INOVASI KONSTRUKSI PADA PERANCANGAN ARSITEKTUR GEDUNG SUPER-TINGGI

Kuliah Tamu ITB
Terbuka untuk Umum
6 Oktober 2017, 9:00 – 11:00
Galeri Arsitektur ITB
Jl.Ganesha 10, Bandung

Ir.Davy Sukamta adalah pendiri Davy Sukamta & Partners - Structural Engineers, Jakarta.
Lulus dari Universitas Katolik Parahyangan tahun 1981.
Ia telah merancang banyak gedung tinggi dan struktur besmen-dalam selama 39 tahun karirnya, termasuk Indonesia-1 Tower , gedung super-tall pertama yang sepenuhnya dirancang konsultan Indonesia.
Bidang keahliannya adalah perancangan gedung tinggi tahan gempa termasuk sistem isolasi dasar.
Ia telah menulis banyak makalah termasuk yang dipresentasikan dalam forum internasional seperti Council on Tall Building and Urban Habitat.

Trend Pembangunan di Berbagai Kota

Compact CBD
Revival of Old City / Business District
Taller Building & Deeper Basement

Mixed-Use and Complex Development
Sustainable Development
Economically Viable Investment

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What is a tall building?

- Height Relative to Context
- Proportion
- Embracing Technologies Relevant to Tall Buildings

Structural design of a tall building is dictated by the stiffness requirement rather than strength

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Tall Building: more than 50 meters
Super-tall Building: more than 300 meters
Mega-tall Building: more than 600 meters

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KULIAH TAMU ITB

Developments of Tall Buildings are due to:
- *economic growth*
- *human ego to build higher*
- *the natural response to dense population*
- *scarcity of land in urban areas*
- *high land costs*
- *technological advancements*

OUTLINE

- *Sejarah Arsitektur dan Struktur*
- *Kemajuan Teknologi Gedung Tinggi*
- *Pengaruh Gempa*
- *Pengaruh Angin*
- *Konfigurasi Arsitektur & Struktur*
- *Kolaborasi Arsitek dengan Enjinir*

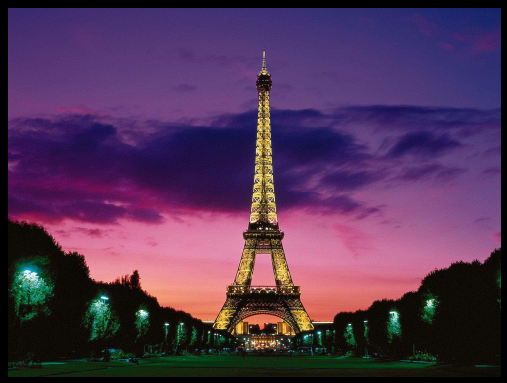
History Of Architecture and Structure

2500 BC: Use of lime & gypsum mortar for binding agent

Il Torrazzo in Cremona – 112 meters:
The tallest medieval brick structure

Engineering makes creative and efficient use of structural elements and materials to build tall buildings

World's tallest structure in the time of Industrial Revolution



324 meters tall use of wrought iron,
a new construction material at the time

The tallest building in the world: 828 M, top floor L 152 @ 584.5 M

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Masa lalu : Pembangunan dibatasi oleh ketersediaan material, pengetahuan konstruksi dan ketersediaan tenaga terampil

Masa kini : Pembangunan dibatasi oleh ketersediaan lahan, peraturan, nilai komersial dan imajinasi perancang tanpa batas wilayah

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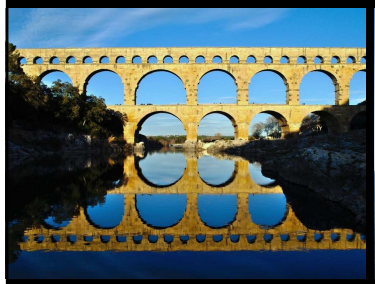
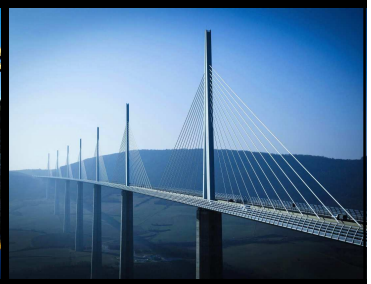
Structural design must be based on knowledge of the structural performance of different materials and geometries





Engineering has been an aspect of life
Since the beginning of human existance

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Seminar dan Pameran HAKI 2016

EVOLUSI GEDUNG TINGGI

- **Kemajuan Bahan Bangunan**
- **Kemajuan Ilmu Pengetahuan**
- **Market Driven (Keperluan Komersial)**

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Greek Era: Post and Lintel

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Roman Era: Arch Structure

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Medieval Architecture - Romanesque Era

Romanesque is characterized by a use of round or slightly pointed arches, barrel vaults, and cruciform piers supporting vaults.

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ESSENSI STRUKTUR ERA ROMANESQUE

- Menggunakan busur dan kubah
- Struktur di ekspos, tampil dengan jelas
- Segi elemen bangunan diperhatikan
- Elemen-elemen struktur tidak dapat menahan gaya tarik

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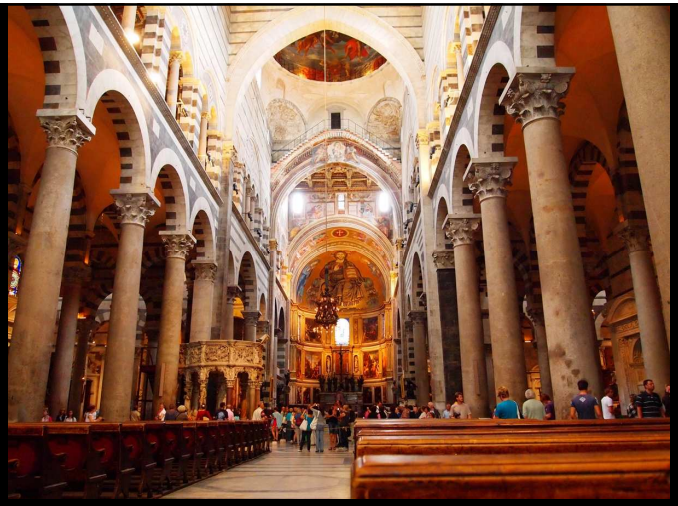

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Medieval Architecture - Gothic Era

Features almost skeletal stone structures with great expanses of glass, pared-down wall surfaces supported by external flying buttresses.

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SISTEM STRUKTUR ERA GOTHIC

- Pemakaian busur runcing
- Pembedaan struktur pilar pendukung dengan dinding penutup non struktural
- Pembedaan rusuk pendukung vault dengan panel perantara
- Pemakaian flying butress
- Bukaan jendela yang besar

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DAVYSU
Structural Engineers

AH TAMU ITB

ESSENSI STRUKTUR ERA GOTHIC

- Ekonomis dan Elegan
- Bentang tengah tinggi
- Elemen-elemen struktur diekspresikan secara arsitektur dan menghasilkan bangunan-bangunan elegan yang menjulang tinggi
- Keseluruhan sistem adalah jalinan sub-sistem dimana elemen-elemennya hanya dapat menahan gaya tekan

INDUSTRIAL REVOLUTION

The biggest impact of the Industrial Revolution on 19th C. architecture was the mass-production of iron and later steel in quantities where it became an economically plausible building material

THE STRUCTURES OF INDUSTRIAL REVOLUTION

The Ironbridge at Coalbrookdale
1779

Crystal Palace
Great Exhibition 1851

Kemajuan Bahan Bangunan (I)

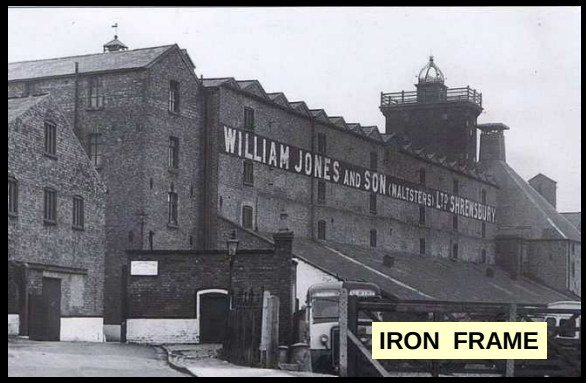
- **Masonry Structure**
- **Iron Frame**
- **Cage Construction**
  - Rangka dalam dari kolom besi tuang dan balok besi tempa
  - Dinding Masonry dengan perkuatannya sebagai sistem lateral

Kemajuan Bahan Bangunan (II)

- **Structural Material**
- **Cladding System**
- **Fire-Proofing Material**
- **Sistem Transportasi Gedung**
- **Mechanical & Service Systems: HVAC / Plumbing, Fire Protection**

MASONRY STRUCTURE

Flaxmill Maltings in Ditherington, Shrewsbury, UK (1797).
The first iron-framed building in the world



IRON FRAME

CAGE CONSTRUCTION

17-story – completed in 1891
- The tallest load-bearing brick building
- Used the first portal system of wind bracing in USA
- Masonry walls braced with interior frame
- Use cast and wrought iron

MONADNOCK BUILDING CHICAGO

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HAUGHWOUT BUILDING

World's first elevator by Otis
Speed 12 mpm
Completed 1857
5-story
24 metres

Shanghai Tower: Mitsubishi Electric 1230 mpm

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Home Insurance Building

12-story 54.9 metres
Modern structural frame

It was completed in 1885 in Chicago, and was the first tall building to use structural steel in its frame.
Architect: William Le Baron Jenney

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FLATIRON BUILDING

22-story steel frame
Completed in 1902

A triangular 22-story steel-framed building
Considered to be a groundbreaking skyscraper.

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ESSENSI STRUKTUR ERA MODERN

- Seluruh kekuatan struktur terhadap gaya gravitasi dan lateral ditahan kerangka struktur
- Penutup gedung hanya sebagai elemen arsitektur saja
- Untuk menahan gaya lateral dan memberi kekakuan digunakan sistem penahan lateral

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WOOLWORTH BUILDING

WOOLWORTH BUILDING
60-Story – 242 metres
Completed in 1912

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CHRYSLER BUILDING

77-story – 318.9 m Year 1930

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EMPIRE STATE BUILDING
102 LANTAI – 385 m

Tahun 1931

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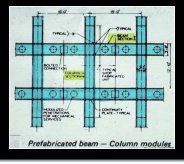
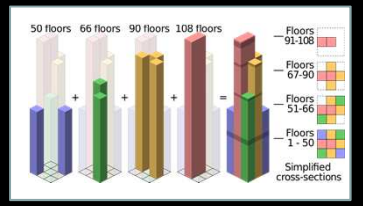
SEARS TOWER / WILLIS BUILDING

108-STORY 442.1 METRES
COMPLETED IN 1973
BUNDLED TUBE SYSTEM





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Petronas Tower
88-story – 451.9 M
Completed 1996

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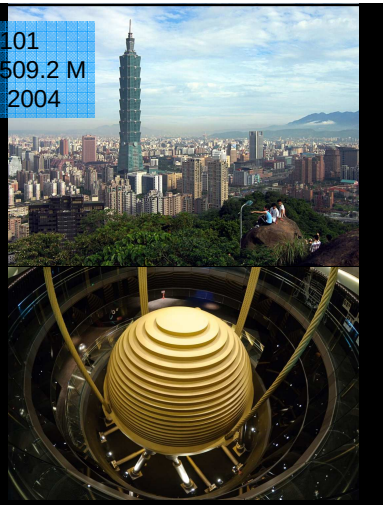
TAIPEI 101
101-story – 509.2 M
Completed 2004



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BURJ KHALIFA
154-story 828 M
Completed 2009

- *Advances in Structural System*
- *Better Knowledges and Codes*
- *Computer Analysis*
- *Sophisticated Wind Tunnel Study*
- *New Materials*

Jeddah Tower
165-story 1000 M
u.c 2020

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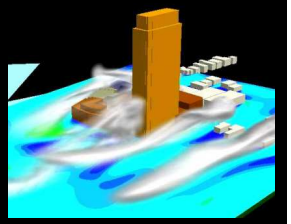
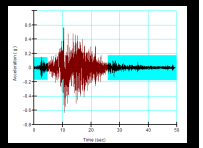
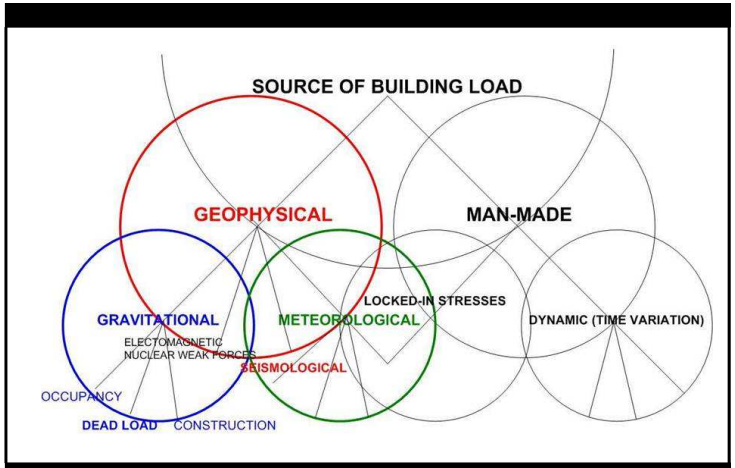
EVOLUTION OF STRUCTURAL SYSTEM APPROACH BUILDING DESIGN CRITERIA



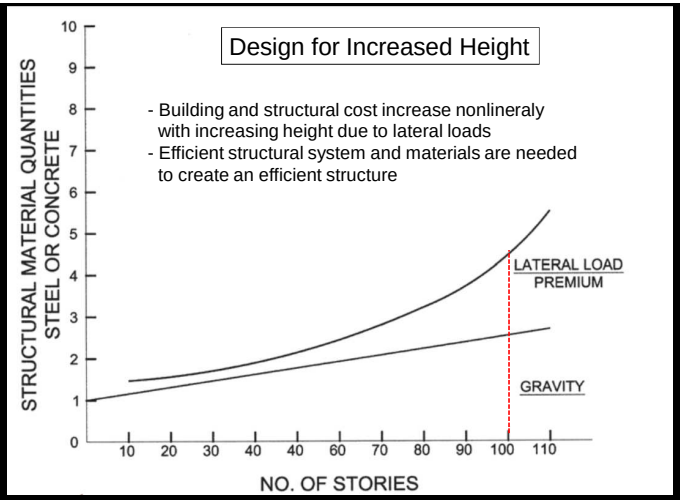
- *Low-rise Building: Strength Design*
  Gravity Load Control / f(H^2)
- *Tall Building: Static Stiffness Design*
  Lateral Load Control / f(H^3)
- *Mega-tall Building: Dynamic Stiffness Design*
  Wind-induced Building Motion Control

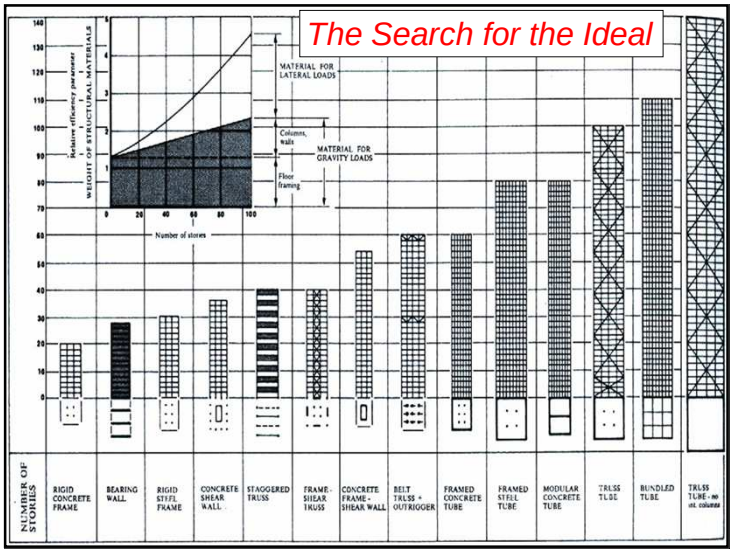


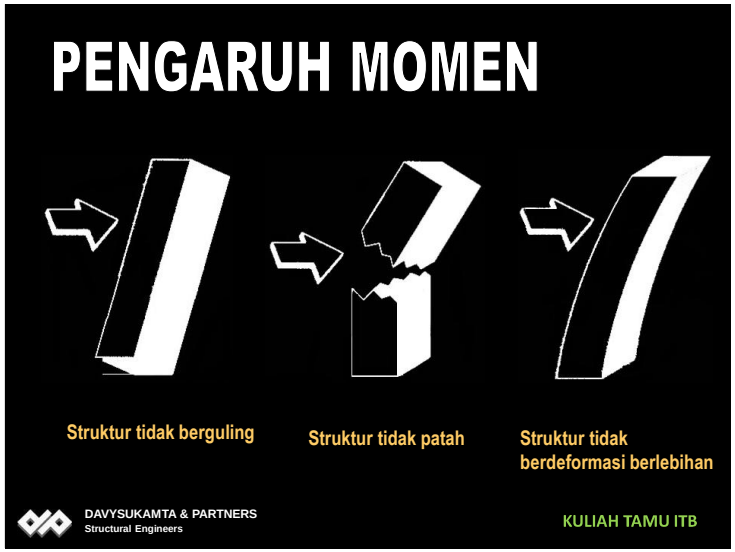


Kekakuan gedung (stiffness) harus cukup karena:

- Stabilitas Struktur
- Architectural Integrity
- Occupant Comfort




The Search for the Ideal
MATERIAL FOR LATERAL LOADS
MATERIAL FOR GRAVITY LOADS
Columns, walls
Floor framing
Number of stories
WEIGHT OF STRUCTURAL MATERIALS
NUMBER OF STORIES
RIGID CONCRETE FRAME
BEARING WALL
RIGID STEEL FRAME
CONCRETE SHEAR WALL
STAGGERED TRUSS
FRAME-SHEAR TRUSS
CONCRETE FRAME-SHEAR WALL
BELT TRUSS + OUTRIGGER
FRAMED CONCRETE TUBE
FRAMED STEEL TUBE
MODULAR CONCRETE TUBE
TRUSS TUBE
BUNDLED TUBE
TRUSS TUBE - no int. columns


PENGARUH MOMEN
Struktur tidak berguling
Struktur tidak patah
Struktur tidak berdeformasi berlebihan
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PENGARUH GAYA GESER
Struktur tidak bergeser
Struktur tidak patah
Struktur tidak berdeformasi berlebihan
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Kekakuan lentur
Material di sisi paling luar
Kekakuan geser
Dinding beton atau mega bracing system
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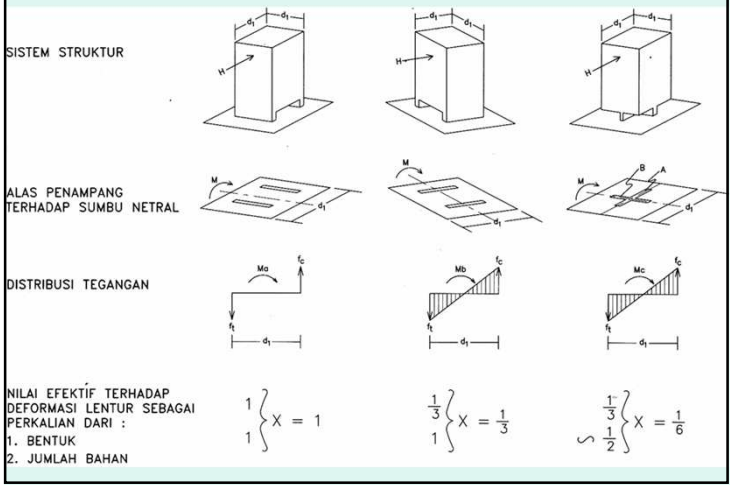
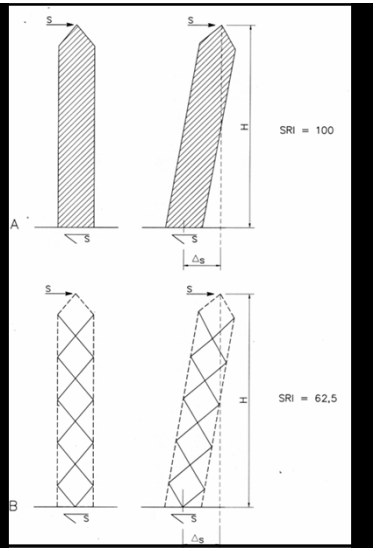
Efektivitas relatif sistem struktur terhadap deformasi lentur



Efektivitas relatif sistem struktur terhadap deformasi geser



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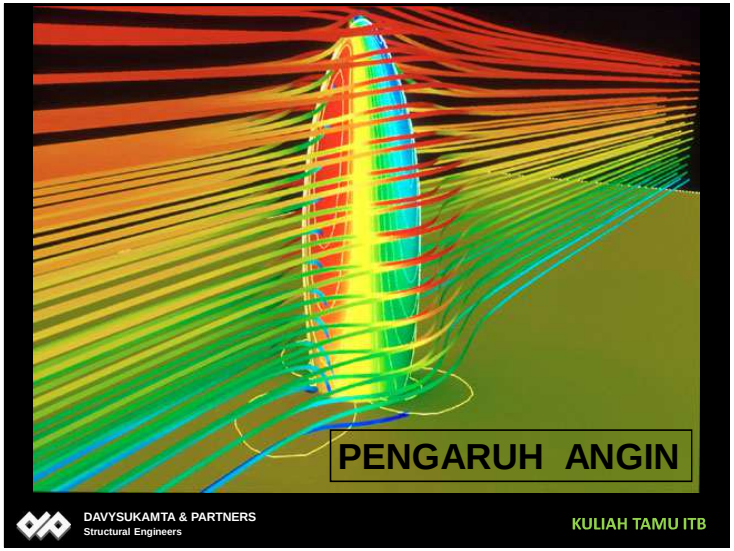
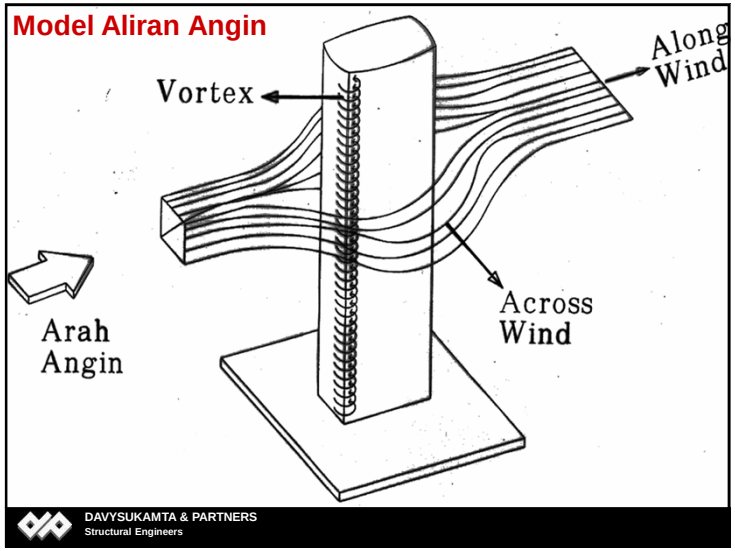


Model Aliran Angin




“Menara Kayu”
John Hancock
BOSTON
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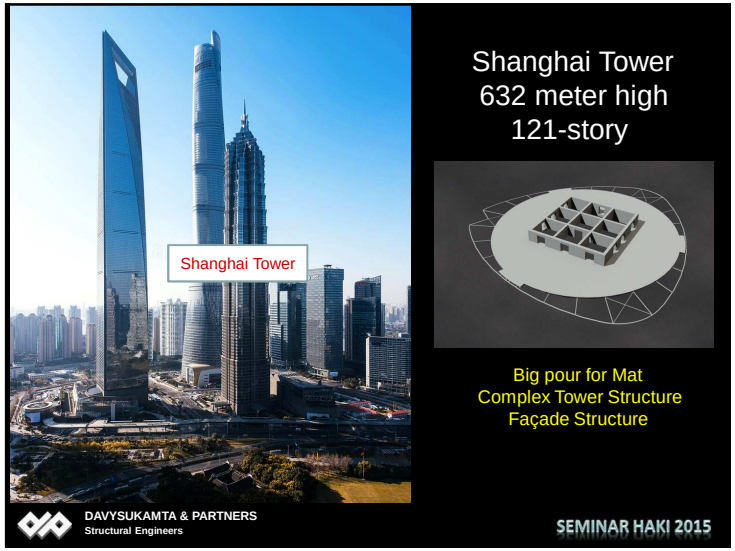
Shanghai Tower
Shanghai Tower
632 meter high
121-story
Big pour for Mat
Complex Tower Structure
Façade Structure
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SEMINAR HAKI 2015


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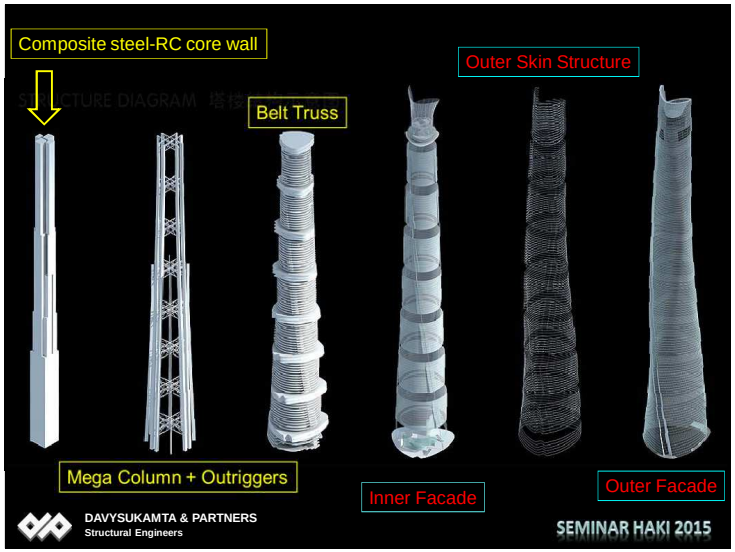
Composite steel-RC core wall
Belt Truss
Outer Skin Structure
Mega Column + Outriggers
Inner Facade
Outer Facade
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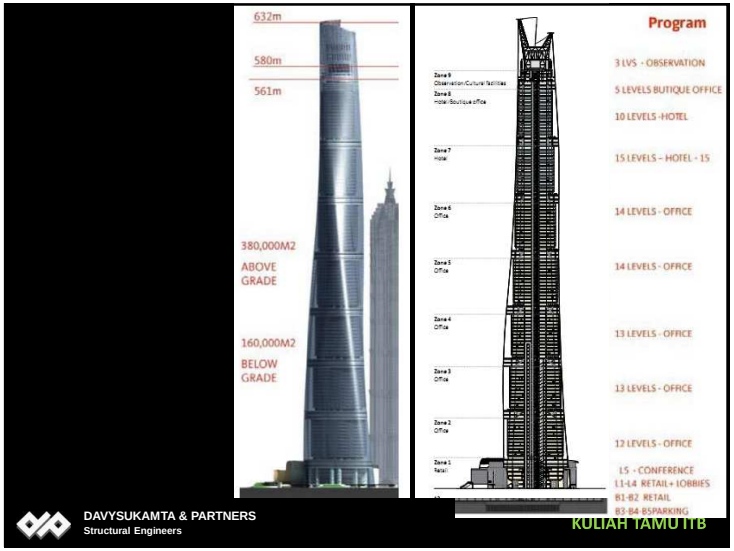

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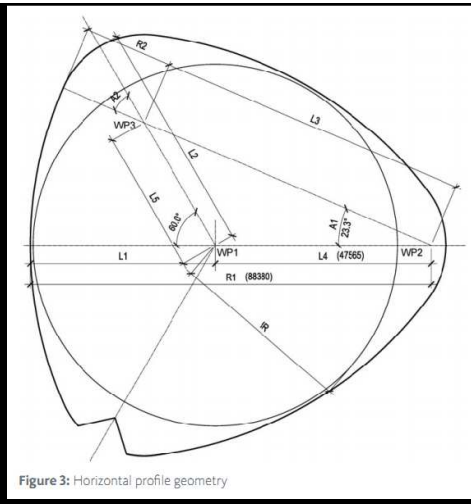

Figure 3: Horizontal profile geometry

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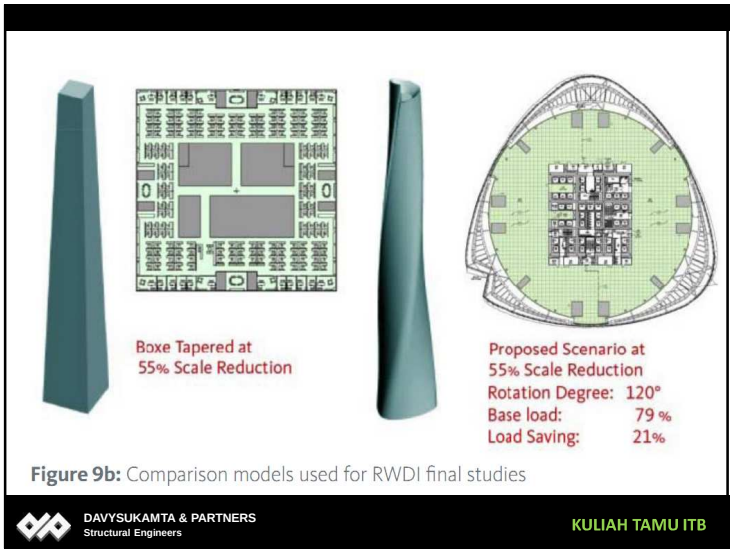

Figure 9b: Comparison models used for RWDI final studies

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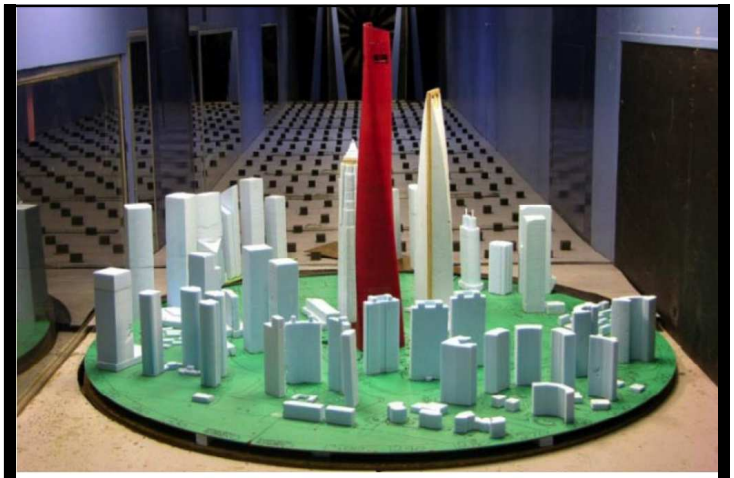

Figure 5: Wind tunnel study model, 1:500 scale

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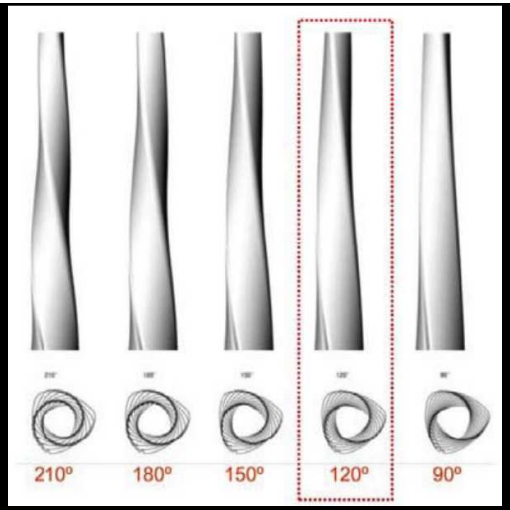

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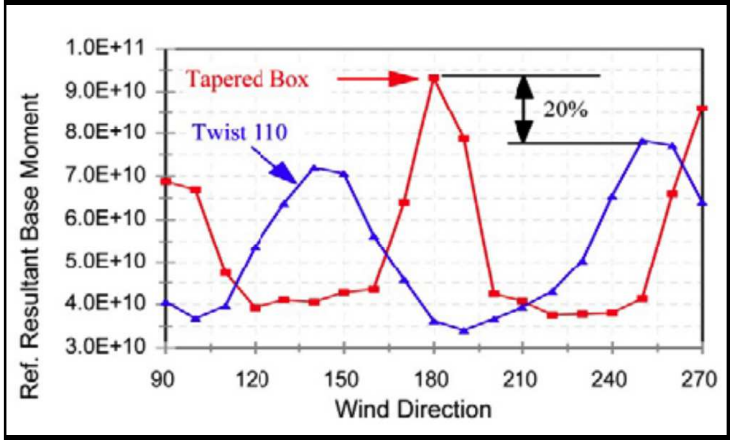

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Configuration	My (N-m)	Ratio	Mx (N-m)	Ratio	Ref.Resultant	Ratio
Base (Tapered Box)	5.45E+10	100%	4.98E+10	100%	6.22E+10	100%
100° (107°)	4.53E+10	83%	4.19E+10	84%	5.18E+10	83%
110° (118°)	3.97E+10	73%	4.31E+10	87%	4.92E+10	79%
120° (129°)	3.43E+10	63%	4.29E+10	86%	4.75E+10	**76%**
180° (193°)	3.39E+10	62%	3.65E+10	73%	4.18E+10	67%

Total Construction Cost 9.0 billion RMB
Structure 24% - 288m USD
5% load reduction = 70 m RMB = 10 million USD

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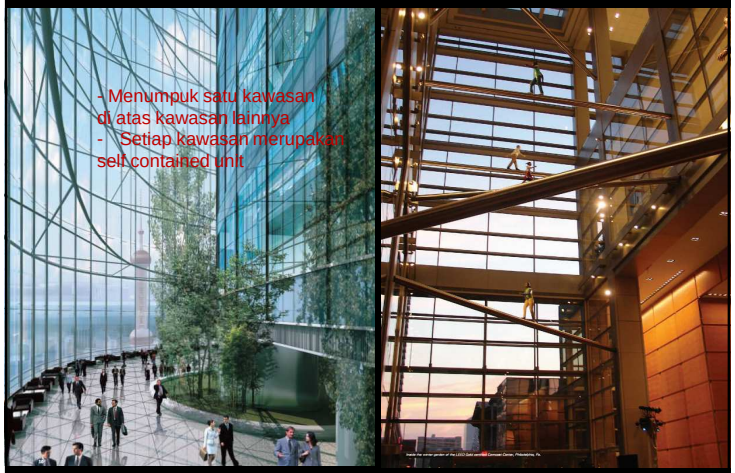

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INTERNATIONAL RUBBER CONFERENCE 2009

Ground floor column failure

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INTERNATIONAL RUBBER CONFERENCE 2009

The Seven Wonders of the Ancient World
Great Pyramid of Giza,
Hanging Gardens of Babylon,
Temple of Artemis,
Statue of Zeus at Olympia,
Mausoleum at Halicarnassus,
Colossus of Rhodes,
Lighthouse of Alexandria

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Structural engineer cannot make a poor structural form behave satisfactory in an earthquake

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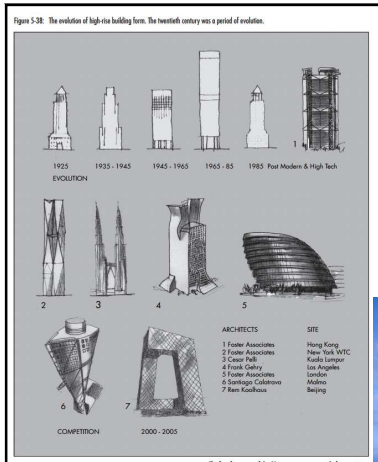
Arsitektur gedung harus memfasilitasi rancangan struktur tahan gempa sebisa-bisanya. Sebaliknya struktur harus dapat mengakomodasi tujuan fungsional dan estetis gedung yang dirancang.

Ada 3 kategori keputusan desain arsitektural yang menentukan kinerja ketahanan gempa suatu gedung

- **Konfigurasi**
- **Detail khusus arsitektur**
- **Komponen non-struktural**

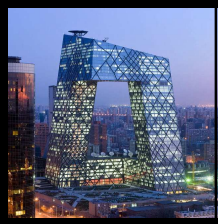
Untuk mencapai gedung tahan gempa yang handal, bentuk gedung harus mempertimbangkan hal-hal sbb:

- **Sederhana dan simetris**
- **Bentuk tidak terlalu memanjang**
- **Bentuk teratur**
- **Seragam dan kontinu dalam kekuatan**
- **Distribusi beban merata**



FEMA 454
Designing for Earthquakes

In general, today's high-rise buildings remain vertical, and have direct load paths, and their exterior walls are reasonably planar. Some high-rise towers have achieved a modest non-verticality by the use of nonstructural components. A more recent development is that of the "torqued" tower, as in the Freedom Tower at the World Trade Center and Santiago Calatrava's "Turning Torso" tower in Malmo, Sweden, shown in Figure 5-38. For very tall buildings, it is claimed that these twisted forms play a role in reducing wind forces, besides their visual appeal, but their forms are not of significance seismically.



Structural Forms

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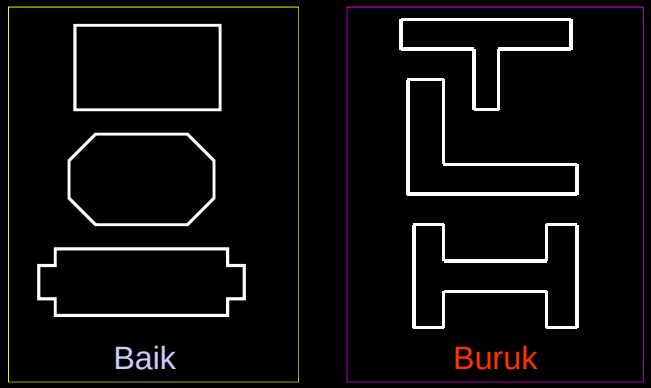
Sederhana dan Simetris



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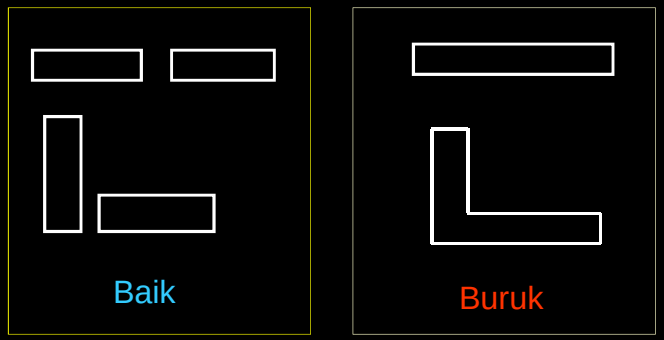
Bentuk tidak terlalu memanjang



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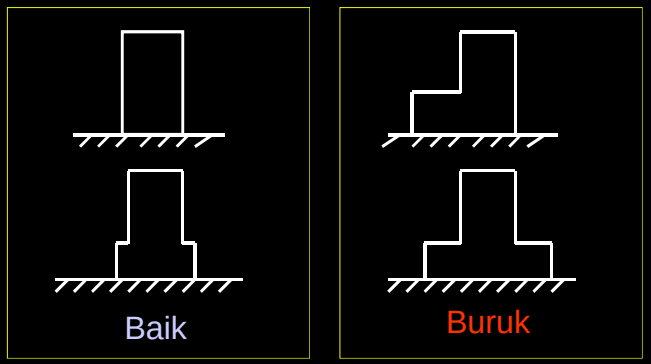
Keseragaman dalam tinggi gedung



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SEISMIC GUIDELINE ON CONFIGURATION IRREGULARITY

1. Stress Concentration
RE-ENTRANT CORNER

Source FEMA 454: Designing for Earthquakes: A Manual for Architects

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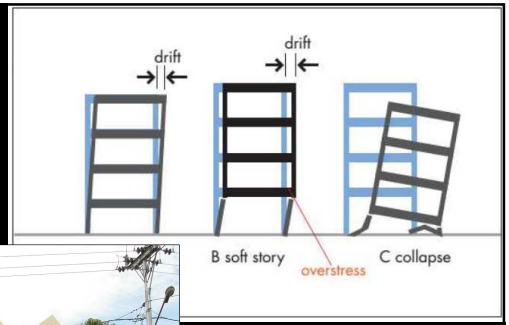
Source FEMA 454



1. Stress Concentration
RTICAL IRREGULARITY:
Soft story effect

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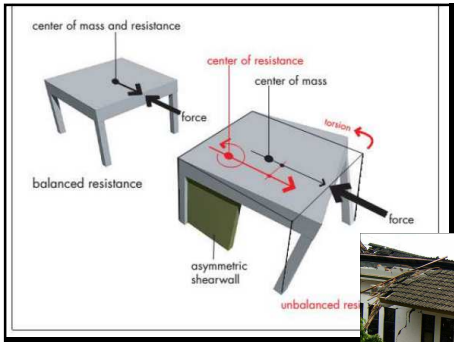

Source FEMA 454

2. Torsion:
Lack of symmetry

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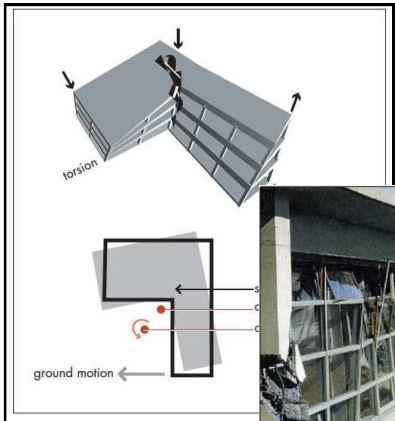

Source FEMA 454

2. Torsion:
Re-entrant Corner p

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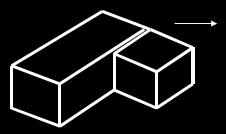
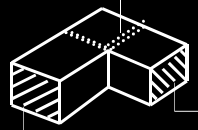
Solusi terhadap masalah Re-Entrant Corner

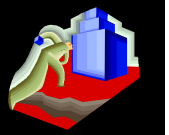


Pisahkan gedung

Collector frames / walls



Perkaku end-bay



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Traditional house in Mentawai island with base isolation system

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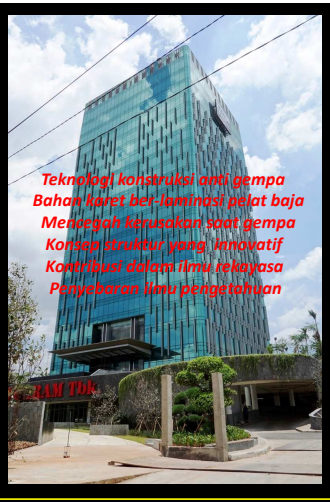

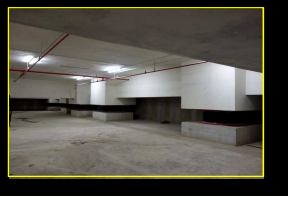

Base Isolation System untuk Gudang Garam Tower

Performance of Seismically Isolated Buildings in Tohoku Area

No structural damage in seismically isolated building

Base-isolated apartment in Sendai City

Does it work??

Structural damage in fixed-base building

Shear cracks on the wall

Fixed-base apartment in Sendai City

No damage or turn over of furniture inside room

Inside of a seismically isolated fire station

Inside of a seismically isolated apartment

Heavy damage inside room

Fixed-base office building in Sendai City

BRIDGESTONE
Your Journey, Our Passion

Modern Tall Buildings

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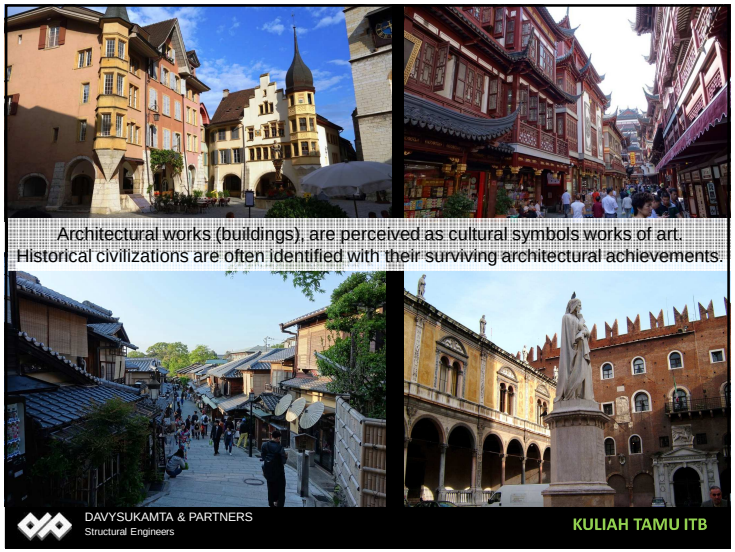
Architectural works (buildings), are perceived as cultural symbols works of art.
Historical civilizations are often identified with their surviving architectural achievements.
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Truning Torso
Infinity Tower Dubai
Evolution Tower Moscow
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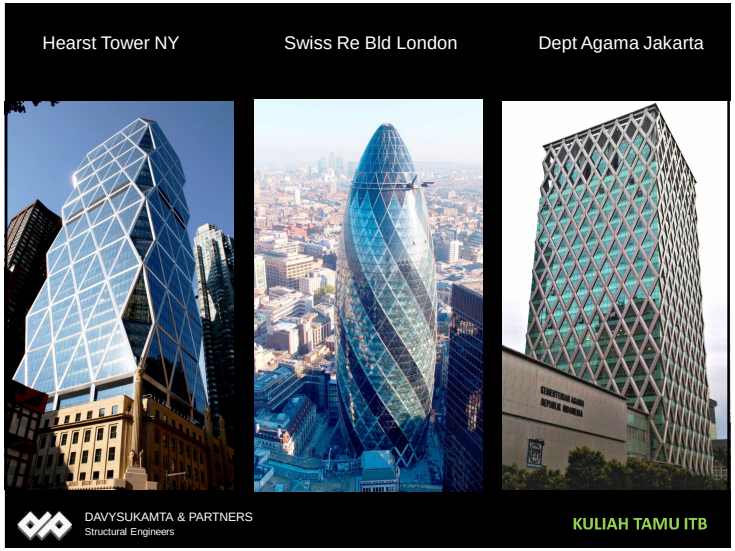
Hearst Tower NY
Swiss Re Bld London
Dept Agama Jakarta
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Architects want to create something for their legacy

Turning Torso Swedia
54-story

SSI Tower Jakarta
40-story

Absolute World Canada
50 & 56-story

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Lalu kita melihat bagaimana kemajuan konstruksi di Indonesia.....

DAVY SUKAMTA & PARTNERS
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Year 2006: Innovation on deep basement construction – Up-Down method
Innovation in deep bored-pile construction with post-grout technique

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Up-Down Construction

for
Deep & Complex Basement
in Dense Urban Space

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Year 2012: Innovation on structural system
RC core-wall & Outriggers designed with PBSD method

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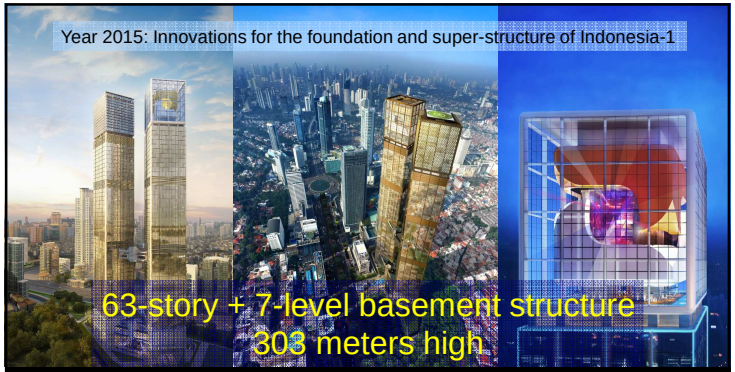
Year 2015: Innovations for the foundation and super-structure of Indonesia-1



63-story + 7-level basement structure
303 meters high

Indonesia-1 is the first development of China Sonangol in Indonesia
Location is in the best premium financial district of Jakarta
The development must offer the highest grade of office space
The two towers fit the purpose

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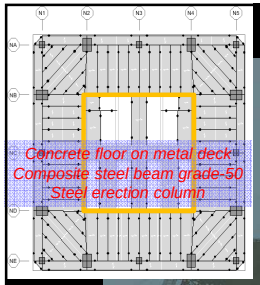

Concrete floor on metal deck
Composite steel beam grade-50
Steel erection column

6 months faster than conventional RC floor system
Reduce the structural weight by 28.5%

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7-level deep basement structure
25 meters excavation depth
08.12.2016
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THE PEAK JAKARTA
8:1 slenderness ratio
Structural Engineers
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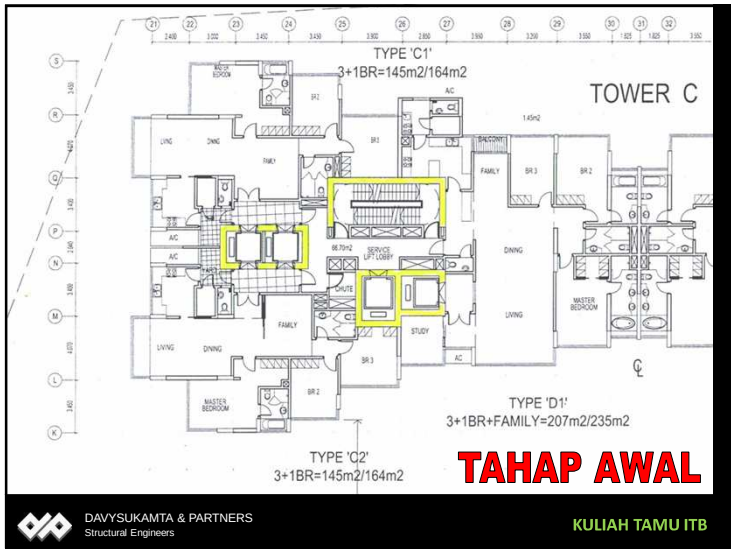
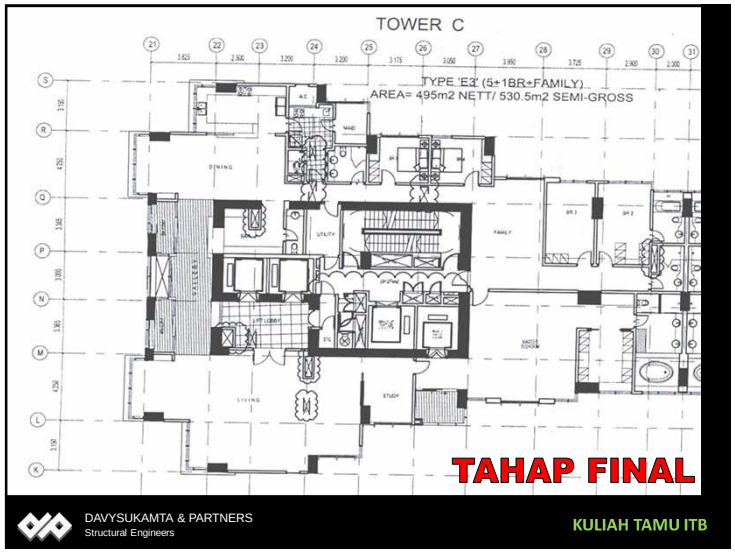

TYPE 'C1'
3+1BR=145m2/164m2
TOWER C
TYPE 'D1'
3+1BR+FAMILY=207m2/235m2
TYPE 'C2'
3+1BR=145m2/164m2
TAHAP AWAL
DAVYSUKAMTA & PARTNERS
Structural Engineers
KULIAH TAMU ITB


TOWER C
TYPE 'E3' (5+1BR+FAMILY)
AREA= 495m2 NETT/ 530.5m2 SEMI-GROSS
TAHAP FINAL
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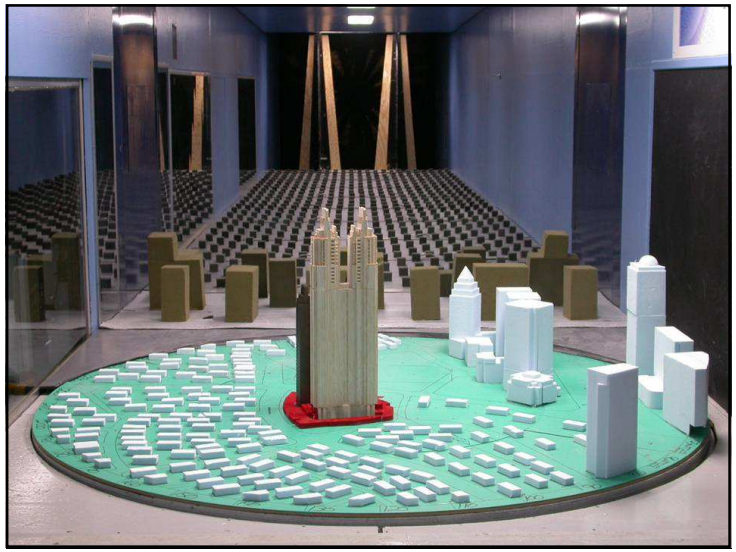


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South Quarter Development

A showpiece of modern architecture incorporating sustainable design, green construction practices and advanced technologies

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The building features rainwater harvesting, double skin facade, HPC, local construction materials, and many other green systems. The structure is a veritable showcase of modern and emerging concrete technology, featuring recycled concrete, use of high dosage flyash and green construction.

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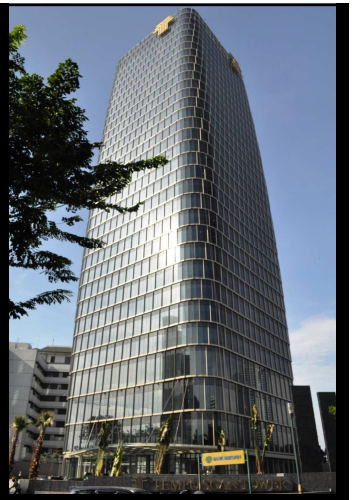
Tempo Scan Tower



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Skycity Convention and Theater Building

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Trusses spanning 17M – 53M, weight varies from 5 tons to 41 tons,
lifted up to the height of around 50 meters.
Heavy-Lifting Method
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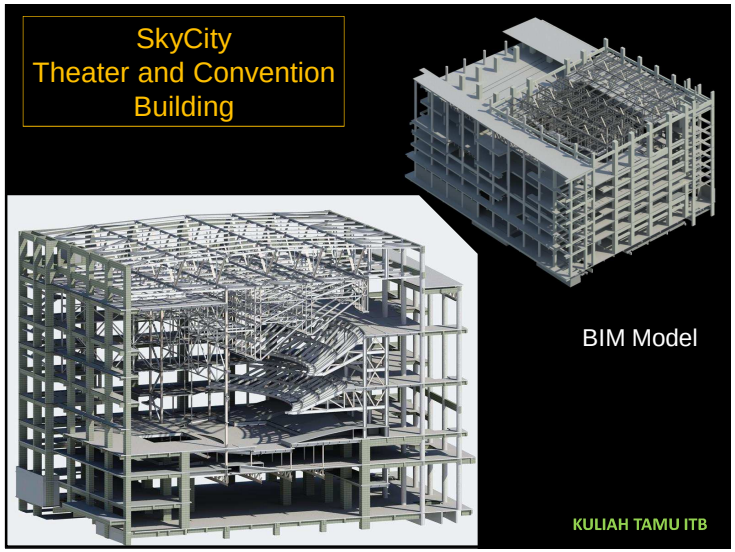
SkyCity
Theater and Convention
Building
BIM Model
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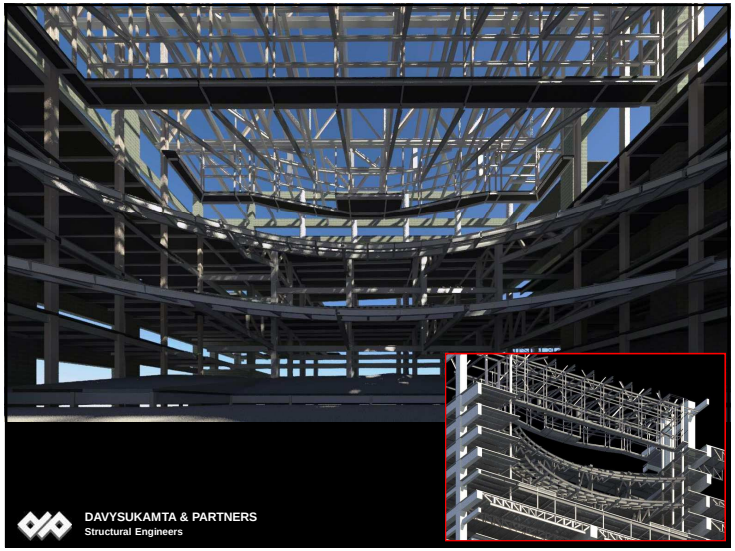
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ICC Tower
The iconic image of the twin “Lighthouses”
on opposite shores of Hongkong harbor
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A Sustainable Paradigm

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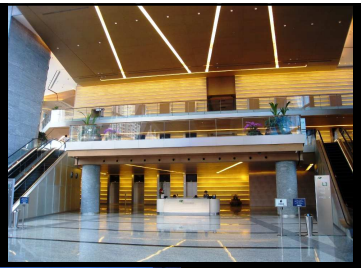

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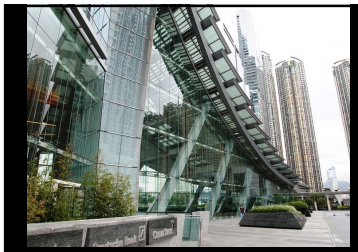

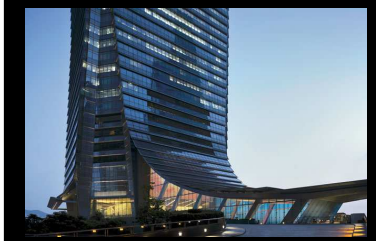

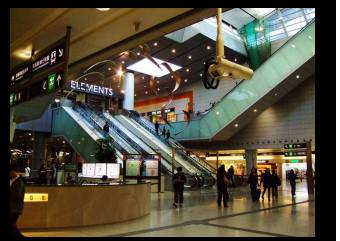

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Bahrain World Trade Center: Harvesting wind energy

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Keterkaitan lanskap, infra-struktur
dan arsitektur
Gedung parkir yang tidak merusak tatanan kota
Atap gedung ditutup rumput seluruhnya
ENTRANCE
DAVYSUKAMTA & PARTNERS
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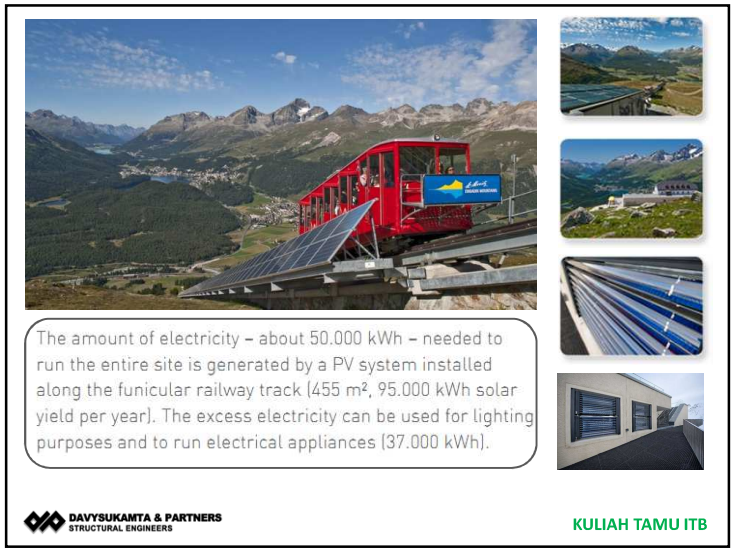
The amount of electricity – about 50.000 kWh – needed to run the entire site is generated by a PV system installed along the funicular railway track (455 m², 95.000 kWh solar yield per year). The excess electricity can be used for lighting purposes and to run electrical appliances (37.000 kWh).
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