

# *Case Study: Taipei 101*

*Arch 631: Structural Systems*  
*Fall 2017*

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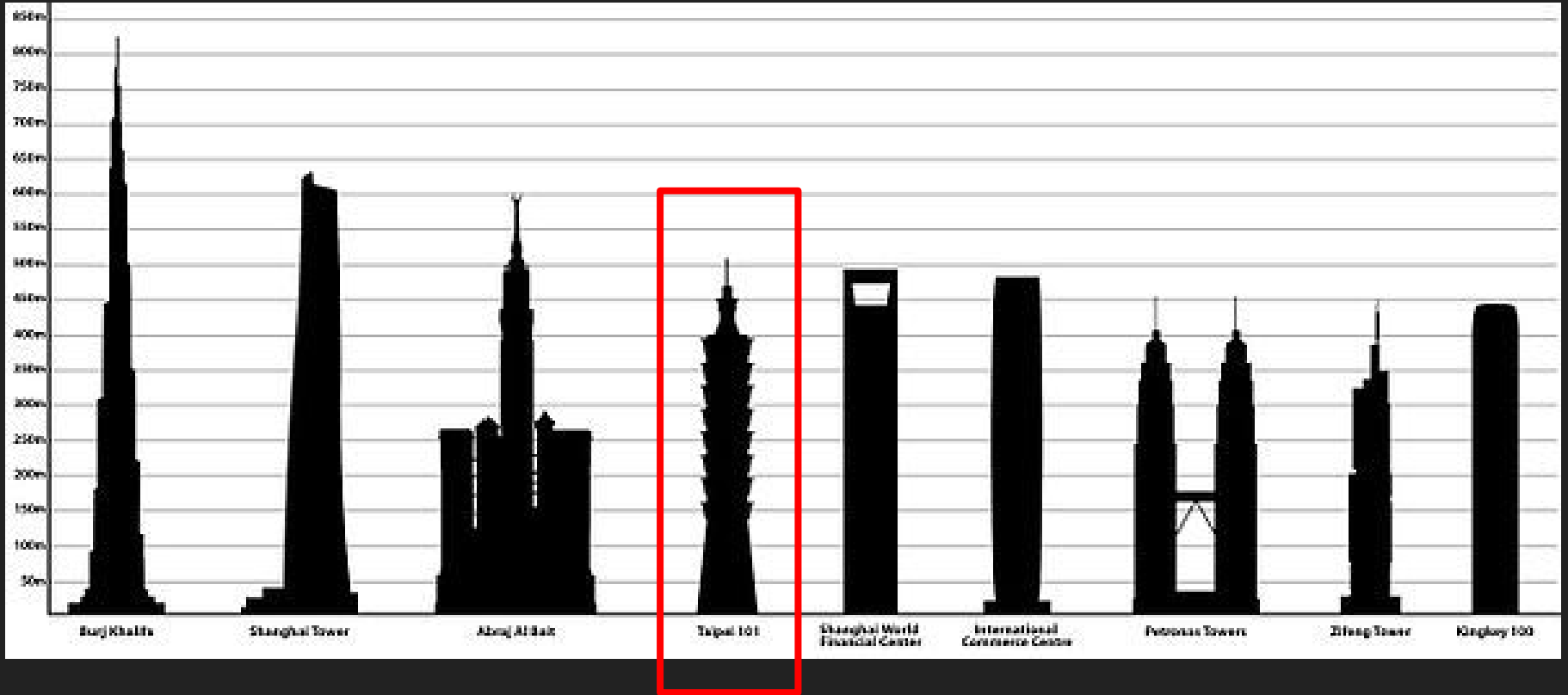
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Jenny Stallones



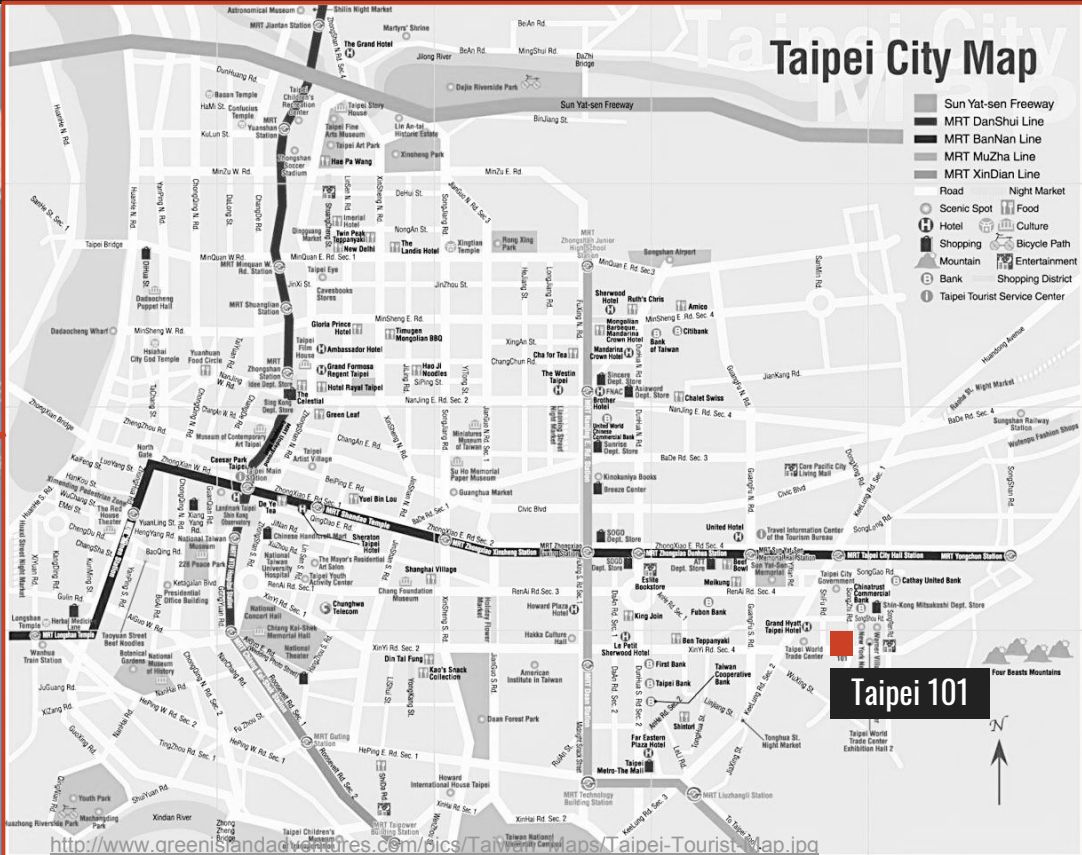
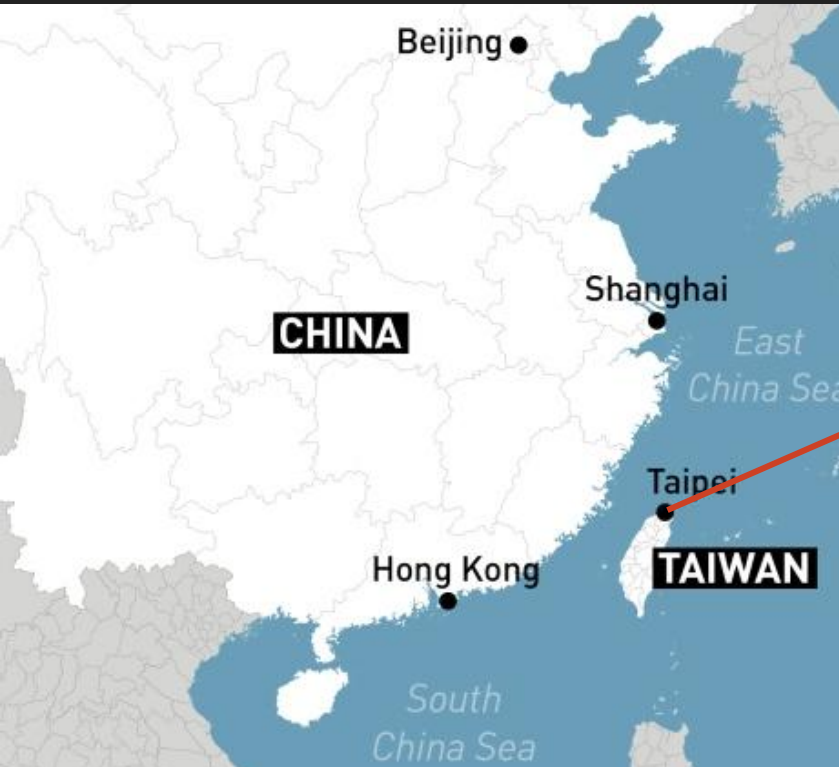
# Introduction

- Taipei 101 has a complex structural system
  - it is needed for the building to withstand its harsh environment and the potential dangers surrounding it.
- Through this case study we have tried to understand
  - the number of unique components of its structure
  - analyze its behavior to natural disaster
  - evaluate its continued ability to serve the occupants within



Tallest building in the world from 2004-2010.

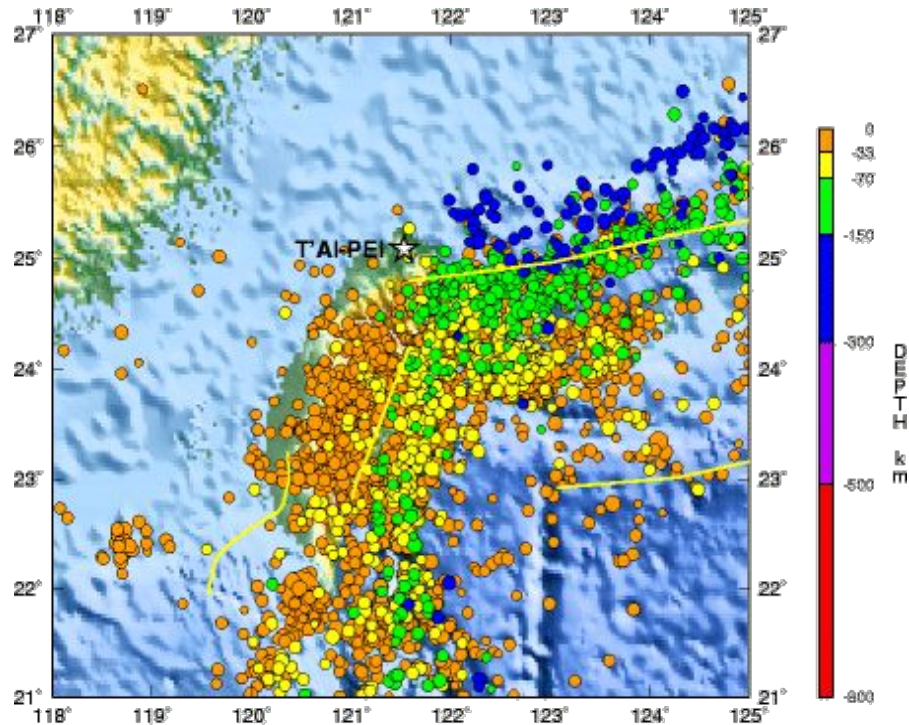
# Building Location



[https://www.bing.com/images/search?view=detailV2&ccid=PFAniks&id=F47968A8E9D4F283F561DF5384D75FCDA7E04E&thid=OIP\\_PFIAniks0QY8UL\\_MO7plfwESDi&mediaurl=https%3a%2f%2f1.cbc.ca%2f1.3884005.14810551081%2ffileImage%2fhttpImage%2fimage.jpg\\_gen%2fderivatives%2foriginal\\_620%2fchina-trump-taiwan-call-real-estate-map.jpg&exph=471&expw=620&q=taipei+location&simid=607986441249948801&selectedIndex=114&](https://www.bing.com/images/search?view=detailV2&ccid=PFAniks&id=F47968A8E9D4F283F561DF5384D75FCDA7E04E&thid=OIP_PFIAniks0QY8UL_MO7plfwESDi&mediaurl=https%3a%2f%2f1.cbc.ca%2f1.3884005.14810551081%2ffileImage%2fhttpImage%2fimage.jpg_gen%2fderivatives%2foriginal_620%2fchina-trump-taiwan-call-real-estate-map.jpg&exph=471&expw=620&q=taipei+location&simid=607986441249948801&selectedIndex=114&)

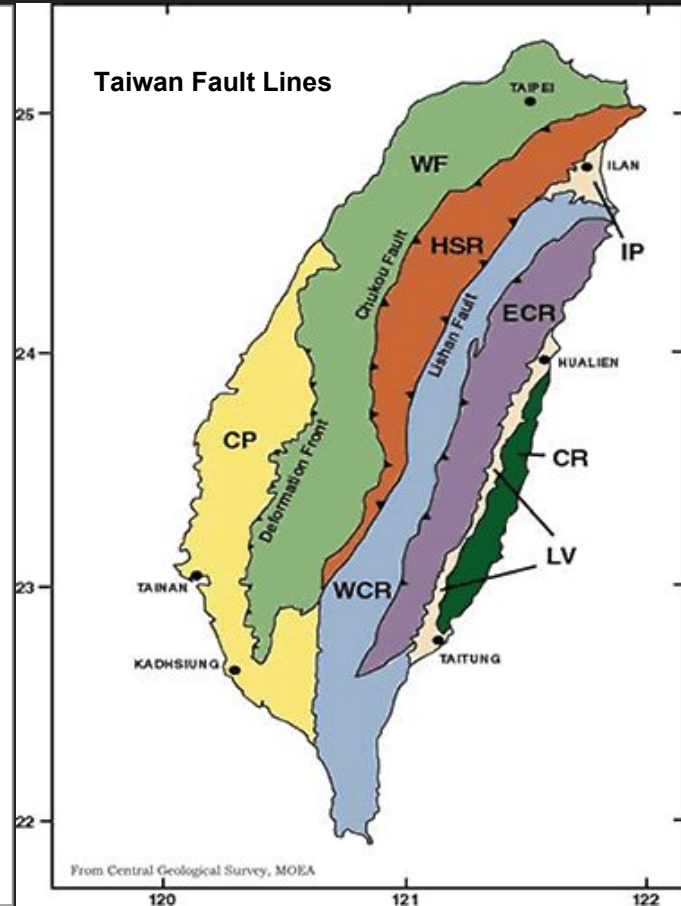
<http://www.greenislandadventures.com/pics/Taiwan/Maps/Taipei-Tourist-Map.jpg>

# Seismic Activities



Seismicity of Taiwan, 1990 - 2006

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<https://watchers.news/data/uploads/2011/05/taiwan.gif>



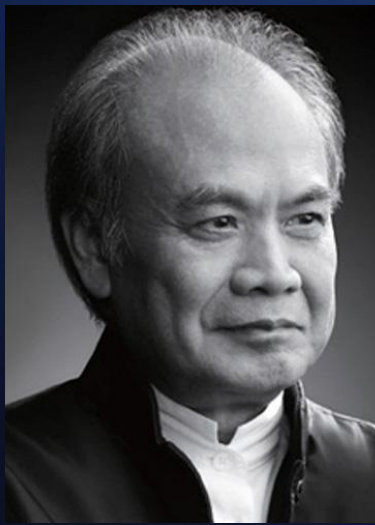
From Central Geological Survey, MOEA



# Overview

Taipei 101 (once known as Taipei World Financial Corporation)

- 1,667 feet (508 meters) from ground to the tip of the spire
- 101 floors above ground & 5 floors underground
- Plan Area - 50m x 50m
- Cost - \$700 million
- Building Use - Office Complex + Mall
- Parking - 83,000 m2, 1800 cars
- Retail - Taipei 101 Mall (77,033 m2)
- Offices - Taiwan Stock Exchange (198,347 m2)
- Construction took 5 years to complete
  - Finished in 2004
  - Cost \$1.8 billion
- Tallest LEED certified building in the world (LEED Platinum)
- Designed to withstand typhoon winds and earthquakes tremors common in the area east of Taiwan
- Designed to withstand gale winds of 134 mph, and the strongest earthquakes in a 2,500-year cycle.
- Designed to be flexible as well as structurally resistant.
- Because of the height of Taipei 101, and the building being located 660 feet away from a major fault line, Taipei 101 used high-performance steel construction and concrete columns.
- Most famously, RWDI designed a 660-tonne steel pendulum that serves as a tuned mass damper.



# Background

Client - Taipei Financial Center Corporation.

## Architect

- C.Y. Lee & Partners -

Founded on the main principle of creating human-centered buildings that are rich in culture and emphasize innovative design.

## Structural Engineer

- Shaw Shieh - Evergreen Consulting Engineering -

One of the largest, engineering consulting companies in Taiwan  
Experienced in wind and seismic activity.

## Structural Consultant

- Thornton - Tomasetti Engineers, New York City -

Designed more than half of the top ten structures in Taiwan  
Recognized for their talents in overcoming special challenges through irregular shaped, high-rise structures



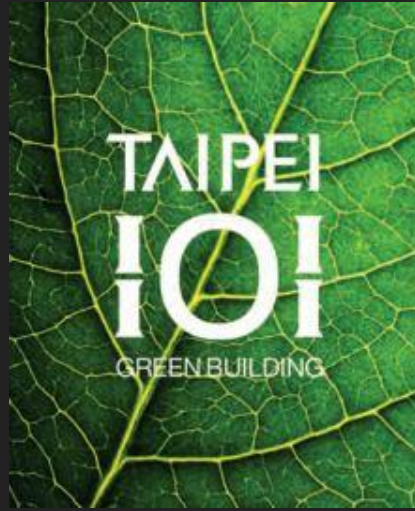
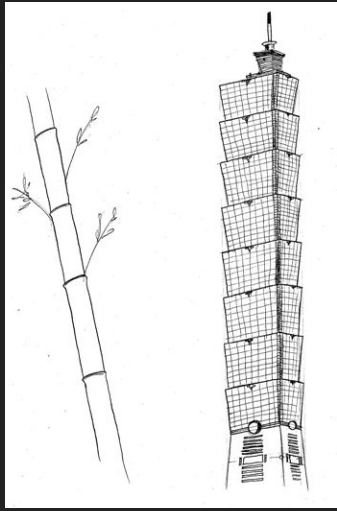
Richard Tomasetti

[http://thornton.s3.amazonaws.com/content\\_images/167/tomasetti.jpg](http://thornton.s3.amazonaws.com/content_images/167/tomasetti.jpg)



# Design Concept

- Pagoda Style
  - Traditional Architecture
  - Ties into Cultural Beliefs
- Bamboo - 8 Segments
  - Everlasting Strength
  - Youth and Longevity
- Icon of Taiwan and Finances
  - Part of Xinyin District
  - Seismically Resistant Area







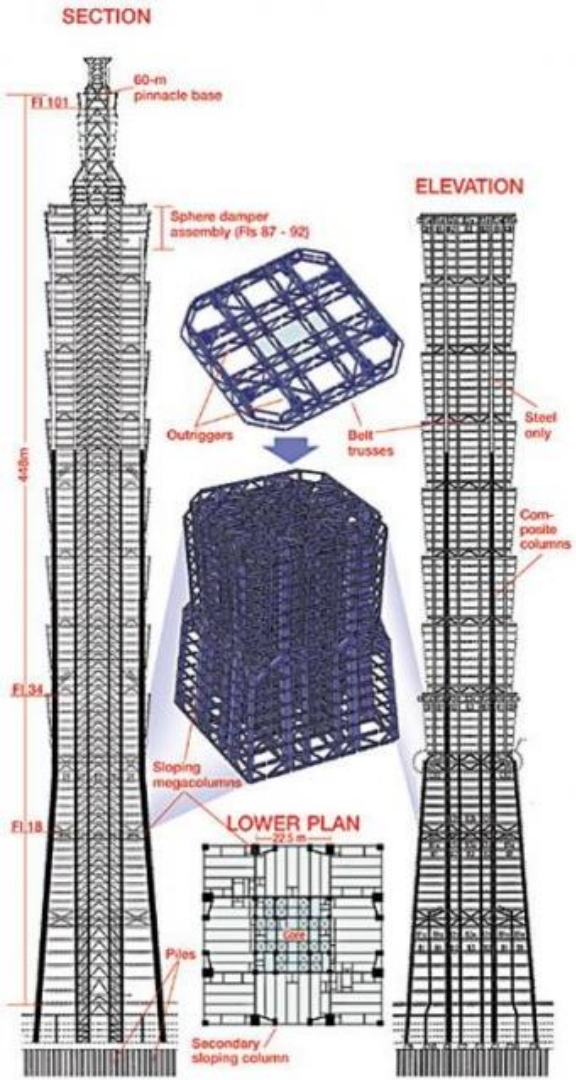
# Structural Features

## Podium

- Retail mall that is home to restaurants, clubs, and hundreds of fashionable stores and attractions.
- The Atrium:
  - the connecting tower
  - twin vierendeel trusses that span the length of the podium.
  - As a lighter mass, its steel structure is not as heavy as the tower, the foundation (piles) are fewer in number and not as deep.
- 6 Stories

## Tower

- 25 story truncated pyramid with an intervening floor taken up by the truss system, and eight stories of smaller segments of eight above.
- There are also exterior curtain panels slope 5 & 7 degrees, resembling a shoot of bamboo, and tying back to the mega-columns
- Facade is able to withstand an impact of up to 7 tonnes.
- Saw-toothed corners greatly reduced crosswind oscillation.
- 101 Stories + 5 Story Basement



# Seismic Design

- Central core
- Trusses and Bracing
- Truncated Pyramid Base
- Flexible but Sturdy Materials
  - 10,000 psi concrete
  - 60 ksi steel
- Mass Damper
- Mini Dampers on Spire



# Building Components & System

## Central Braced Core

- Resists Moments and Gravity Loads

## Large Perimeter Mega-Columns

- Concrete Filled Steel Boxes - Reinforced by Moment Frame

## Outrigger Trusses

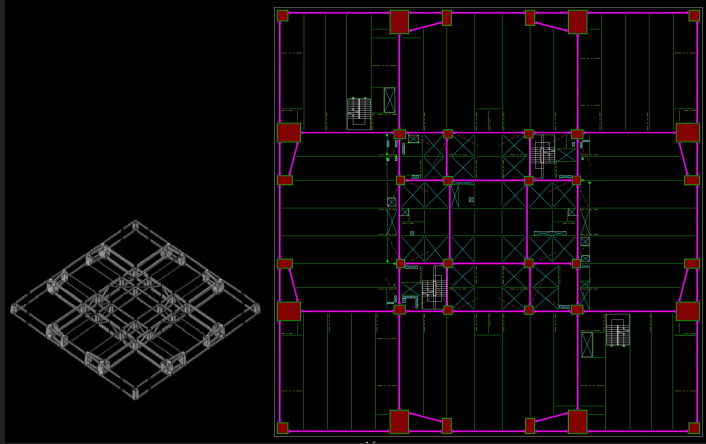
- 8 Segments of 8 Include a Story for Structure

## Diagonals

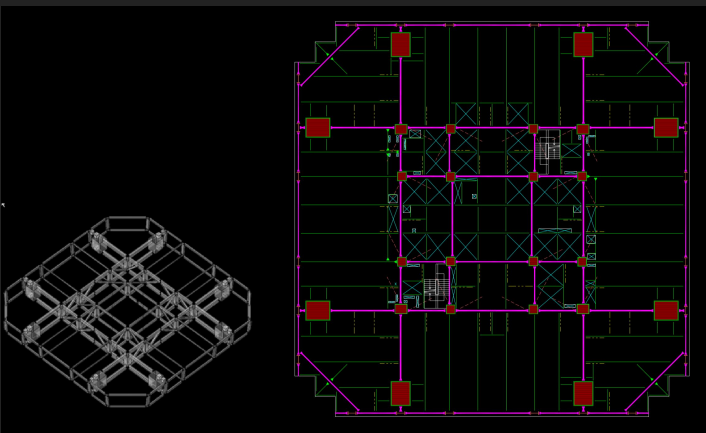
- Through Occupied Space

## Connections

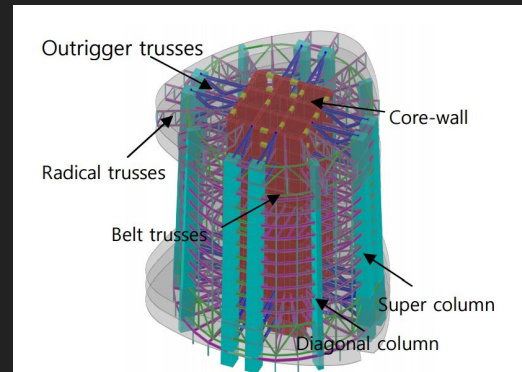
- 5 Different Types



Typical Floor Framing Plan - Lower Stories (1st-26th)



Typical Floor Framing Plan - Upper Stories (27th-91st)



Outrigger Trusses with Central Braced Core

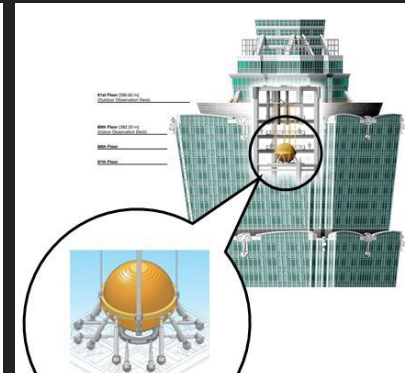
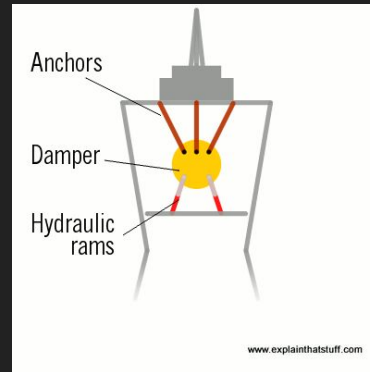
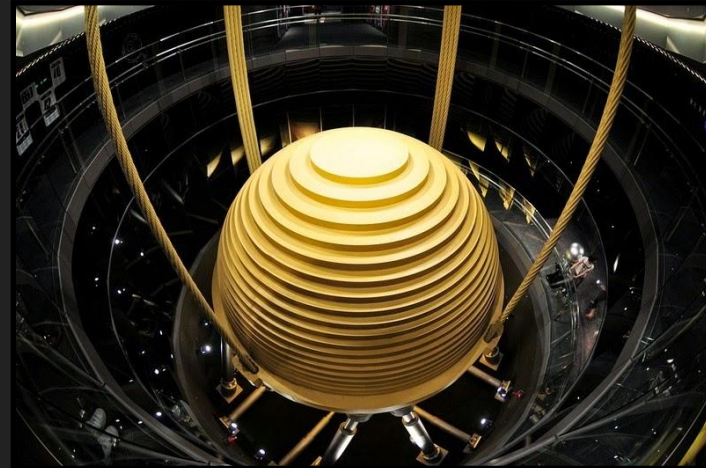
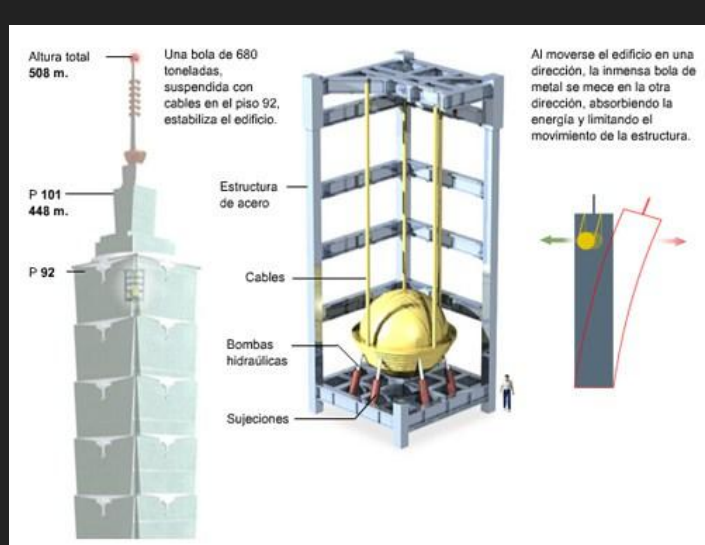
# Building Components & System

## Mass Tuned Damper

- 18' Diameter (Largest in World)
- 728 - ton tuned
- Suspended from the 92nd-87th floor
- Reduces overall building sway by 40%
- \$4 million
- 41 steel plates in varying diameters each 125 mm thick welded together

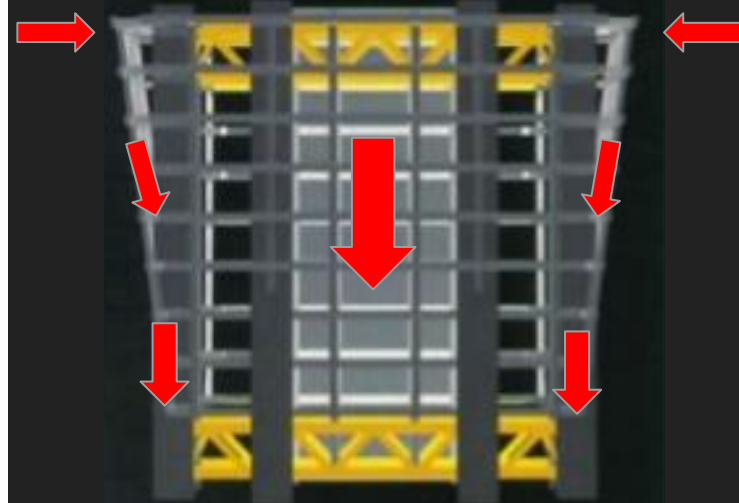
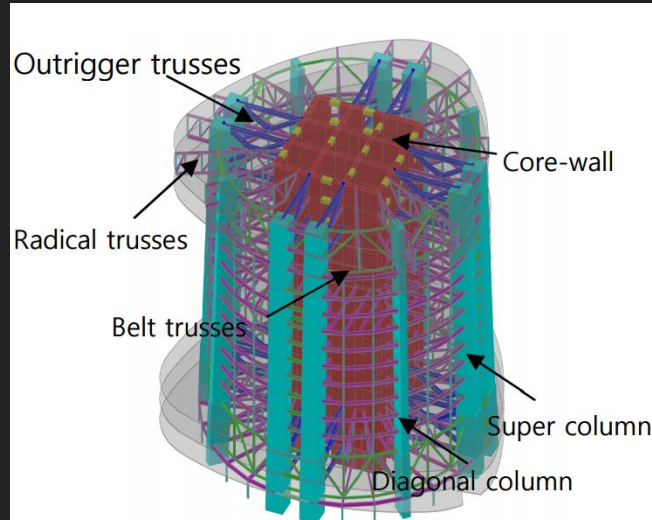
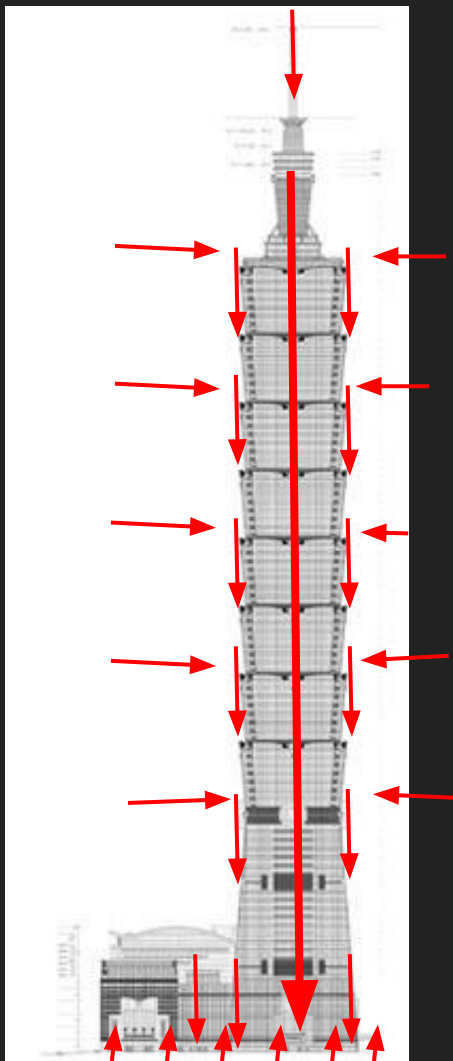
## Spire

- 2 - 7 ton dampers

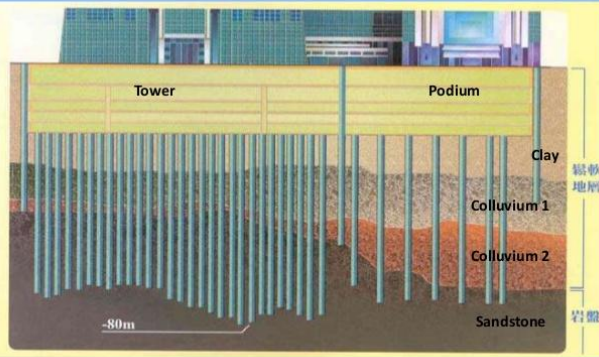


# Load Tracing

- Core adds Stiffness
  - Carries Gravity Loads
- Outrigger Trusses add Lateral Stability - Moment Frame Connections
- Super Columns along Perimeter for Strength
  - Carries Wind Loads

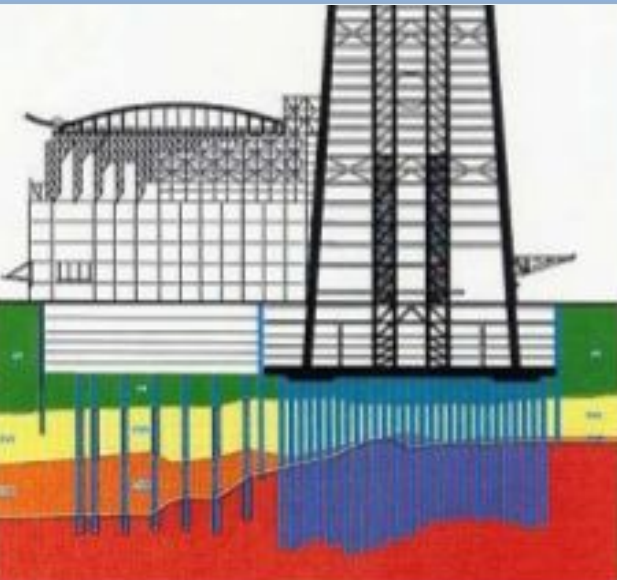


FOUNDATION DEPTH 80 METERS

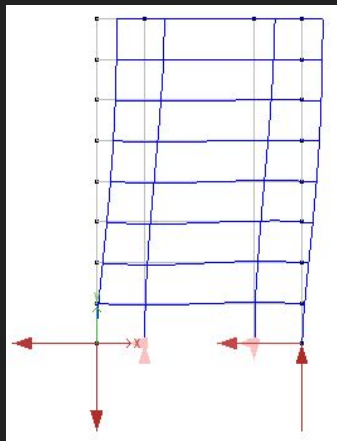
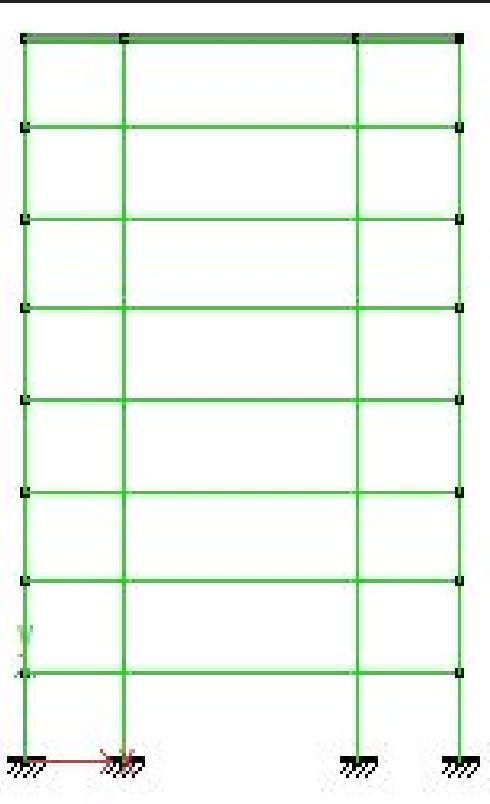


# Foundation & Soil Type

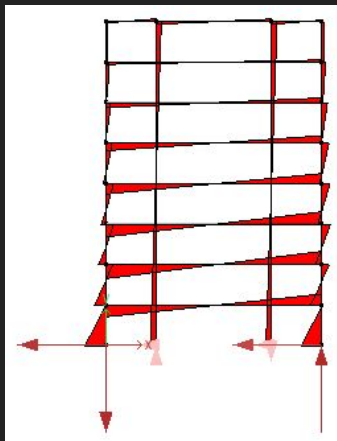
- **660 feet away from a fault line**
- **21m deep basement**
  - **Groundwater usually 2m below the surface**
  - **Soft rock usually 40-50m below colluvial soils and clay**
- **2 Slurry Wall System**
  - **One around both the tower and the podium foundation**
  - **Second around just the tower foundation**
- **Drilled Piers**
  - **Continuous concrete matt transfers point loads**
  - **380 piers driven 262ft into the ground**
  - **5ft in diameter and can withstand 1100-1450 tons each**



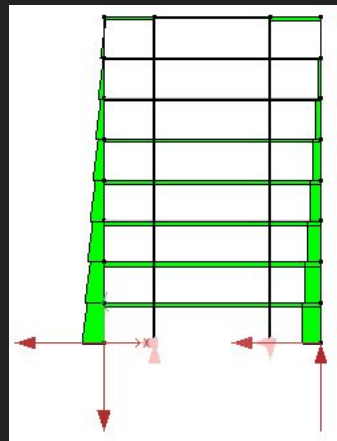
# Multiframe Analysis: Perimeter Columns



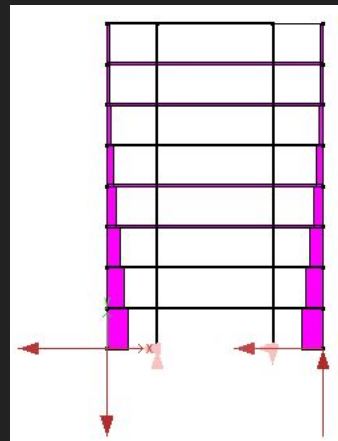
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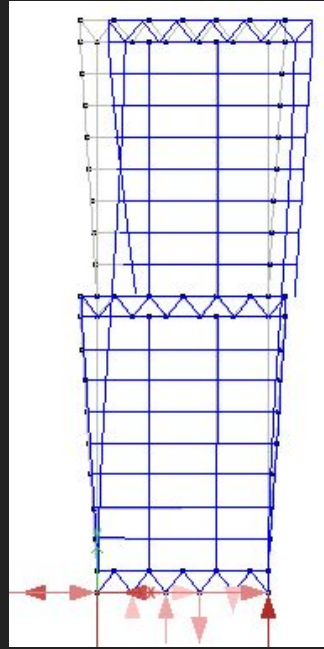
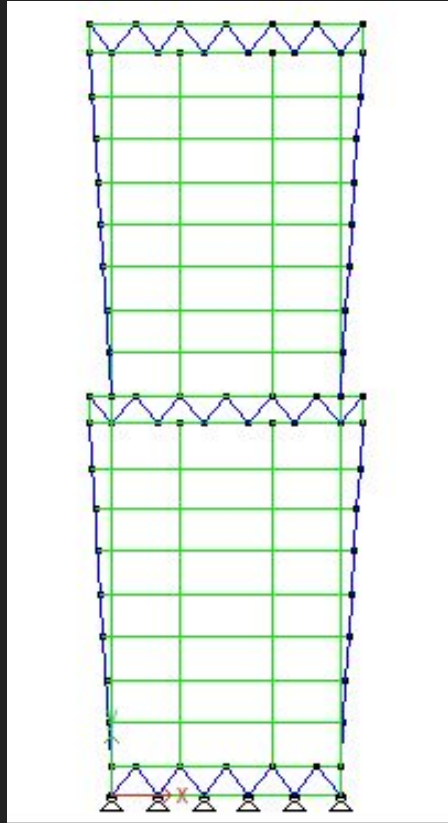


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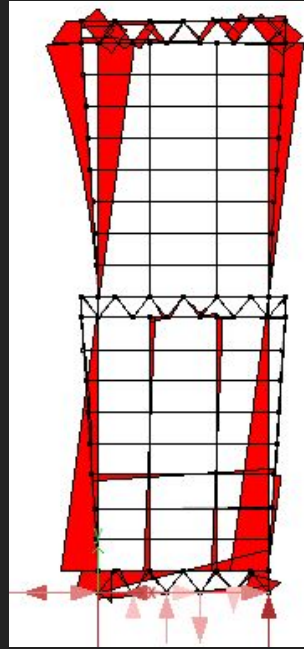


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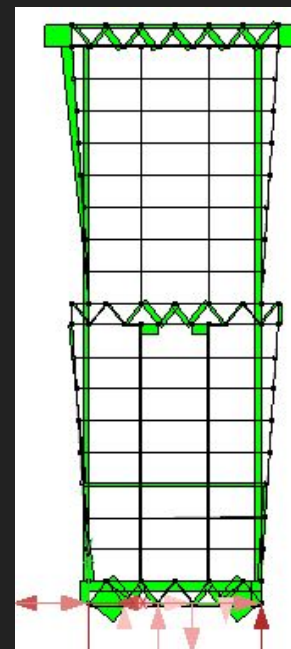
# Multiframe Analysis 2 : Outrigger Truss



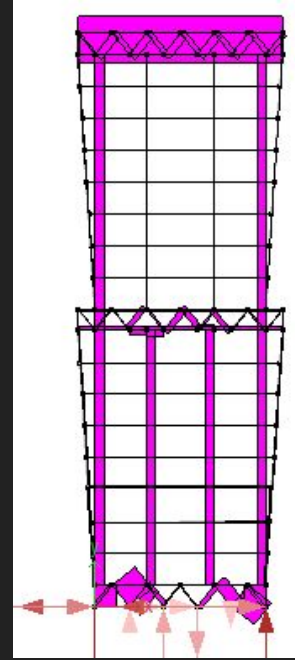
D



M



V



P



# Conclusion

## Challenges

Wind

Height

Seismic

Foundation

## Structural Strategies

Central core

Trusses and Bracing

Truncated Pyramid Base

Flexible but Sturdy Materials

Mass Damper

2 Slurry Wall System

Drilled Piers

Taipei 101 honors the traditional Chinese Pagoda style with an innovative twist on handling the extreme lateral loads that come from being one of the tallest buildings in the world.

# References

<https://www.tripsavvy.com/taipei-101-tower-facts-1458242>

<https://www.phase-trans.msm.cam.ac.uk/2005/t101/t101.html>

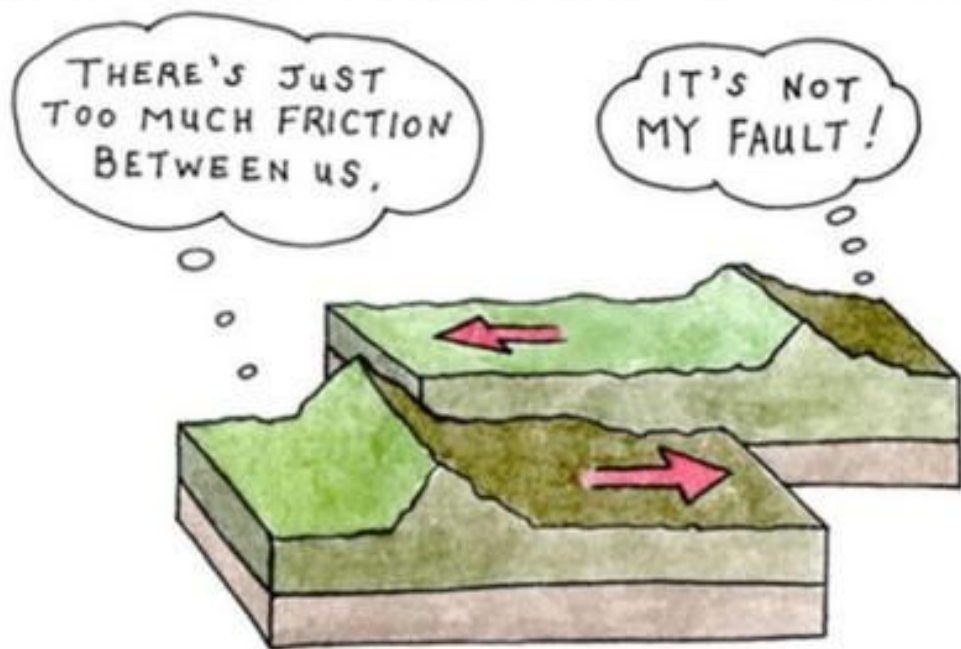
<https://www.cylee.com/about>

<http://www.egc.com.tw/index.php?lang=en-us>

<http://www.archinomy.com/case-studies/671/taipei-101-a-case-study>

<https://www.skyscrapercenter.com/building/taipei-101/117>

<http://global.ctbuh.org/resources/papers/download/1650-structural-design-of-taipei-101-the-worlds-tallest-building.pdf>



TECTONIC RELATIONSHIPS



"Perhaps it's not a good idea to build skyscrapers that reach this far up."