Taipei Performing Arts Centre

Taipei, Taiwan

OMA

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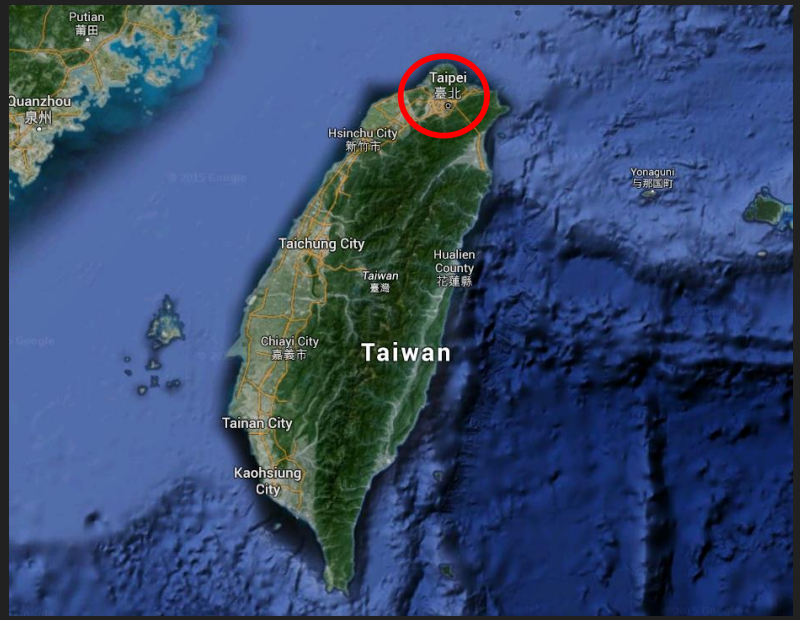
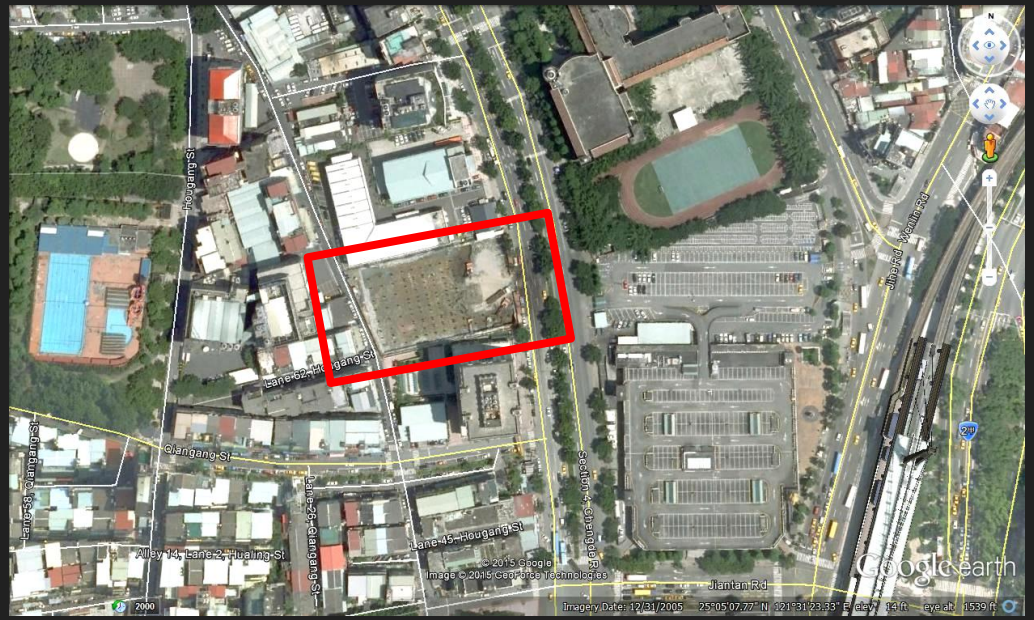
http://www.archdaily.com/541253/oma-s-taipei-performing-arts-center-tpac-tops-out

CONTEXT



google earth



google earth

TPAC

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·DESIGN YEAR:

2009

·CONSTRUCT YEAR:

2012

·COMPLETION YEAR:

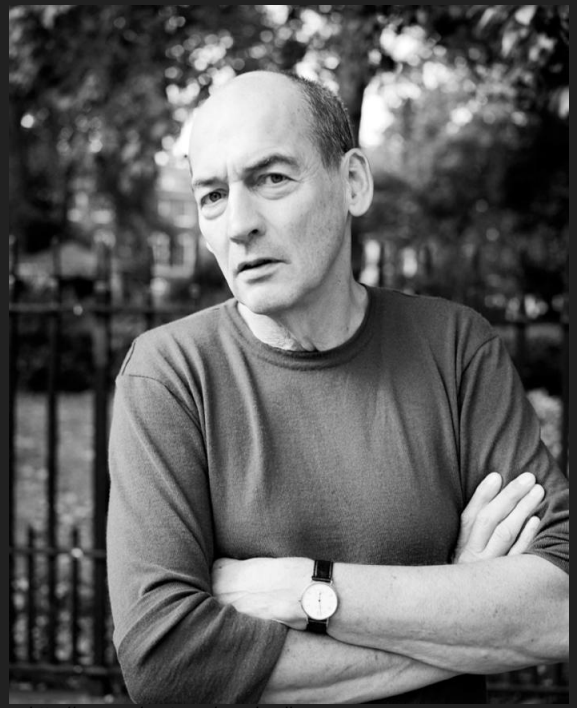
In Progress

·CLIENTS:

Department of Cultural Affairs, Taipei City Government

·SIZE:

ARCHITECT - OMA



http://oma.eu/partners/rem-koolhaas

Rem Koolhaas [*founder*]

http://oma.eu/partners/david-gianotten

David Gianotten [*Managing Partner-Architect*]

collaborators

LOCAL ARCHITECT:

Artech Architects

STRUCTURAL ENGINEER:

Evergreen & Arup

THEATRE CONSULTANT:

dUCKS scéno, CSI

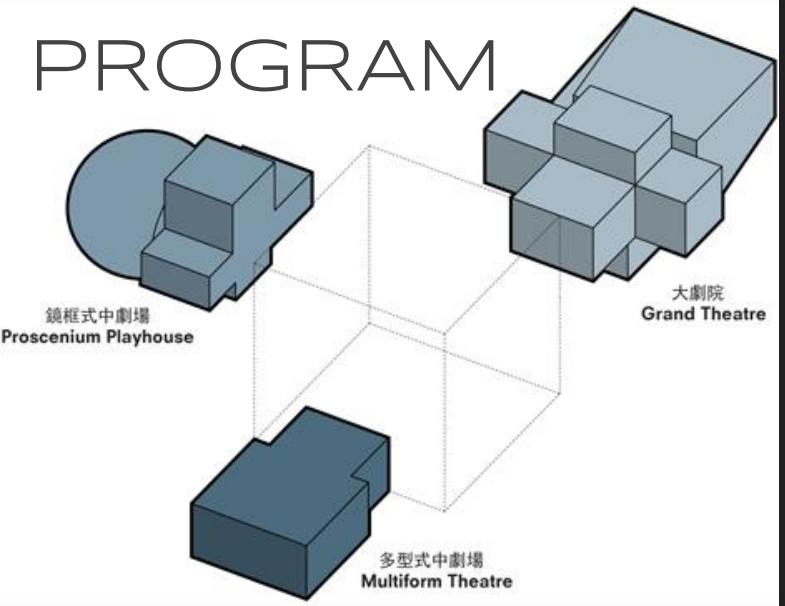
MEP ENGINEER:

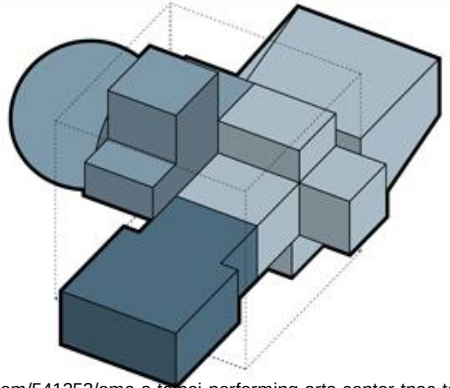
Heng Kai, IS Lin

FIRE ENGINEER:

TFSC

PROGRAM





THEATER		20,250 m2
PARKING		15,050 m2
PUBLIC SPACE		5,700 m2
OFFICE		3,500 m2
SERVICES		2,000 m2
		46,500 m2

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INSPIRATION

Volumes appear to be autonomously supported

Integrated Components that interact with one another

Complex form is not structurally obvious

To gain an understanding of the structural behavior of this level of complexity in building form

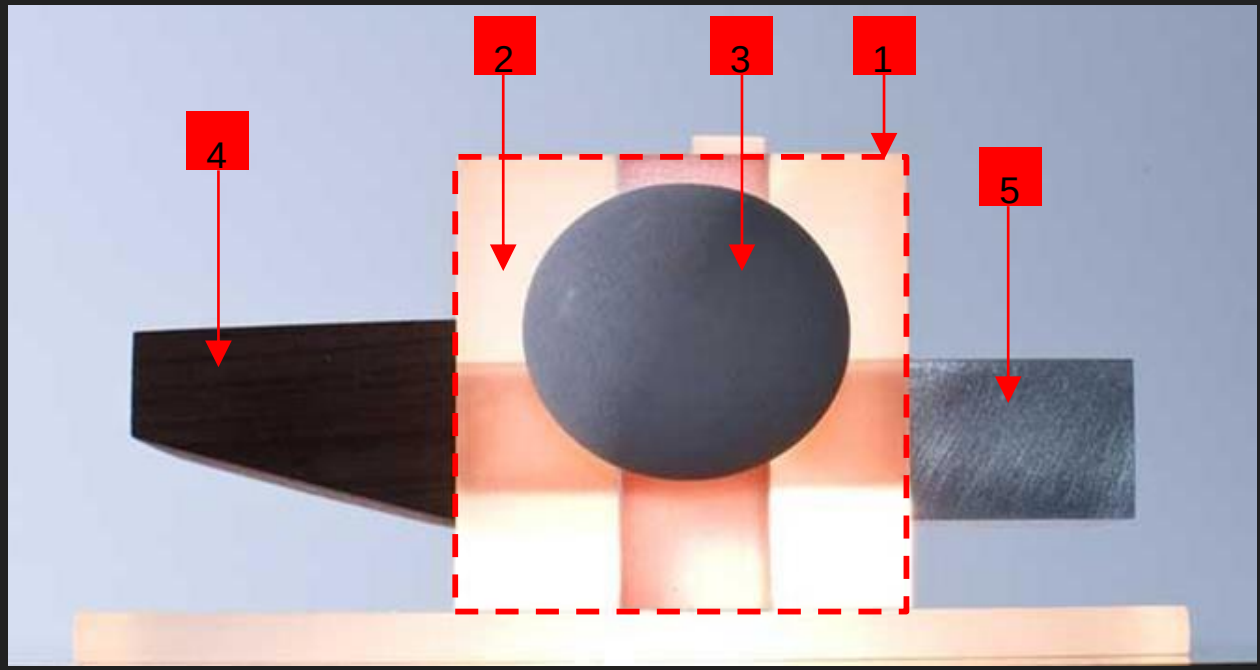
Specifically how the sphere protrusion structurally interacts with the rest of the building

http://www.e-architect.co.uk/images/jpgs/taiwan/taipei_performing_

http://www.royalhaskoningdhv.com/en-gb/projects/taipei-performing-arts-centre-taiwan/2402

MAIN STRUCTURE SYSTEM

1. Super Structure
2. Cube Structure
3. Proscenium Playhouse
4. Grand Theatre
5. Multiform Theatre



http://oma.eu/projects/taipei-performing-arts-centre

MAIN STRUCTURE SYSTEM

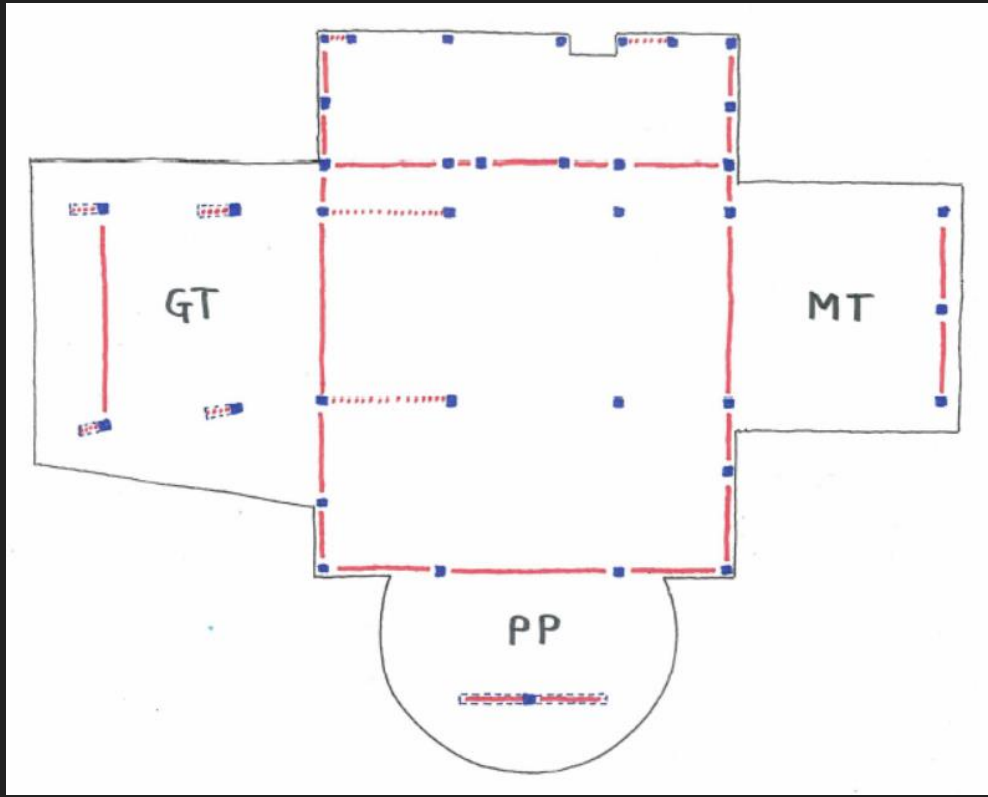
SUPER STRUCTURE

- Exterior steel braced framing
- Interior one way planar steel trusses and columns
- Composite concrete-steel decking
- Composited concrete-steel columns

MAIN STRUCTURE SYSTEM

SUPER STRUCTURE

- mainly located around the perimeter of the Cube and providing a system with high lateral and torsional resistance
- Further lateral stiffening is added to the columns supporting the auditoria



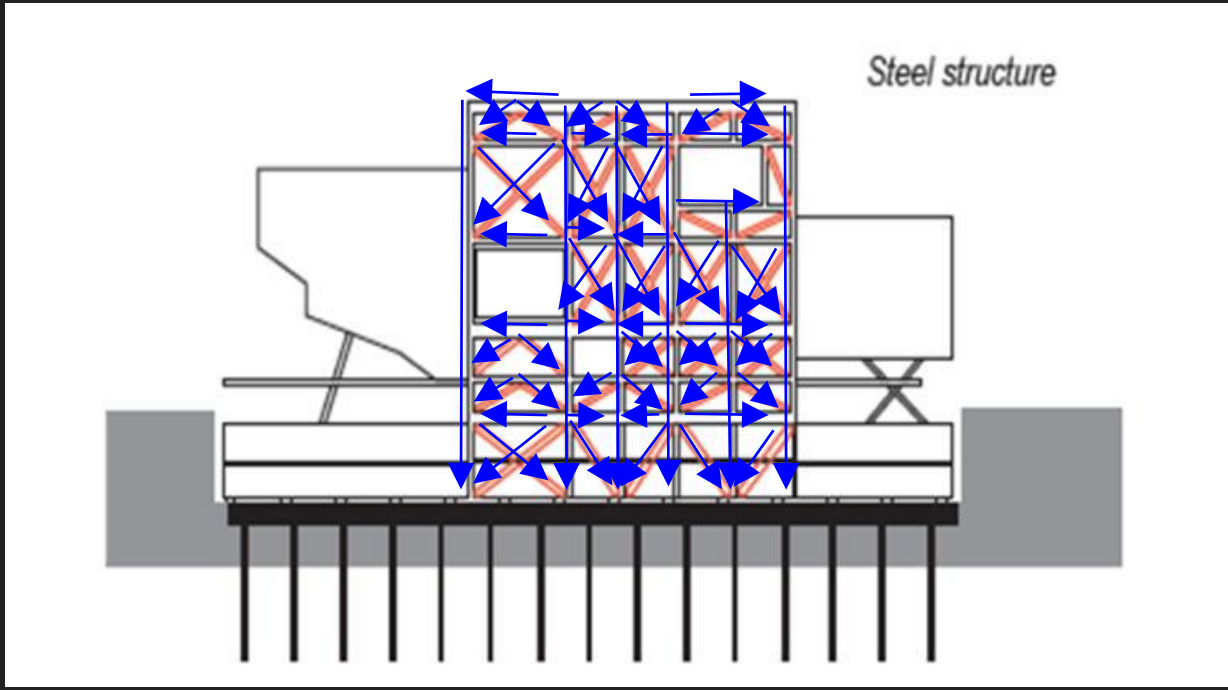
Source: http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

MAIN STRUCTURE SYSTEM

SUPER STRUCTURE

- Gravity load transfer path

- Loading transfer inside super structure



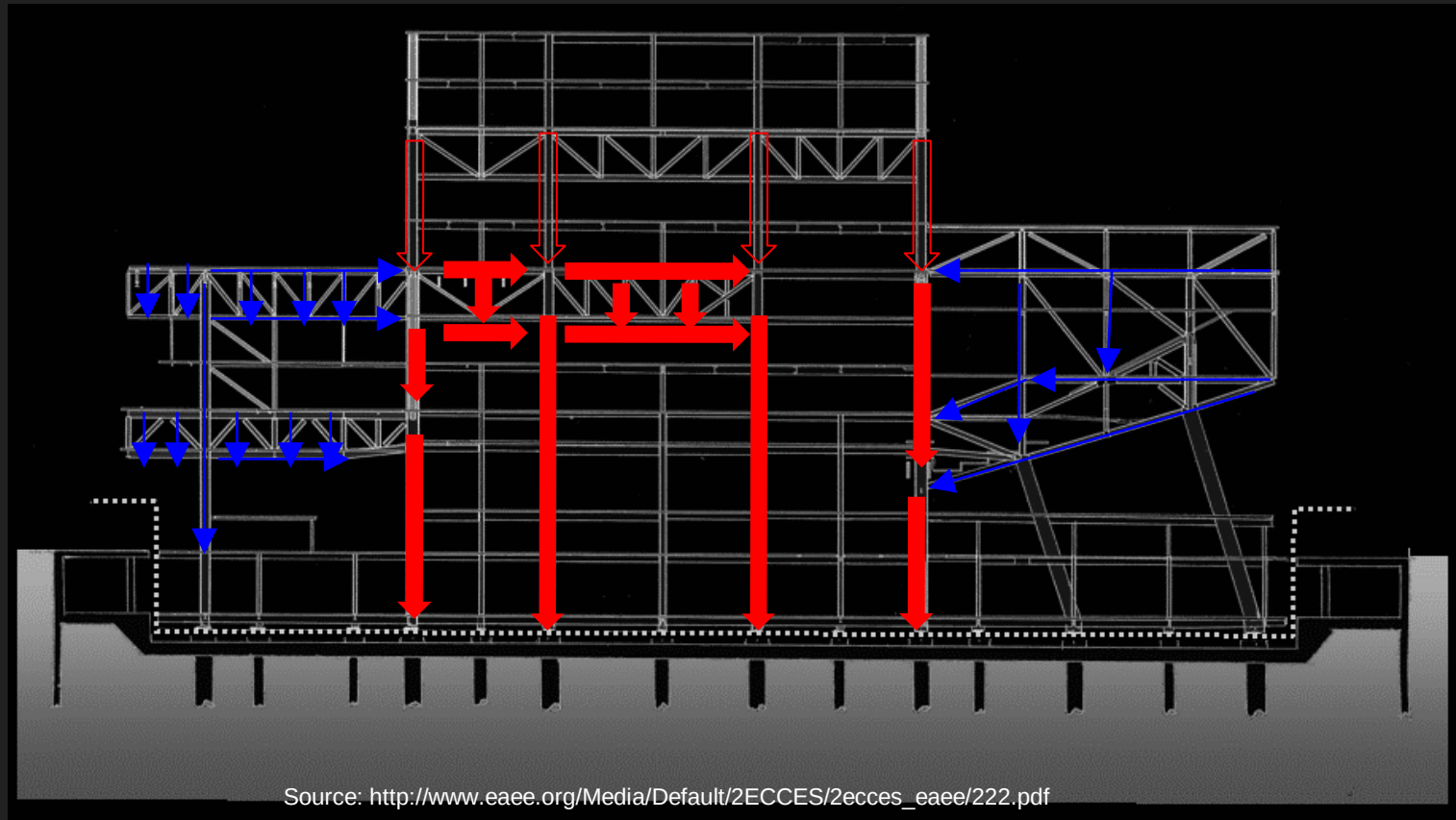
Source: http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

MAIN STRUCTURE SYSTEM

SUPER STRUCTURE

Gravity load transfer path

- Loading transfer from three theatres
- Loading transfer to Super Structure



Source: http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

MAIN STRUCTURE SYSTEM

CUBE STRUCTURE

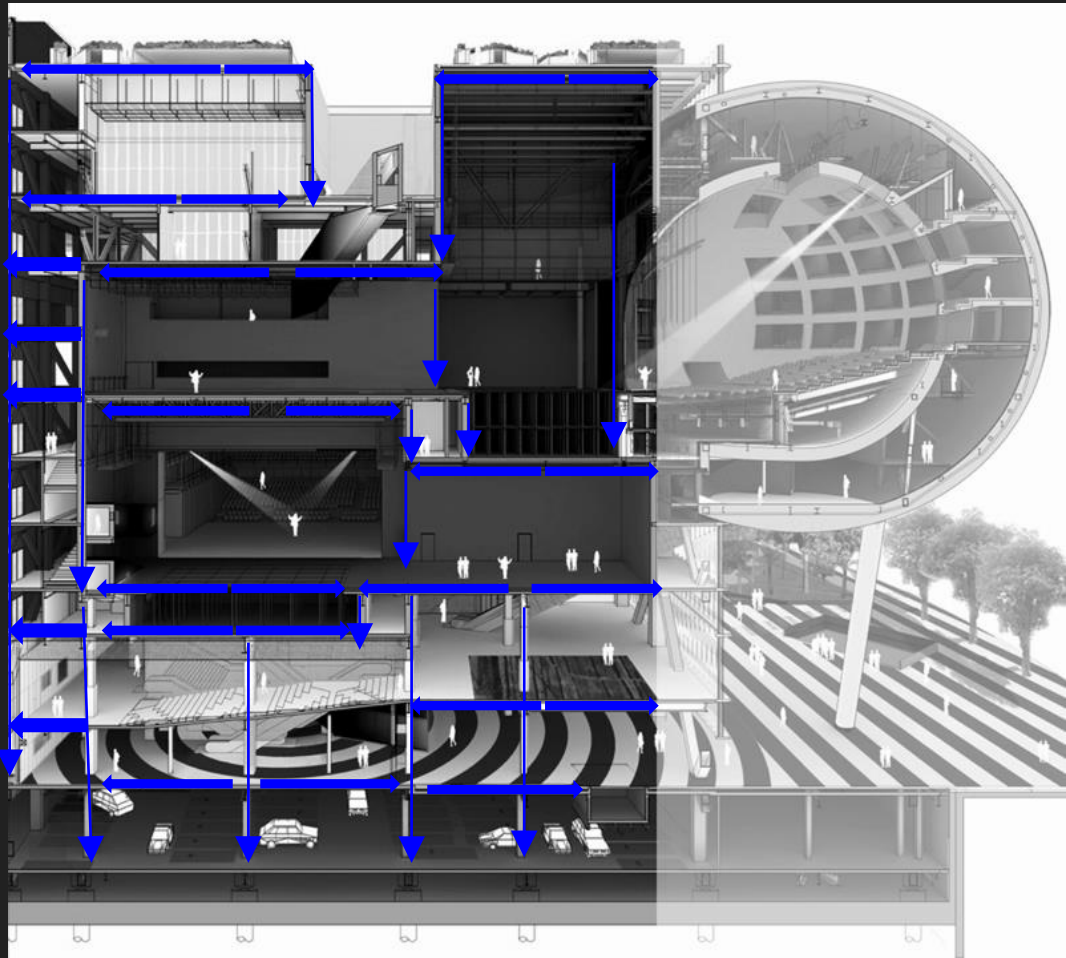
- The dimension of the cube is 175.5ft (53.5m) long by 175.5ft (53.5m) wide by 180.4ft (55m) tall with twelve stories, 16.4ft (5m) high for each typical floor.
- Several large span spaces and a limited amount of columns within the cube.
- The structural system of this part is composed of a large number of one story deep steel trusses.

MAIN STRUCTURE SYSTEM

CUBE STRUCTURE

Gravity load transfer path

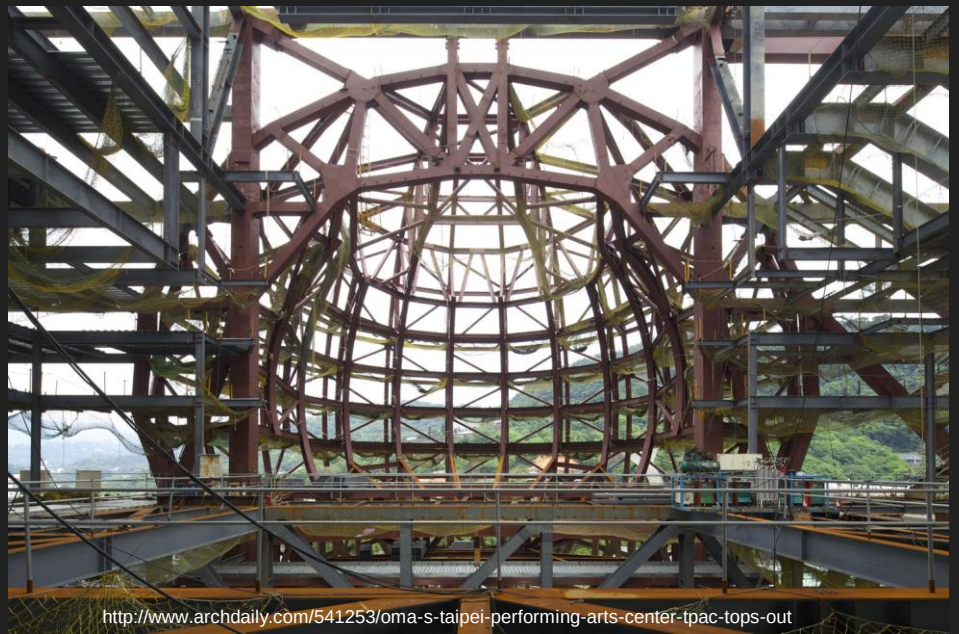
- Loading transfer inside super structure



MAIN STRUCTURE SYSTEM

PROSCENIUM PLAYHOUSE

- This portion of the system is essentially an ellipsoidal shell structure
- Steel “three dimensional space truss”
- It may be thought of as several vertical planar arched trusses radially spaced, and braced horizontally in a circular fashion.
- The entire ellipsoidal structural unit is supported by the cube perimeter columns and an external inverted-V-column



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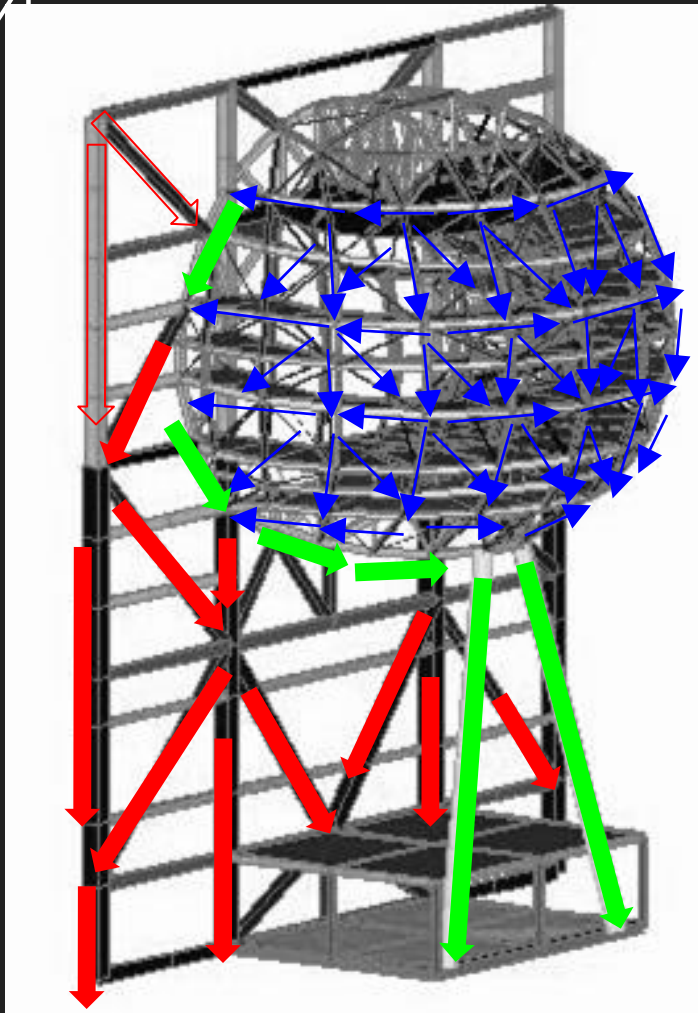
MAIN STRUCTURE SYSTEM

PROSCENIUM PLAYHOUSE

Gravity load transfer path

- Loading transfer from Proscenium Playhouse
- Loading transfer to Arched Trusses
- Loading transfer to Super Structure



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MAIN STRUCTURE SYSTEM

GRAND THEATRE

- This portion of the system is 121.4ft (37m) long and 128ft (39m) wide.
- It is supported by columns and steel trusses which are continuous from the cube.
- The roof of this part is also supported by steel trusses.

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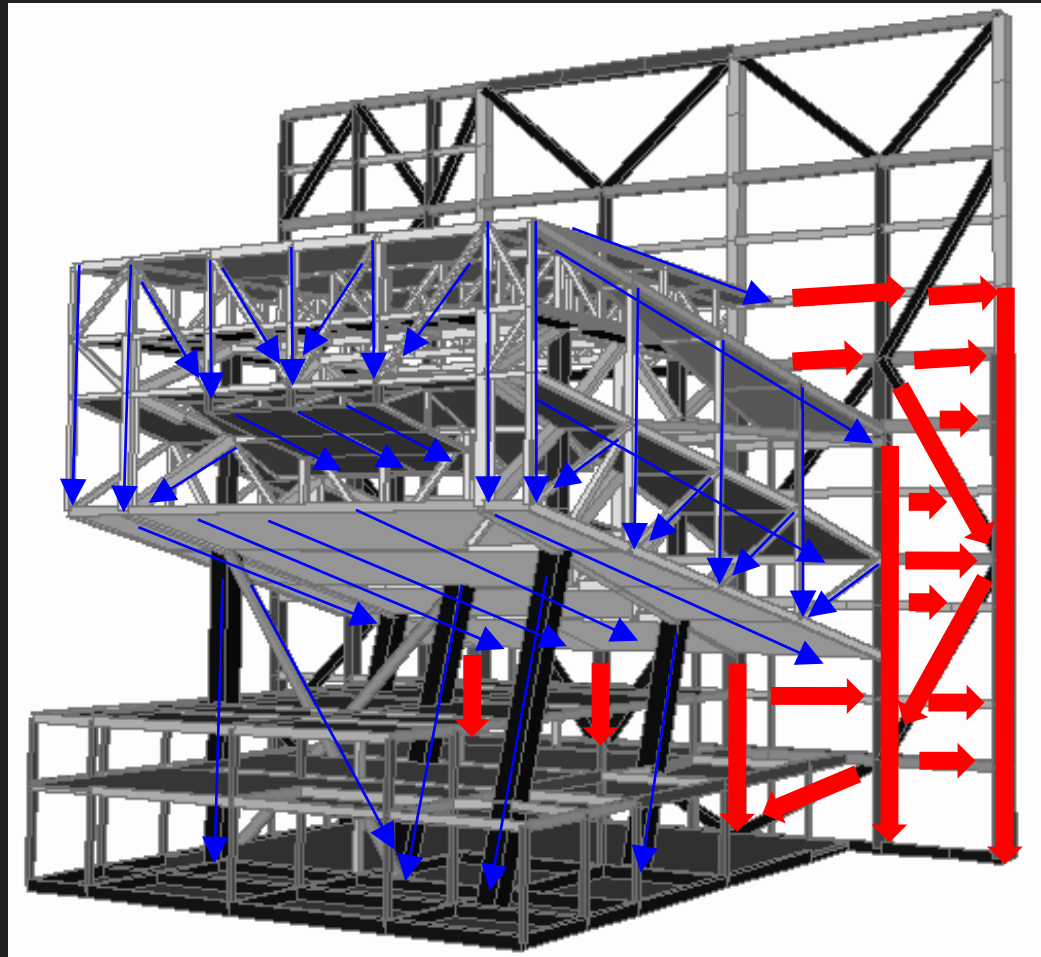
MAIN STRUCTURE SYSTEM

GRAND THEATRE

Gravity load transfer path

- Loading transfer from Grand Theatre
- Loading transfer to Super Structure



Source: http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

MAIN STRUCTURE SYSTEM

MULTIFORM THEATRE

- This portion of the system is 95ft (29m) long by 101.7ft (31m) wide.
- Its structural system is also that of a steel truss and column system which supports both floors and roof.

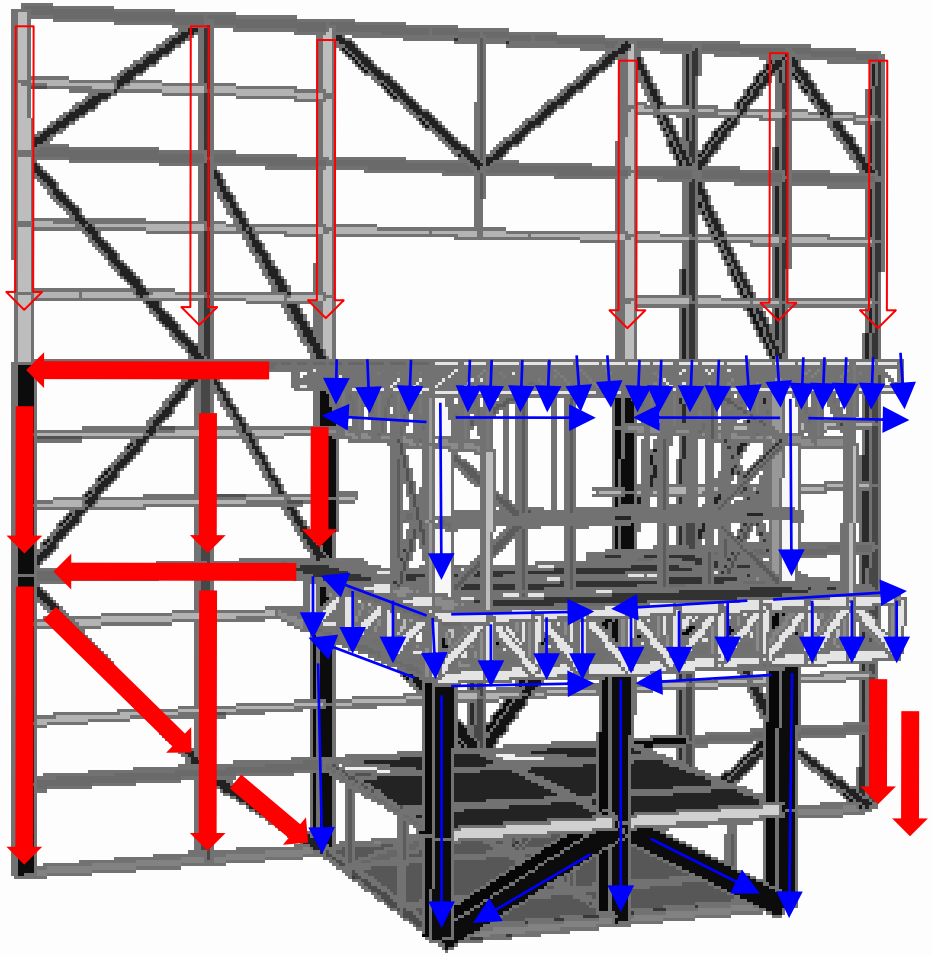
http://www.photodirk.com/tpac/h1742A1BC#h1742a1bc

MAIN STRUCTURE SYSTEM

MULTIFORM THEATRE

Gravity load transfer path

- Loading transfer from Multiform Theatre
- Loading transfer to Super Structure

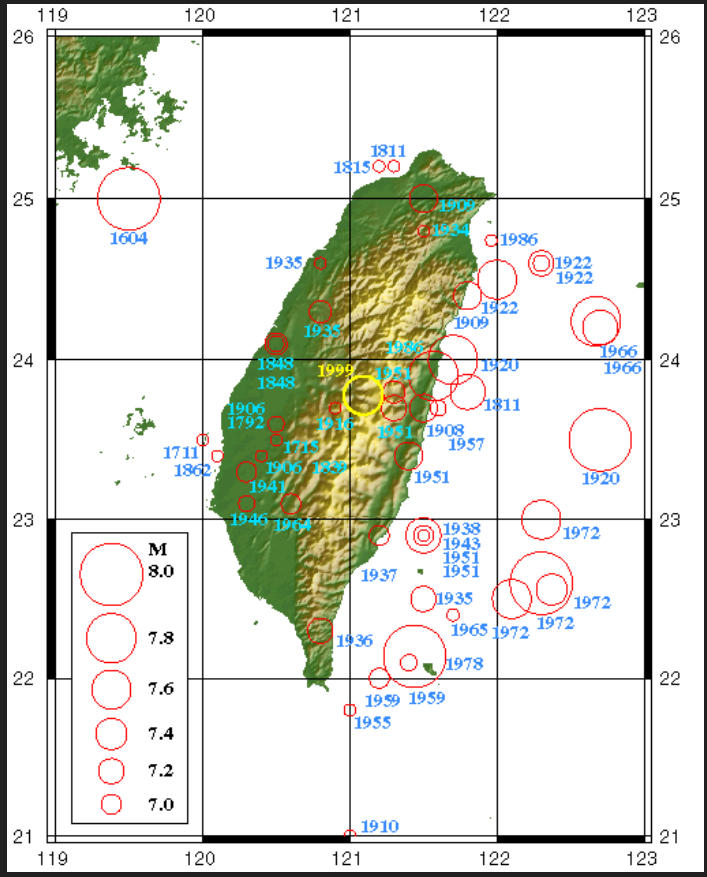


Source: http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

Lateral concerns:

SEISMIC ACTIVITY

- Taiwan region is seismically active and historically experiences large earthquakes.
- The clear earthquake risk of the TPAC location has raised the seismic performance of the facility to the highest priority for Taipei Government.
- TPAC was decided to be designed for a high level of safety, complying with the requirements of hospital building.



Lateral concerns:

WIND

- Also an important consideration for Taipei.

Table 2. Basic Design Wind Speed of Different Return Period

Station Name	25 Years Return Period (m/sec)	50 Years Return Period (m/sec)	100 Years Return Period (m/sec)
Taipei	35.85	39.87	43.88

Source: http://jmst.ntou.edu.tw/marine/5/55-63.pdf

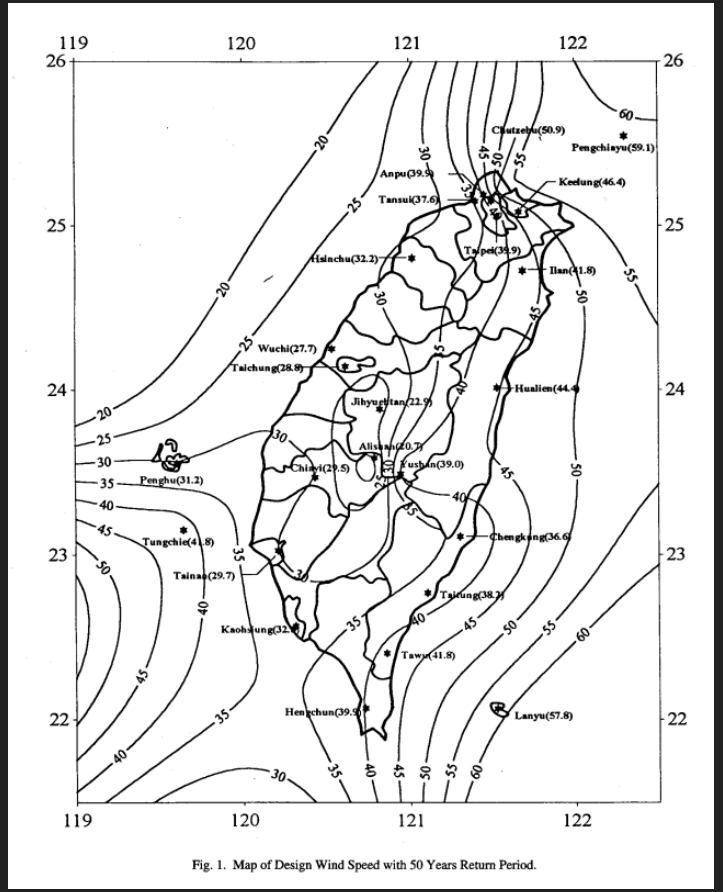


Fig. 1. Map of Design Wind Speed with 50 Years Return Period.

Source: http://jmst.ntou.edu.tw/marine/5/55-63.pdf

Lateral Resisting System/Components : Identification

1.) Diagonal Bracing

2.) Rigid Frames

3.) Shear Walls

4.) Base Isolation Mechanisms

Lateral Resisting System/Components : Identification

1) Diagonal Bracing

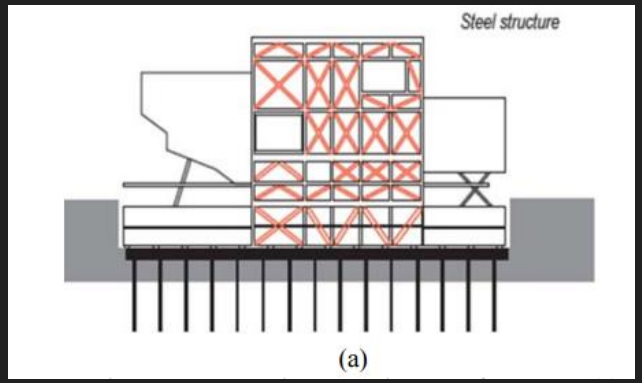
- ***Perimeter*** **Frame: Diagonally braced on all four sides of central cube; external-most sides of cantilever portions**

Creates:

- **Vertical shear planes;**
- **Stiffness**

Allows for:

- **Truss Action (mostly rigid joints; pin joints at base)**



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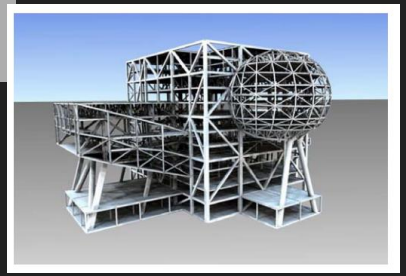

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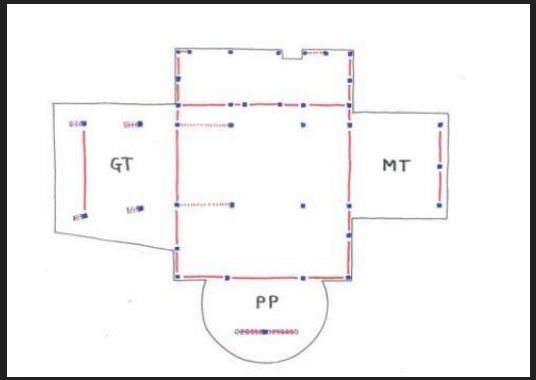
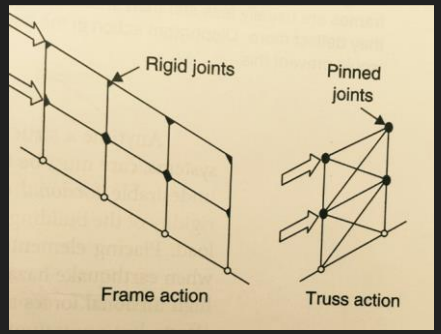


Source:

Lateral Resisting System/Components : Identification



Source: Textbook p.465

2.) Rigid Frames

Location:

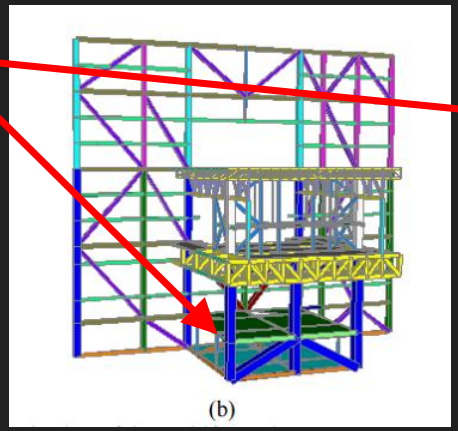
- Perimeter: Super-structure
- Integrally within building
- Roof/Floor Diaphragms

Creates:

- Vertical and horizontal shear planes
- Stiffness

Allows for:

- Frame Action; Long ends
- Truss Action; Short ends
- Diaphragm Action; Floors



Source: http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

Source: http://www.archdaily.com/462482/considering-the-quake-seismic-design-on-the-edge

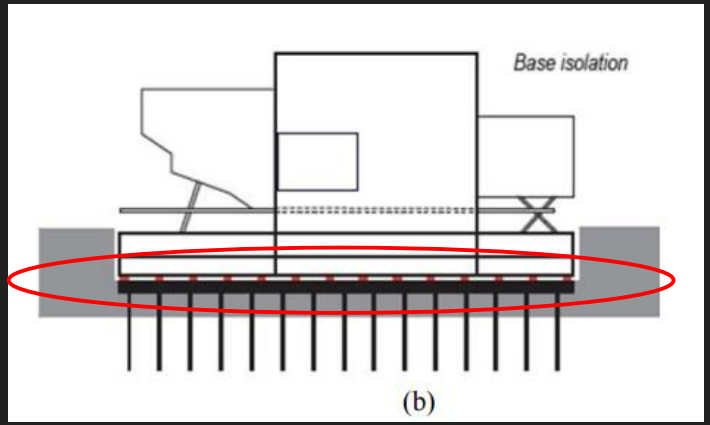
Lateral Resisting System/Components : Identification

3.) Shear Walls

Source: http://www.archdaily.com/462482/considering-the-quake-seismic-design-on-the-edge

4.) Base Isolation

- Foundation and building shake separately



Source:
http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

Lateral Resisting System/Components :Load Tracing

Wind

Exterior Cladding/Bracing

Roof/Floor Diaphragm

Column

Diagonal Column

Source: http://www.archdaily.com/462482/considering-the-quake-seismic-design-on-the-edge

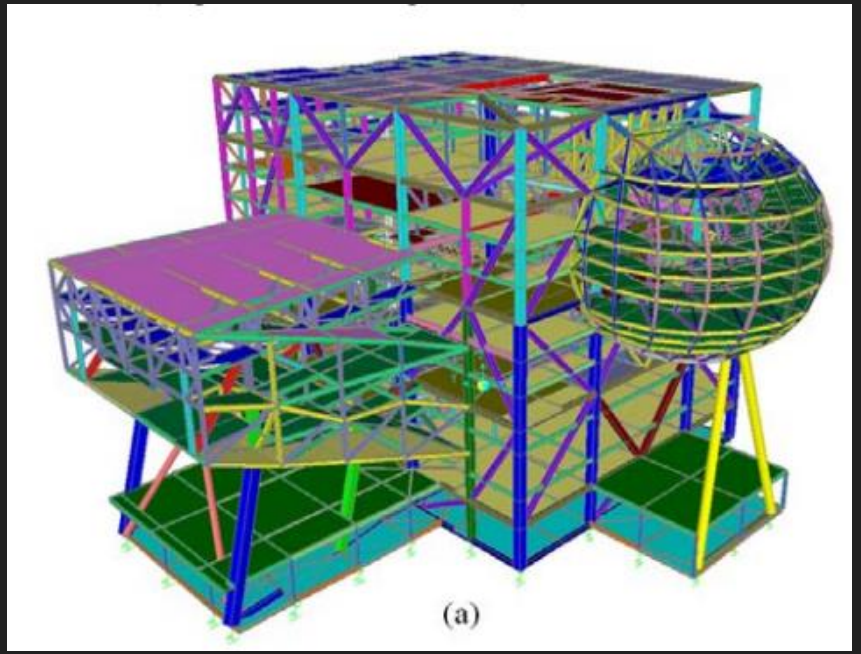
Lateral Resisting System/Components:

Structural Performance/ Response to Lateral Loading

- Floor/Roof diaphragms coupled with diagonal bracing around the periphery provide for "excellent resistance to horizontal racking and torsional deformations." –TB, p. 461

- However, strong enough loads could potentially still cause some torsional deformation, due to there being no lateral resistance on the interior of the building (apart from the floor/roof diaphragms)—such as pinned columns

- This type of deformation could include story drift, or deformation on the local level, such as within individual members.



Source:
http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf

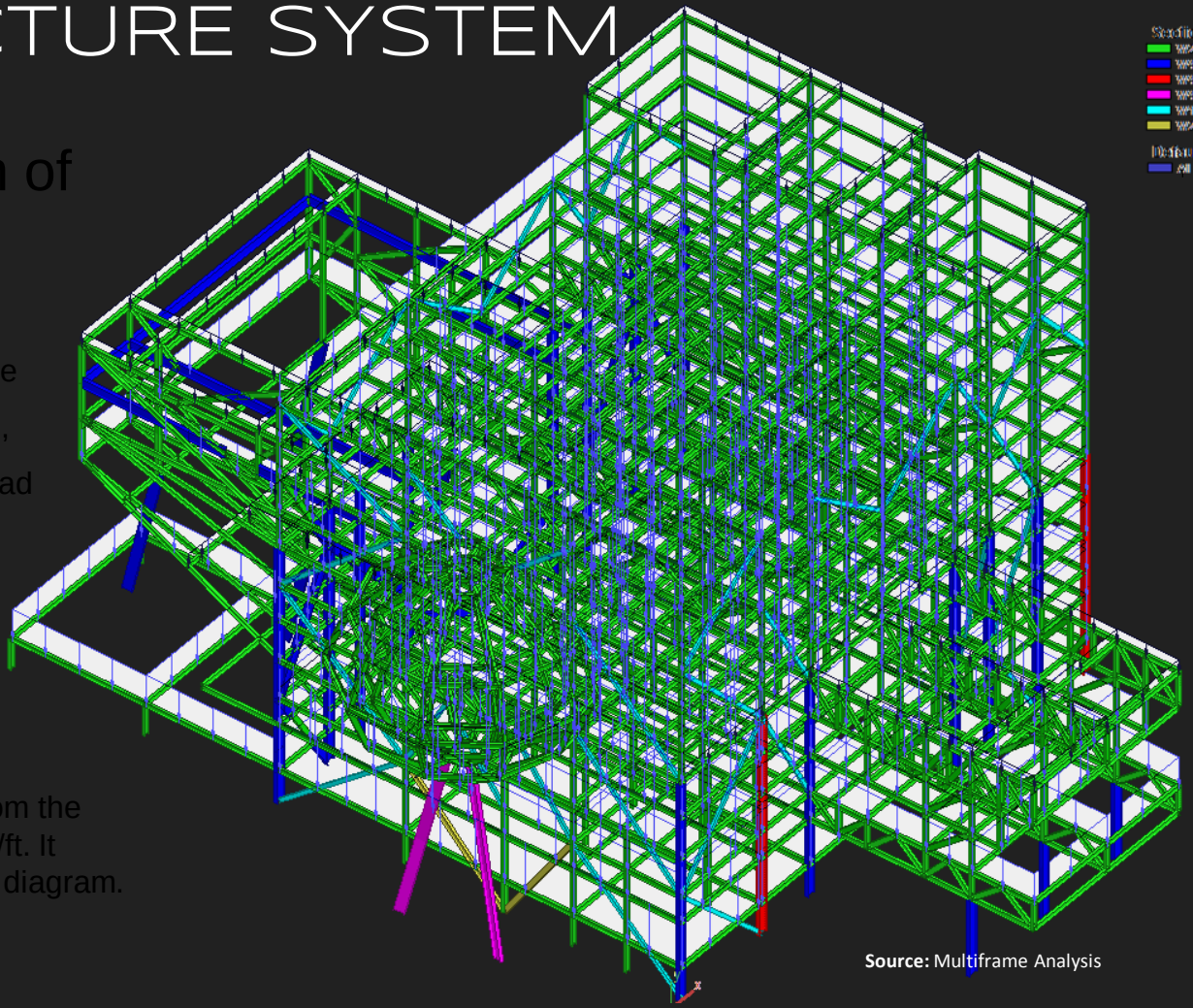
MAIN STRUCTURE SYSTEM

General description of the primary load

The general load which including the live load and dead load, in our case, we took a general number as the load factor.

The Quantization was 0.5 kips/ft2.

Identify: The Gravity load comes from the floor, The quantity of that is 0.5kips/ft. It shows through the white part in the diagram.

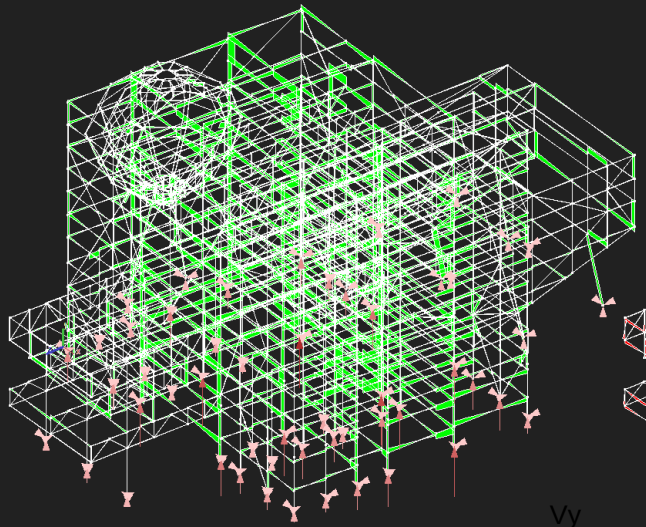


Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM UNDER GRAVITY LOAD

Shear Diagram

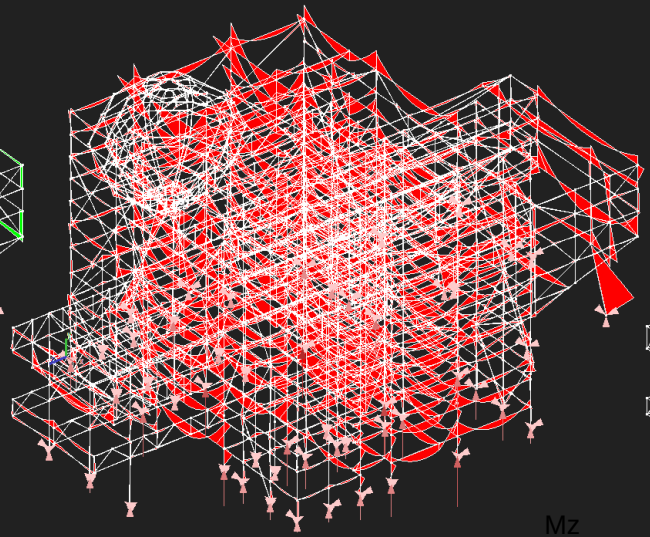
- Largest Shear located where largest gravity loads induced: the building interior.



Vy

Moment Diagram

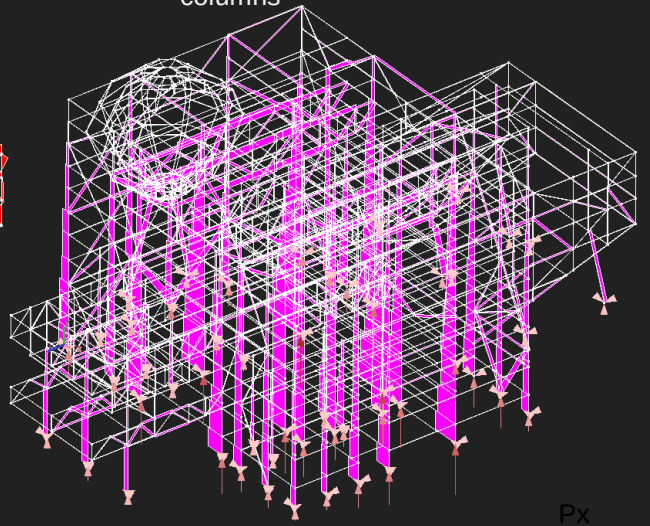
- Locally, negative moment clearly largest at supports of continuous beams; largest positive moment at center spans
- Overall, largest moment located at end support for beams



Mz

Load Diagram

- Mostly interior (perimeter frames dedicated to lateral loads; interior dedicated to gravity loads
- Efficient; Loads transferred almost directly to ground via columns



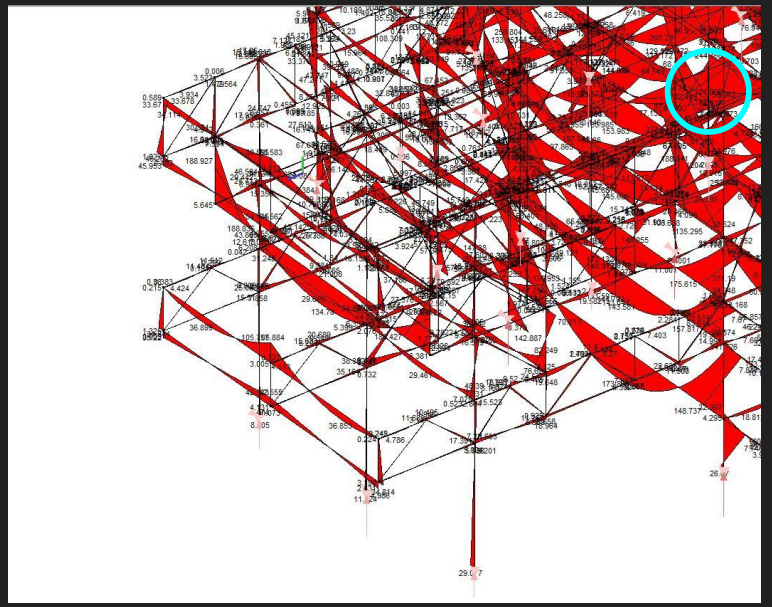
Px

Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM

Quantification (For the Multi-Function Treater)

Identify: The Gravity load comes from the floor, The maximum shear force which is 28.77kips happened in the horizontal beam which overhanging outside.

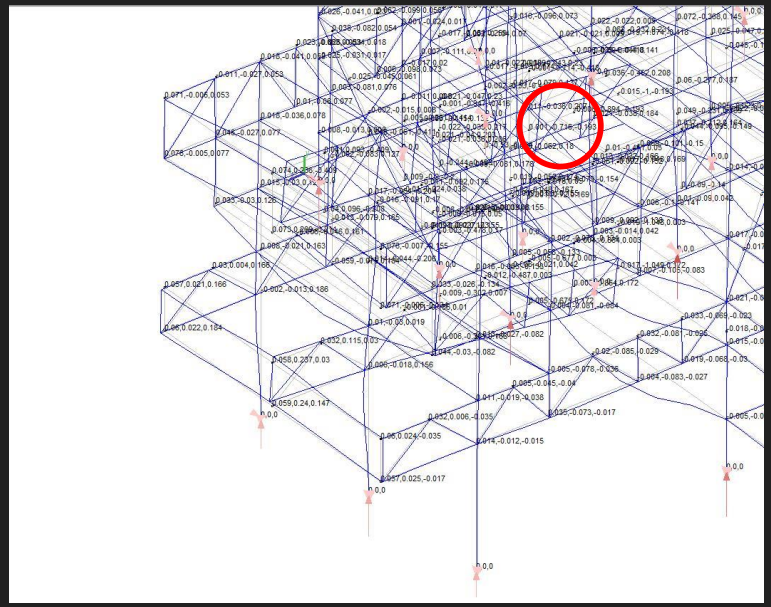


Identify: The Gravity load comes from the floor, The maximum shear force which is 250 lb-ft happened in the horizontal beam which overhanging outside.

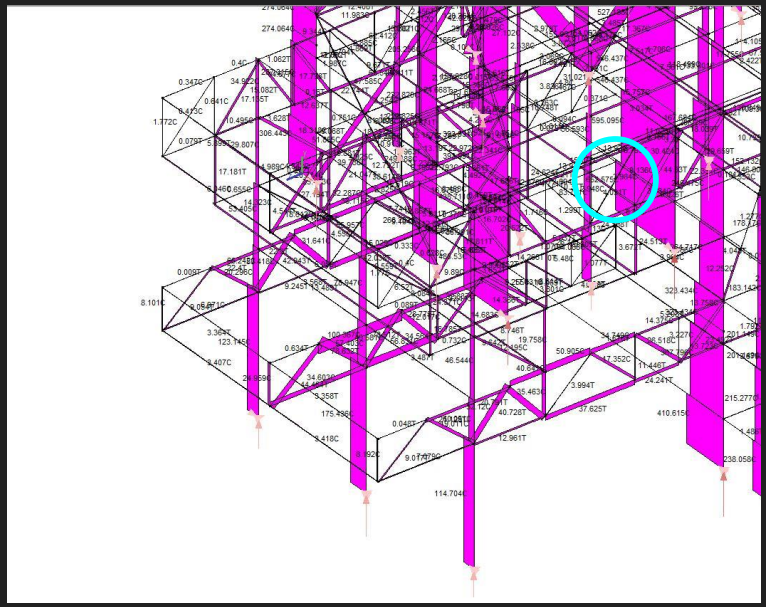
Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM

Quantification (For the Multi-Function Treater)



Identify: The maximum deformation is 0.716 ft which is in the middle of the beam.



Identify: The maximum compression is 948 lbs which is in the middle of the column.

Source: Multiframe Analysis

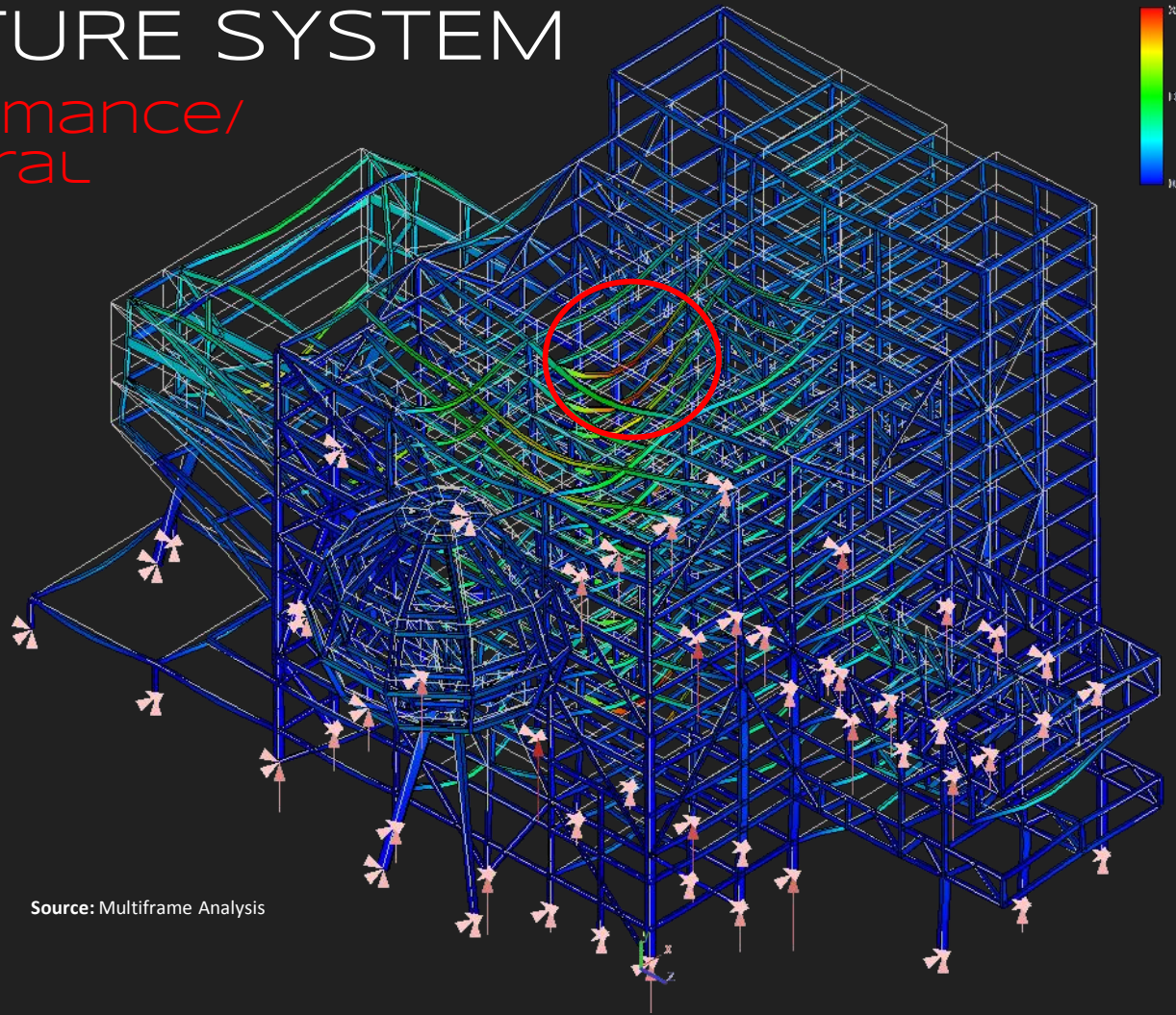
MAIN STRUCTURE SYSTEM

STRUCTURAL PERFORMANCE/ RESPONSE TO LATERAL LOADING

Deflection Diagram

- **Fixed connections shown**

- Deflection occurs mainly at locations of largest load placement
  - Notice the heaviest load from cantilever portion being picked up by the cube.
- Deformation could include story drift, or deformation on the local level, such as within individual members.



Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM

STRUCTURAL PERFORMANCE/ RESPONSE TO LATERAL LOADING

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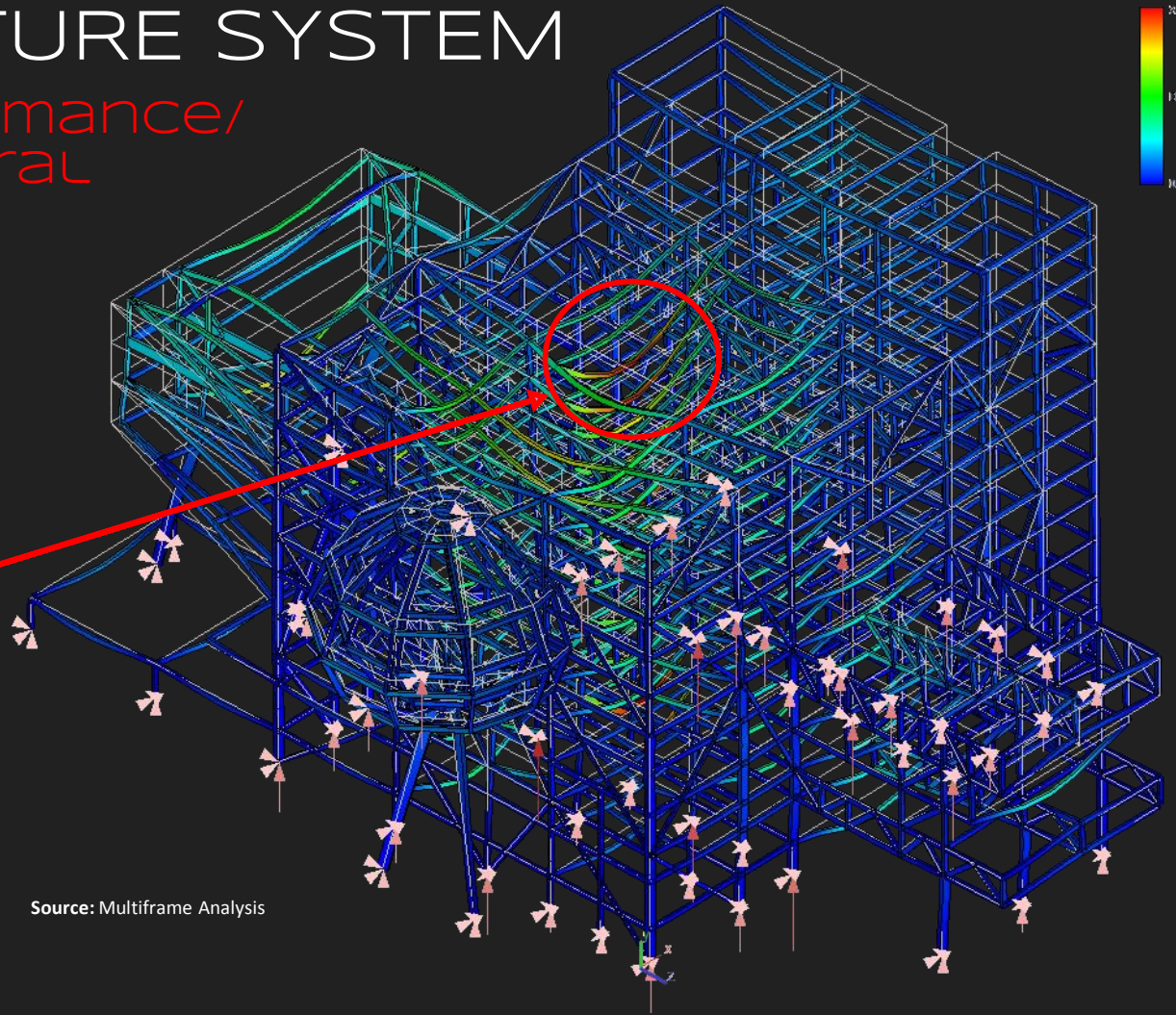


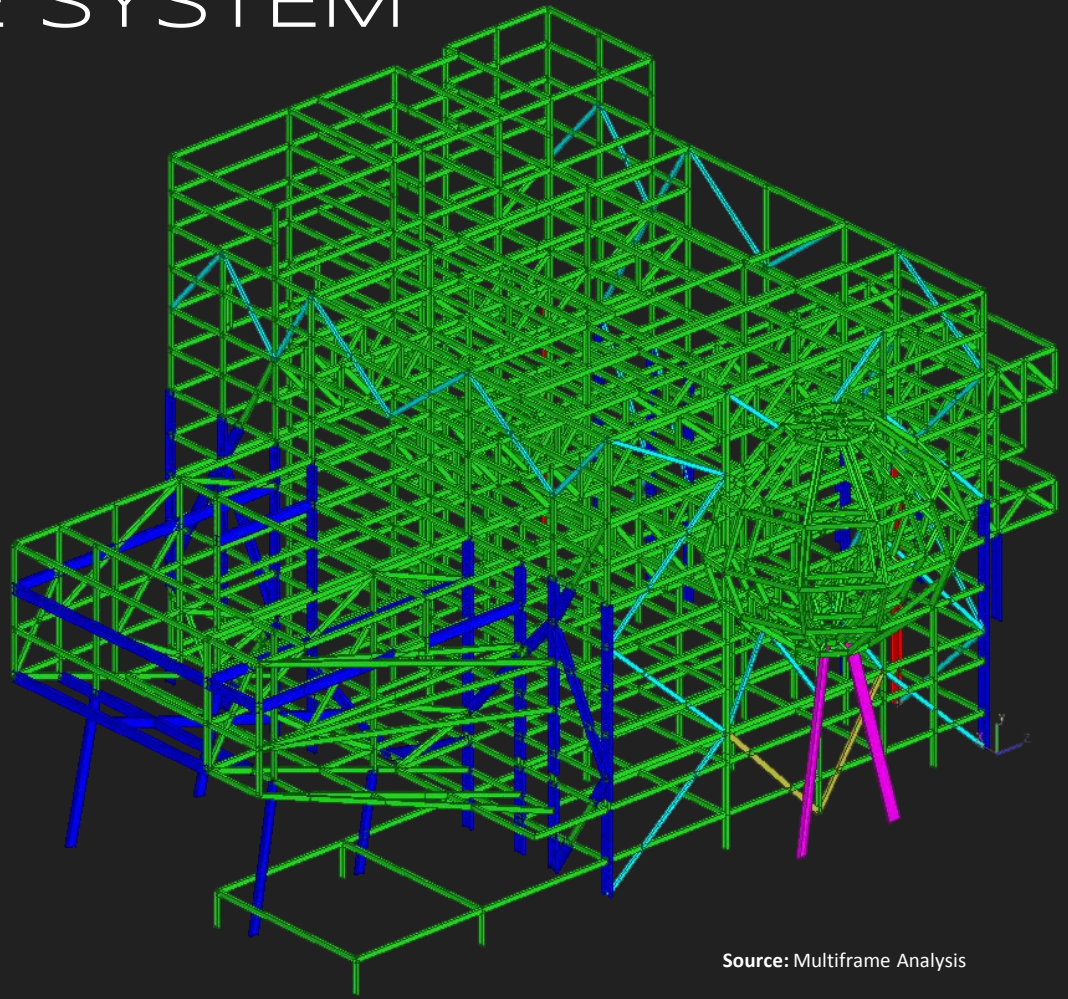
Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM

Deformation Under General Load

Because of the system designed to deal with the deformation even under seismic, so that the performance of the building actually is good with that.

There are very little twisted and deformation in the building under general load.



Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM

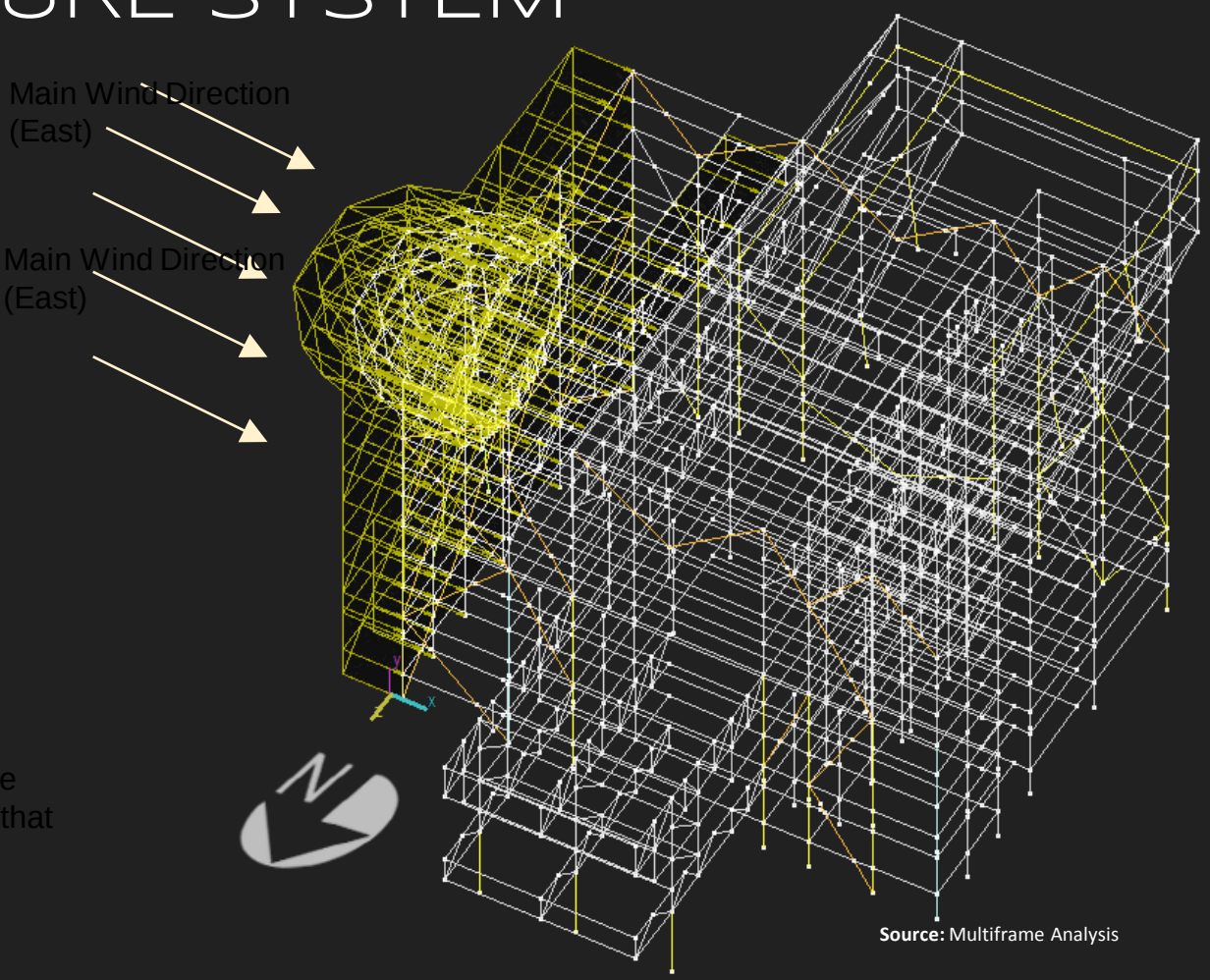
Lateral Load

The Lateral load including both wind load and seismic load, in our case, we took a wind load to make our analysis.

The main wind direction of Taipei facing east.

The Quantization was 0.2 kips/ft.

Identify: The Lateral load comes from the east side of the building,The quantity of that is 0.2kips/ft



Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM UNDER LATERAL LOAD

Shear Diagram

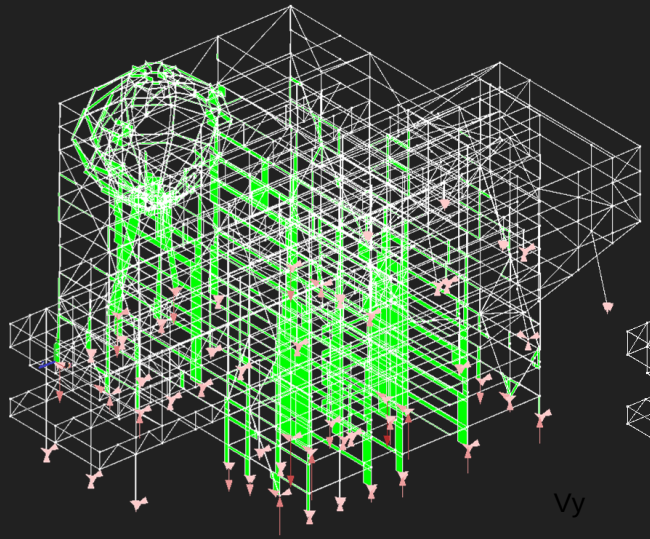
- Largest Shear located where largest lateral loads occur, on either side of the large boxed theaters

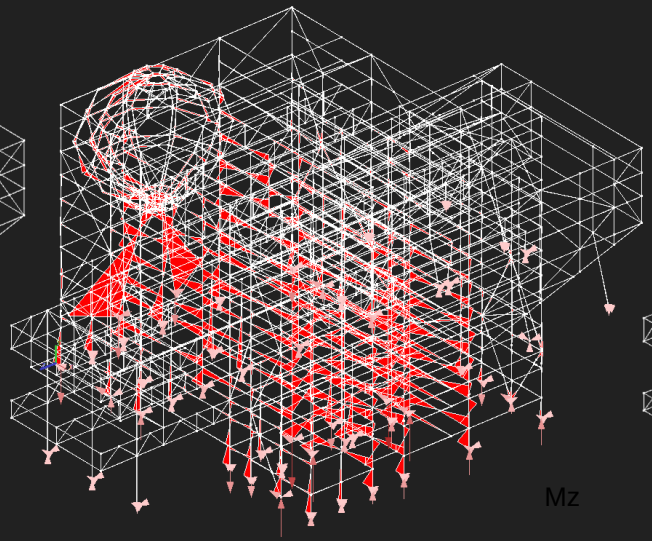
Moment Diagram

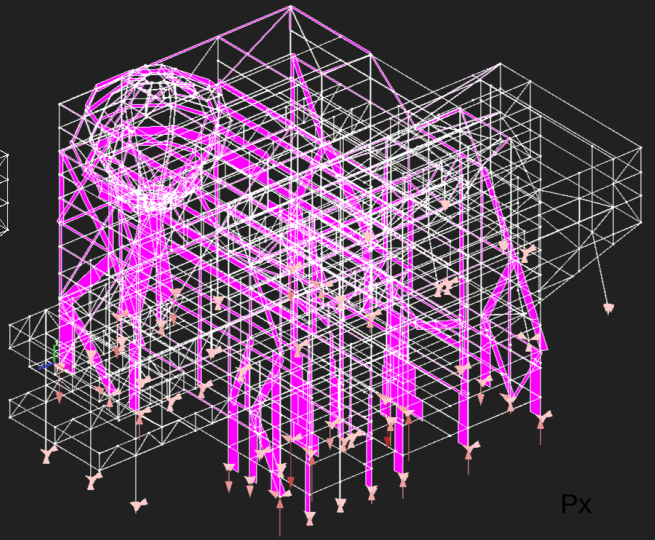
- Column to support half dome receives the largest moment
- there was a change in the column angle from the original scheme to support the dome

Load Diagram

- Mostly exterior
- Efficient; Loads transferred almost directly to ground via columns







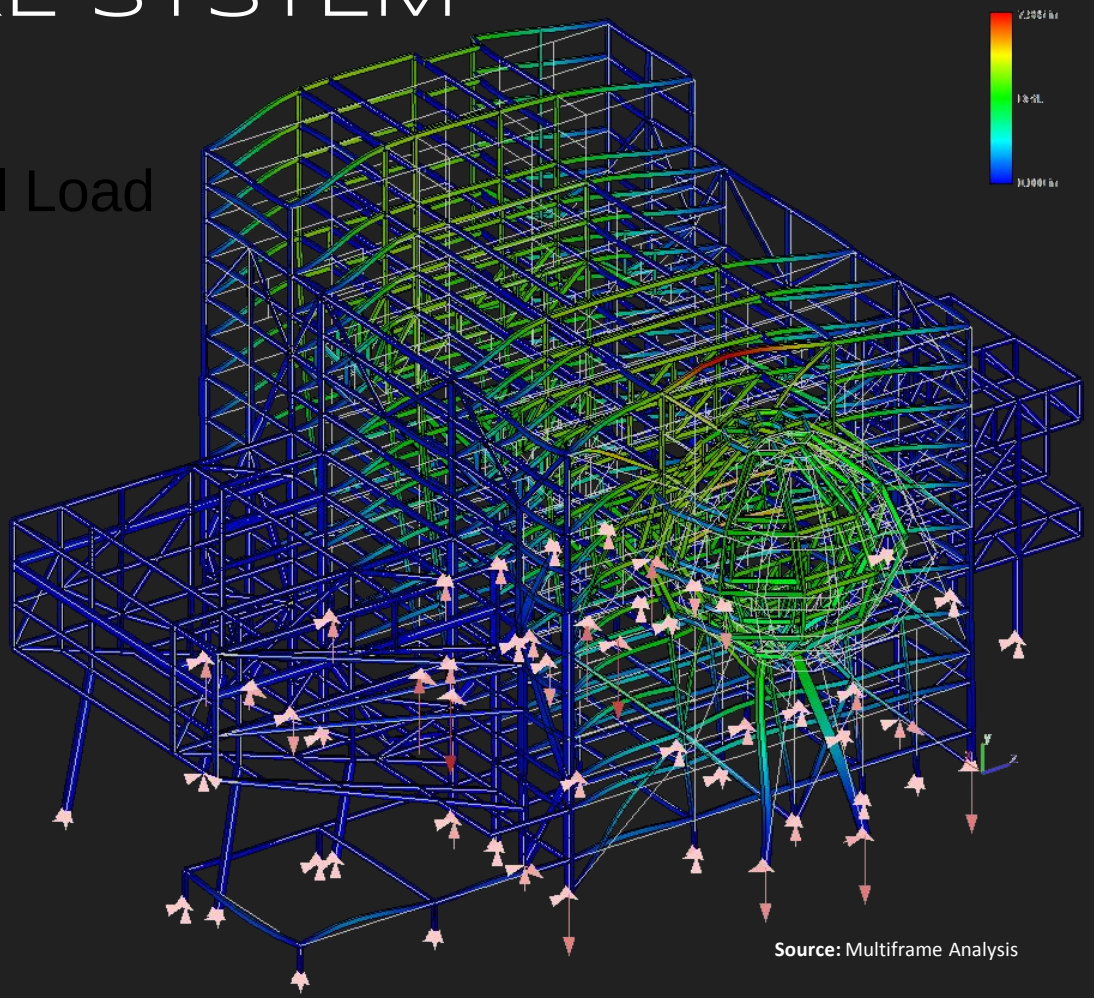
Source: Multiframe Analysis

MAIN STRUCTURE SYSTEM

Deformation Under Lateral Load

Because of the system designed to deal with the deformation even under seismic, so that the performance of the building actually is good with that.

There are very little twisted and deformation in the building under lateral load.



Source: Multiframe Analysis

SOIL DESCRIPTION

Taiwan is located at the boundary between the Philippine Sea Plate and the continental margin of the Eurasian plate and is within the Taipei Basin.The city is surrounded by 3 rivers as well as the Tatun Volcano Group.

The soil consists of a grayish black silt on the uppermost layer, followed by a mix of alternating yellow and grey sands, gravel and silt. All of this is resting on the bedrock layer which can be up to 80 m below in some cases.

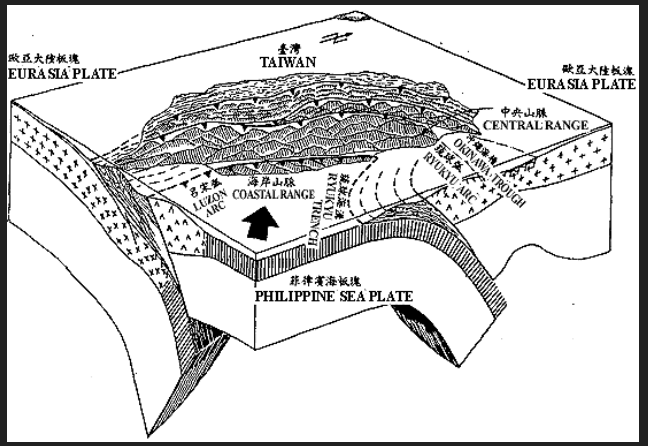
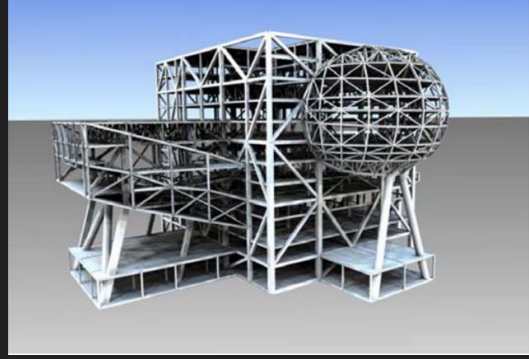


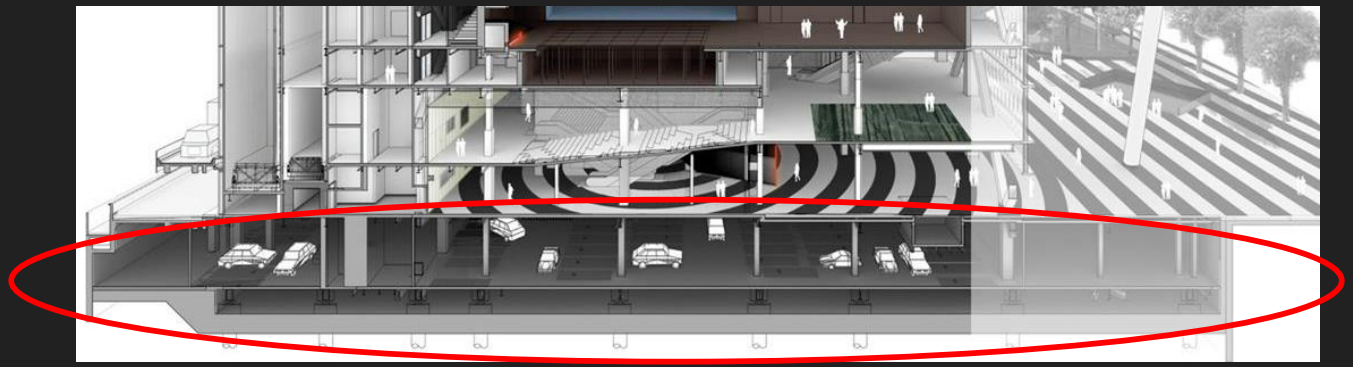
Table 1 Distribution of Sublayers in the Taipei Basin

Sublayer	Soil Description	Thickness m	Distribution
VI	yellowish brown or gray silty clay (CL-ML)	0-6	6 m at Hsinyi; slightly thinner along Tamshui River; not found at Kwantao Plain and Hsiehchi; top of this sublayer inclines towards NW direction.
V	grey silty fine sand	0-20	15-20 m at Kwantao Plain and Hsiehchi; not found at Hsinyi, Mingchuan E. Rd., Neihu; top of this sublayer varies from El.+2 m to El.-4 m.
IV	gray silty clay	5-30	25 m at Hsinyi; 15 m east of Fushing S. Rd.; <10 m at Chungchung, Chien Chen Districts and Kwantao; 25-30 m at Shihlin, Peitou; <5 m along Tamshui River; top of this sublayer inclines towards NW direction with elevation varies from -5 m to -15 m.
III	grey medium dense sand interstratified with silt or silty cely seams	0-15	10-15 m at Lungshan, Yenping, Chungchung Districts; <4 m at east of Fushing S. Rd. and south of Mingchuan E. Rd.; not found at Hsinyi; 2-4 m at Shihlin, Peitou.
II	grey silty clay	2-15	10-15 m at east of Shinshan S. Rd. to Chungheiao E. Rd. Sect. 5<10 m at west of Shinshan S. Rd. 2 m at Peitou, Shihlin; not known at Kwantao.
I	medium dense to dense silty sand or sand gravel	0-5	thicker at west of Chungshan, Ta-an Districts; thinner or not found at Neihu, Sungshan, Nankang; not known at Peitou, Shihlin.

FOUNDATION



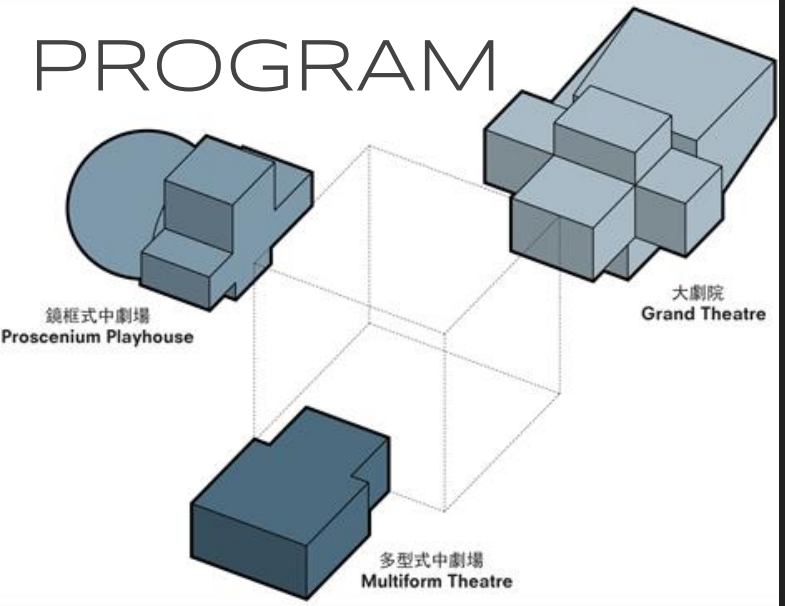
- Foundation elements:
  - Base isolators (for lateral load resistance from seismic activity)
  - Basement Walls (on periphery of underground parking garage underneath the building; which attach at the top to the floor slab)
  - Piles (driven into soil deep enough to reach past the clay layer to stable soil--the rock bed below in order to directly transfer loads and distribute them more evenly.

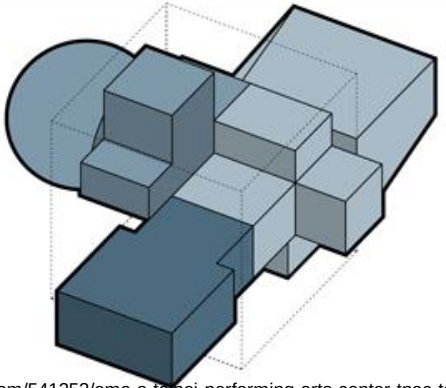


resources:

- http://www.arup.com/Projects/Taipei_Performing_Arts_Centre?sc_lang=en-GB
- http://www.archdaily.com/462482/considering-the-quake-seismic-design-on-the-edge
- http://peer.berkeley.edu/tbi/wp-content/uploads/2010/09/Irwin.pdf
- http://www.eaee.org/Media/Default/2ECCES/2ecces_eaee/222.pdf
- http://jmst.ntou.edu.tw/marine/5/55-63.pdf
- https://weatherspark.com/averages/33158/Taipei-City-T-Ai-Pei-Shih-Taiwan
- http://oma.eu/projects/taipei-performing-arts-centre

PROGRAM





http://www.archdaily.com/541253/oma-s-taipei-performing-arts-center-tpac-tops-out

THEATER		20,250 m_2
PARKING		15,050 m_2
PUBLIC SPACE		5,700 m_2
OFFICE		3,500 m_2
SERVICES		2,000 m_2
		46,500 m_2