MIDAS SQUARE

MIDAS SQUARE 공학 기술강연

미래 건축의 높이를 넘어:
초고층 건축물의 기술 혁신

정광량 | ㈜CNP동양

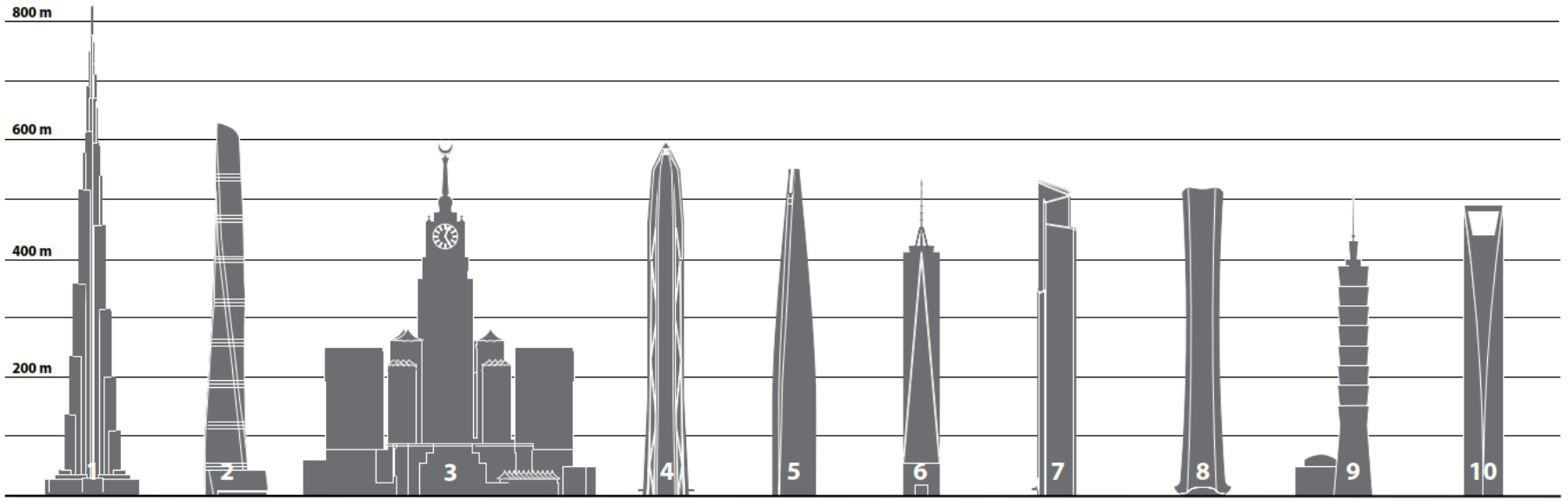
Dr. Kwangryang Chung | CNP DongYang
CTBUH Fellow

CONTENTS

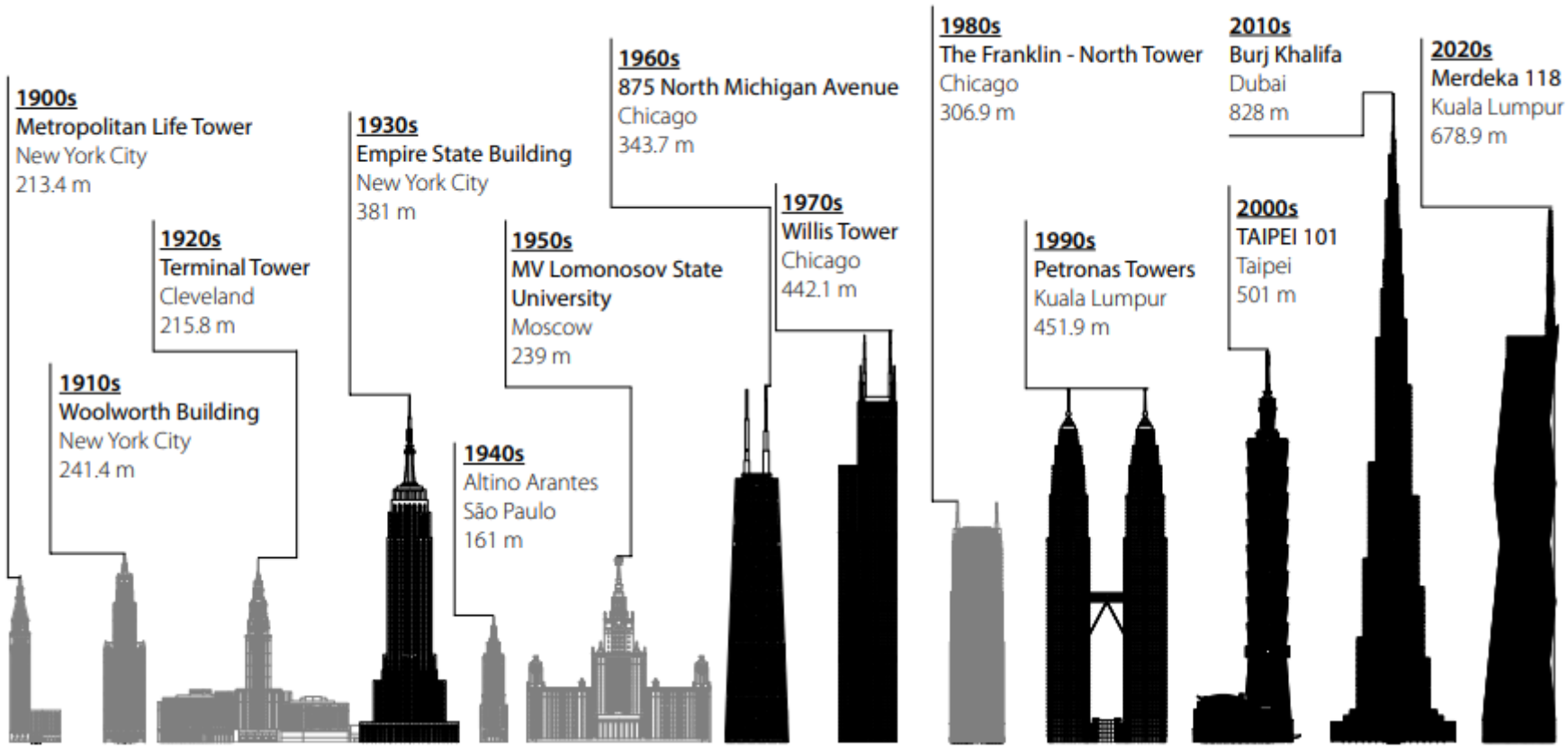
국내 초고층 건축물

전세계
초고층 건축물

Tallest Completed Buildings in the World



전세계
초고층 건축물



https://global.ctbuh.org/

국내 초고층 건축물

1970 종로31빌딩

⋮

1978 중구 롯데호텔 38층

종로 31빌딩

출처 : https://namu.wiki/

중구 롯데호텔

출처 : https://namu.wiki/

국내 초고층 건축물

1985 여의도 63빌딩

⋮

1988 트레이드 타워

여의도 63빌딩

출처 : https://namu.wiki/

삼성동 트레이드 타워

출처 : https://ko.wikipedia.org/

국내 초고층 건축물

2003 목동 하이페리온

⋮

2004 타워팰리스

목동하이페리온 1차

타워팰리스 3차

국내 초고층 건축물

해운대 아이파크 마리나 (2011)

위치 : 부산 해운대구, 대한민국
층수 : B6F, 72F
높이 : 292 m
용도 : 주상복합

해운대 아이파크 마리나

국내 초고층 건축물

송도 포스코 타워 (2011)

위치 : 인천, 대한민국
층수 : B3F, 68F
높이 : 305 m
용도 : 업무시설, 판매시설, 호텔

송도 포스코타워(NEATT)

국내 초고층 건축물

서울 국제금융센터 IFC (2012)

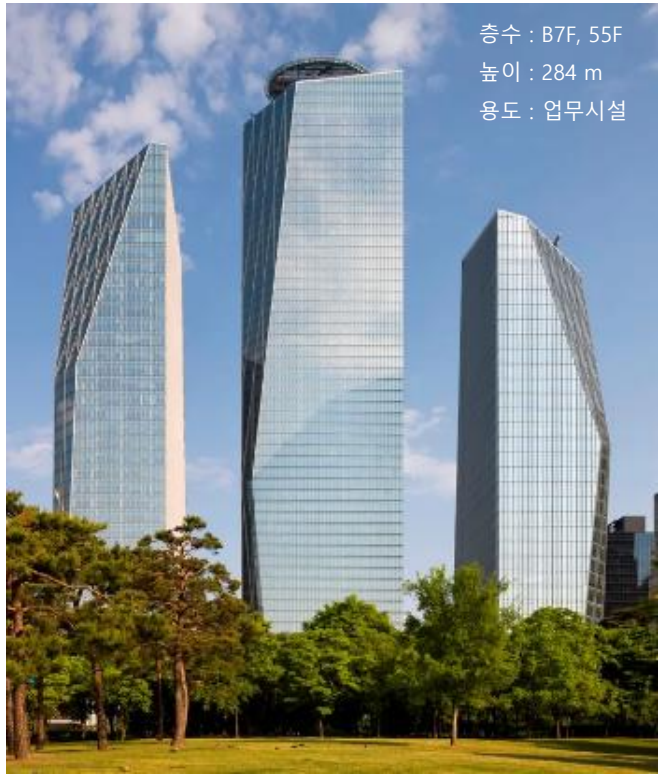
⋮

여의도 전경련 회관 (2013)

⋮

부산 IFC (2014)

서울 국제금융센터(IFC)



여의도 전경련 회관(FKI)

부산국제금융센터(BIFC)

출처 : https://namu.wiki/

국내 초고층 건축물

잠실 롯데타워 (2016)

층수 : B6F, 123F

높이 : 555 m

용도 : 업무시설, 판매시설, 호텔

잠실 롯데타워

출처 : https://www.skyscrapercenter.com/

국내 초고층 건축물

해운대 LCT

해운대 LCT (2019)

위치 : 부산 해운대구, 대한민국
층수 : B5F 101F(랜드마크)
높이 : 411 m
용도 : 주상복합, 공동주택, 판매시설, 호텔

국내 초고층 건축물

여의도 파크원

여의도 파크원 (2020)

위치 : 서울, 대한민국
층수 : B7F, 69F
높이 : 318 m
용도 : 업무시설, 판매시설, 호텔

국내 초고층 건축물

부산 이진베이시티 (2022)

위치 : 부산 서구, 대한민국
층수 : B6F, 69F
높이 : 246 m
용도 : 주상복합

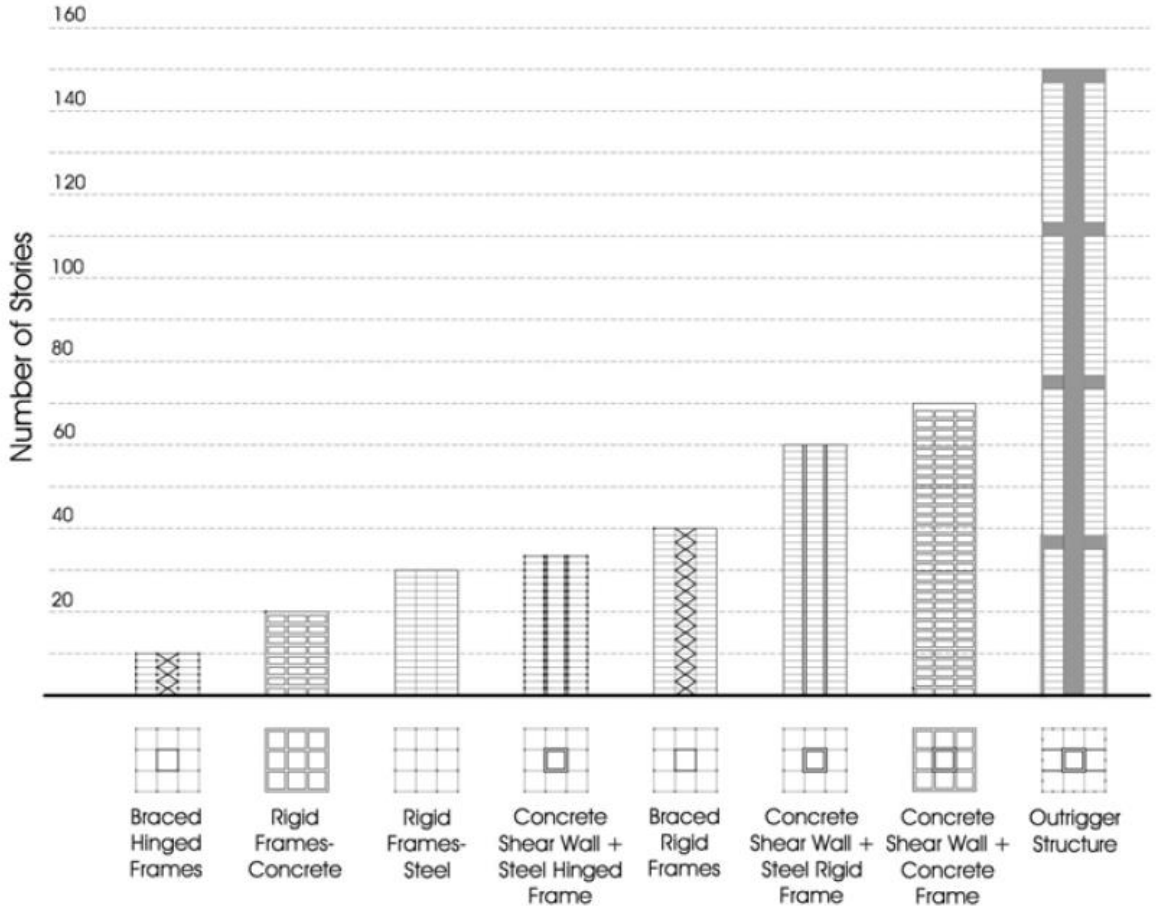
부산 이진베이시티

초고층 건축물 구조 기술

초고층 건축물 구조 기술

Tall Building Structural System

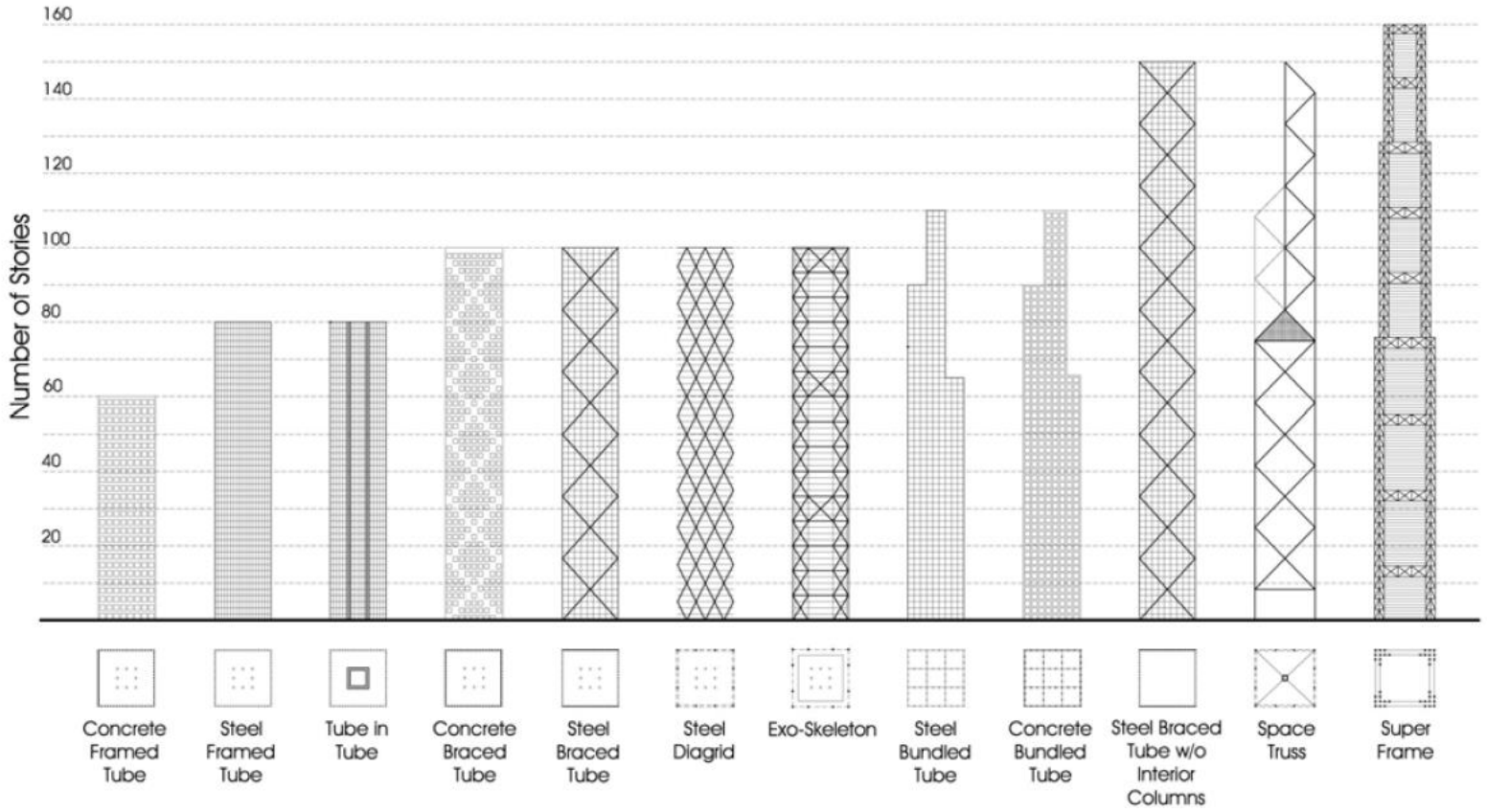
Interior Structural System



초고층 건축물 구조 기술

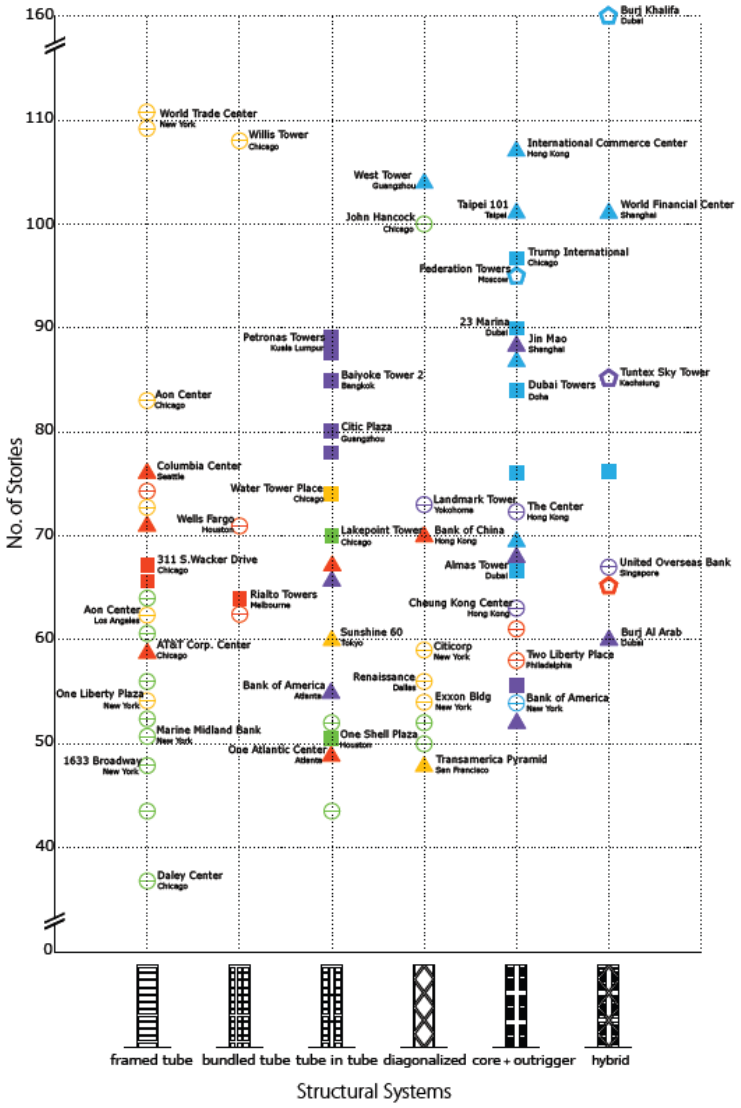
Tall Building Structural System

Exterior Structural System



초고층 건축물 구조 기술

Tall Building Structural System



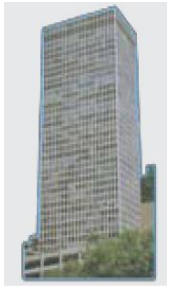
1961–1970
1971–1980
1981–1990
1991–2000
2001–2010

steel
concrete
composite
mixed

Structural Systems	No. of Buildings
framed tube	20
bundled tube	4
tube in tube	15
diagonalized	10
core + outrigger	19
hybrid	7
Total	**75**

Prior 1990 :
75% of tall building
Frame Tube w/ steel

2000's
73% of tall buildings
Core + outrigger
approx. 50% Concrete



CTBUH

year		1970s	1980s		2000s			2010s			2020s			
Building Name		31 Build.	63 Build.	Trade Tower	Mokdong Hyperion Ⅰ	Tower Palace Ⅲ	Busan The # Centum Star	Sondo NEATT	FKI Tower	Haeundae I Park Marina	Parc1 Tower	GBC	Busan LCT	Busan Ijin Bay City Tower
Function		Office	Office		Residential			Office		Residential	Office		Residential	
Completion		1970	1985	1988	2003	2004	2008	2011	2013	2011	2020	-	2019	2022
Floors		31F	60F	54F	69F	69F	60F	68F	50F	72F	69F	105F	101F	69F
Height		110 m	250 m	228 m	256 m	264 m	212 m	305 m	246 m	292 m	318 m	569 m	411 m	246 m
Structural System	Floor System	Steel Beam					RC Slab	Steel Beam		Conc Flat Slab	Steel Beam		RC Slab	
	Column	Steel Braced Column			SRC Column		RC Column	SRC Column		RC Column	Mega Column		RC Column	
	Core	Steel Core			Con'c Core									
	Lateral Resistance System	Steel frame	Steel Braced Frame		Outrigger System						Mega Braced System		Fin Wall System	

초고층 건축물 구조 기술

1970’, 80’

Tall Building Structural System _ Steel

31 Building

1971’ 31F, 114m

Steel Frame

63 Building

1984’ 60F, 249m

Steel Braced Frame

LG Twin Tower

1986’ 33F, 144m

Steel Tube

Trade Center

1987’ 55F, 228m

Steel Braced Frame

초고층 건축물 구조 기술

2000’

Tall Building Structural System _ Outrigger System

Hyperion

2003’ 69F, 256m

Outrigger

Tower Palace Ⅲ

2004’ 69F, 264m

Outrigger

The # Centum Star

2008’ 60F, 212m

Outrigger

초고층 건축물 구조 기술

2010’

Tall Building Structural System _ Outrigger System

NEATT

2011’ 68F, 305m

Outrigger

FKI Tower

2013’ 50F, 246m

Outrigger

Haeundae I Park Marina

2011’ 72F, 292m

Outrigger

초고층 건축물 구조 기술

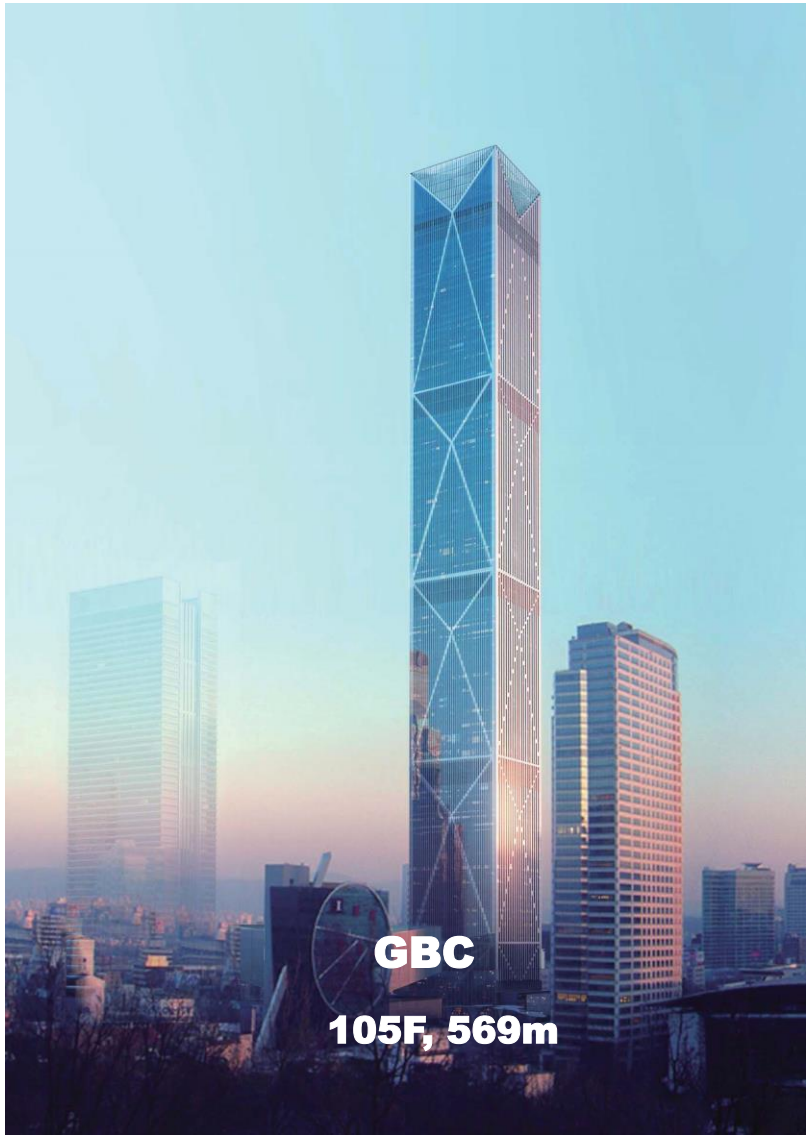
2020’

Tall Building Structural System

_ Mega Braced System

PARC1

2020’ 69F, 318m



초고층 건축물 구조 기술

2020’

Tall Building Structural System

_ Fin Wall & Belt Wall

LCT

2019’ 101F, 411m

IJINBAY CITY

2022’ 69F, 246m

횡력저항시스템

- Outrigger System
- Mega-Braced System
- Fin Wall & Belt Wall

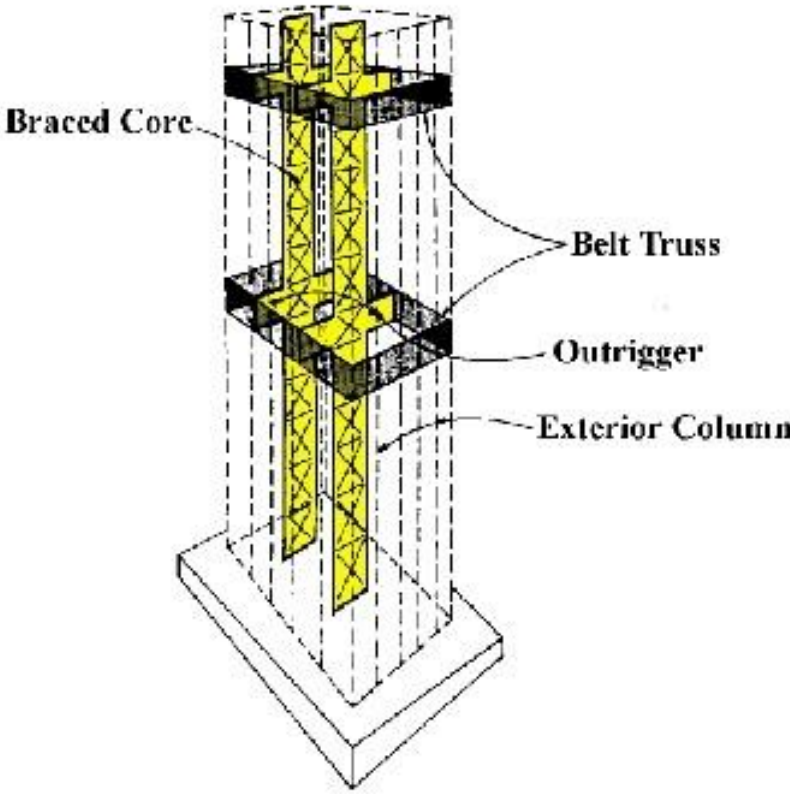
Outrigger System

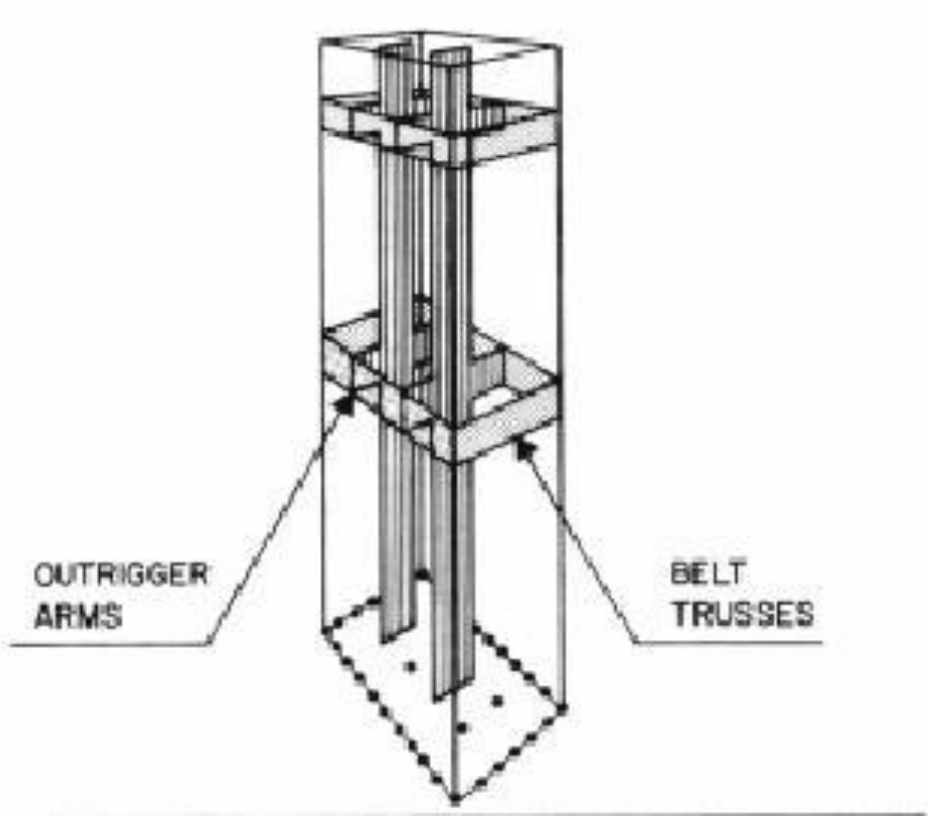
초고층 건축물 횡력저항 시스템

Outrigger System

Concept

Outrigger System





초고층 건축물 횡력저항 시스템

Outrigger System

Concept

Outrigger System

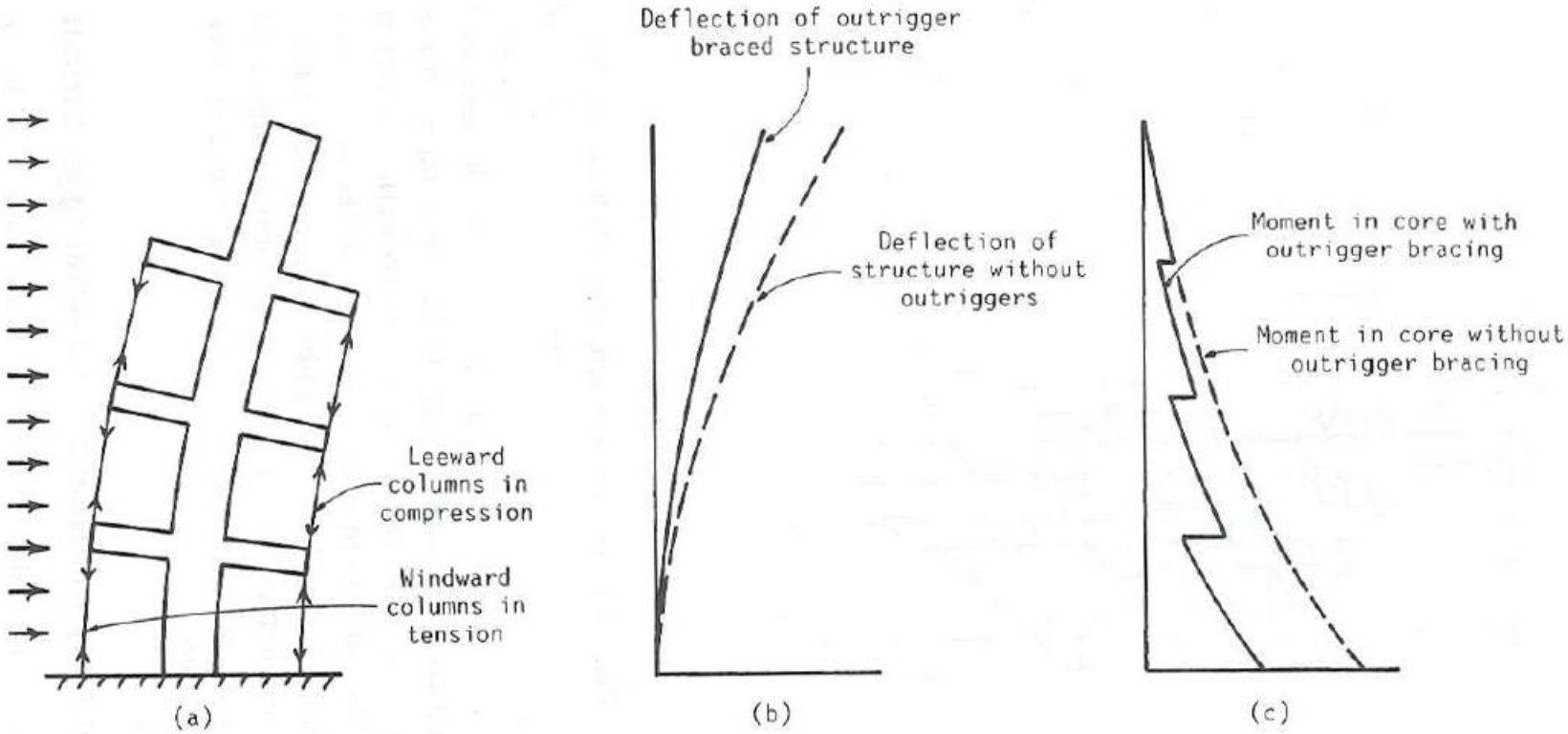


Fig. 14.2 (a) Outrigger structure displaced under lateral loading; (b) resultant deflections; (c) resultant core moments.

초고층 건축물 횡력저항 시스템

Outrigger System

challenge

- **Connection With Con’c Core**
- **Mitigation for Differential Shortening**

초고층 건축물 횡력저항 시스템

Outrigger System

Classification

Outrigger System

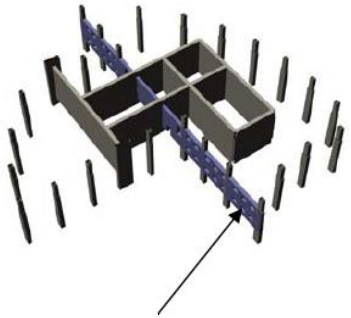
1. 배치에 따른 분류

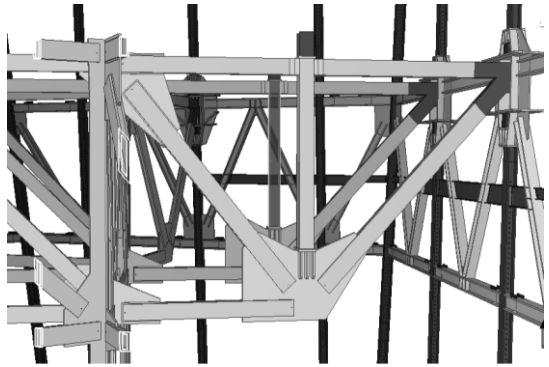
Core Outrigger
Offset Outrigger

2. 재료에 따른 분류

Concrete
Outrigger wall
Vierendeel

Steel
Truss
Composite





초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Effect of the Axial Shortening

Between Outrigger and Core

1. Embedded Plate
2. Encased top and Bot. chod
3. Encased Outrigger Truss

Between Outrigger and Column

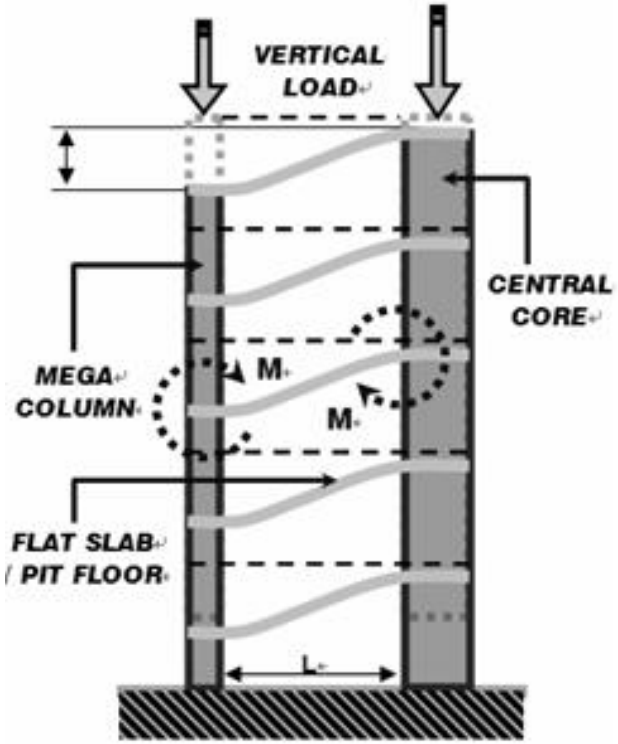
1. Delayed Joint
2. Adjusted Joint
3. Auto-leveling

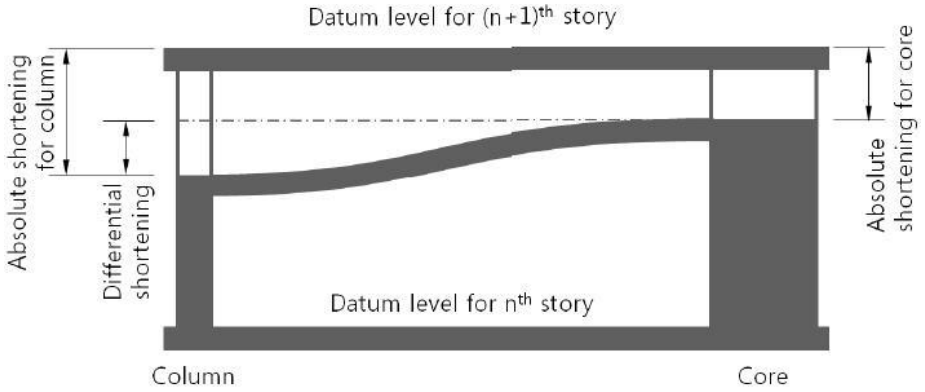
초고층 건축물 횡력저항 시스템

Outrigger System

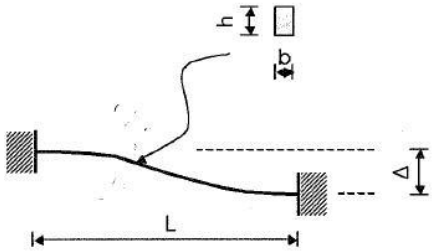
Connection Method

Outrigger System





Absolute shortening vs. differential shortening



$$M = Z \cdot \sigma \ , \quad \Delta M = \frac{6EI}{L^2}\Delta$$

$$\frac{\Delta M}{M} = \frac{6EI\Delta}{L^2 Z\sigma} \quad \text{여기서} \ \frac{I}{Z} = \frac{h}{2} \ \text{이므로}$$

$$\frac{\Delta M}{M} = \frac{3Eh\Delta}{L^2\sigma} = \frac{h}{L^2}\frac{3E\Delta}{\sigma}$$

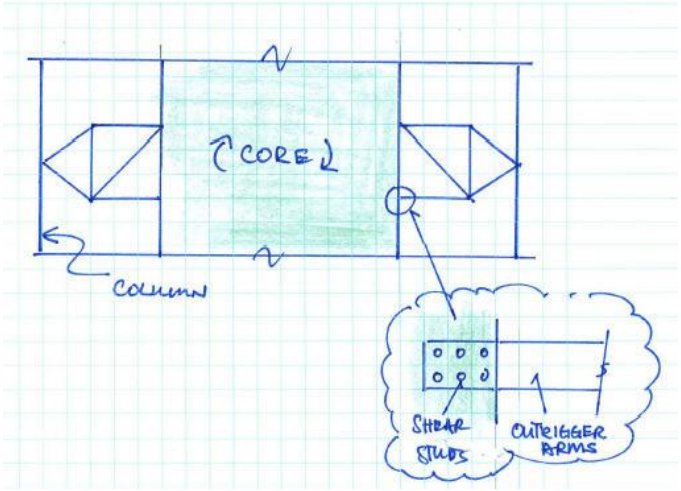
초고층 건축물 횡력저항 시스템

Outrigger System

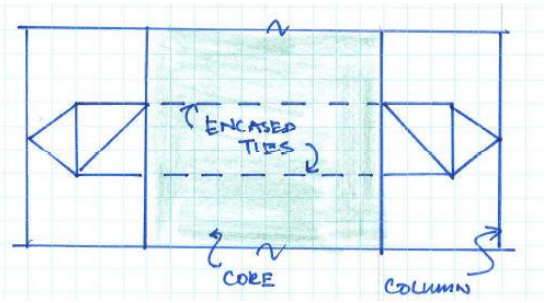
Connection Method

Outrigger System

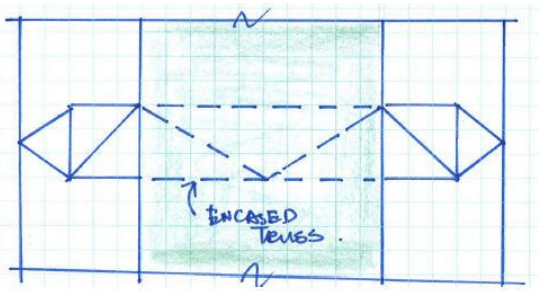
Connection between Outrigger and Core



Embedded Plate



Encased top and bot. tie detail



Encased Truss

초고층 건축물 횡력저항 시스템

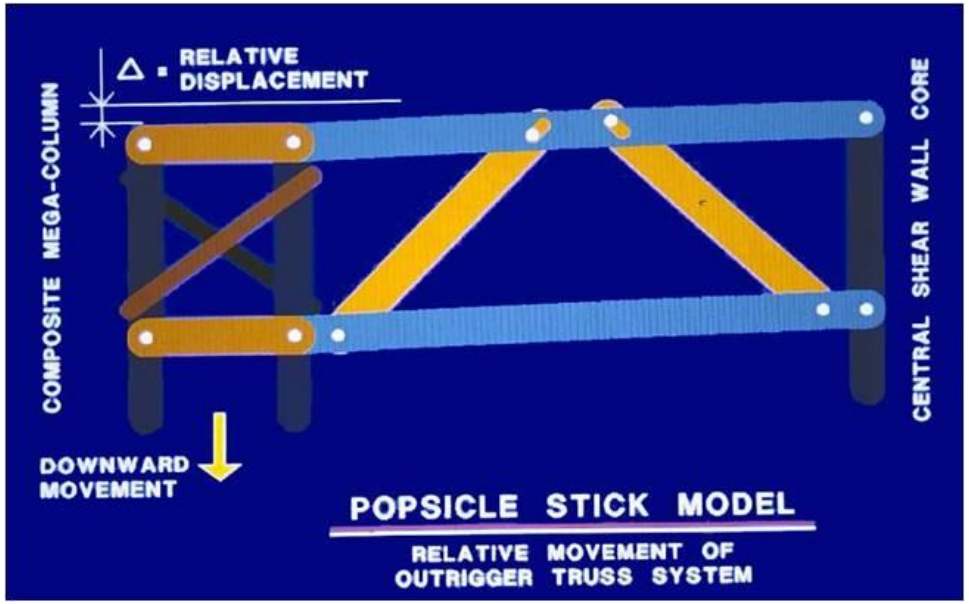
Outrigger System

Connection Method

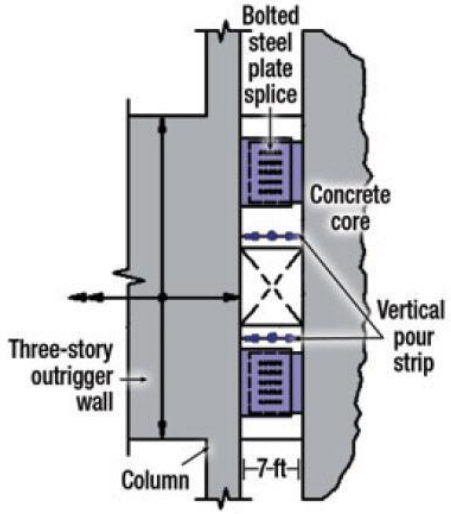
Outrigger System

Connection between Outrigger and Column

- **Delay Joint Method**



Jin Mao Tower



Divorced. *Vertical strip is cast later to accomodate different settlement.*

Nashville Tower

초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Connection between Outrigger and Column

- **Delay Joint Method**

Jin Mao Tower, China

Nashville, USA

경남 밀레니엄 타워, 베트남

목동 현대 하이페리온 I

초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Connection between Outrigger and Column

· **Delay Joint Method**

Pros

- Shim plate method에 비하여 관리가 수월함
- 접합상세 및 시공이 간단하다

Cons

- 시공완료시 까지 지속적인 관리 필요
- 기둥접합 상세가 단순
- 공사중 발생하는 횡력에 대하여 Outrigger 없이 안전해야함
- 추가보강 시 골조물량 증가

초고층 건축물 횡력저항 시스템

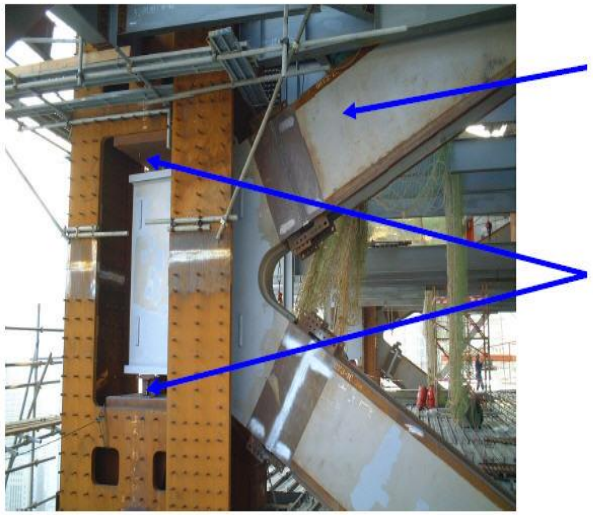
Outrigger System

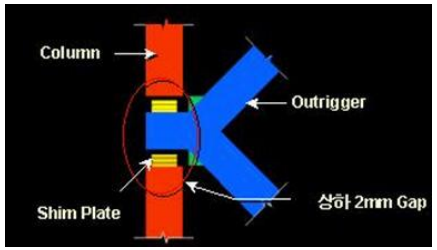
Connection Method

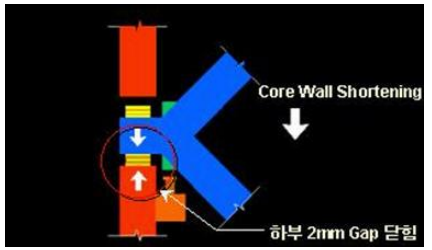
Outrigger System

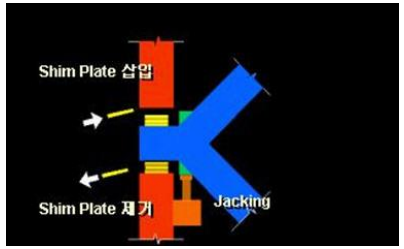
Connection between Outrigger and Column

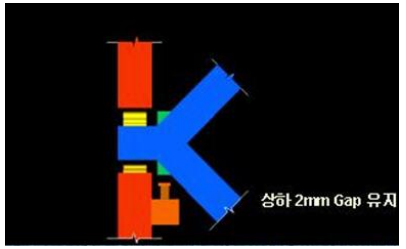
- **Adjustment method**











초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Connection between Outrigger and Column

· **Adjustment method**

목동 현대 하이페리온 I

2IFC, Hong Kong

NINA Tower, Hong Kong

Cheung Kong Center
Hong Kong

초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Connection between Outrigger and Column

· Adjustment method (Shim Plate Correction Method)

Pros

- 시공중 태풍발생 시 아웃리거가 횡력저항 요소로 저항
- 공사도중 발생할 수 있는 횡력에 대하여 추가보강 불필요

Cons

- 시공완료시 까지 지속적인 관리와 조정 필요
- 기둥접합 상세가 복잡
- 유지관리 비용증가

초고층 건축물 횡력저항 시스템

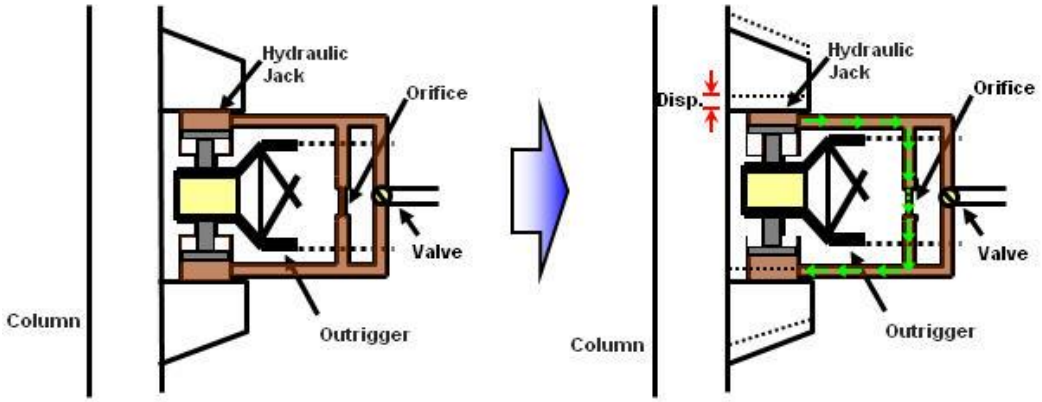
Outrigger System

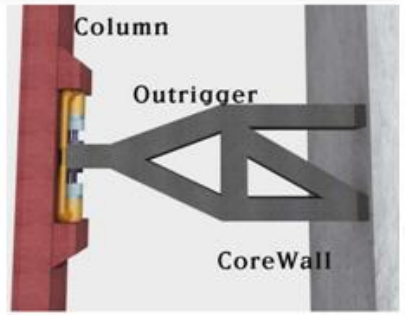
Connection Method

Outrigger System

Connection between Outrigger and Column

· Auto-leveling Joint Method (Oil Jack Joint System)





- Install bi-directionally

  Interlocked oil Jack
- Interlocking Operation
- Schematic View after installation

초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Connection between Outrigger and Column

- **Auto-leveling Joint Method**

Northeast Asia Trade Tower

St. Francis Shangri la Place, Philippines

초고층 건축물 횡력저항 시스템

Outrigger System

Connection Method

Outrigger System

Connection between Outrigger and Column

· **Auto-leveling Joint Method**

Pros

- Shim plate method에 비하여 관리가 수월함
- Outrigger Damper로 사용 시 Hydraulic Damper 기능 수행

Cons

- 시공완료시 까지 지속적인 관리와 조정 필요
- 접합상세가 복잡
- 초기 Set up 비용이 증가

초고층 건축물 횡력저항 시스템

2000’

Hyperion

- Location : Seoul, Korea
- Height : 69 Story (256m)
- Use : Residential
- Completion : 2003
- Structural System :
  Composite Column +
  Steel Beam +
  Outrigger Truss

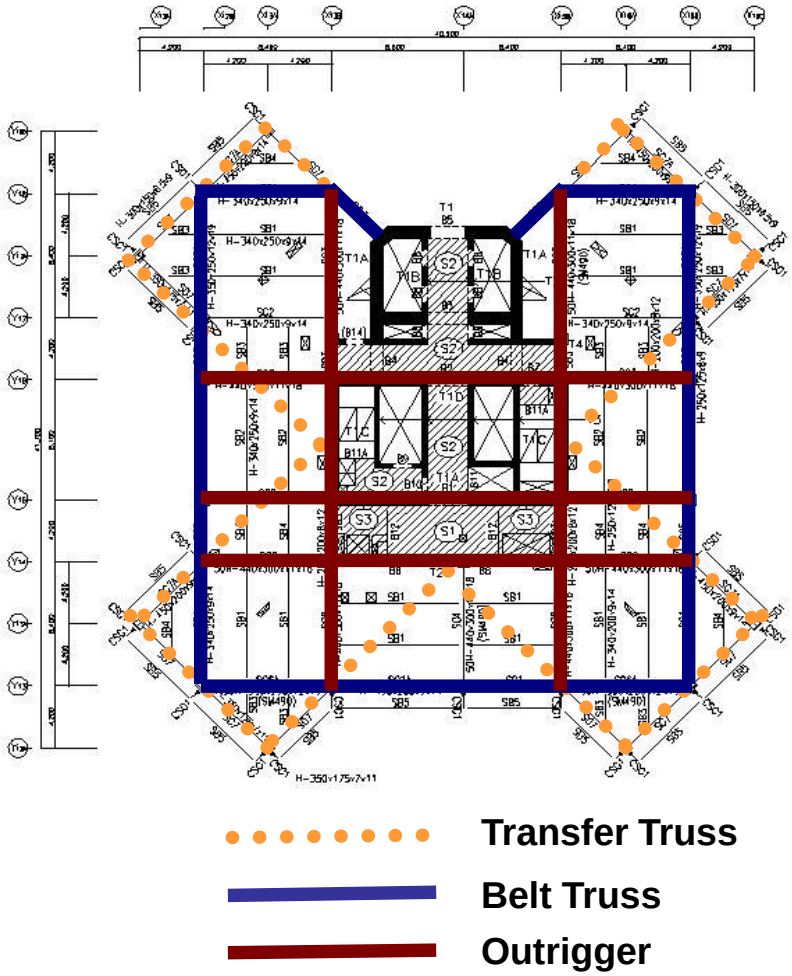
Outrigger System

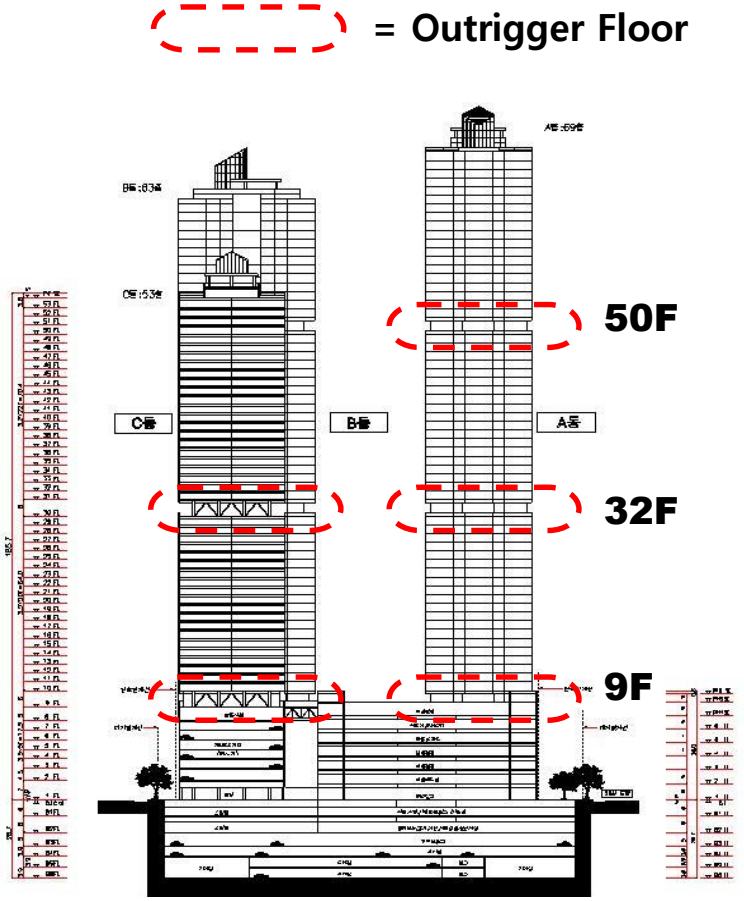
초고층 건축물 횡력저항 시스템

2000’

Hyperion

Outrigger System





초고층 건축물 횡력저항 시스템

2000’

Hyperion

Outrigger System

초고층 건축물 횡력저항 시스템

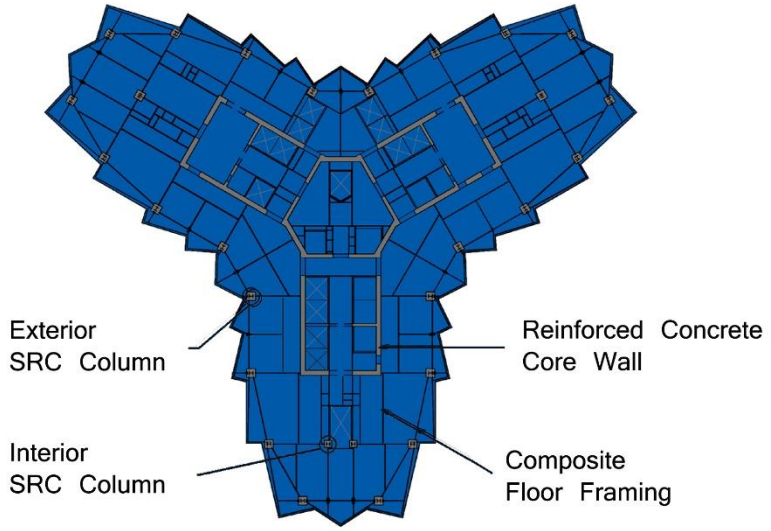
2000’

Tower palace Ⅲ

- Location : Seoul, Korea
- Height : 69 Story (261.8m)
- Use : Residential
- Completion : 2004
- Structural System :
  Composite Column +
  Steel Beam + Core Wall +
  Concrete Belt Wall

Outrigger System

STRUCTURE PLAN



초고층 건축물 횡력저항 시스템

2000’

Tower palace Ⅲ

Outrigger System

초고층 건축물 횡력저항 시스템

2000’

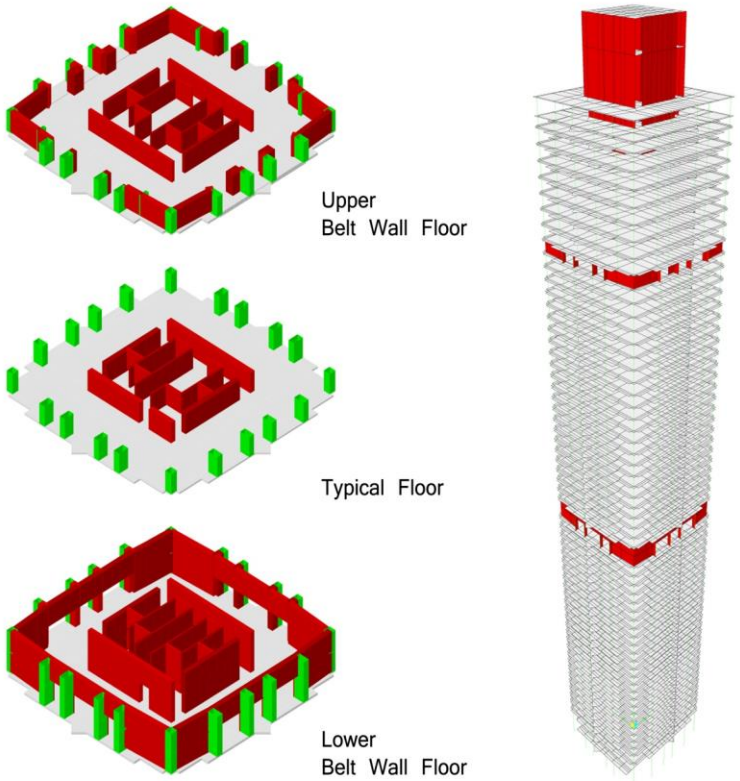
The # Centum Star

- Location : Busan, Korea
- Height : 60 Story (209.8m)
- Use : Residential
- Completion : 2008

Outrigger System

LATERAL SYSTEM

Core Wall + Outrigger Wall + Belt Wall

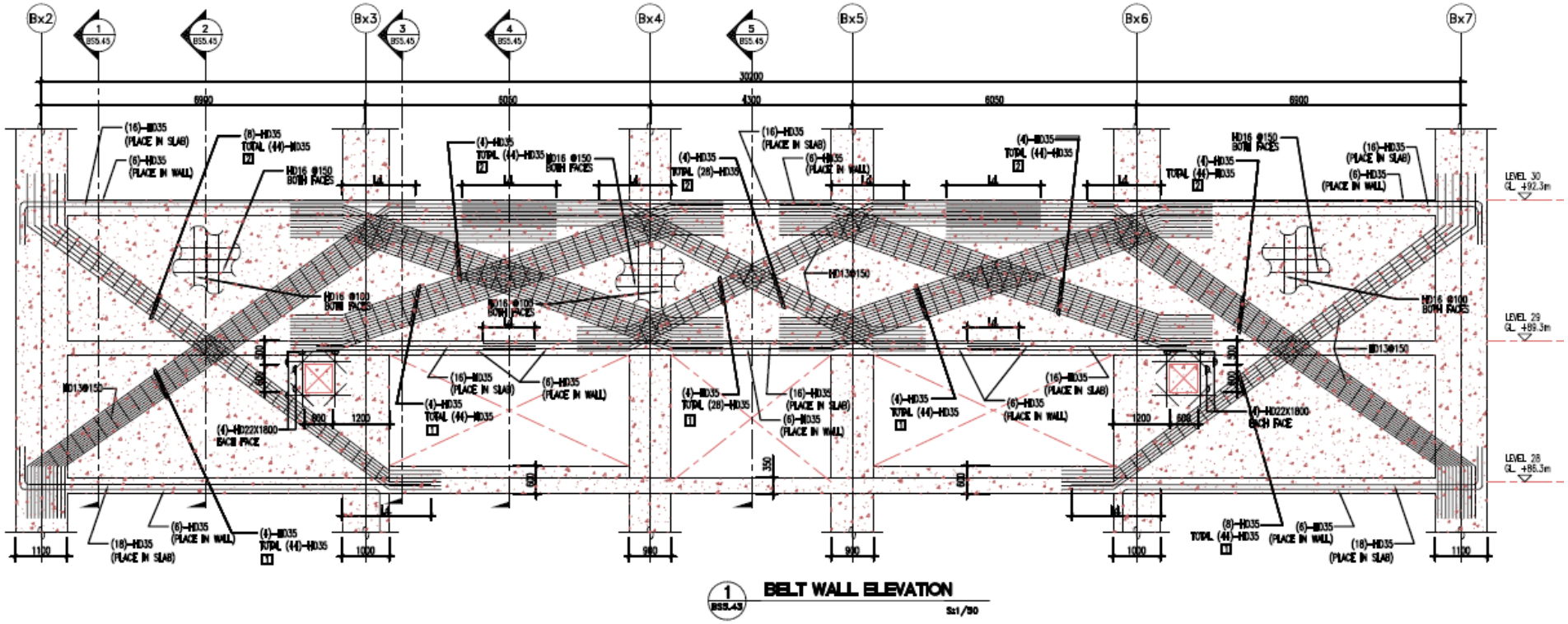


초고층 건축물
횡력저항 시스템

Outrigger System

2000’

The # Centum Star



1 BELT WALL ELEVATION
S:1/50

초고층 건축물 횡력저항 시스템

2000’

The # Centum Star

Outrigger System

초고층 건축물 횡력저항 시스템

2010’

NEATT

- Location : Incheon, Korea
- Height : 69 Story (304m)
- Use : Office + Hotel
- Completion : 2014
- Structural System : Composite Column + Steel Beam + Outrigger Truss

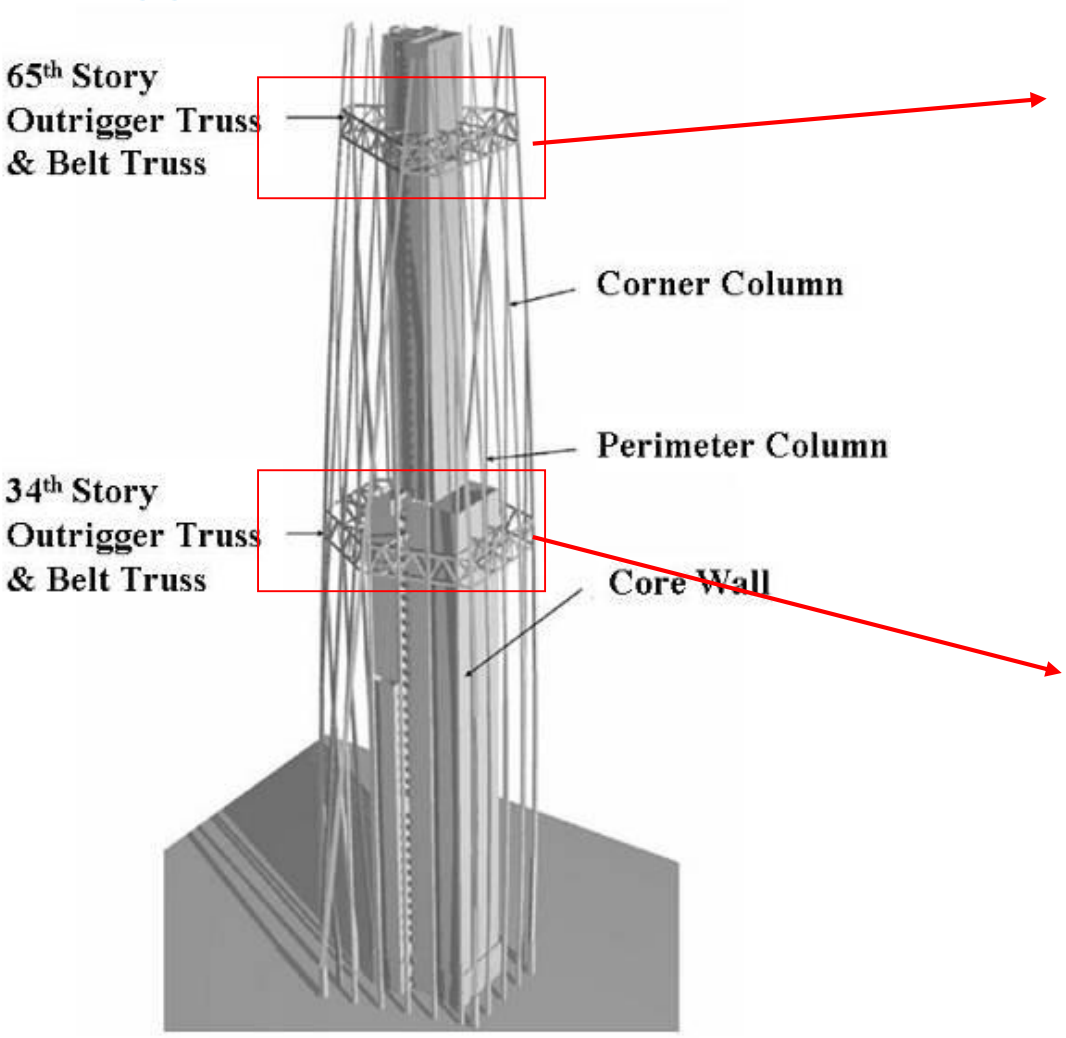
Outrigger System

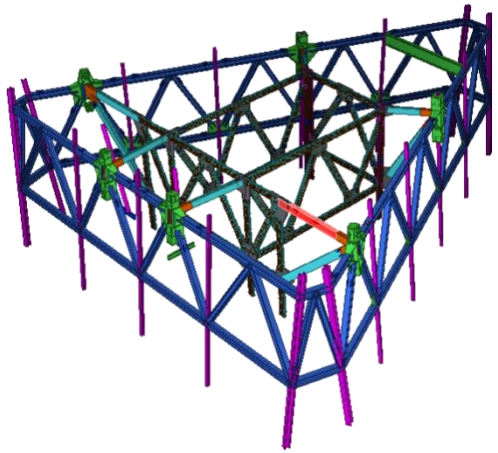
초고층 건축물 횡력저항 시스템

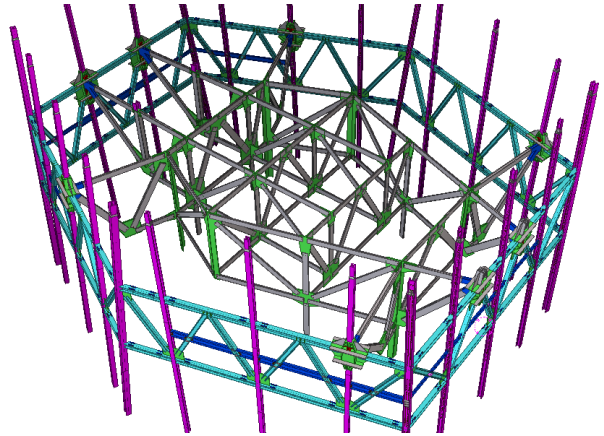
2010’

NEATT

Outrigger System







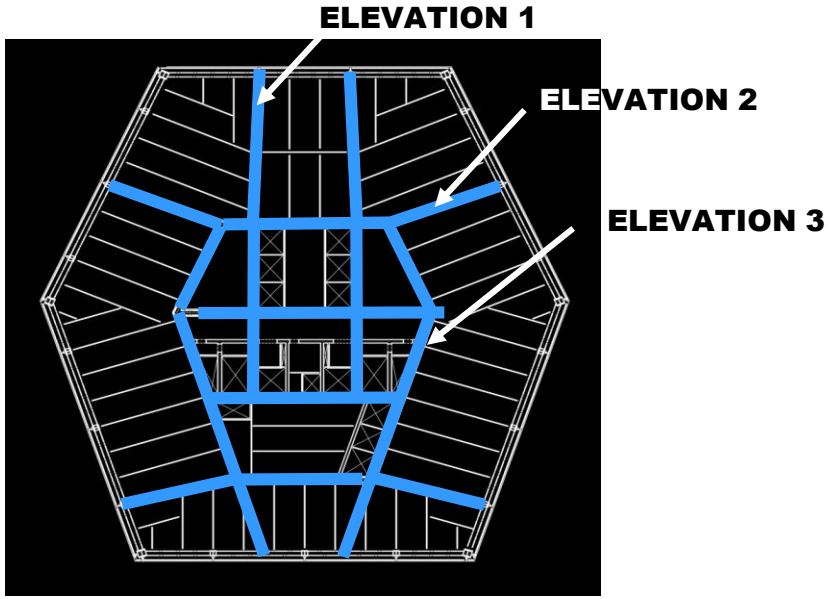
초고층 건축물 횡력저항 시스템

2010’

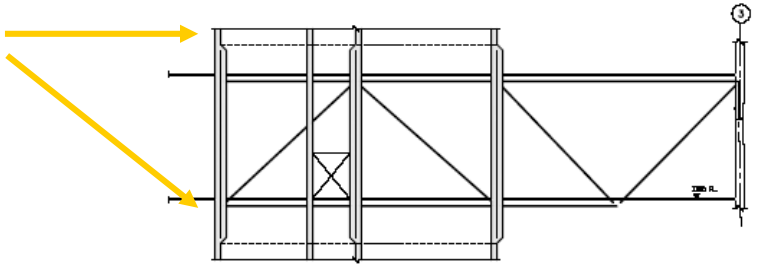
NEATT

Outrigger System

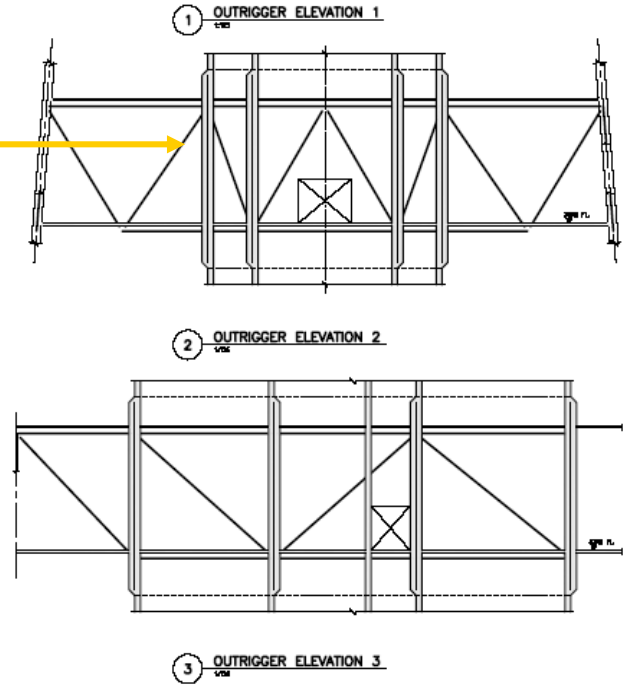
Outrigger Layout Elevations – 33rd Floor Level



Thick Core Wall to be Extended into Adjacent Floors



Core Walls Thickened to 800mm At Outrigger Levels



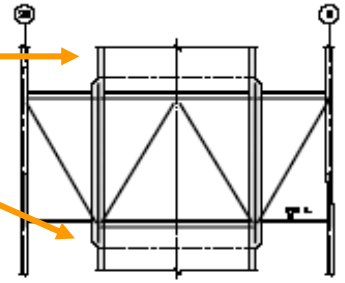
초고층 건축물 횡력저항 시스템

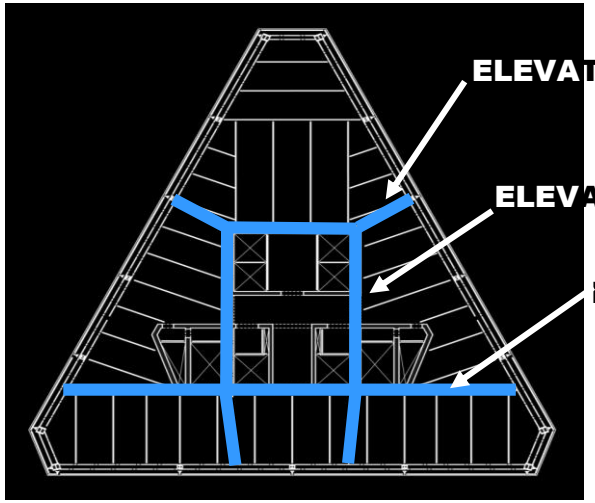
2010’
NEATT

Outrigger System

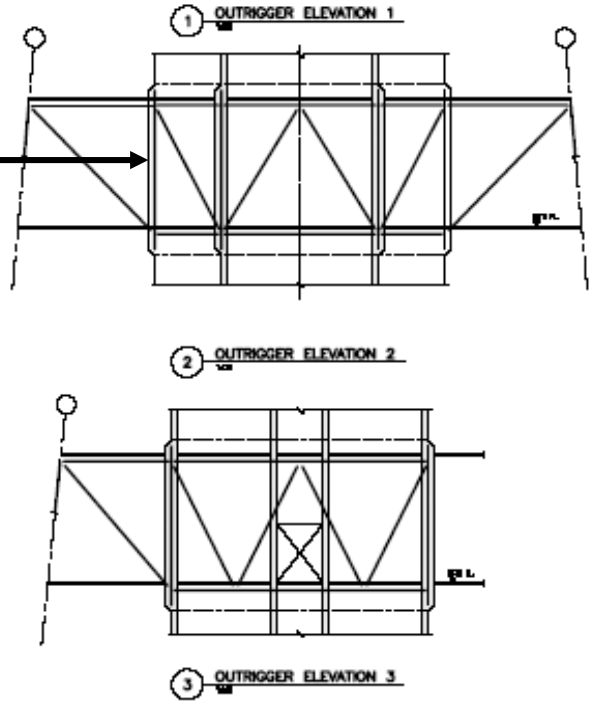
Outrigger Layout Elevations – 64rd Floor Level

Thick Core Wall to be Extended into Adjacent Floors





Core Walls Thickened to 800mm At Outrigger Levels



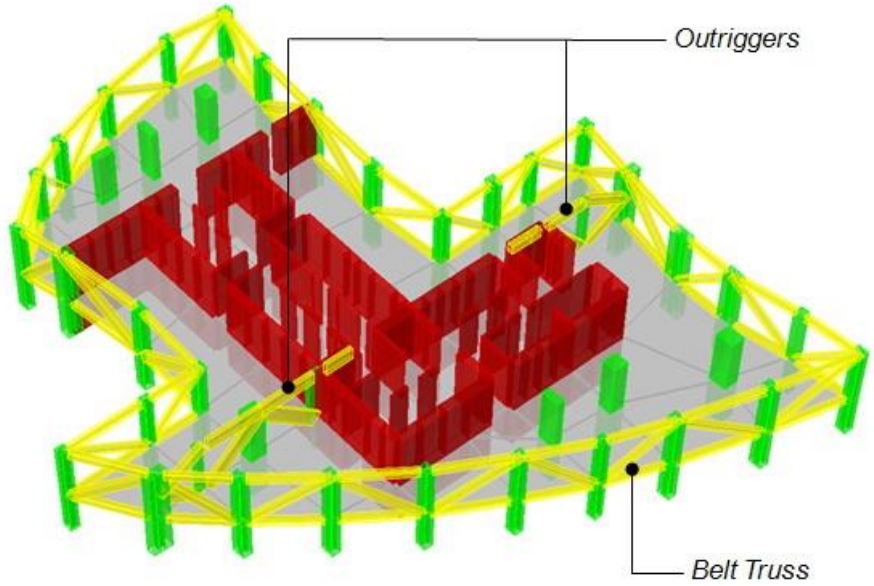
초고층 건축물 횡력저항 시스템

2010’

I Park Marina

- Location : Busan, Korea
- Height : 72 Story (291.6m)
- Use : Residential
- Completion : 2011
- Structural System :
  RC Flat Slab + Core Wall +
  Steel Outrigger Truss

Outrigger System



초고층 건축물
횡력저항 시스템

Outrigger System

2010’

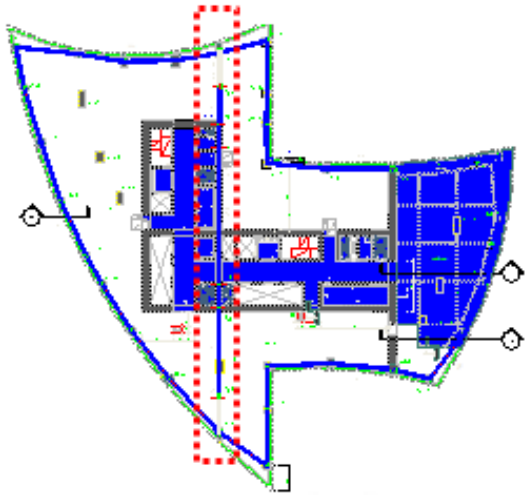
I Park Marina

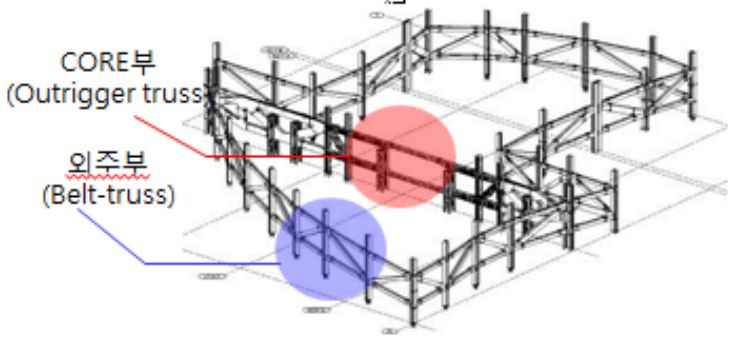
초고층 건축물 횡력저항 시스템

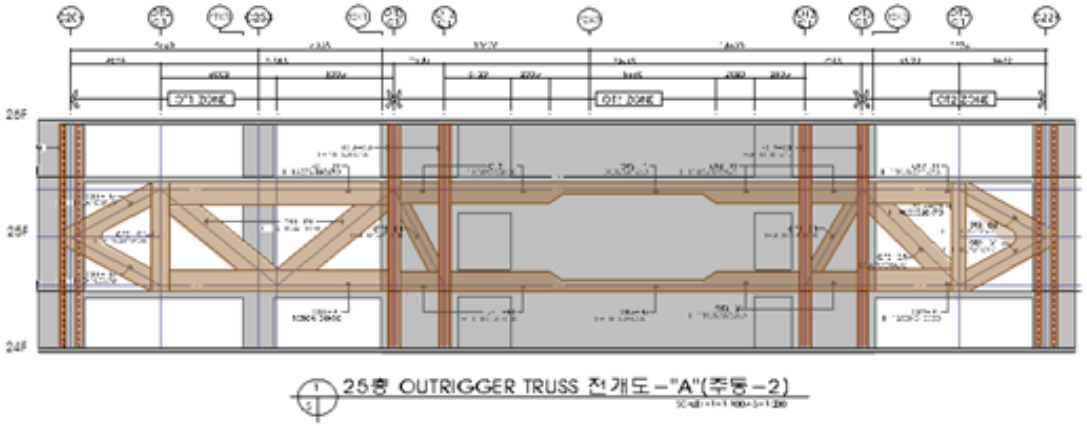
2010’

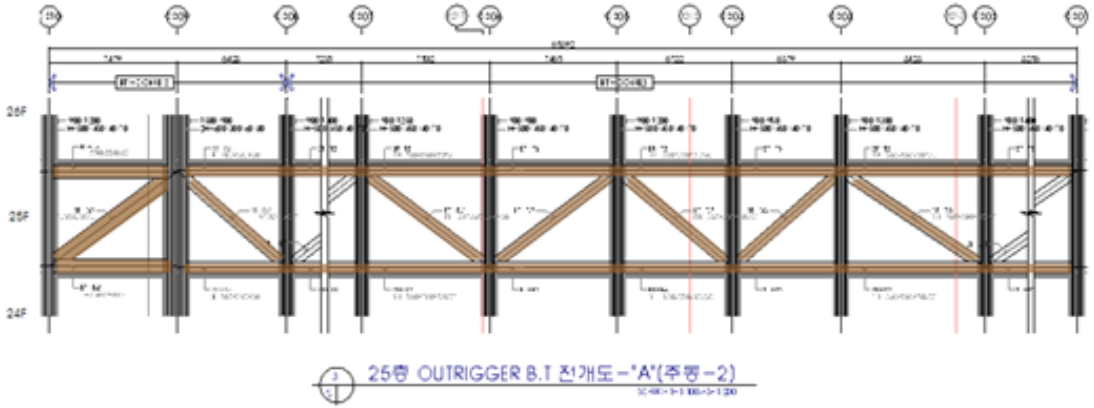
I Park Marina

Outrigger System

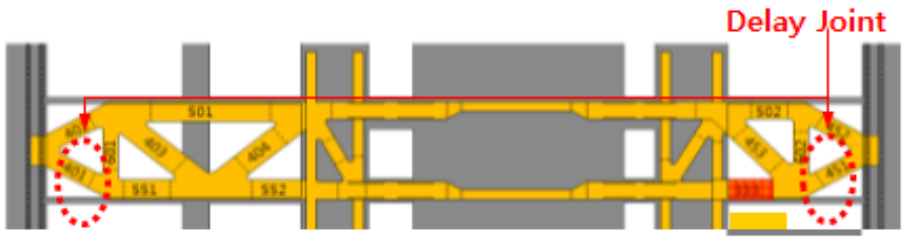


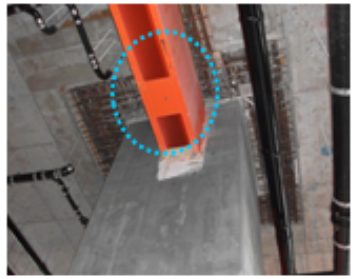






Outrigger Truss





초고층 건축물 횡력저항 시스템

Outrigger System

Project Name	Story	Structural System	Outrigger Connection		Outrigger Depth	Outrigger Materials
			Core	Column		
Hyperion I	69	Core+O/T+B/T +SRC column	Direct	Adjust. Delay	6.0m	Steel
Tower Palace III	69	Core+B/W +SRC column	Indirect	-	8.0m	RC
Busan the# Centum Star	60	Core+B/W +RC column	Indirect	-	6.0m	RC
NEATT (Northeast Asia Trade Tower)	68	Core+O/T+B/T +SRC column	Direct	Adjust. (Oil Jack)	9.1m	Steel
Busan Haeundae I'Park	72	Core+O/T+B/T +SRC column	Direct	Delay	6.4m	Steel
Hanoi Landmark Tower	70	Core+O/T +RC column	Direct	Delay	8.0m	RC
FKI Head Office (Federation of Korea Industries)	50	Core+O/T+B/T +SRC column	Direct	Delay	9.2m	RC
Busan Lotte Town	107	Core+O/T+B/T +RC column	Direct	Delay	14.0m	Steel
Hanoi City Complex	65	Core+O/T +RC Column	Direct	-	7.0m	Steel

Mega-Braced System

- Single Column & Mega-Brace
- Double Column & Mega-Brace

초고층 건축물 횡력저항 시스템

Mega-Braced System

challenge

- **Conner Column Connected to Mega-Brace**

초고층 건축물 횡력저항 시스템

GBC

- Location : Seoul, Korea
- Height : 105 Story (569m)
- Use : Office
- Structural System :
  Mega-Braced System

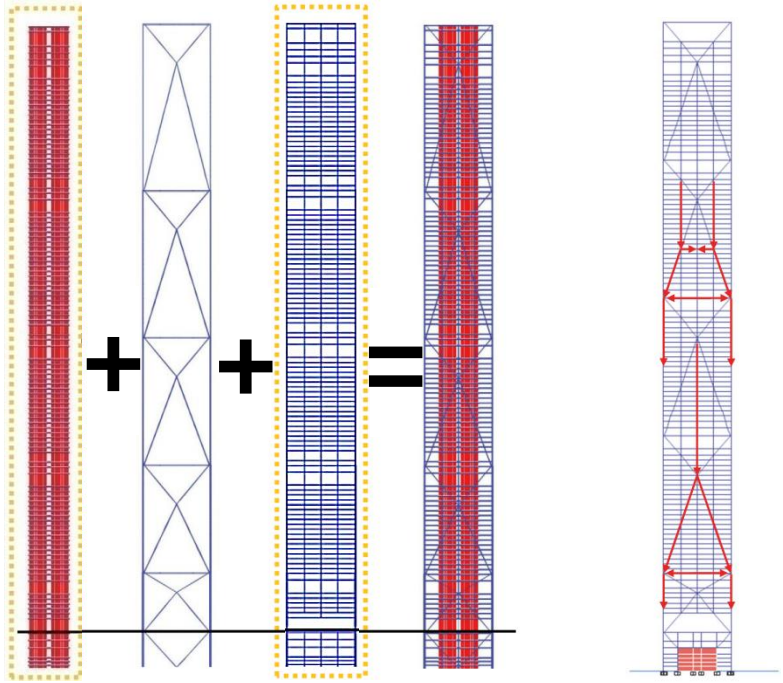
Mega-Braced System

초고층 건축물 횡력저항 시스템

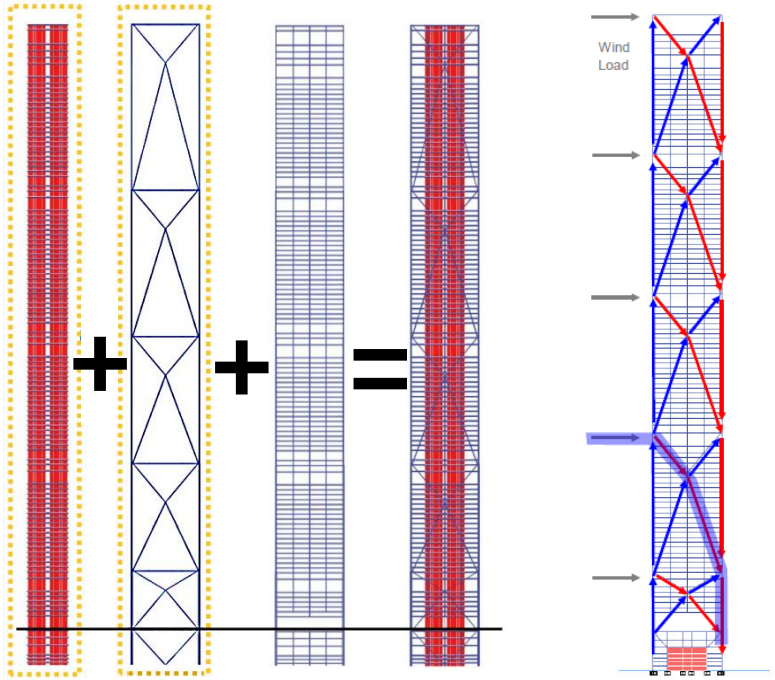
GBC

Mega-Braced System

Gravity Load Resisting System



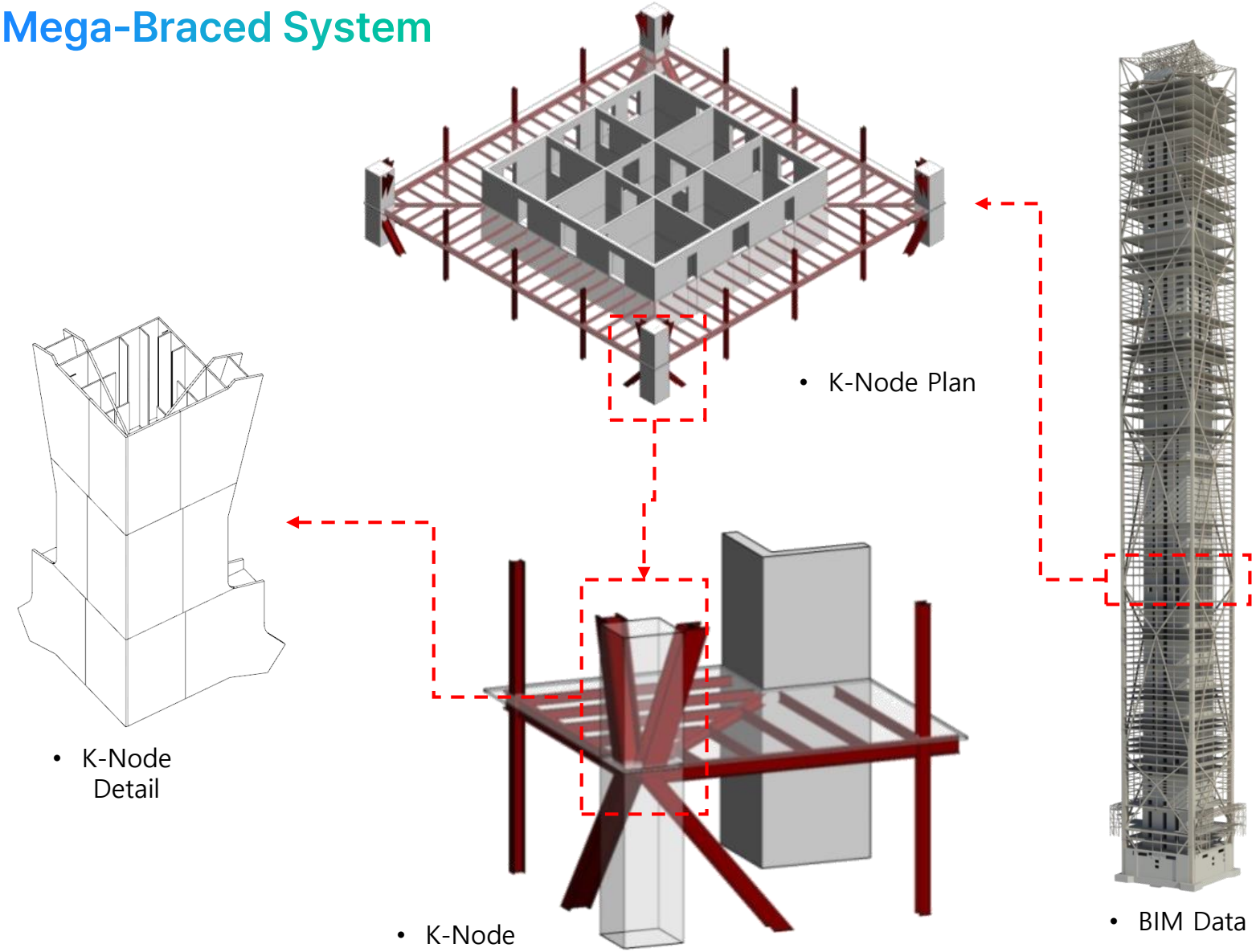
Lateral Load Resisting System



초고층 건축물 횡력저항 시스템

GBC

Mega-Braced System



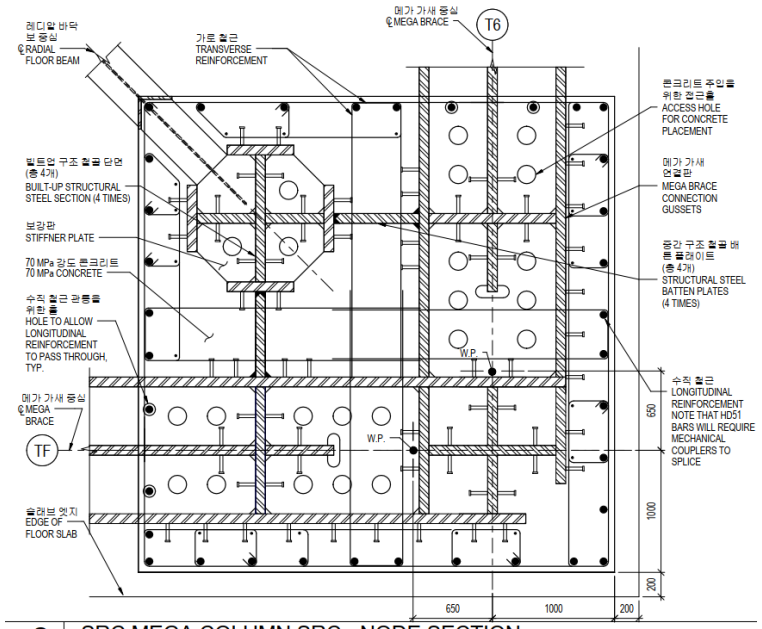
- K-Node Plan
- K-Node Detail
- K-Node
- BIM Data

초고층 건축물 횡력저항 시스템

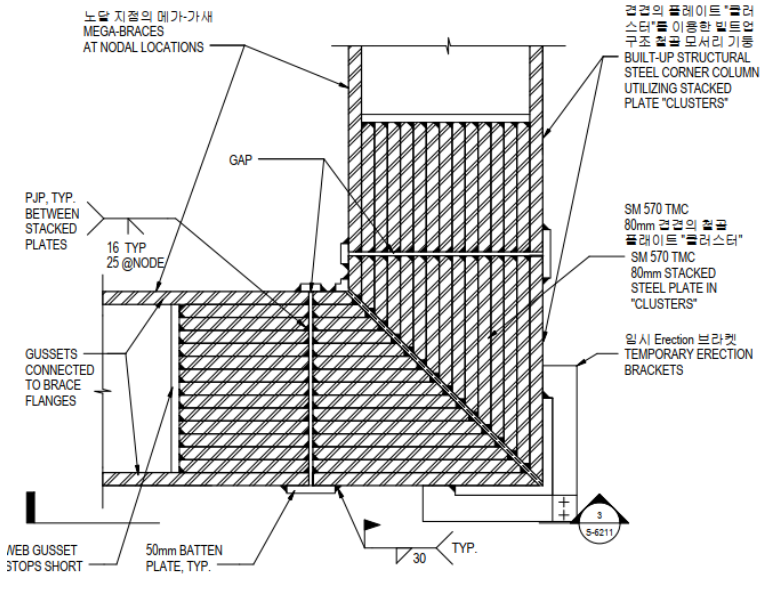
Mega-Braced System

GBC

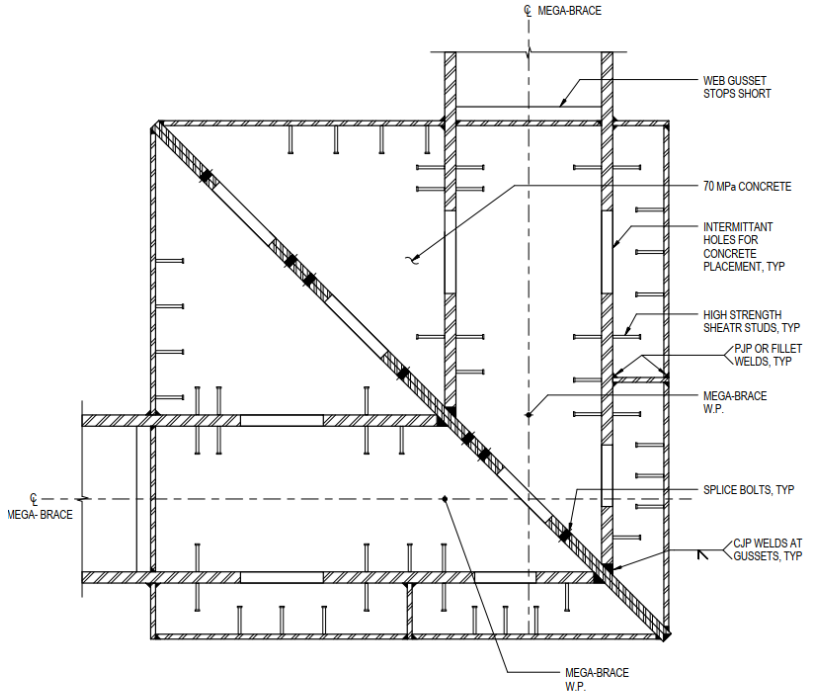
MEGA-COLUMN DETAIL - CFT OPTION AT NODE LEVE



3 SRC MEGA COLUMN SRC - NODE SECTION
SCALE: 1 : 20



TYPICAL STEEL MEGA COLUMN DETAIL - DOUBLE GUSSET CONFIGURATION 1200 WIDE
SCALE: NTS



MEGA-COLUMN DETAIL - CFT OPTION AT NODE LEVEL
SCALE: NTS

출처 : S.O.M

초고층 건축물 횡력저항 시스템

2020’

Parc1

- Location : Seoul, Korea
- Height : 69 Story (318m)
- Use : Office
- Completion : 2020
- Structural System :
  Mega-Braced System

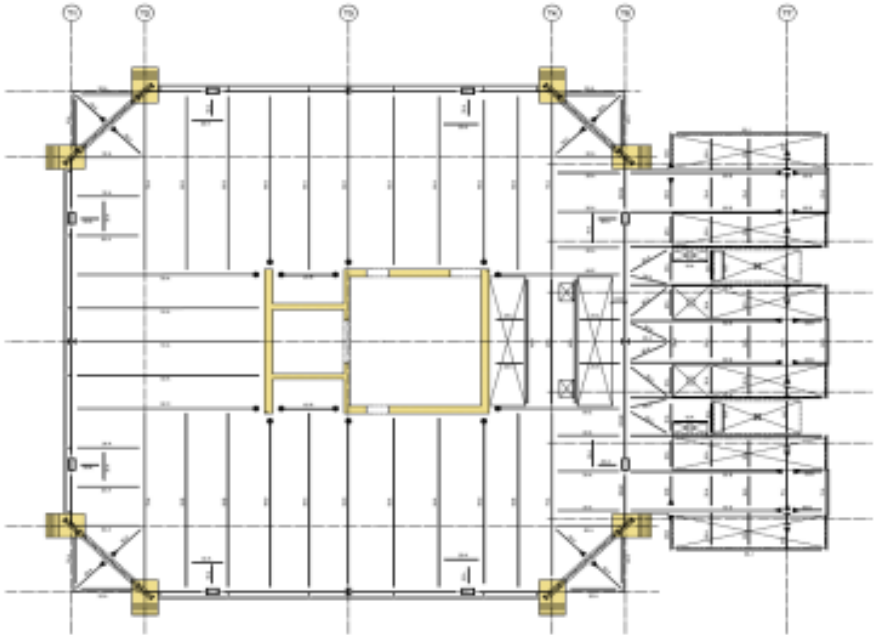
Mega-Braced System

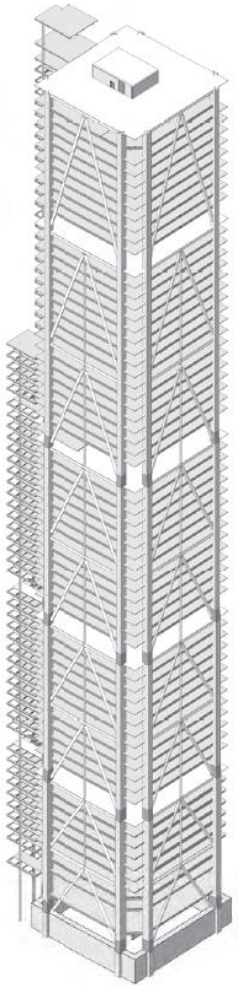
초고층 건축물 횡력저항 시스템

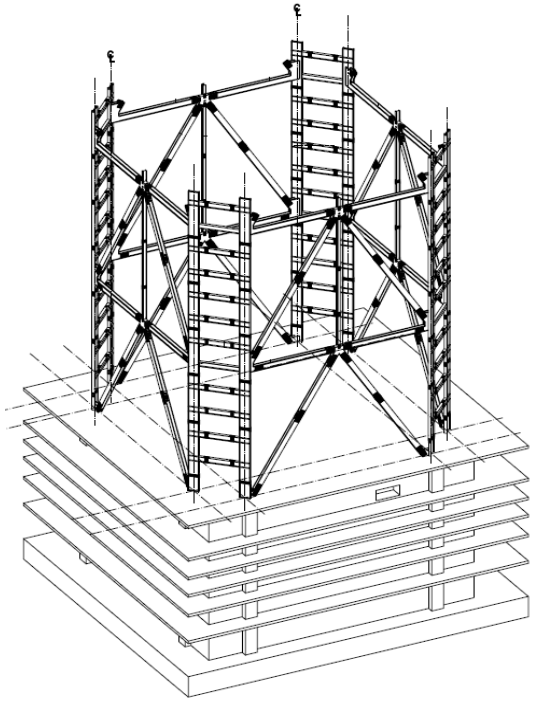
Mega-Braced System

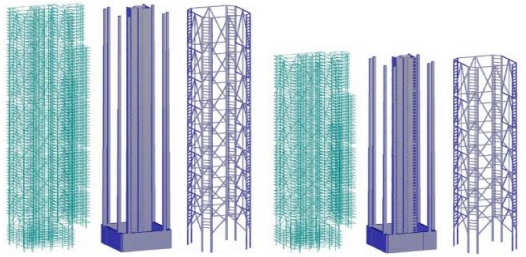
2020’

Parc1







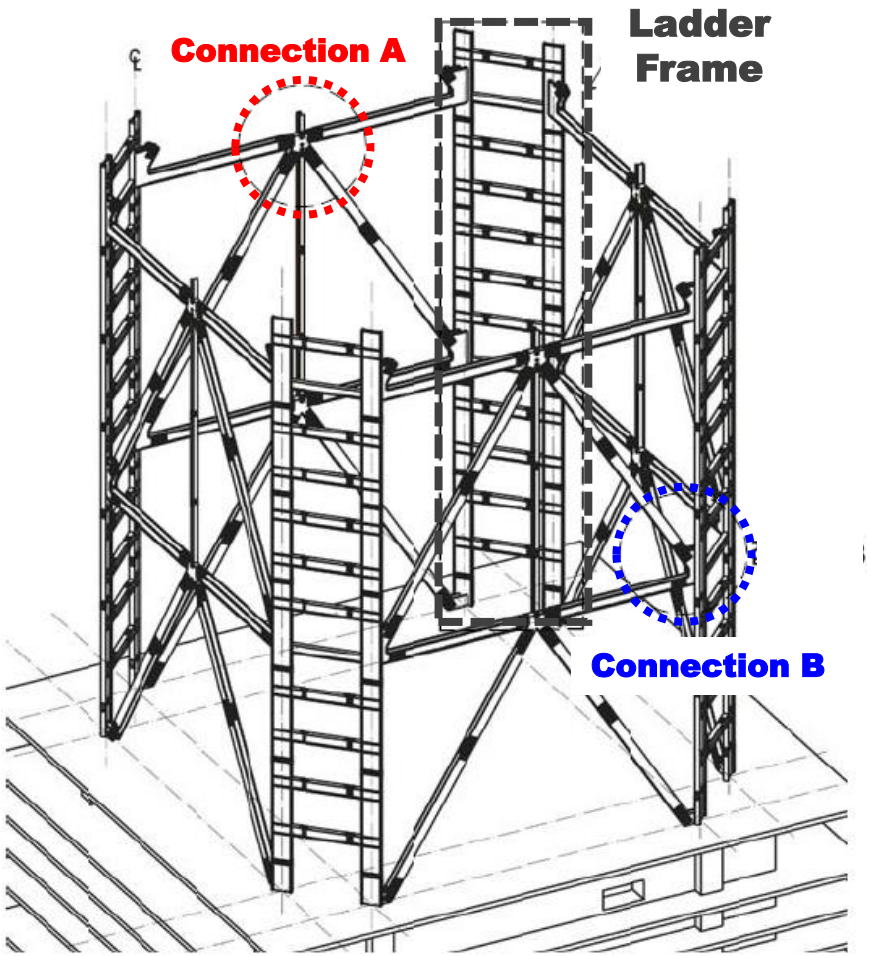


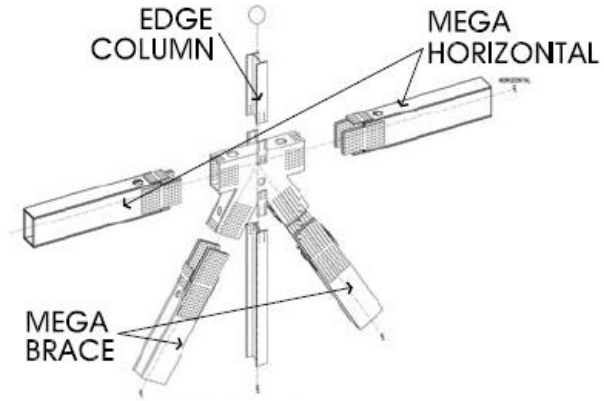
초고층 건축물 횡력저항 시스템

2020’

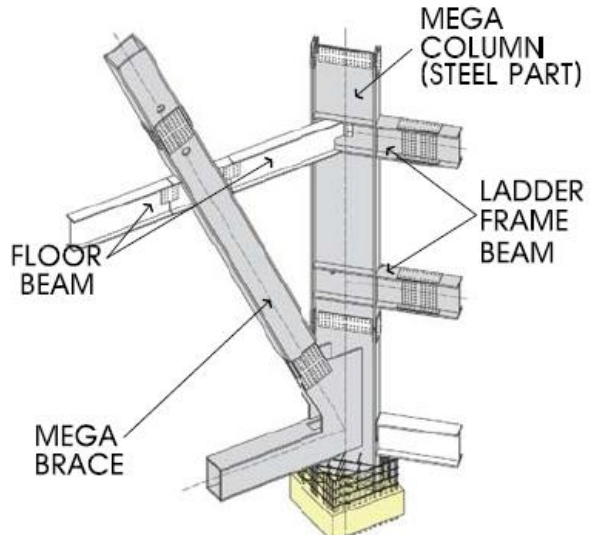
Parc1

Mega-Braced System





Connection A



Connection B

출처 : ARUP

Fin Wall & Belt Wall

- Post-tension
- RC

초고층 건축물 횡력저항 시스템

Fin-Wall & Belt-Wall System

challenge

- **Fin-Wall & Belt Wall Rebar Arrangement**

초고층 건축물 횡력저항 시스템

2020’

LCT

- Location : Busan, Korea
- Height : 101 Story (411m)
- Use : Residential
- Completion : 2019
- Structural System :
  Fin Wall & Belt Wall

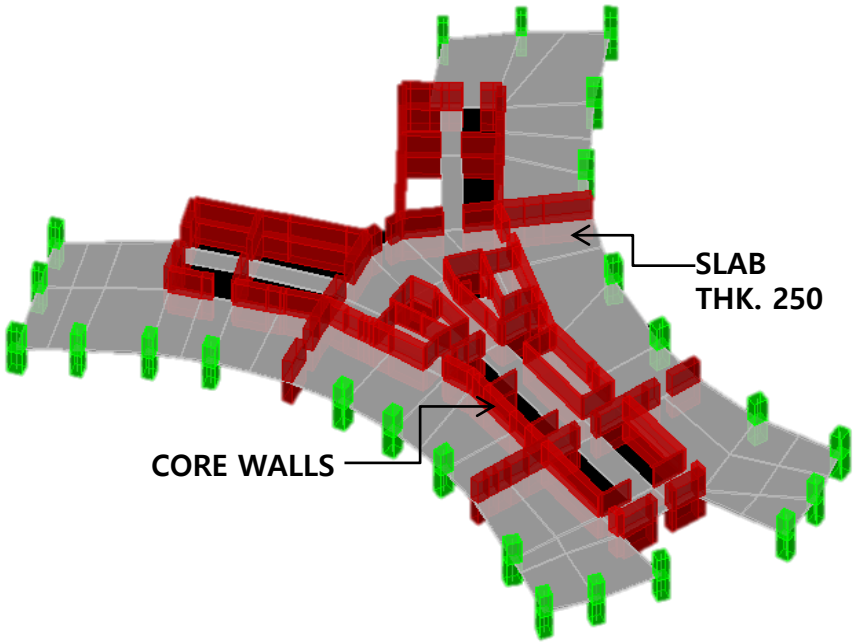
Fin Wall & Belt Wall

초고층 건축물 횡력저항 시스템

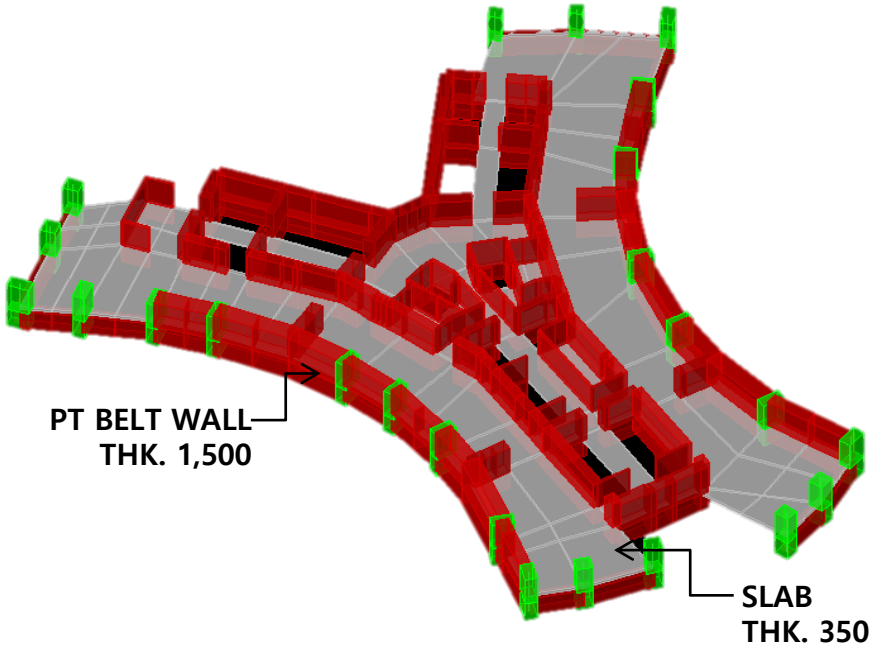
2020’

LCT

Fin Wall & Belt Wall



TYPICAL FLOOR



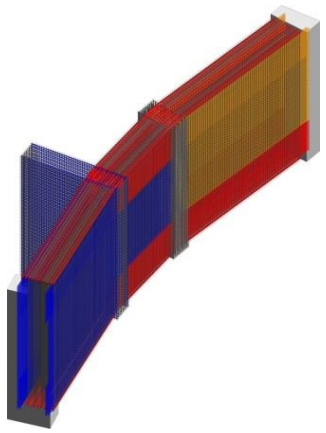
MECHANICAL FLOOR

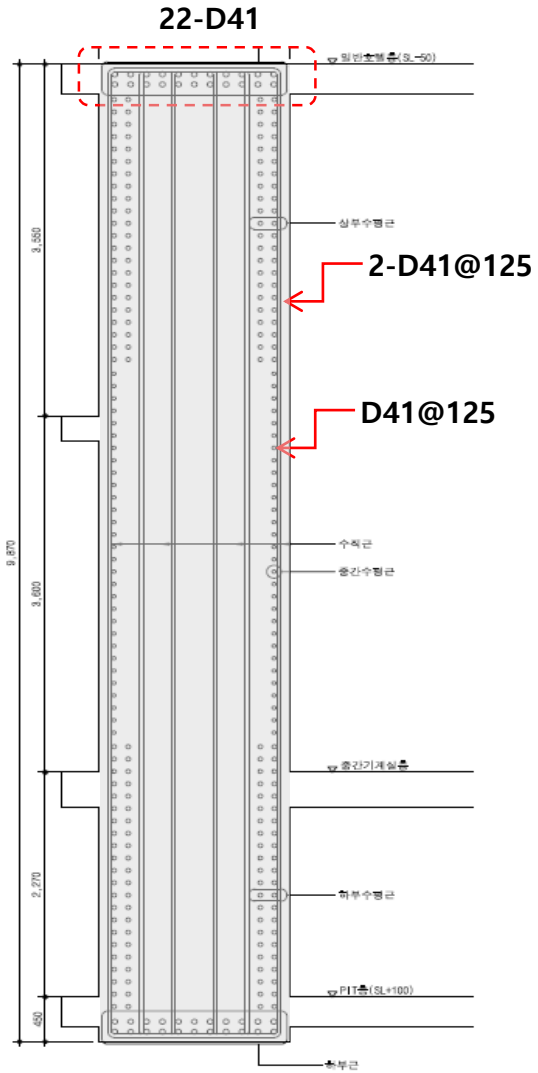
초고층 건축물 횡력저항 시스템

2020’

LCT

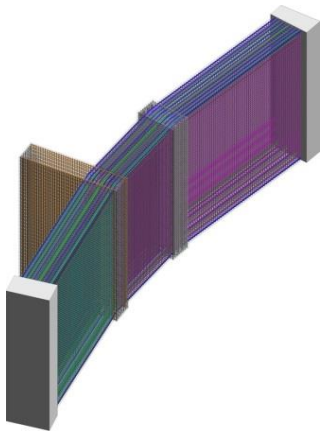
< RC BELT WALL >





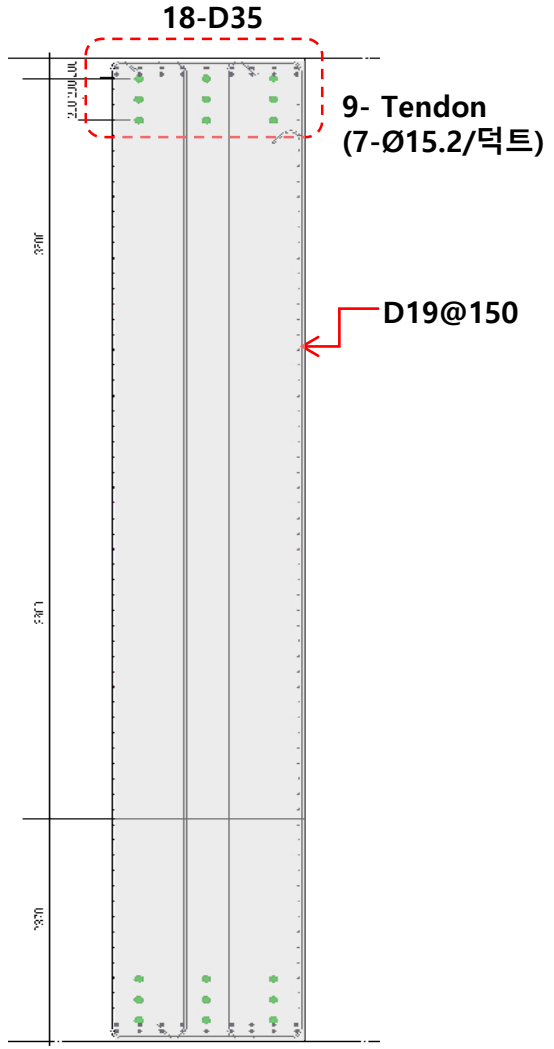
A_s = 3,500cm²

< PT BELT WALL >



A_{ps} = 176.4cm²

A_s = 1,000cm²



< PT Belt wall >

초고층 건축물 횡력저항 시스템

2020’

LCT

■ POST-TENSIONED BELT WALL 시공

초고층 건축물 횡력저항 시스템

2020’

LCT

■ POST-TENSIONED BELT WALL 시공

초고층 건축물 횡력저항 시스템

2020’

IJINBAY CITY

- Location : Busan, Korea
- Height : 69 Story (246m)
- Use : Residential
- Completion : 2022
- Structural System :
  Fin Wall & Belt Wall

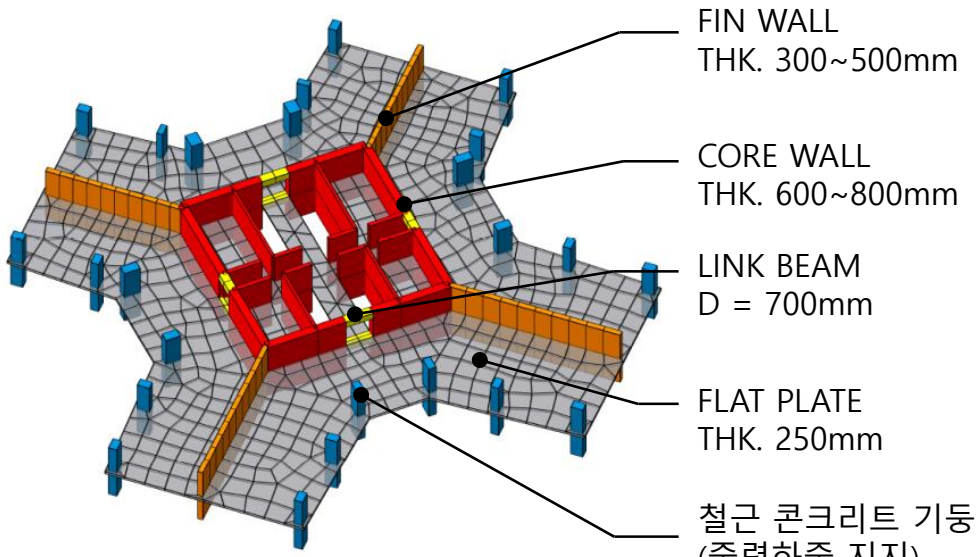
Fin Wall & Belt Wall

초고층 건축물 횡력저항 시스템

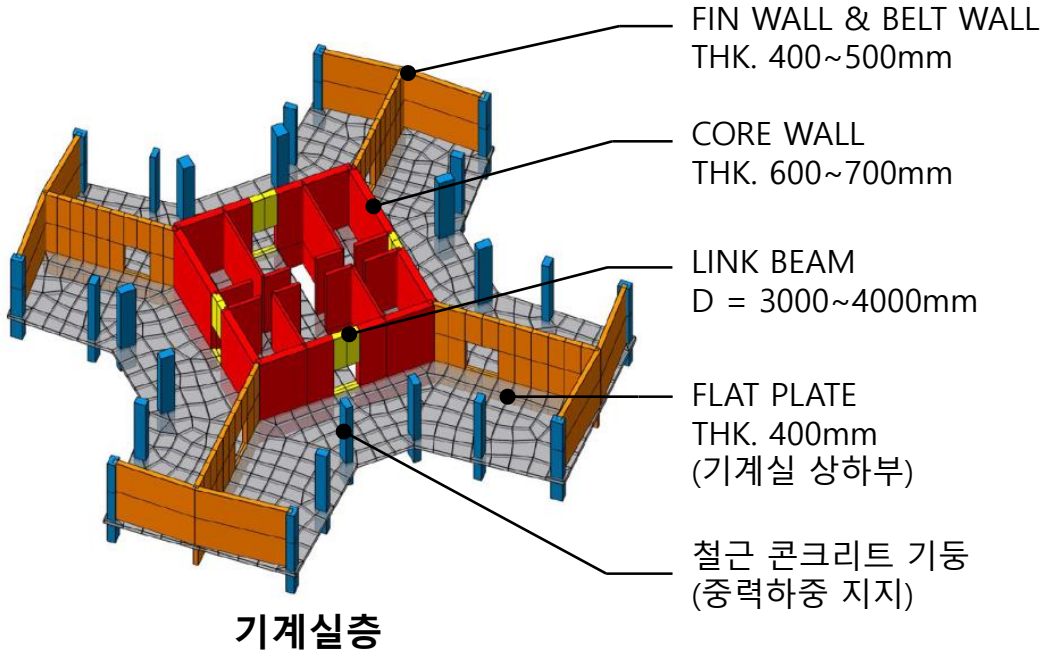
Fin Wall & Belt Wall

2020’

IJINBAY CITY



공동주택 기준층



기계실층

초고층 건축물 횡력저항 시스템

2020’

IJINBAY CITY

Fin Wall & Belt Wall

초고층 건축물 주요 고려사항

초고층 건축물 주요 고려사항

Specialists

Special Consultants

- Geotechnical
- Foundation
- Facade
- Wind
- Seismic
- Damper
- Nonlinear
- Axial Shortening
- Cost
- Materials
- Welding
- BIM
- etc

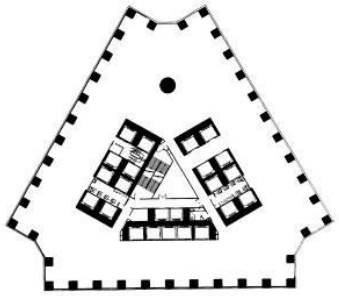
Structural Engineer

1. Network
2. Coordination

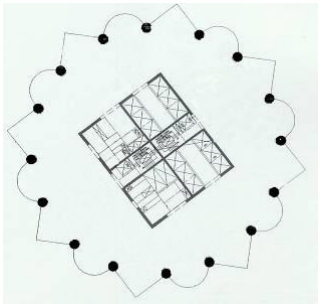
초고층 건축물 주요 고려사항

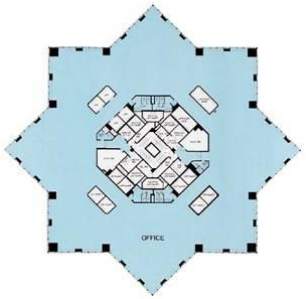
Core Design

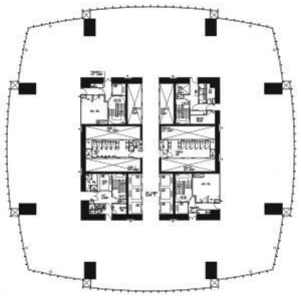
Special Consultants

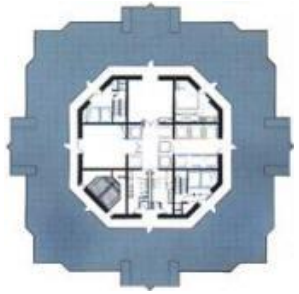

Central Plaza

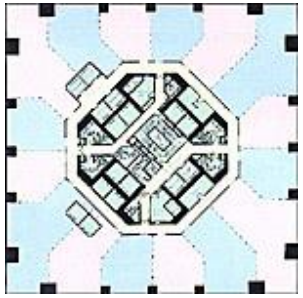

Taipei 101 Tower

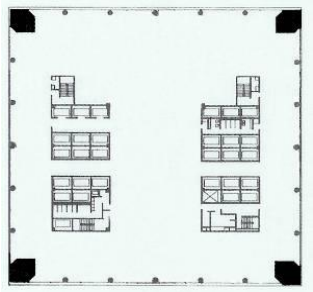

Petronas Tower

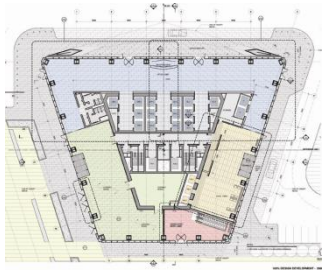

The Centre

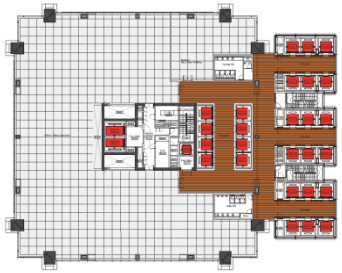

International Finance centre


Jin Mao Tower


CITIC Plaza


Bank of China Tower


NEATT


Parc 1

- Lift Engineer
- ACS Form
- Fire Engineer
- MEP Engineer
- Conc Material Consultant

Coordination

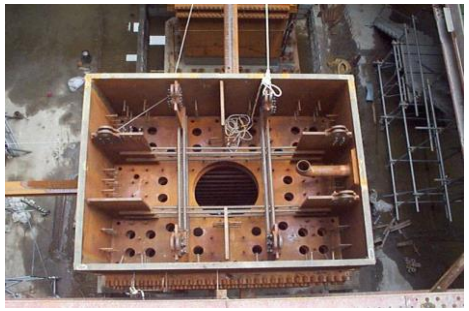
Structural Engineer

초고층 건축물 주요 고려사항

Mega Structure

Special Consultants



- Steel Worker
- Steel Fabricator
- Welding
- Cranage
- Monitoring
- Conc Material Consultant
- Curtain Wall Consultant

Coordination

Structural Engineer

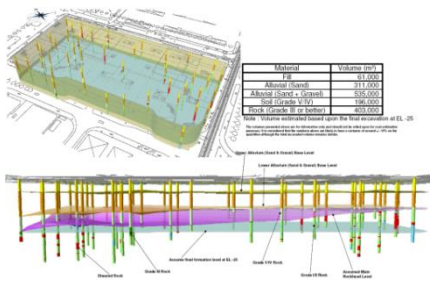
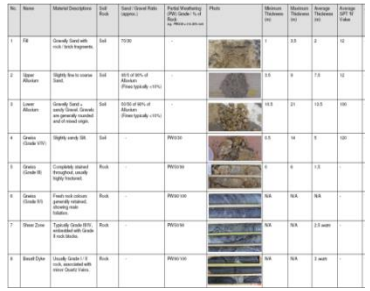
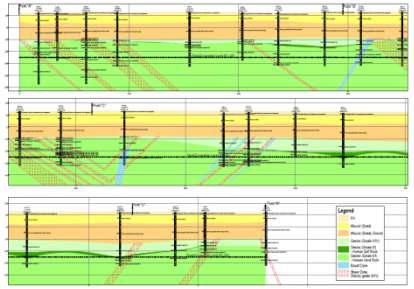
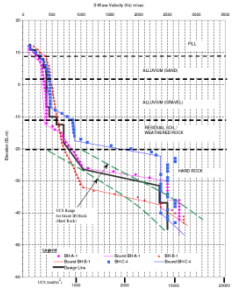
초고층 건축물 주요 고려사항

Sub-Structure Design

Special Consultants






- Geotechnical Engineer
- Foundation Engineer
- Excavation
- Earthwork
- MEP Engineer
- Q.C Consultant

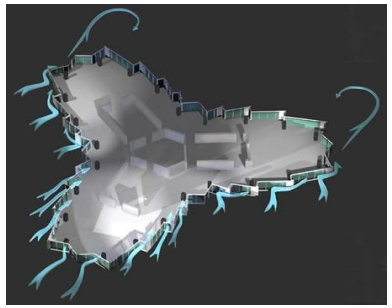
Coordination

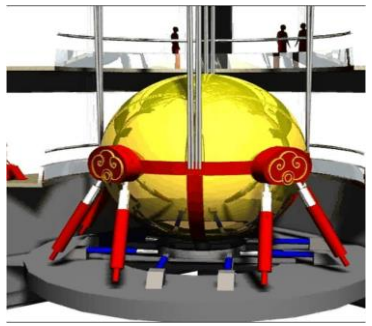
Structural Engineer

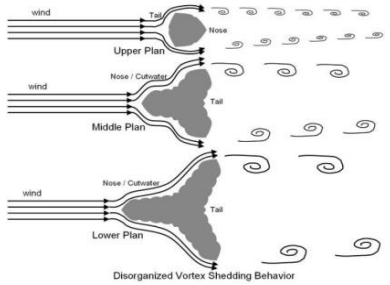
초고층 건축물 주요 고려사항

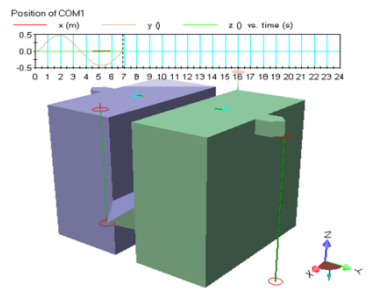
Building Shaping

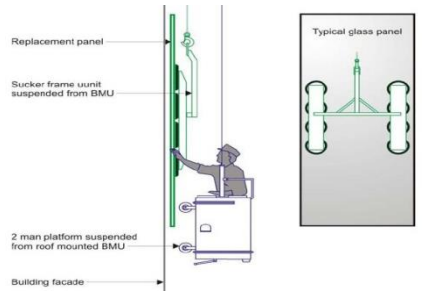
Special Consultants











- Wind Engineer
- Vibration Consultant (Damper)
- Curtain Wall Consultant
- BMU Consultant

Coordination

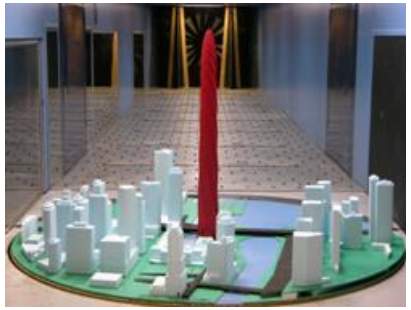
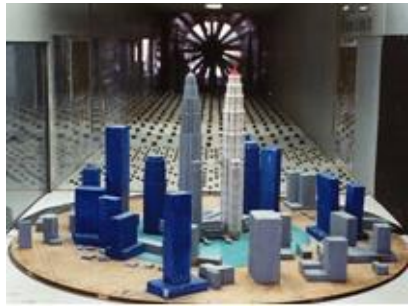
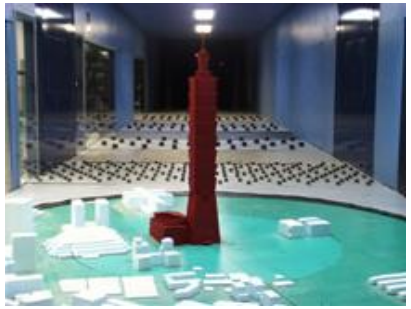
Structural Engineer

초고층 건축물 주요 고려사항

Wind Engineer

Special Consultants



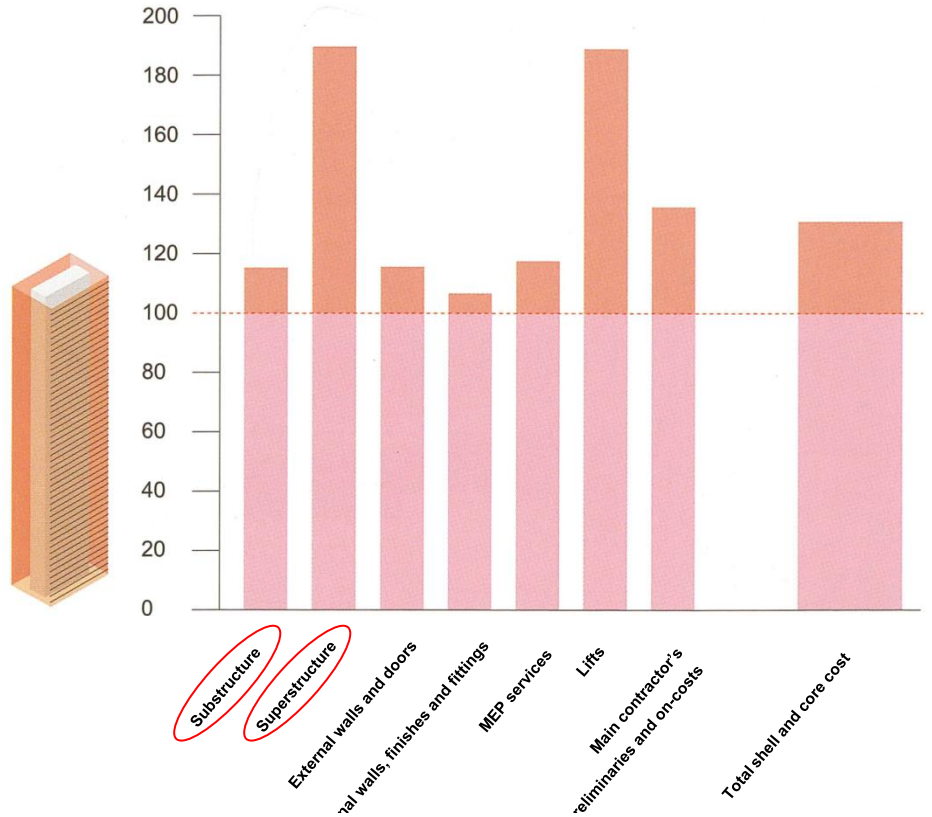





- Climate Study
- High Frequency Force Balance Test
- Aero-elastic Test
- Aero-dynamic Stability Test
- Cladding Pressure Test
- Pedestrian Level Comfort Test
- Spire Wind Fatigue Test
- Stack Effect
- Auxiliary Damper Study
- Thermal Comfort Study
- Special Reynolds Test
- Pinnacle Vortex Shedding Mitigation Test

초고층 건축물 주요 고려사항

Cost Consultant

Special Consultants

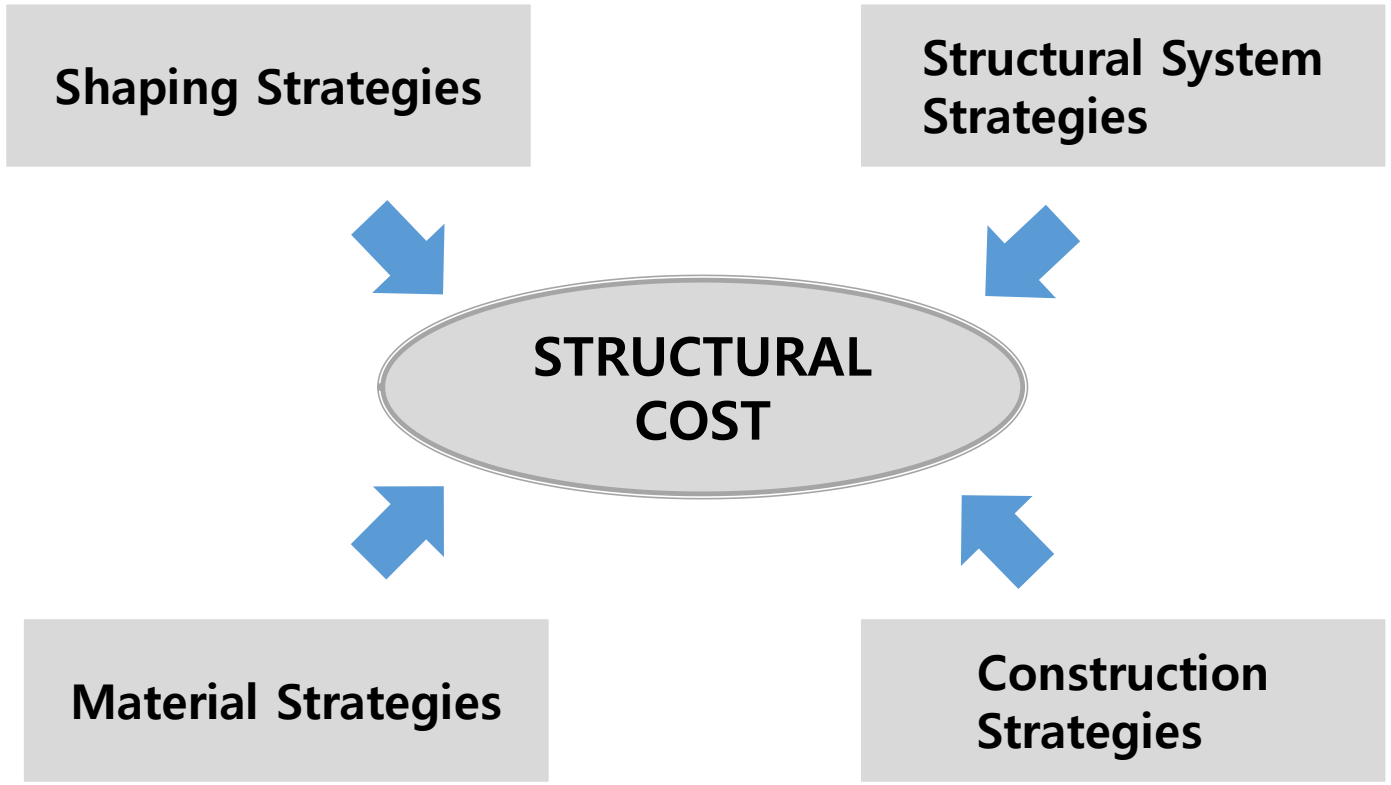


Elemental costs for a 60 story building
(baseline costs for a 15 story building).

초고층 건축물 주요 고려사항

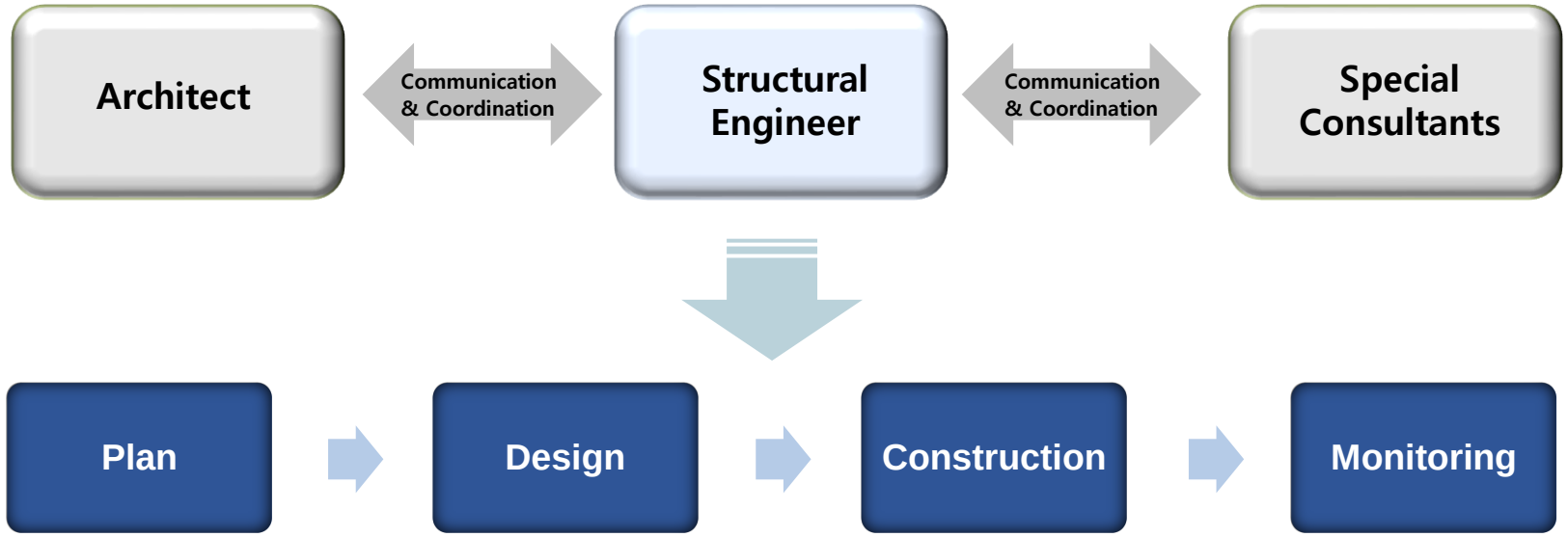
Cost Consultant

Special Consultants



Structural Engineer's Role

Structural Engineer ≠ Supporting Engineer



Structural Engineer Leads the High-rise with Various Knowledge and Experience