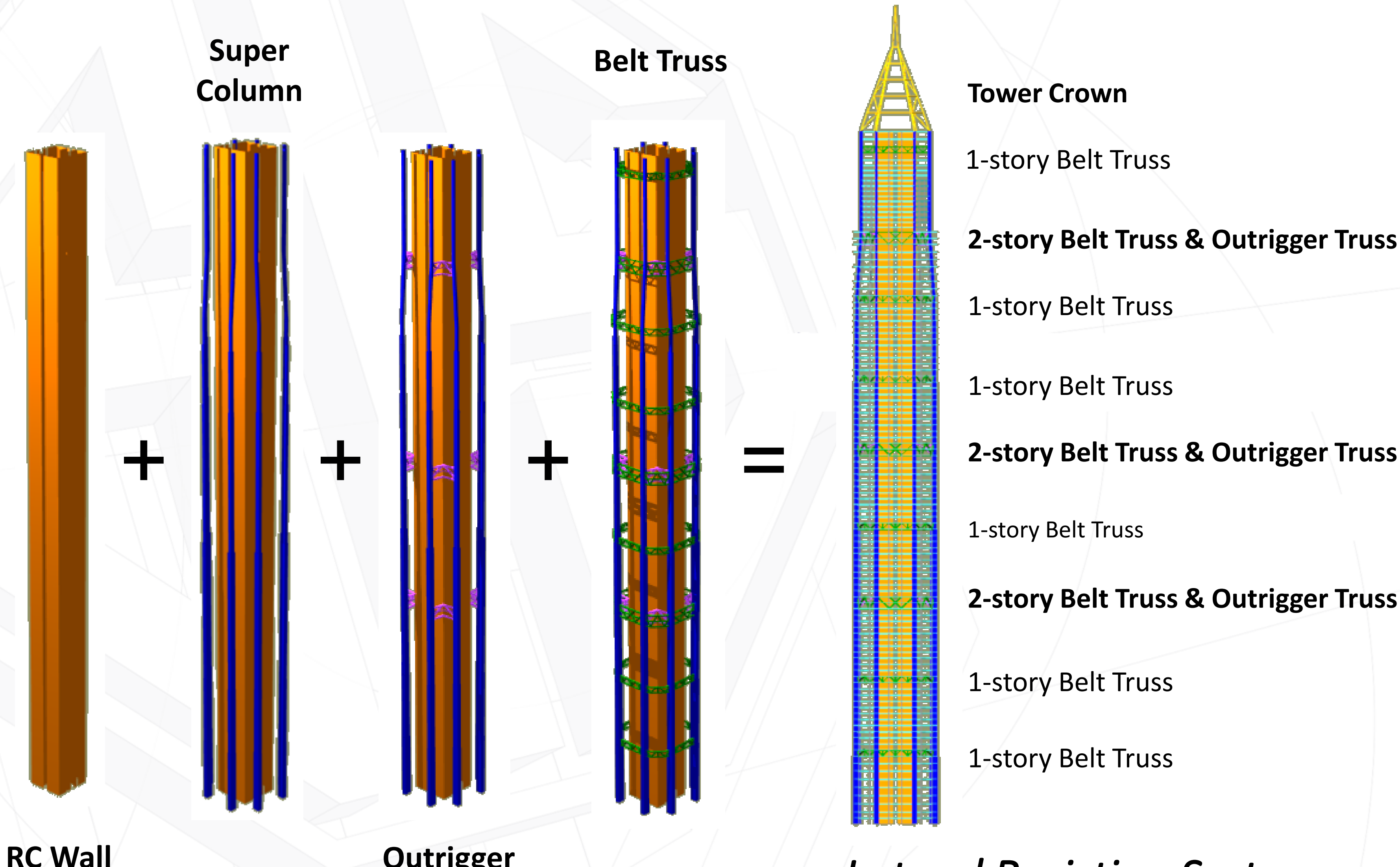


1. Core Wall + Super Column (SC) + Outrigger Truss

2. Core Wall + SC + Outrigger Truss + Belt Truss

3. One-Storey Belt Truss

Structural System



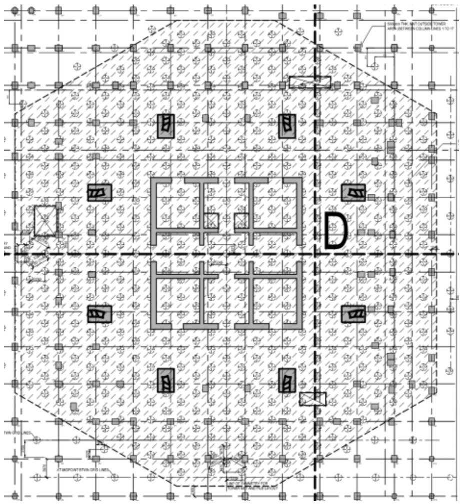
Lateral Resisting System

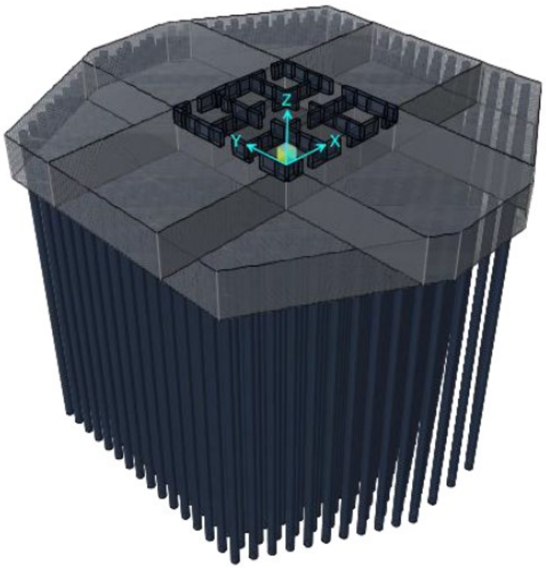
Foundation and Basement Wall

Drilled shaft bored piles with a mat foundation system was used for this project to support the weight of the building and resist overturning moments from wind and seismic loads.

The drilled shaft pile foundation under the tower-mat is ***1.5 m in diameter***, with an effective length of 90-100 m to transfer the axial load of the tower to the hard silt and very dense sand. Estimated pile capacity is ***18,000kN***

The tower mat is relatively thick to distribute vertical loads from columns and core to the piles.





mat with piles

Foundation and Basement Wall

Basement Wall:

a) Slurry Wall Construction

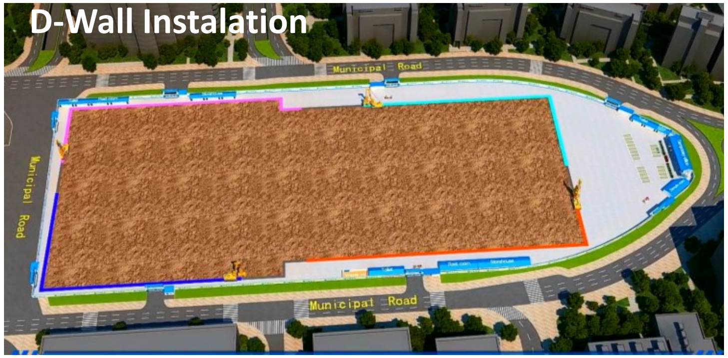
b) 1200mm thick

c) Total depth excavation of 23.5 m

d) Check wall at two stages

- Construction Stage
  - Retaining soil
  - ***Top-down construction*** implications

- Service Stage
  - Resist soil at-rest pressure
  - Resist groundwater pressure



Courtesy of CSCEC

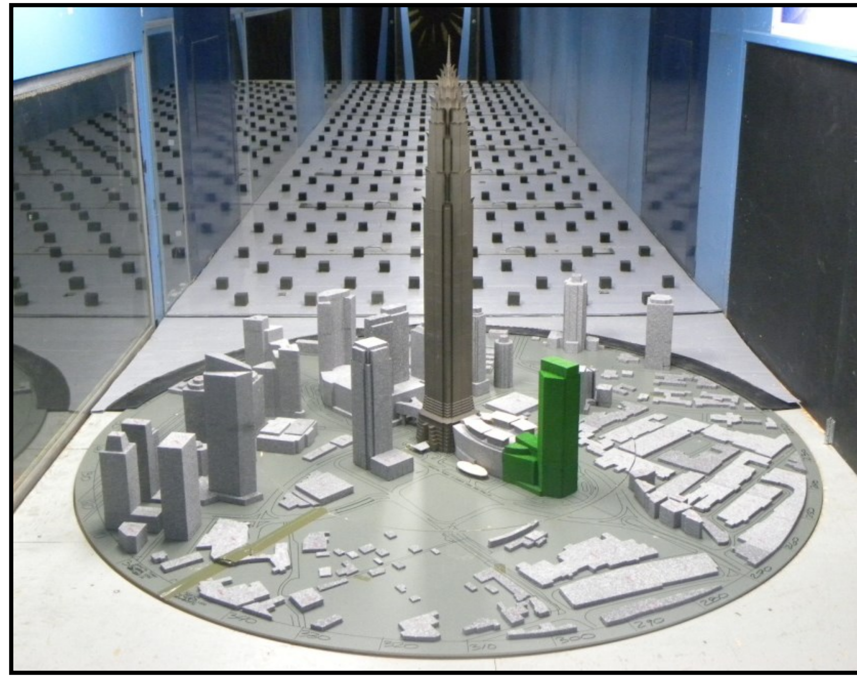
Method of Analysis for Lateral Load Resisting System

- Code-Based Design (SNI)
  - Gravity Loading
  - Wind Loading
  - EQ Loading
- Service Level Earthquake
- Performance-Based Design

Wind Tunnel Test

a) a 1:500 scale model, including its proximity surroundings within a 600 m diameter.

a) The wind climate model was scaled so that the magnitude of the wind velocity for the 100 yrp corresponded to a mean hourly wind speed of 40 m/s at gradient height in open terrain.



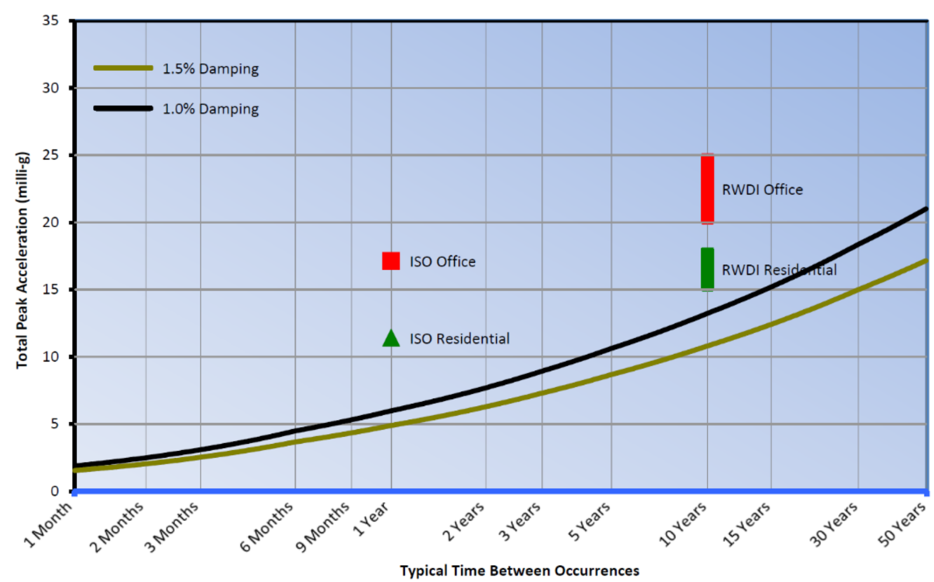
(Source: RWDI, 2012)

Predicted Peak Accelerations and Torsional Velocities

(Worst Case Configuration)

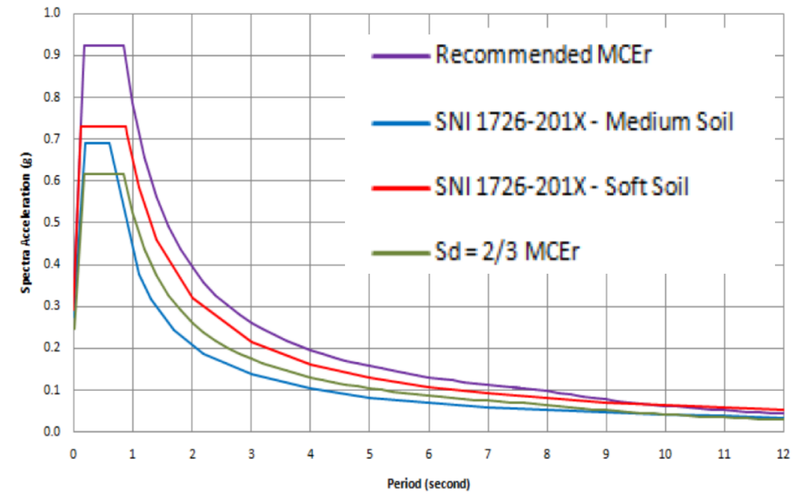
Meet ISO, RWDI & CTBUH standard

No need additional dampers



Seismic Design Criteria - Prescriptive Code-Based

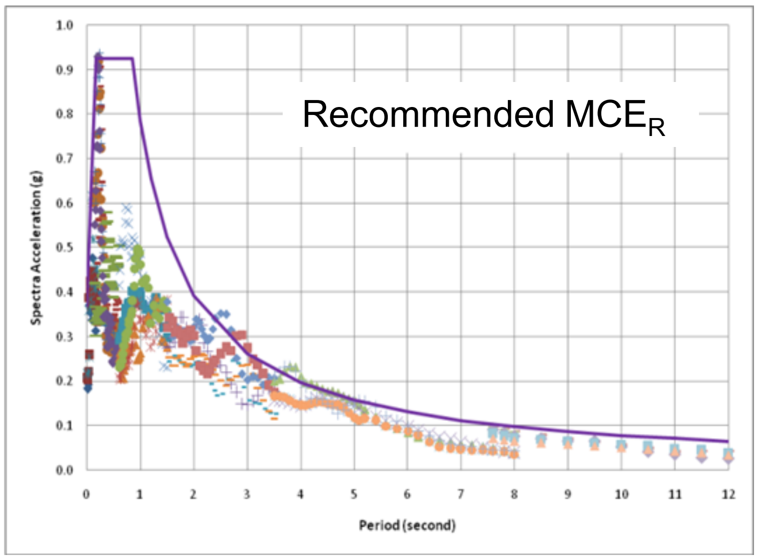
- Codes: SNI 1726-2012 / ASCE-7-10
- Building Occupancy Category – III
  Importance Factor, I_e = 1.25
- Medium Soil
- Seismic Design Category = D



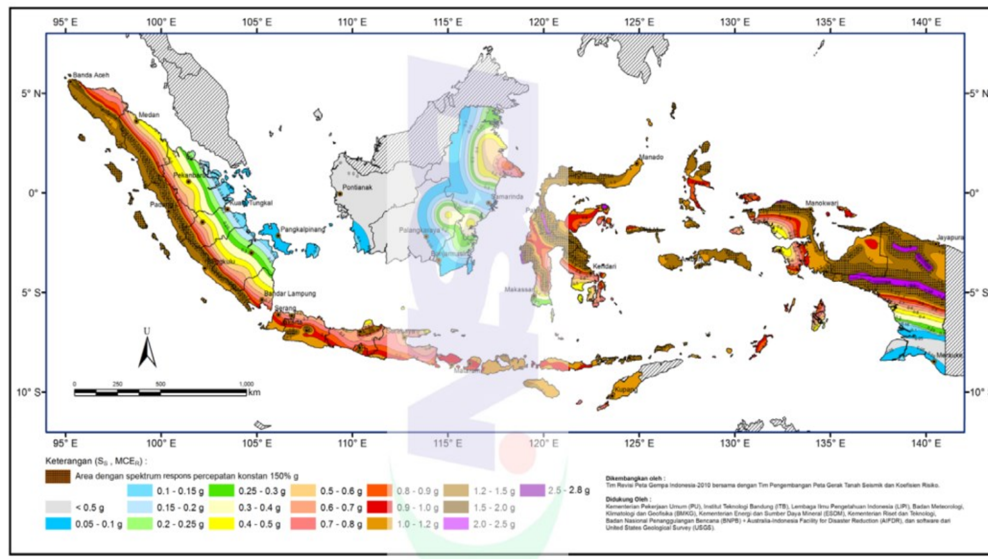
- Use Modal Response Spectrum Analysis
- Site specific response spectra for MCE_R (1% in 50 year)
  - S_{MS} = 0.925g ; S_{M1} = 0.786g
  - S_{DS} = 0.617g ; S_{D1} = 0.524g
- Minimum Base Shear Controlled by minimum 'C_s' Factor
  $(C_s)_{min}$= 0.044*0.925*2/3*1.25 = 3.39%

Seismic Input Ground Motions

NLTH structural analysis requires a set of 7 pairs of seismic time-history input-motions at reference ground-surface or base of the structure. This should be developed in correspondence to the site and seismic source characteristics.



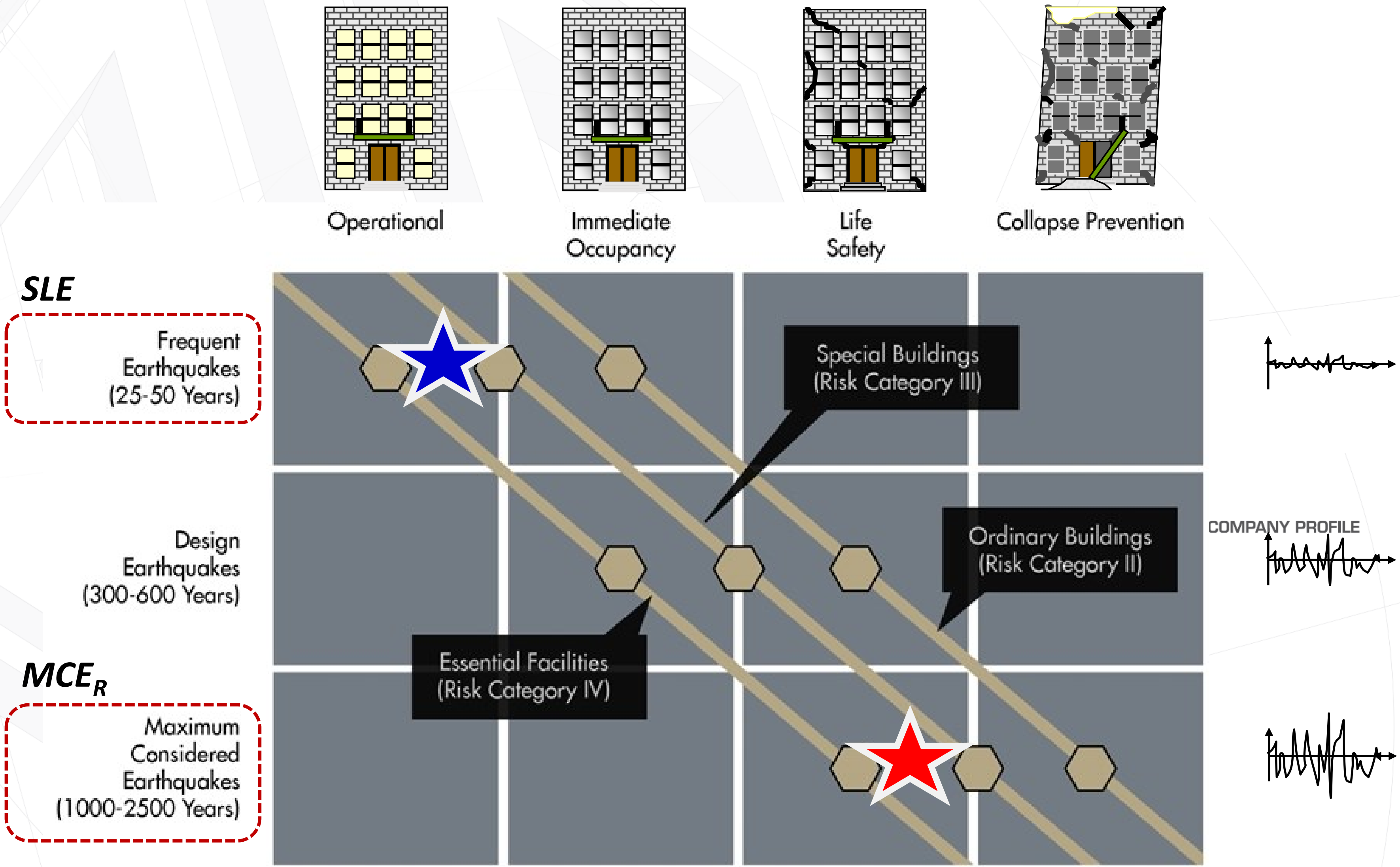
Recommended site-specific ground-surface MCE$_R$ spectra of a site in Jakarta



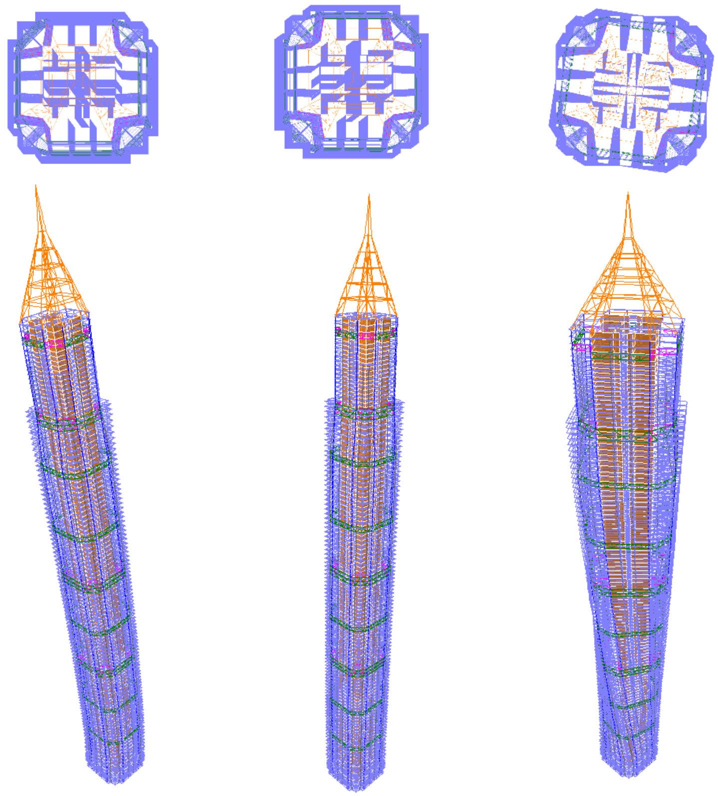
Gambar 9 - S_S, Gempa maksimum yang dipertimbangkan risiko-tertarget(*MCE$_R$*),kelas situs *SB*

MCE$_R$ map at base rock soil class-B (SNI 1726:2012)

Building Performance Level Matrix



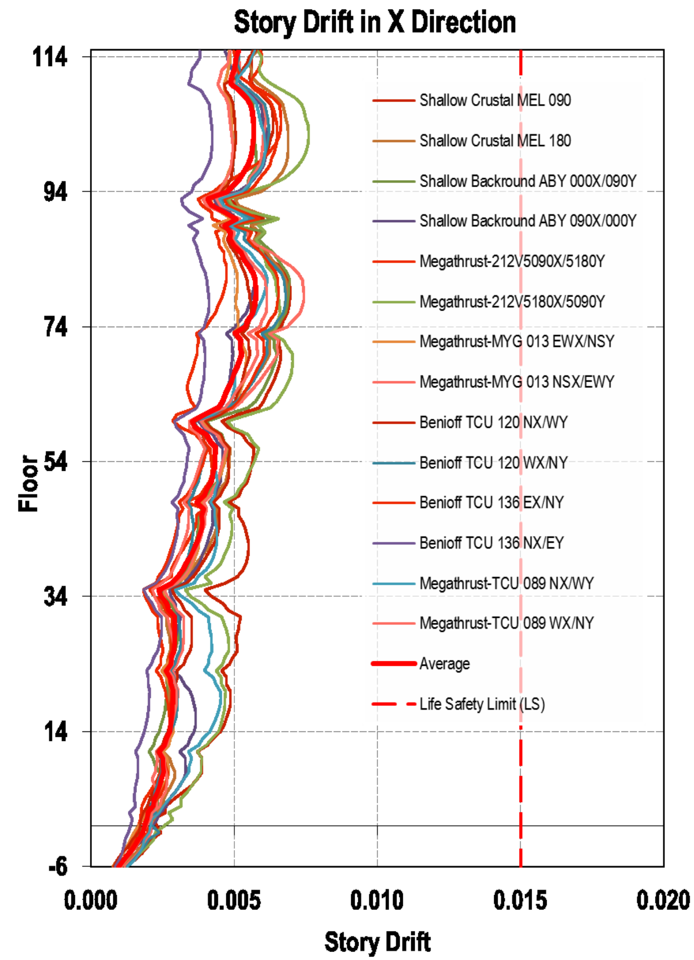
Result of Analysis:



Mode 1
Y Translation
T1 = 11.68s

Mode 2
X Translation
T2 = 11.52s

Mode 3
Z Torsion
T3 = 7.16s



Note:
the code limit for the drift is 1.5% (MCE Level)

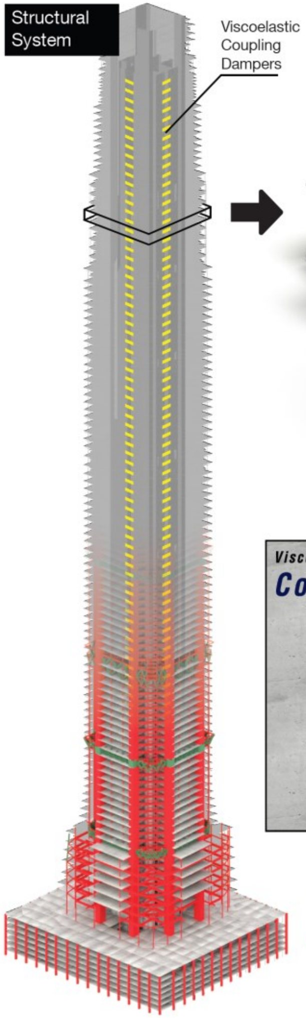
Wijanto, S., et al, Best Practices in Seismic Design of Tall to Mega Tall Building Structures in Indonesia, Proceedings on 16th WCEE, Chile, January 2017

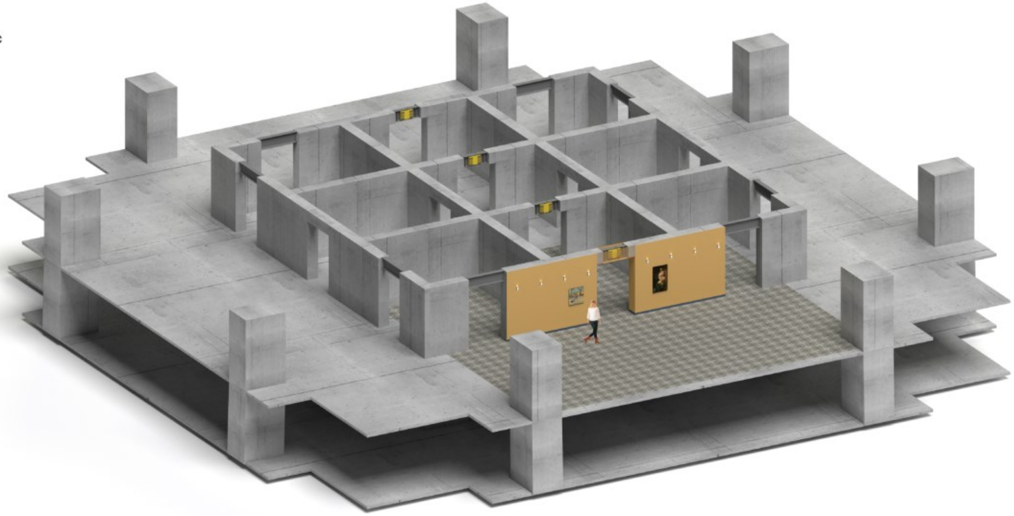
Viscous Elastic Coupling Link Beams (Alternative Option)

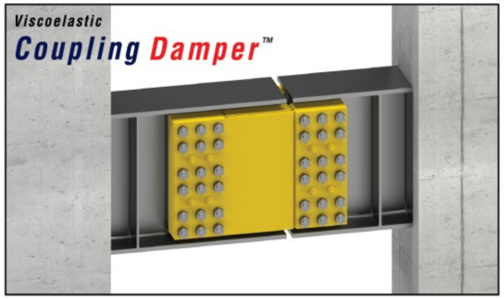
A worldwide icon for centuries to come.

World leading structural engineers **Thornton Tomasetti** and **PT Gistama Intisemesta** have brought the world's most stringent structural engineering standards to Jakarta. The Signature Tower has been designed using **state-of-the-art** Performance Based Seismic Design with standards elevated to significantly beyond those for commercial properties in Southeast Asia to maintain **functionality and business continuity** in the event of a severe natural disaster.

Thornton Tomasetti has been a driving force behind Supertall and Megatall buildings worldwide including three of the ten tallest buildings (Shanghai Tower, Ping An Tower and Taipei 101) as well as the soon to be **world's tallest building**, the 1 km tall Kingdom Tower in Saudi Arabia.







In order to **enhance the structural performance even further**, the Signature Tower uses special high-performing, **Viscoelastic Coupling Dampers**, to ensure occupants are **safe** and businesses have an **enhanced** level of **business continuity and asset protection**. The **Viscoelastic Coupling Damper (VCD)** uses 3M VE material, which is protecting over **250 buildings** in the world in some of the most demanding seismic and wind environments including Japan, Taiwan, Philippines, Canada, Mexico and USA. The VCDs are seamlessly embedded in the Reinforced Concrete walls in the building's structural core, and **act like shock absorbers**, keeping occupants safe and businesses secure in the event of an earthquake or wind storm.

Thornton Tomasetti

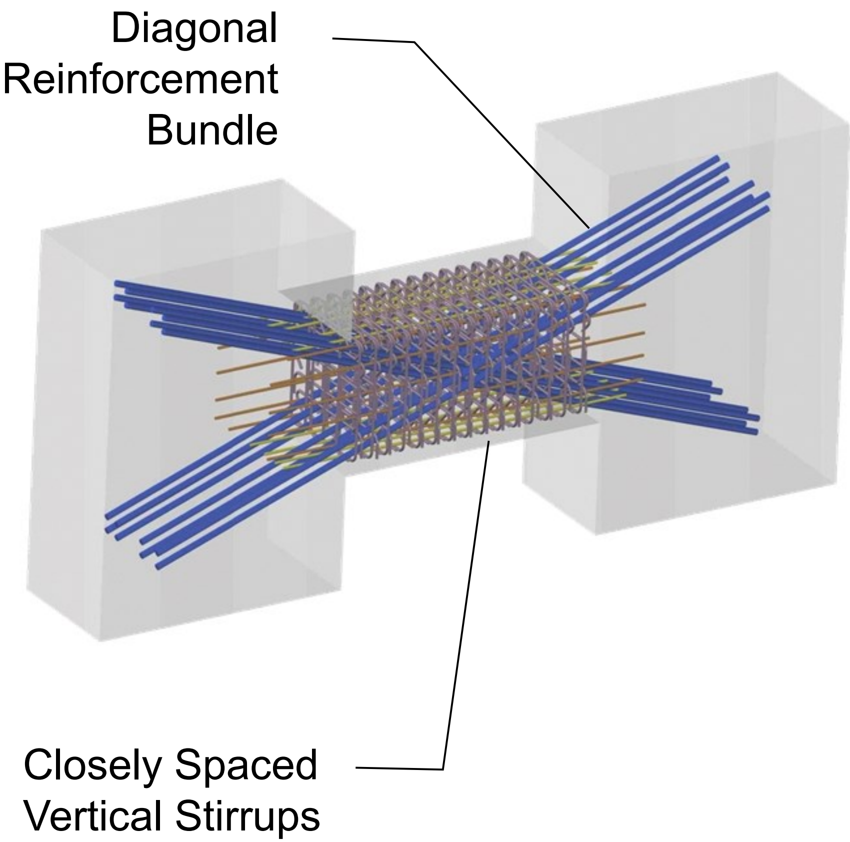
PT. GISTAMA INTISEMESTA

kinetica

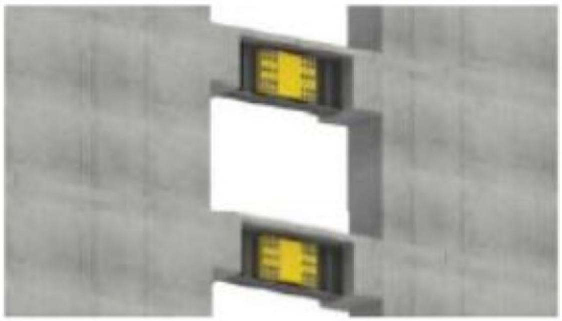
NSENGI
NIPPON STEEL & SUMIKIN ENGINEERING

Conventional Link Beams

<u>Diagonally Reinforced Link beam</u>



Viscous Elastic Coupling Link Beams



VCD configuration in core wall

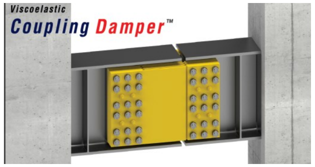
VE damper panel

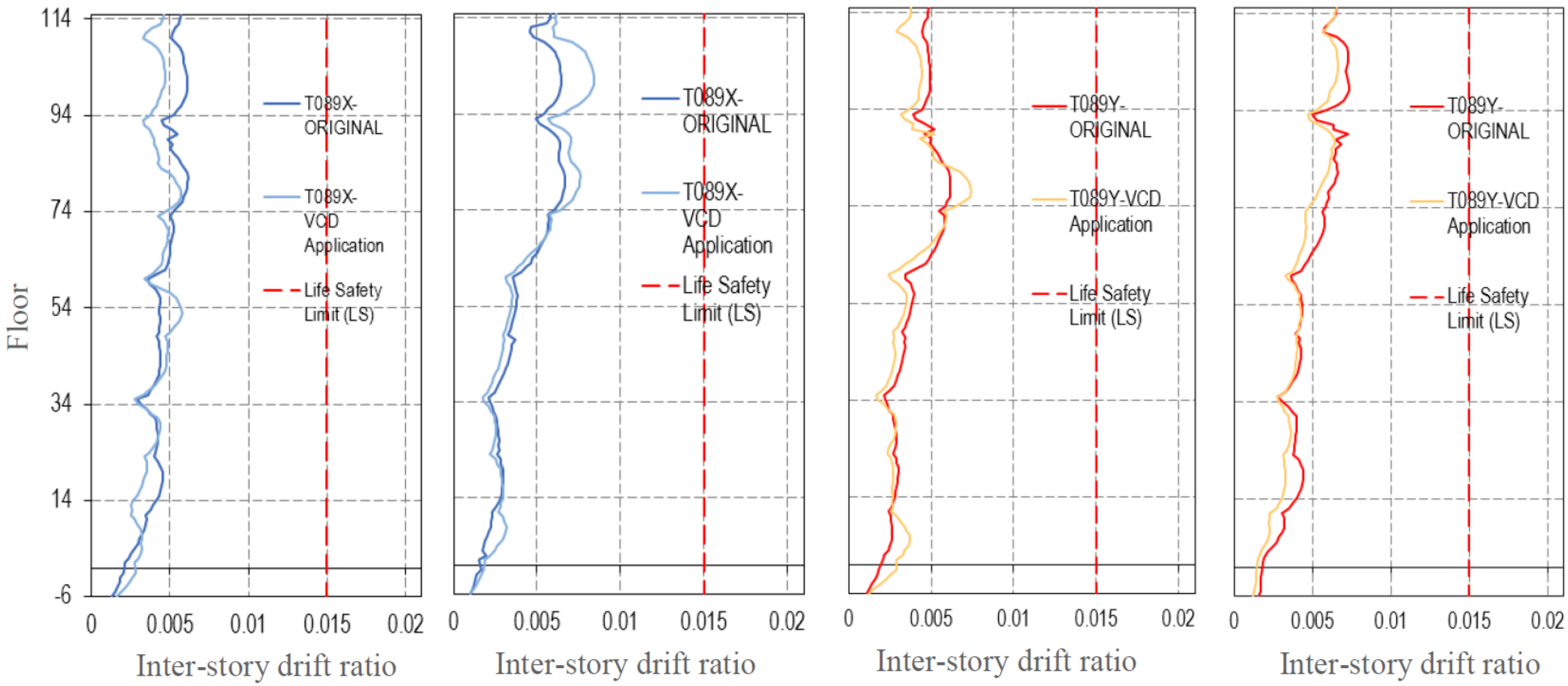
Increase in Speed of Construction time

Installation of Viscous Elastic Damper Panels

Impacts of VCD Link Beams in Signature Tower

- Inter-storey drift ratios

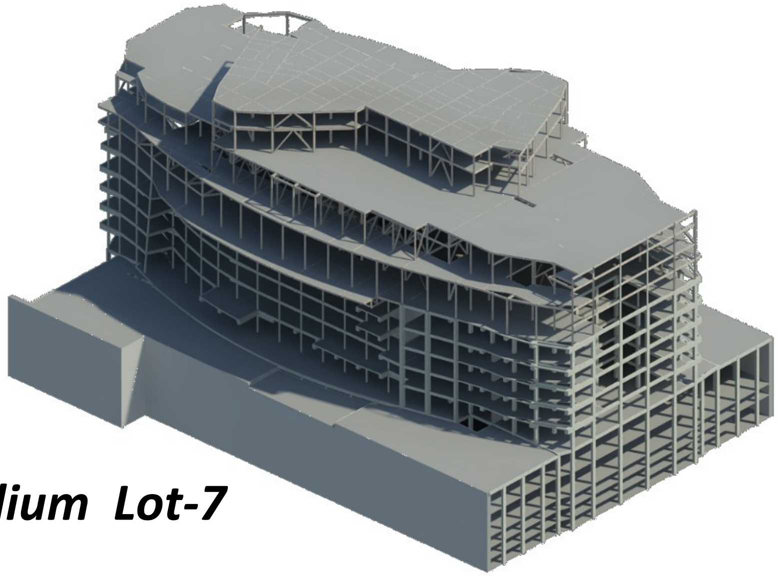




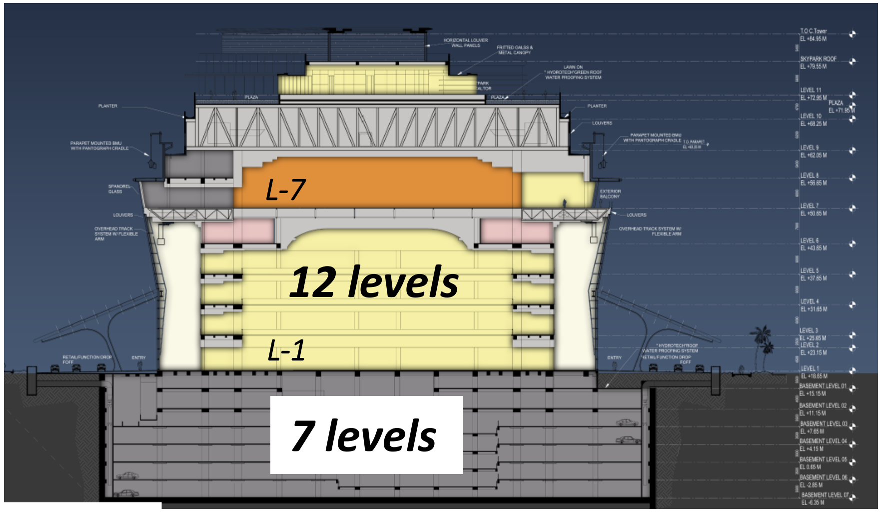
X-dir. for T089X **Y-dir. for T089X** **X-dir. for T089Y** **X-dir. for T089Y**

➢ Savings in material, labor and time

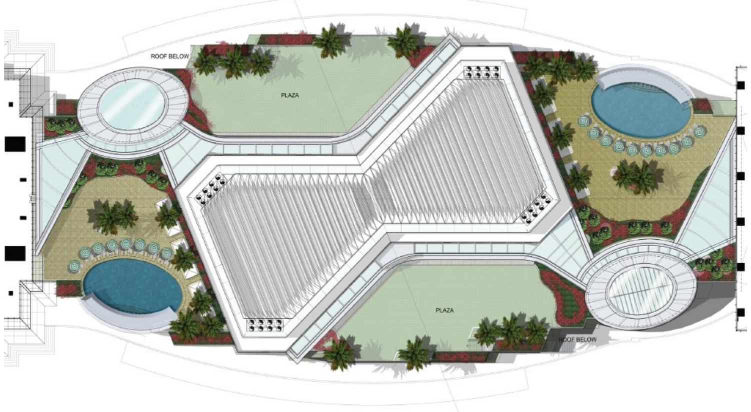
Long Span – Steel Structure



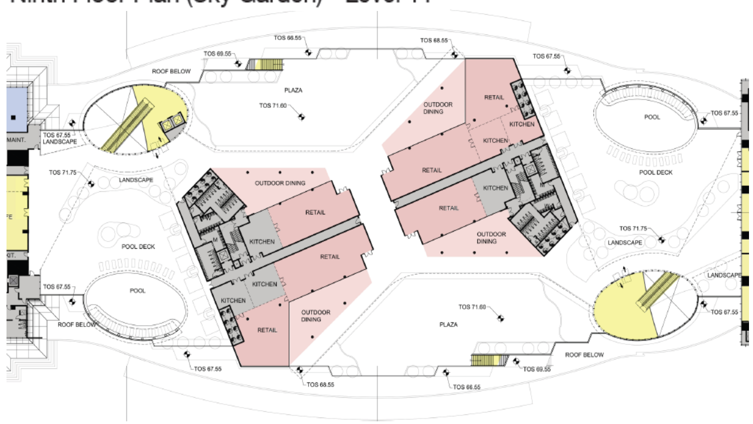
Podium Lot-7



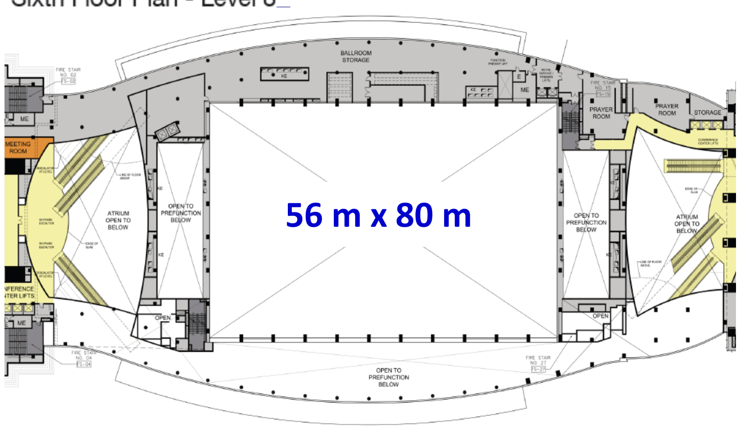
Tenth Floor Plan (Sky Roof Plan) - Level 12



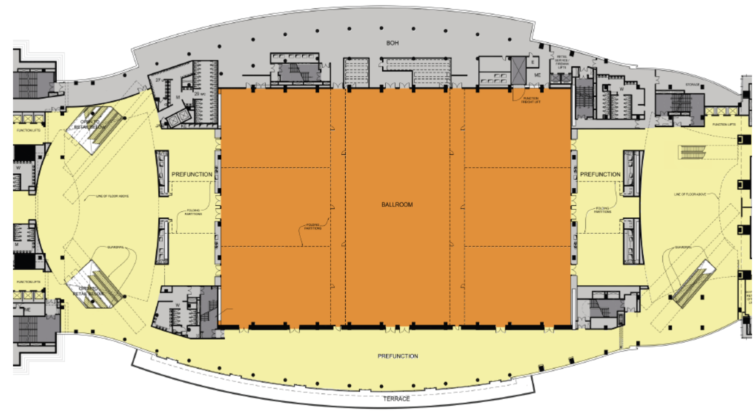
Ninth Floor Plan (Sky Garden) - Level 11



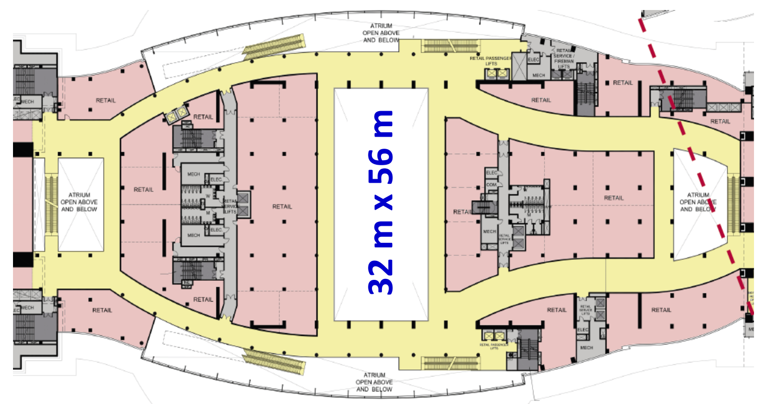
Sixth Floor Plan - Level 8

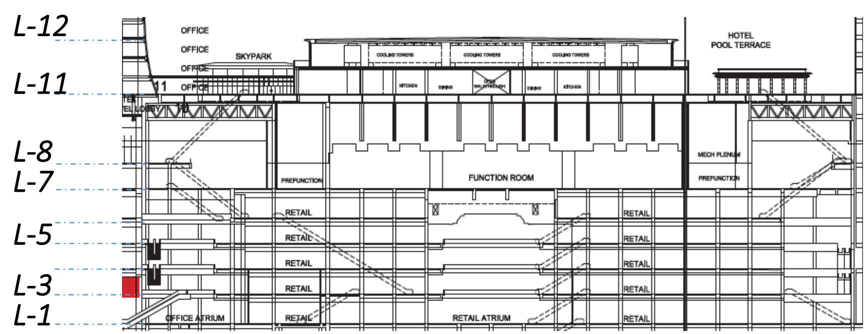


Fifth Floor Plan - Level 7



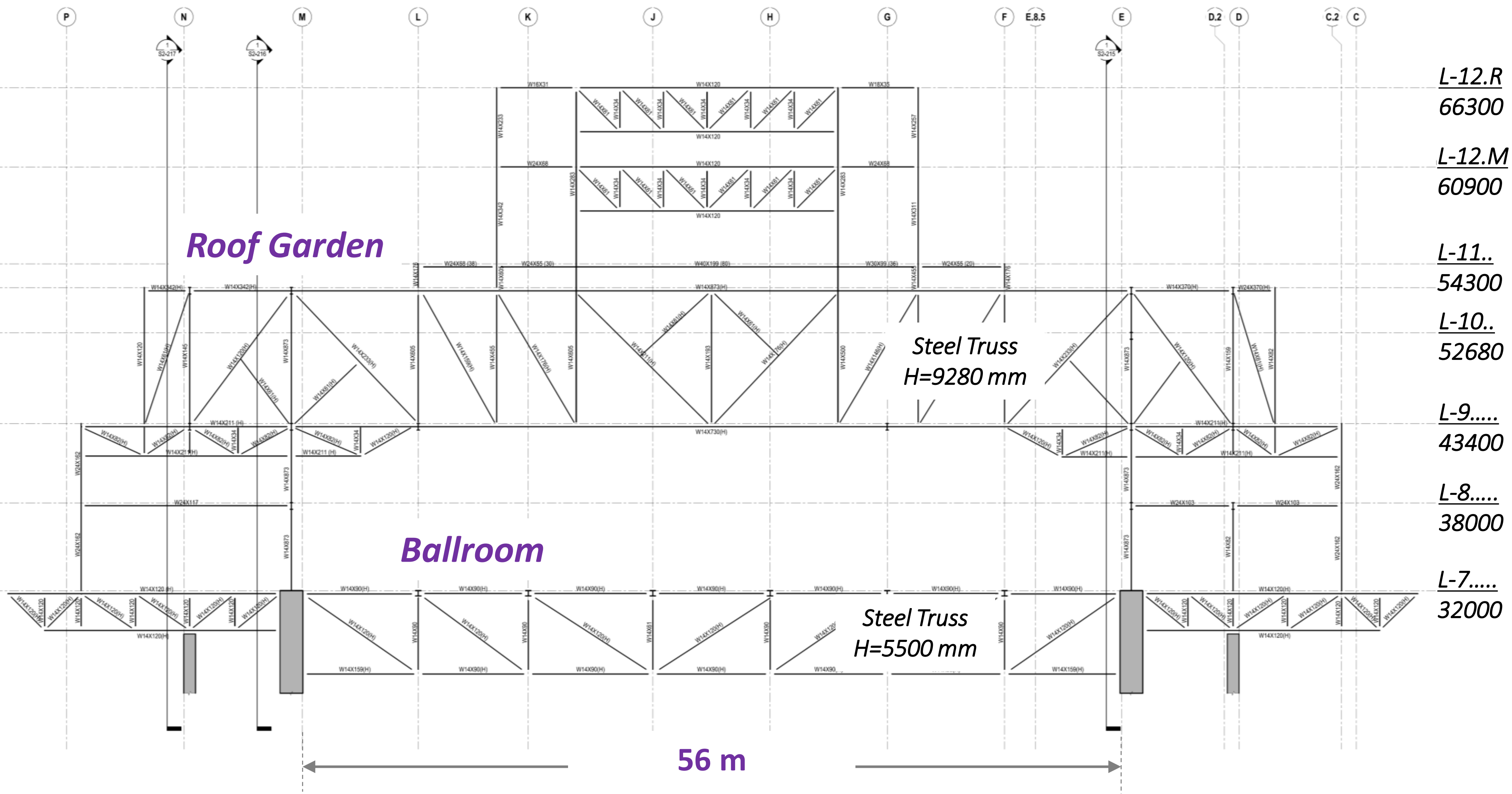
Third Floor Plan - Level 5





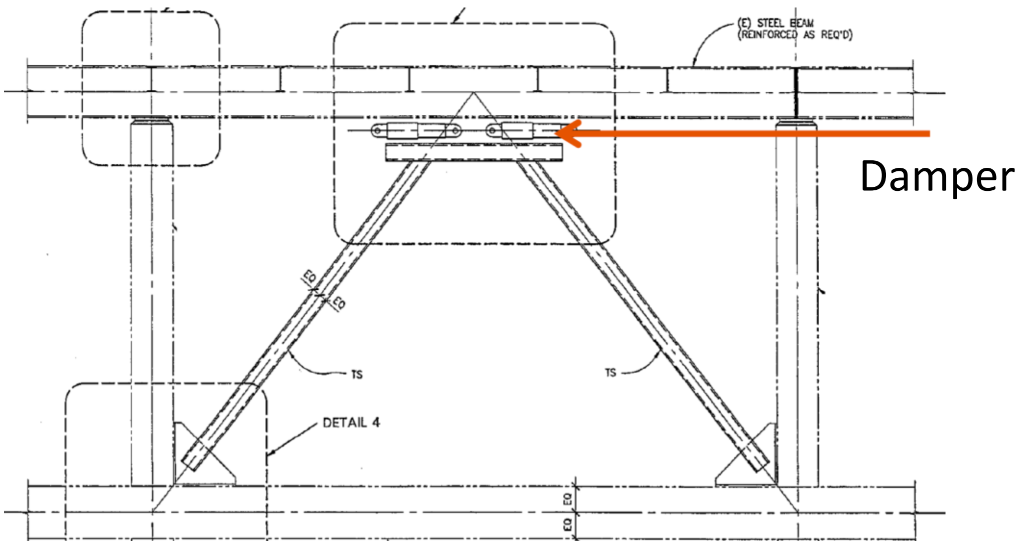
Building Section – Podium Lot 7

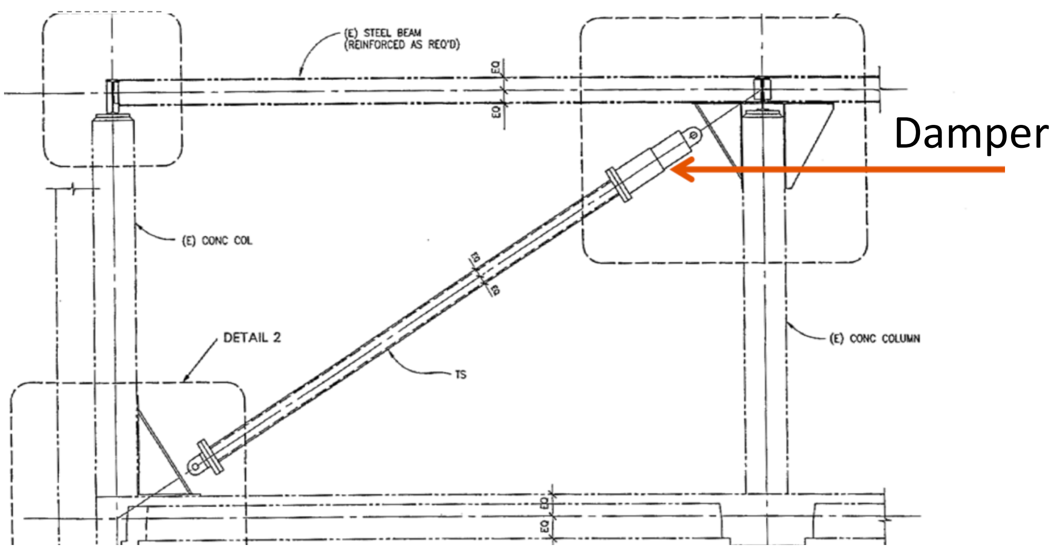
Long Span – Steel Structure



Grid 22

Floor Vibration Problem



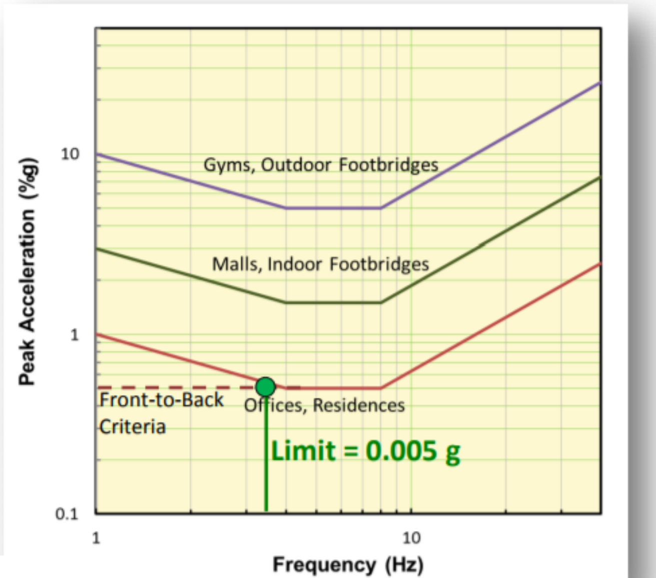


If Rhythmic activities (e.g. dancing) is required, a tune mass damper will be required in this area to reduce the floor vibration.

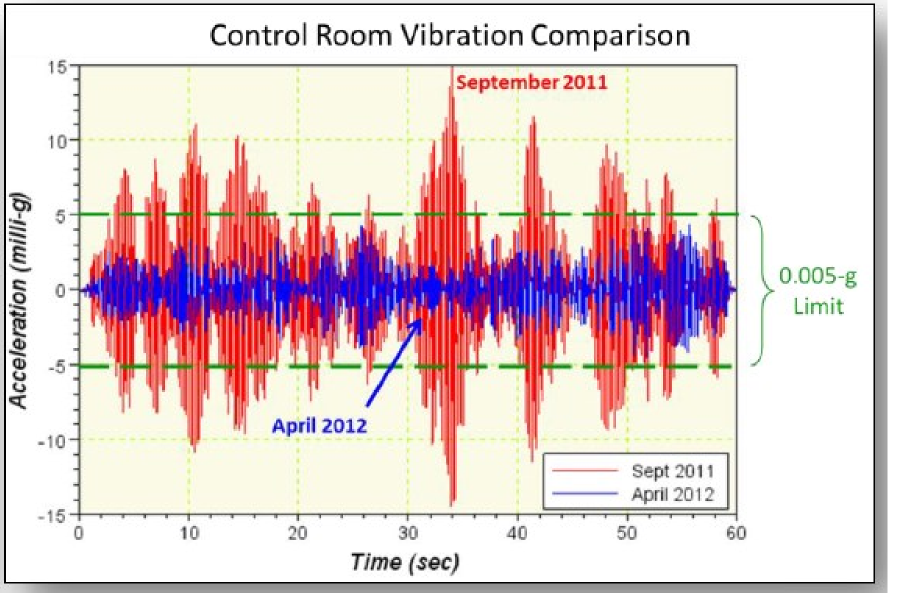
Tuned-Mass Dampers (a case study)

- A tuned-mass damper is a mass-spring-damper system that is attached to a structure to reduce the amplitude of undesirable motion
- The mass, spring stiffness, and damping factor must be "tuned" relative to the existing structure's dominant mode (frequency $f_{Mode} \approx f_{TMD}$) responsible for the motion
- The location on the structure where the TMD(s) is/are attached is critical
- TMDs can have many different forms depending upon the application:

Human Vibration Sensitivity



Before/After Vibration



Dr. James L. Lamb

AG&E/Structural Engenuity

Long Span – Steel Structure *(Other Project)*

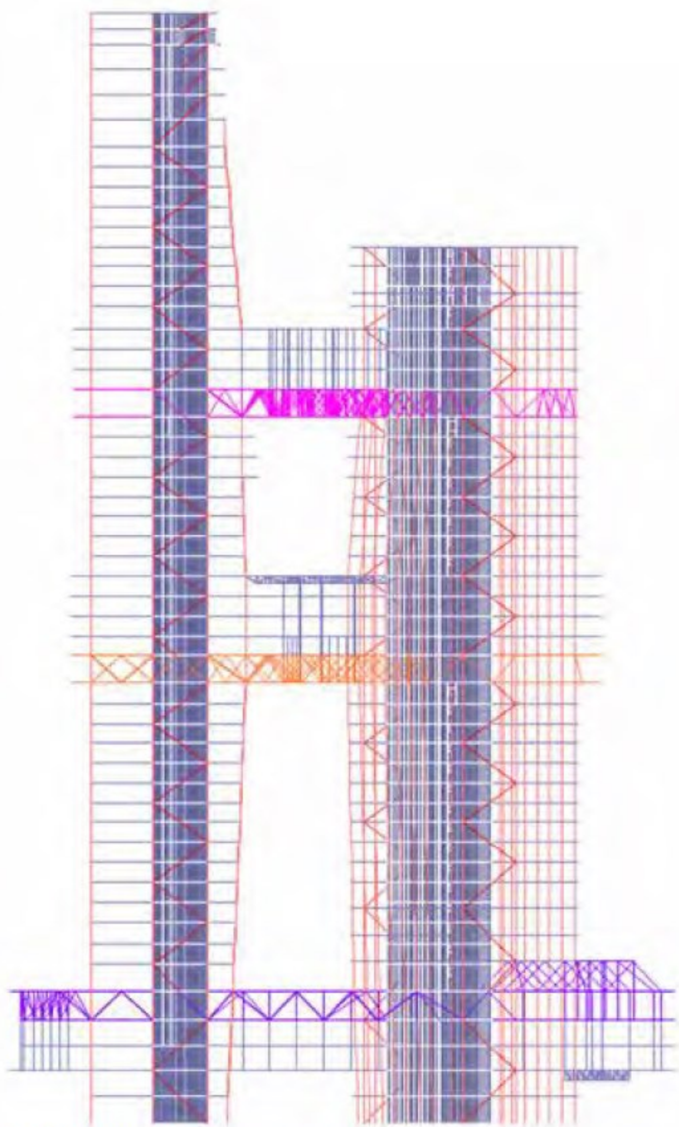
The Tencent Corporate Headquarter in Shenzhen, China. (source NBBJ) 50 stories and 41 stories, GFA 270,000 sqm

Figure 6. The gymnasium, located in the Health Link. (Source: NBBJ)

Figure 8. A level 26 plan, with a landscaped Health Link bridge to encourage connections with nature. (Source: NBBJ)

Figure 9. A first level floor plan, illustrating how activity at the ground level is promoted by a unified lobby experience. (Source: NBBJ)

Ward, J. and Ivan, 2016, The Impact of Tech Companies in Rethinking the High Rise, CTBUH seminar 2016



Structural section (Source: TJA)

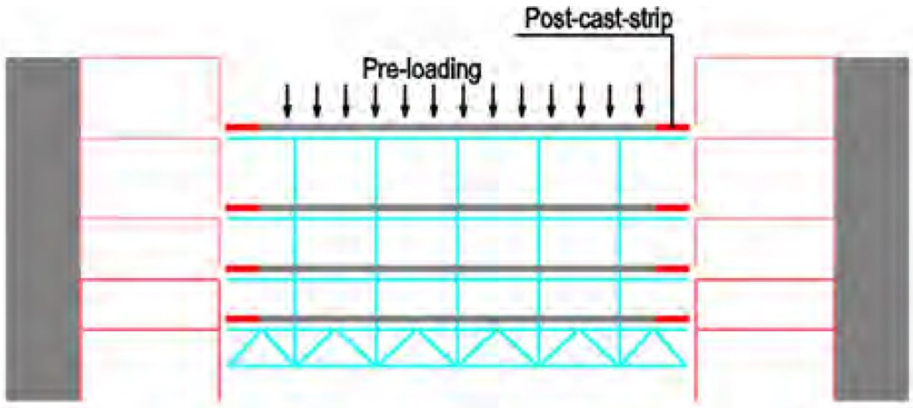


Figure 10. Construction slabs (Source: TJA)

South Tower 250 m and
North Tower 190 m

Gigantic Frame Structure connected:

L3-L6
L21-L26 connection length of 45 m

L34-L38 and connection length of 47 m

Ward, J. and Ivan, 2016, The Impact of Tech Companies in Rethinking the High Rise, CTBUH seminar 2016


34
Canterbury Magazine