

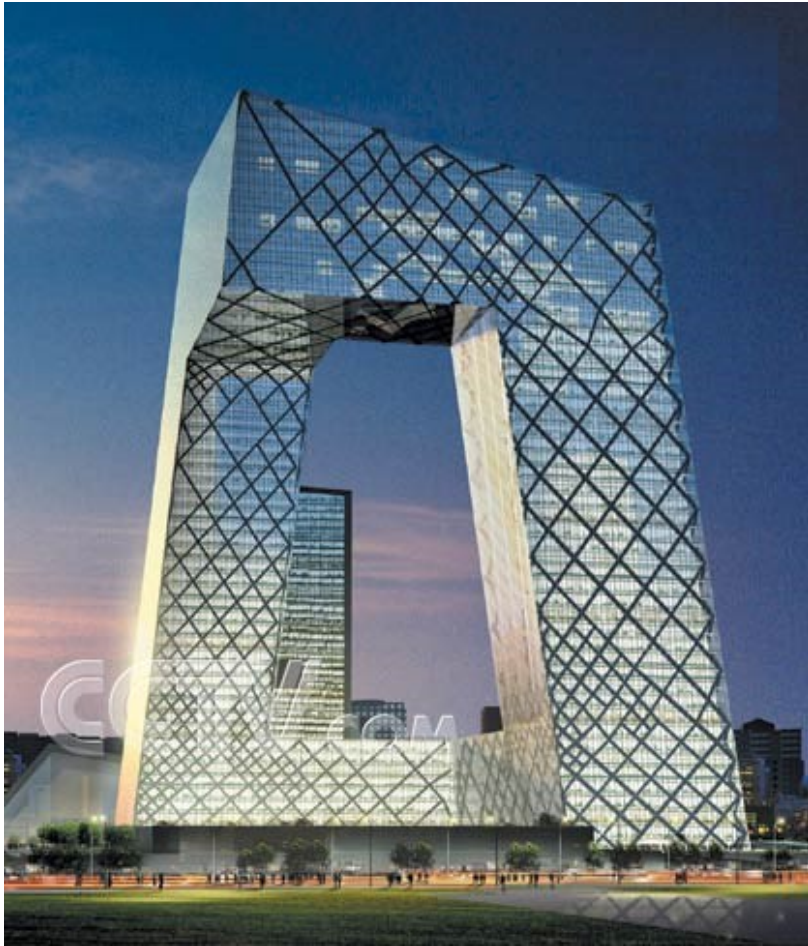
# CCTV Headquarters Case Study



ARCH 631

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# Introduction



CCTV Headquarters

Location: Beijing, China

Architect: Rem Koolhaas

Engineer: Arup

Completion date: May 16, 2012

Floor Count: 51

Floor Area: 389079 m<sup>2</sup>

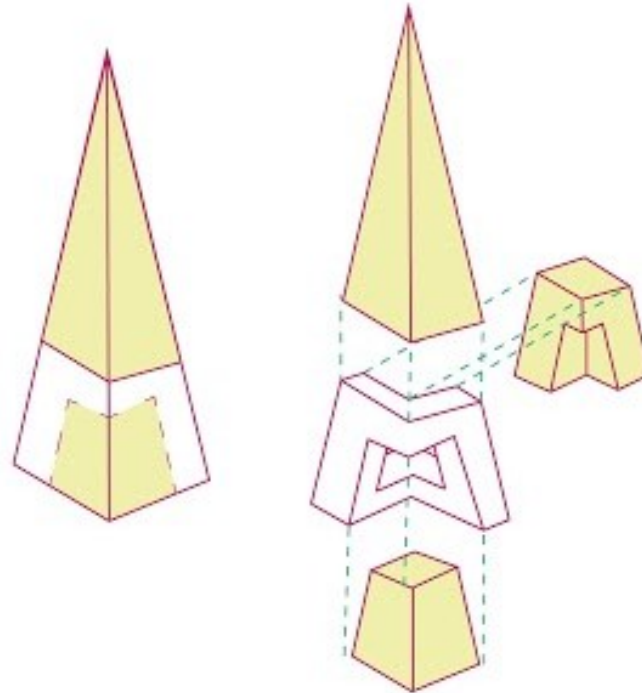
Height: 234m (768 ft)

# Design Concept

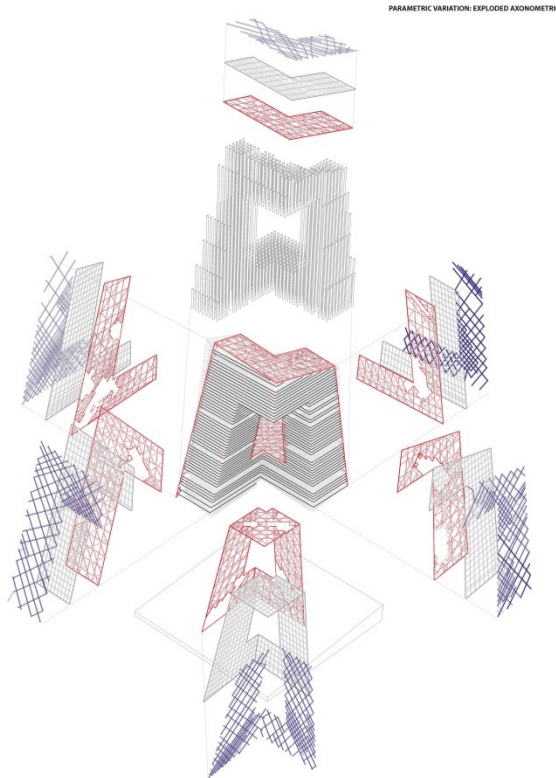


PYRAMID

Leftover packing material  
for an object that has been  
removed



# Problems and Challenge



## Design Issues:

- Instability due form: The building form: the continuous loop, sloping tower and cantilever overhang add the complexity of structure
- Instability due to weight: dead load caused by steel structure

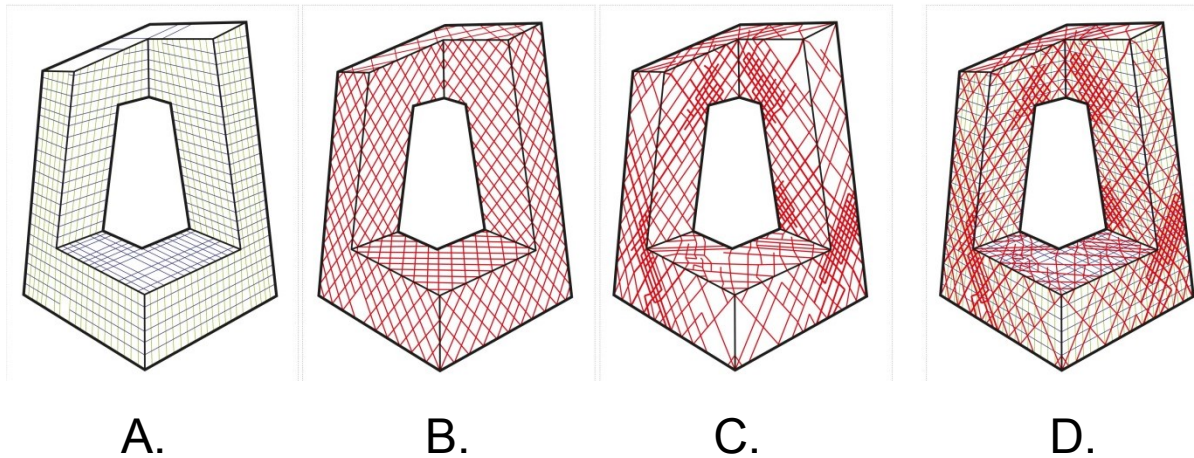
## Site Issues:

- Beijing is an earthquake zone
- Shallow subsoil condition
- High Settlement risk
- Large amount underground water

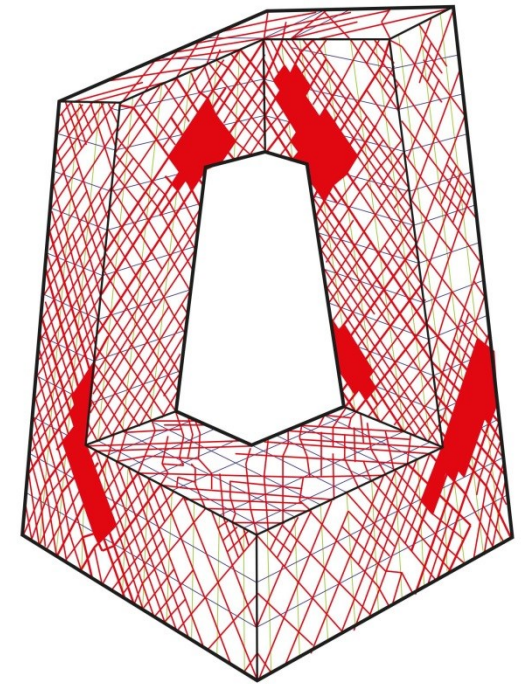


# External Structure System

## Diagrid Frame System (Continuous tube system)



- A. Edge structure
- B. 12m\*12m diagrid structure
- C. Stress distribution structure
- D. Combined structure



Final Grid System

# External Structure System

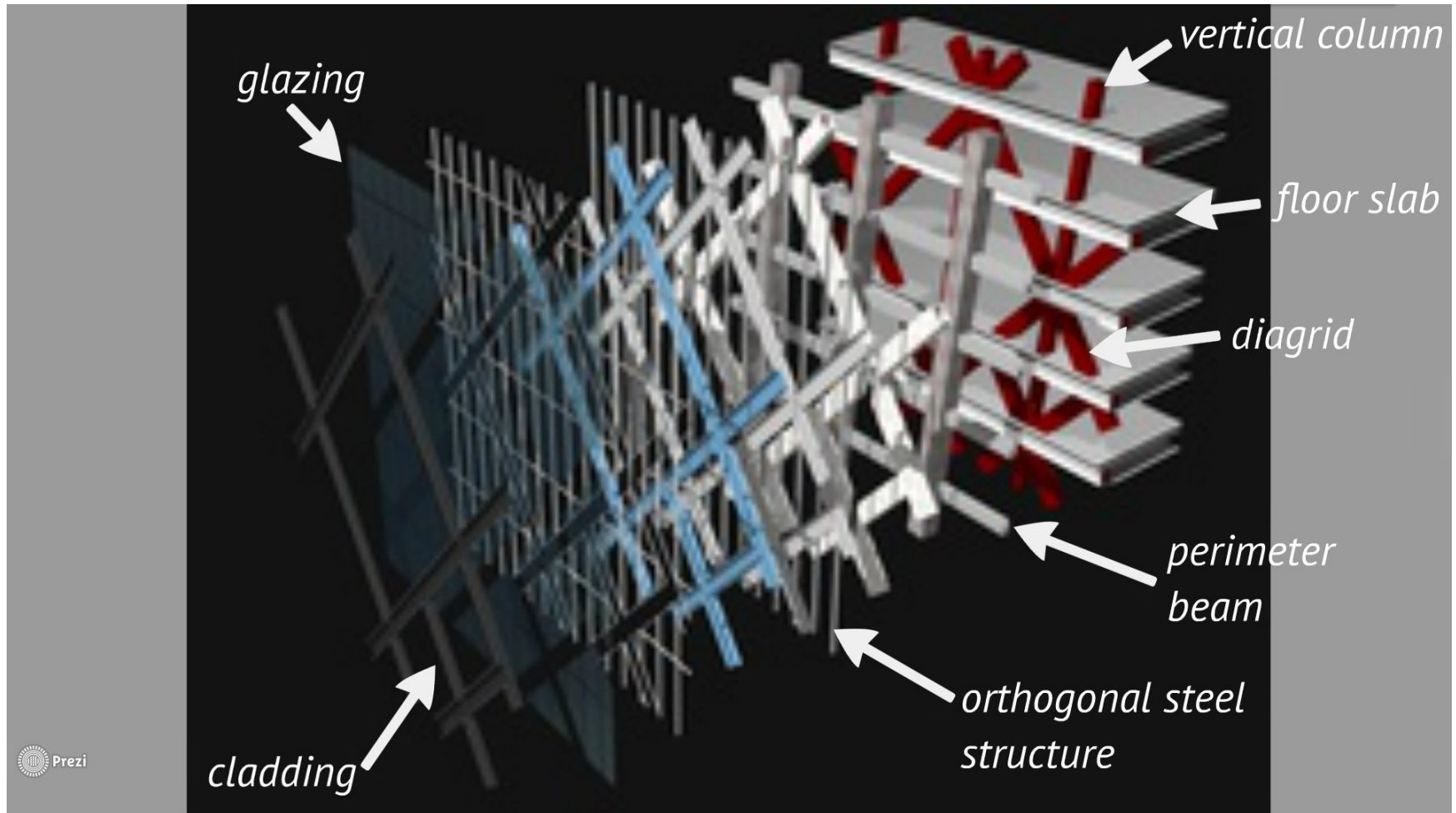
## Diagrid Frame System

- Triangulate structure with diagonal support beams
- Triangles connected at *Nodes* and *Rings* intersect the nodes
- Combines a hollow tube with a truss
- Loads follow diagonals, gravity and lateral loads can be transferred by the system to the ground
- Steel is typical because of high tensile and compressive strengths
- Essentially marrying columns, diagonals and bracings into one system



# External Structure System

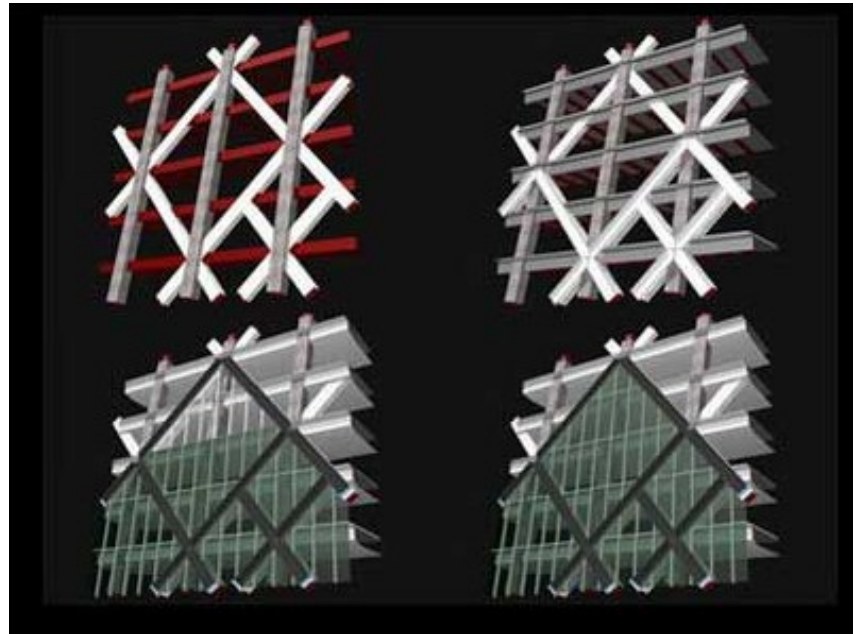
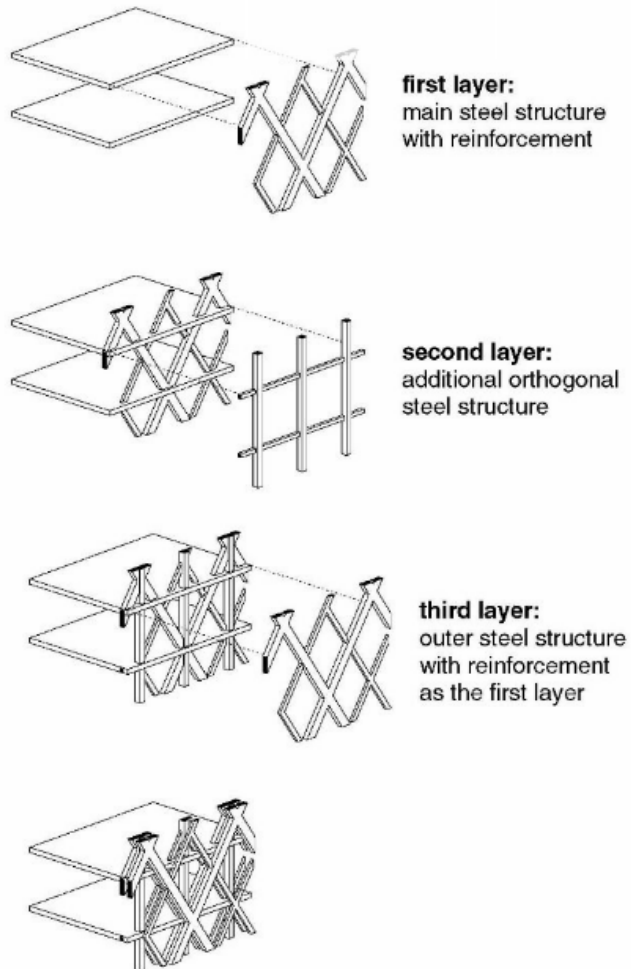
## Diagrid Frame





# External Structure System

## Diagrid Frame



<https://prezi.com/anmn7ckwvtj/cctv-structural-analysis/>

# Diagrid System

## Load Transfer

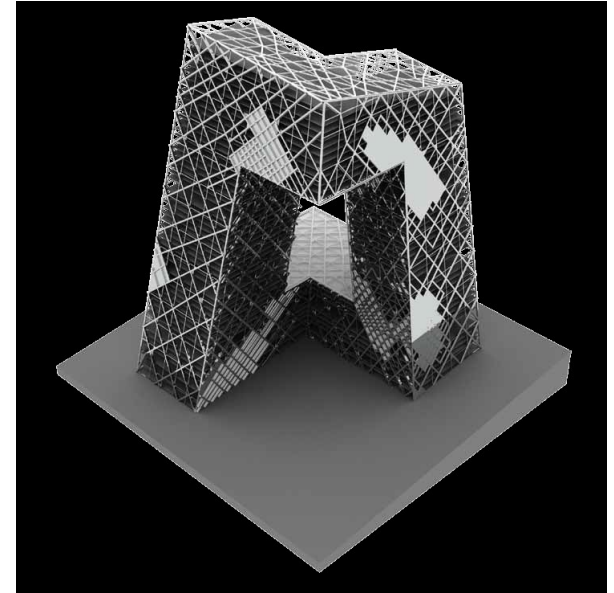
- Load transfer happens primarily through diagrid
  - a) Internal Cores will transfer minimal amounts of gravity loads
  - b) Floor Slabs do not have to transfer lateral loads
  - c) Less internal columns required = more space
  - d) Floor plates do not have to be of the same shape on each floor
- Continuous and Uninterrupted Load Transfer
- Rings help to resist Buckling Loads transforming whole system into one big tube



# Diagrid System

## Advantages:

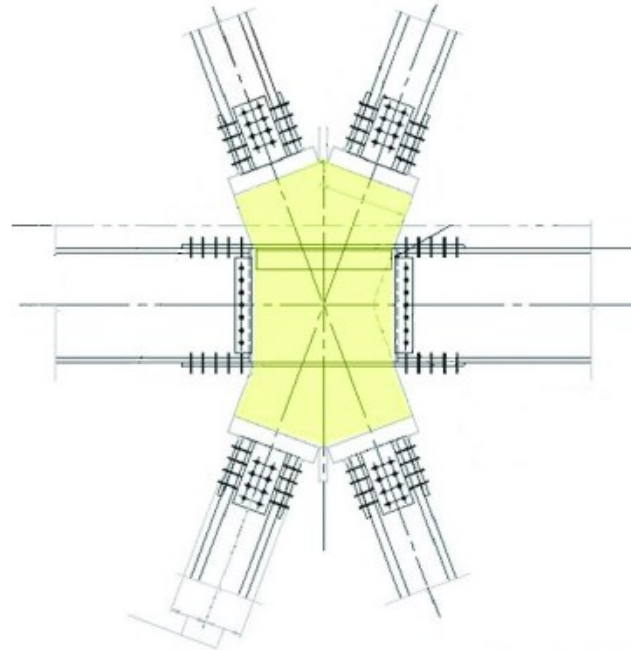
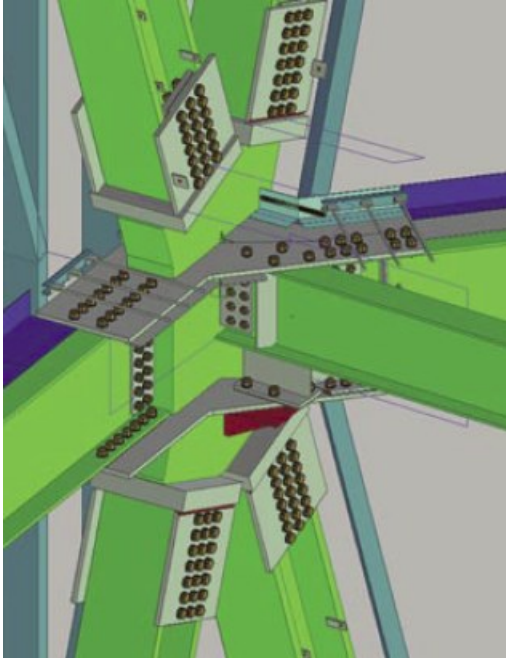
- Structurally very strong
- Less material required (~20% reduction in steel as opposed to typical moment frame method)
- Aesthetically Pleasing – Blends in together with façade
- Floor plan becomes open and free – more internal space
- Most forms can be created with a triangulated form– architectural freedom
- Self-reliant structure, simple in shape
- Simple Construction Technique
- Skyscraper Structural Failure minimized by diagrid construction
- Better ability to redistribute loads than a moment frame (Failure of one portion does not mean complete structural failure)



<https://prezi.com/anmn7ckwvjty/cctv-structural-analysis/>

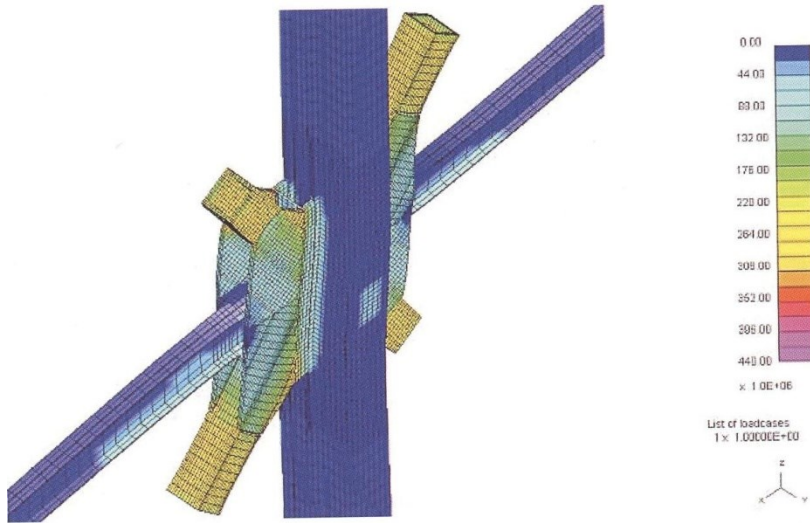
# Diagrid System Connection Details

## Connections – Butterfly Plates



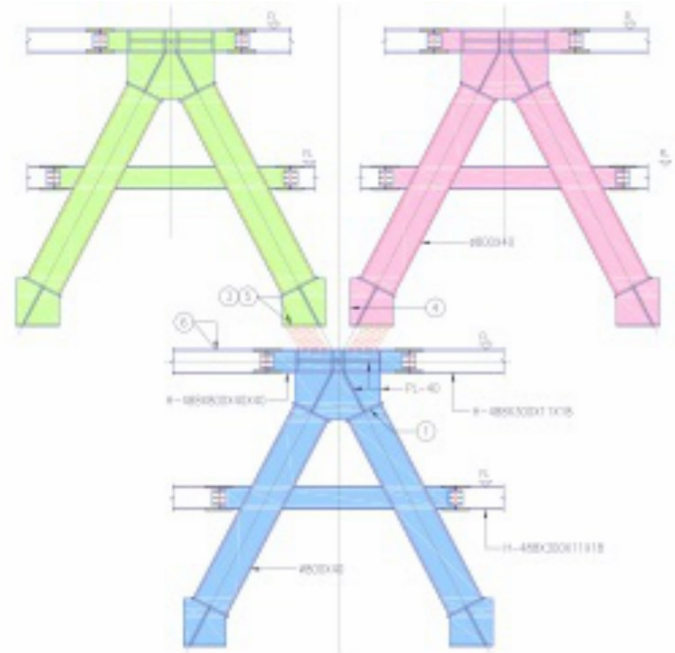
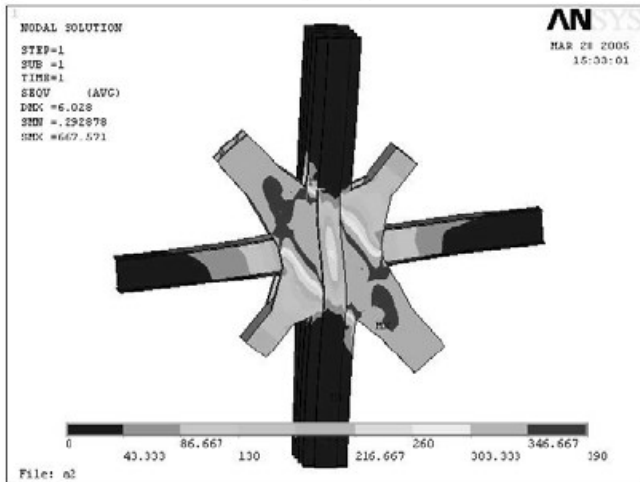
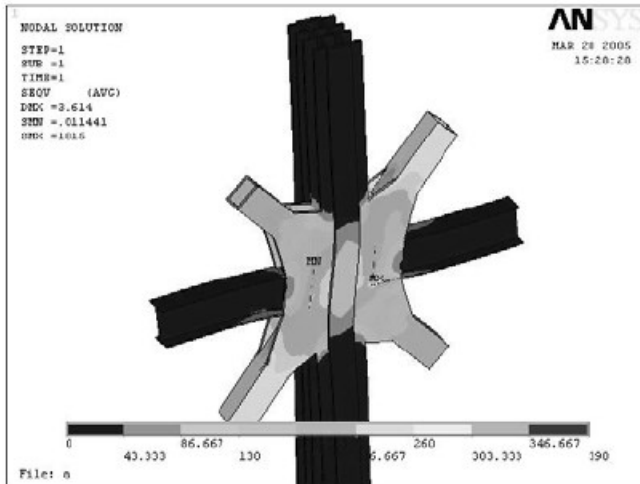
- The meeting of vertical columns, diagonal members & perimeter beams at nodes
- Butterfly plates will be welded to bring all these 3 members together
- Enabling the vertical and horizontal elements to remain comparatively unstressed in an earthquake

# Diagrid System Connection Details



- Critical Members in the Structural System
- Must ensure a “strong joint-weak member” system
- Must resist maximum probable load from braces with minimum yielding and stress concentration
- Butterfly plates used to assist smooth load transfer
- Finite Element Analysis of Connection

# Diagrid System Connection Details



## Node construction

- In-place steel shop welding
- Lifting up piece by piece
- Trial shop assembly of parts with high strength bolts
- In-place welding
- High strength bolts assembly
- Setting up perimeter girders

# Internal Structure System

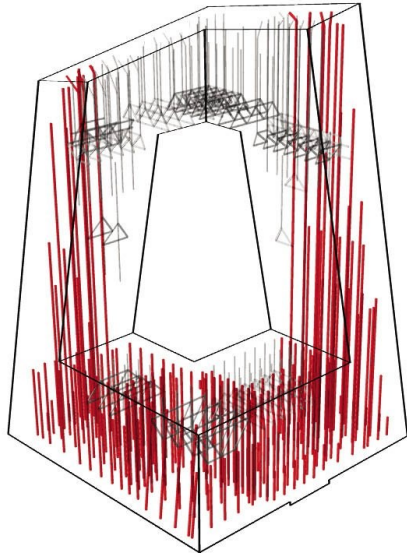


## Columns

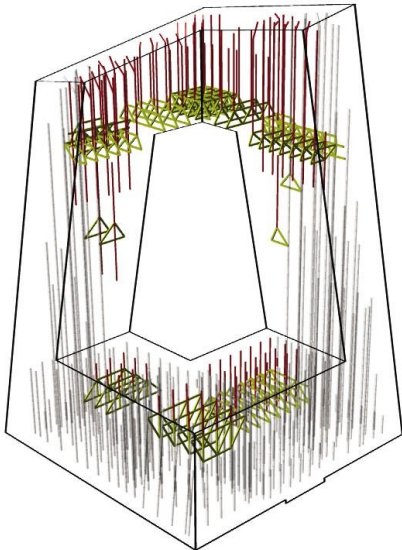
- The Columns mean to transfer load from the top to the foundation level
- Vertical internal tube structure results different configuration for every floor, some of those columns are needed to transfer the load to transfer trusses



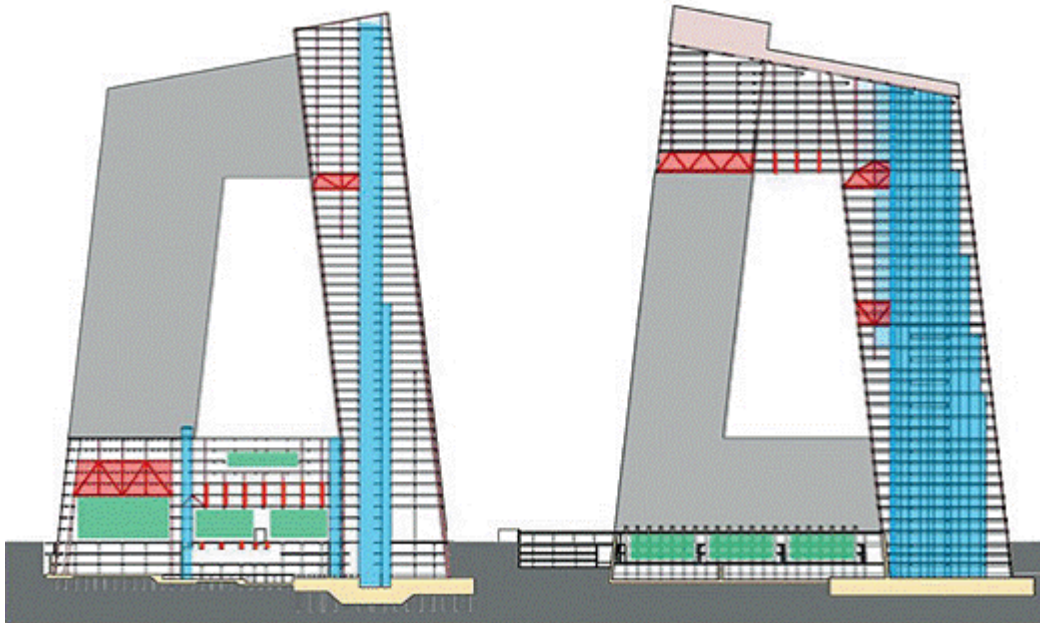
# Column Types



Different types of concrete column are also used to reach their maximum carrying capacity.

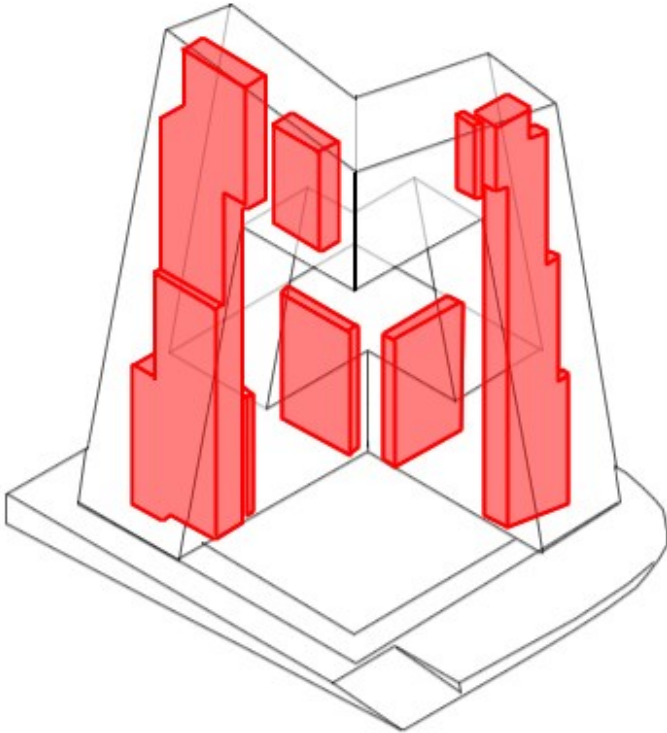


# Transfer Trusses



- Transfer Trusses are used for the large open space such as studios and facilities
- Connecting internal core and exterior tube structure horizontally
- Connecting columns Vertically

# Vertical Core



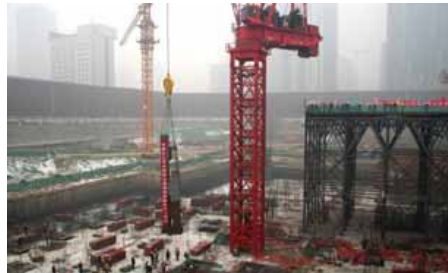
- make each floor a specific spatial configuration
- Making stability of overall system

# Construction Sequencing

1. Building foundation Raft



2. Setting Up the Column



3. Using Craning to build up structure



4. Connecting Overhang

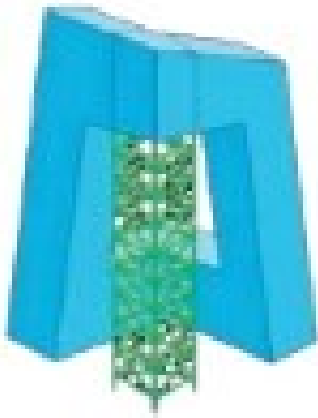


5. completed overhang structure 6. Installing the exterior glass

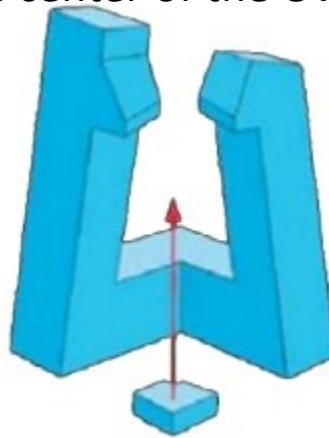


# Construction Sequencing

- In addition to regular gravity and lateral forces acting on the structure, there are significant additional construction stage forces due to the fact that the building comprises two separate leaning Towers with cantilever up until the point at which they are joined to become one structure.
- First method is to construct a temporary tower the full 162m height to the underside of the Overhang, providing a working platform to build the Overhang connection
- Second method is to construct the lower part of the Overhang at ground level and strand jack the assembly into position
- Third method is to construct incremental cantilevers from each Tower until the two met and connected at the center of the Overhang



Method1



Method2



Method3



# Construction Sequencing



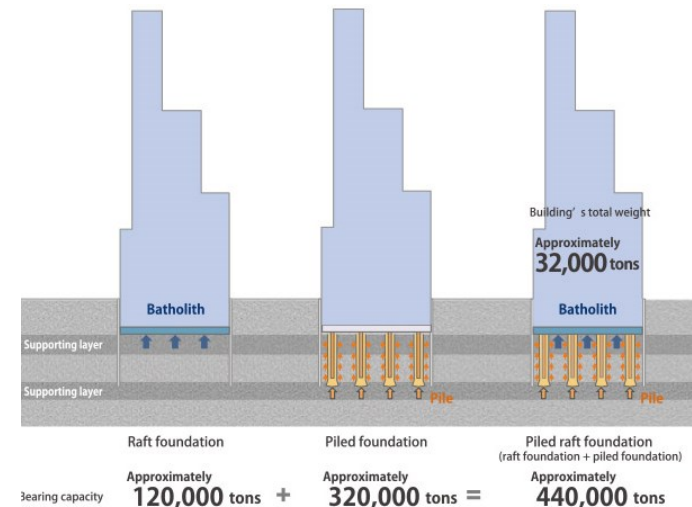
The Arup Journal 2/2005



*Time lapse images courtesy of OMA*

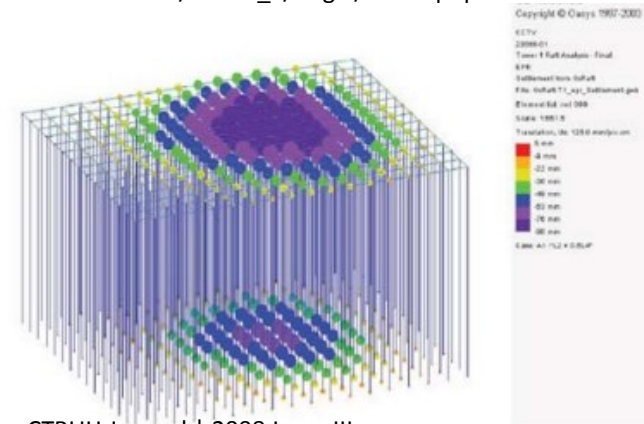
# Foundation-Piled Raft

- Reason
- The bearing capacity of the subsoil around the main towers of CCTV is not sufficient to support the entire load from the superstructure whilst remaining within acceptable settlement limits. Piles and a raft foundation are integrated to transfer a large force affecting the building to the ground.



[http://www.abeno.project-takenaka.com/abeno\\_e/saigai/sai-01.php](http://www.abeno.project-takenaka.com/abeno_e/saigai/sai-01.php)

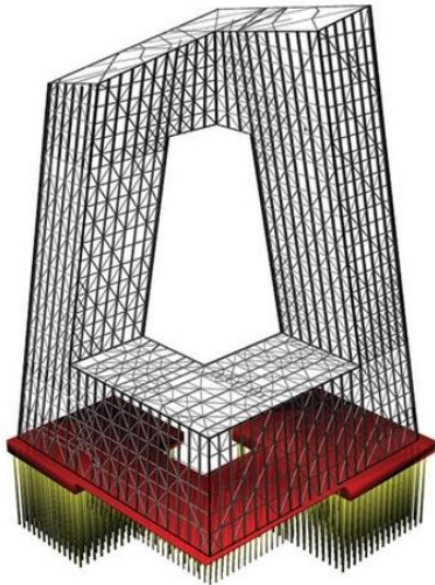
- Total Settlement estimated as <100mm
- Differential Settlement kept to 1:500
- Piles are 1.2m diameter and 52m long
- Piled Raft is up to 7.5m thick and has a footprint greater than the towers
- Arranged for center of raft to be close to center of load underneath each tower



CTBUH Journal | 2008 Issue III  
Case Study: CCTV Building - Headquarters & Cultural Center

# Foundation-Piled Raft

- For the Base plus three - story basement, a traditional raft foundation is used, with tension piles between column locations to resist uplift from water pressure acting on the deep basement. 15-20m long, 600mm diameter tension piles will be arranged under the raft with additional 1.2m diameter piles under secondary cores and columns supporting large transfer trusses from the studio areas



The CCTV foundation system.

[http://www.360doc.com/content/10/1210/02/16546\\_76642178.shtml](http://www.360doc.com/content/10/1210/02/16546_76642178.shtml)



CCTV Building, A Structural Design Overview

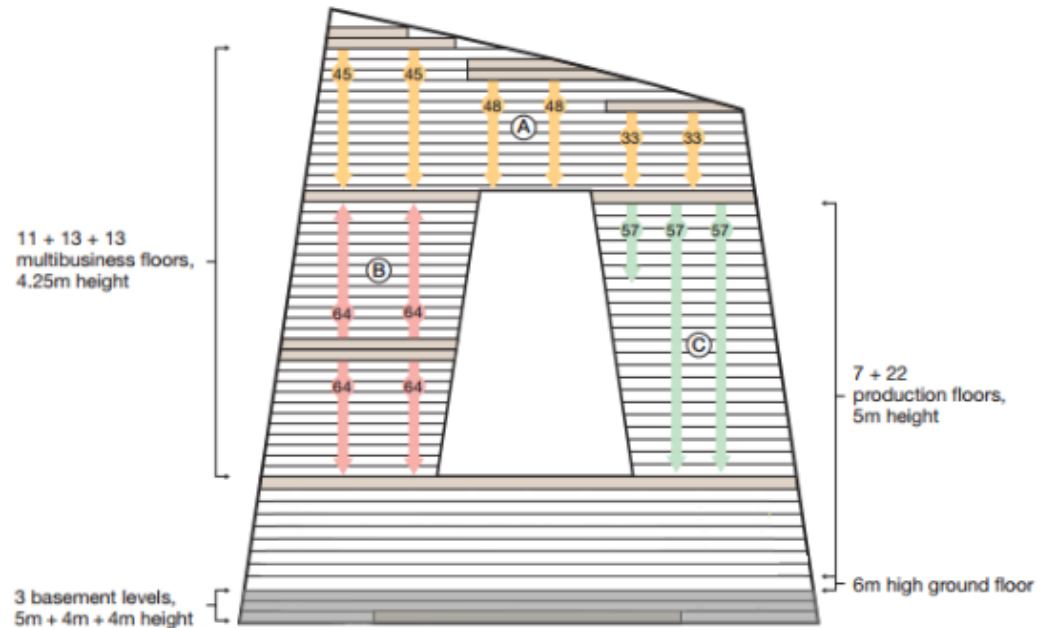
<http://www.slideshare.net/peterbach/cctv-building-a-structural-design-overview>

# Basement

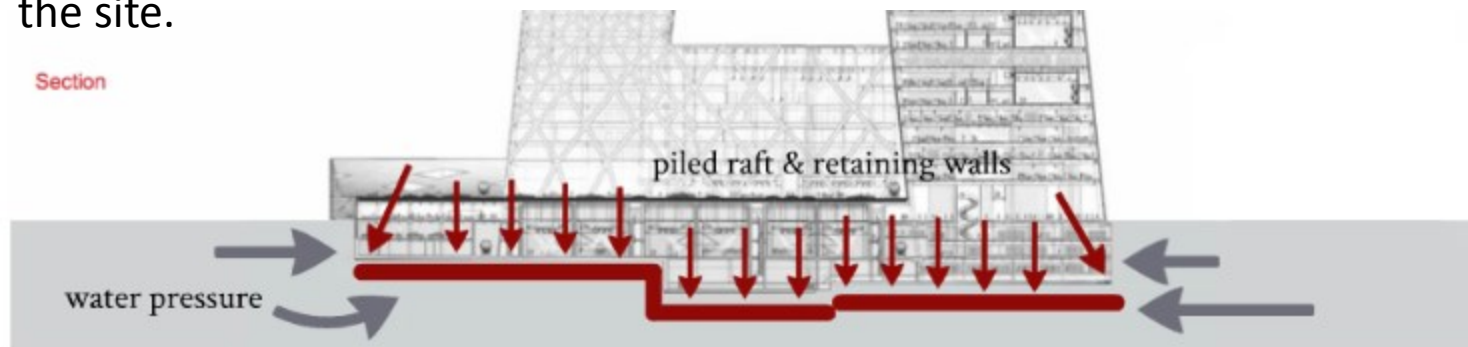
## Function of Basement

- Water Storage
- Air Exchange
- Electrical
- Parking

Three story basement with retaining walls & with the help of the piled raft resist the upward force of the water pressure around the site.



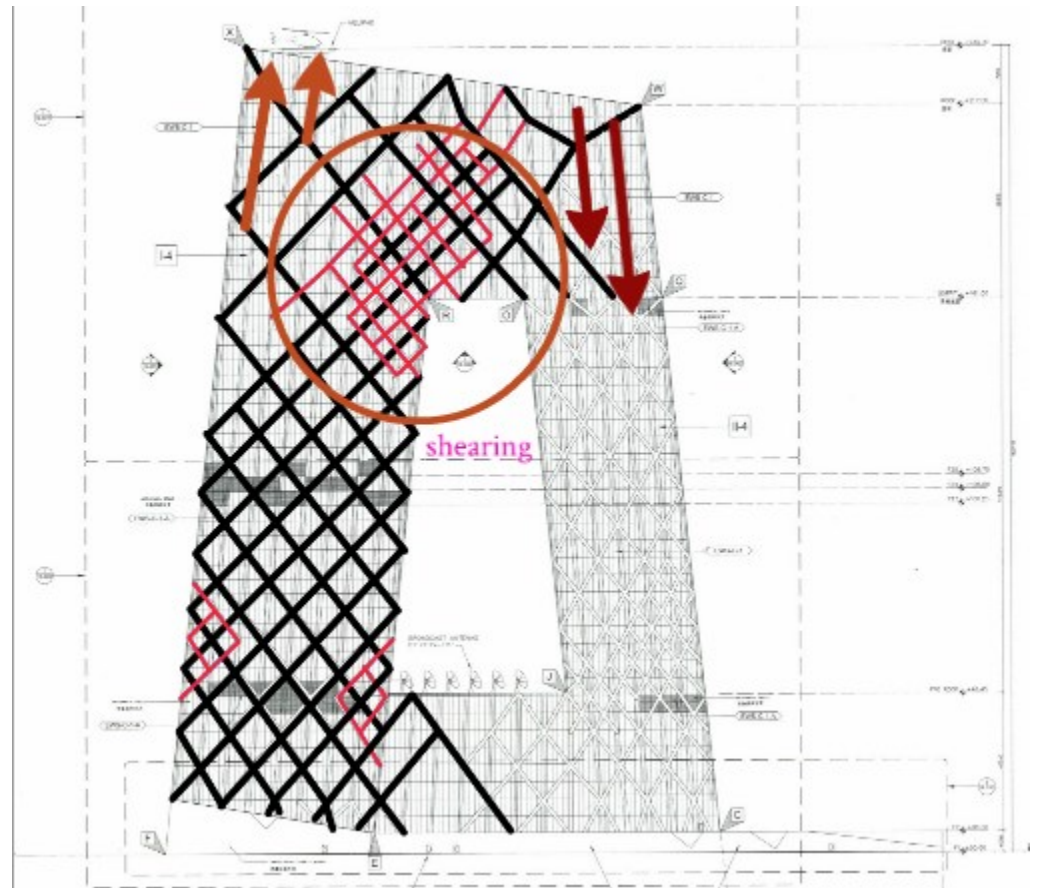
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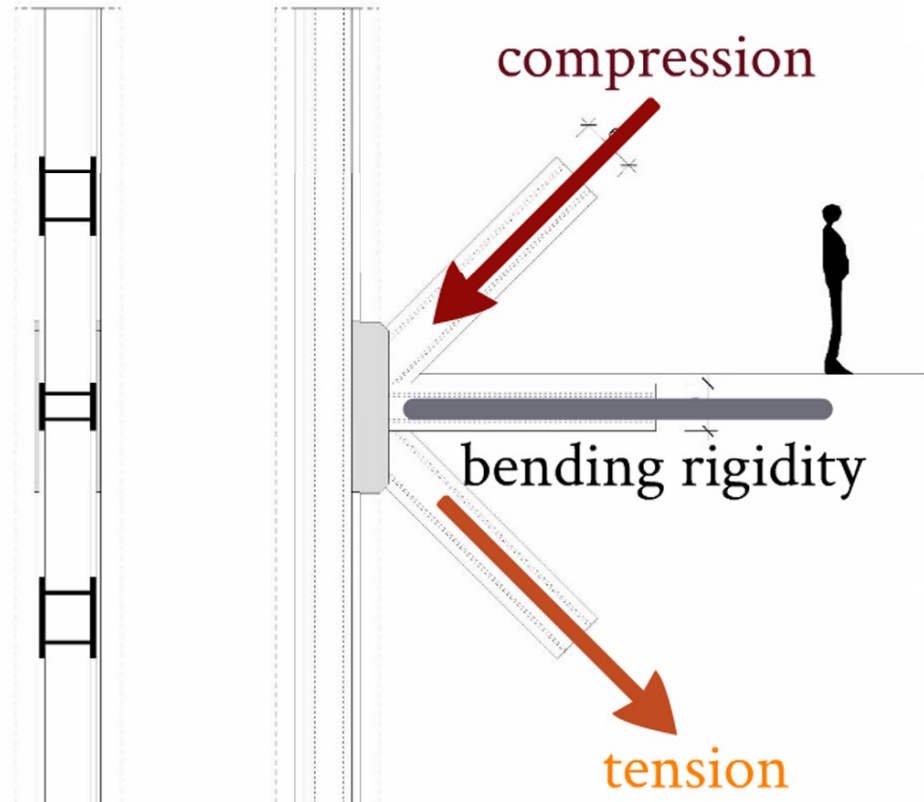
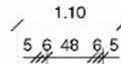
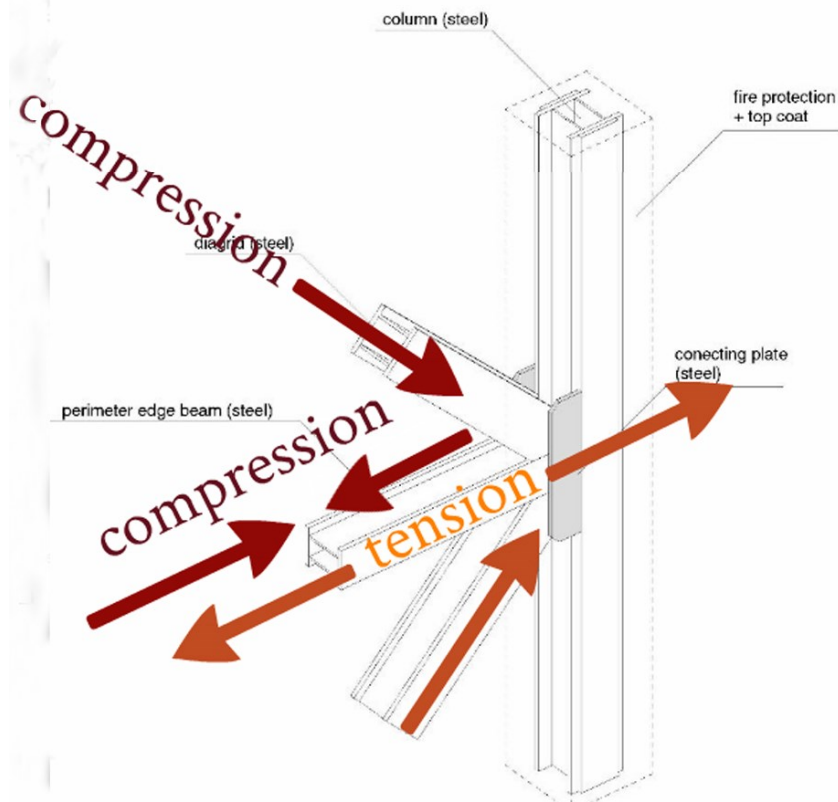
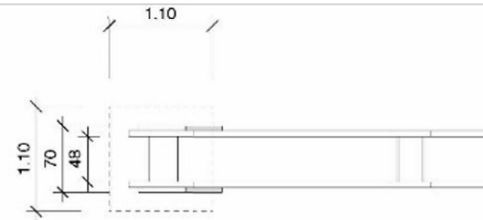
# Force Acting on the structural elements

Triangular modules with diagonal beams diffusion of forces along the façade  
(hence, the elimination of large vertical columns)



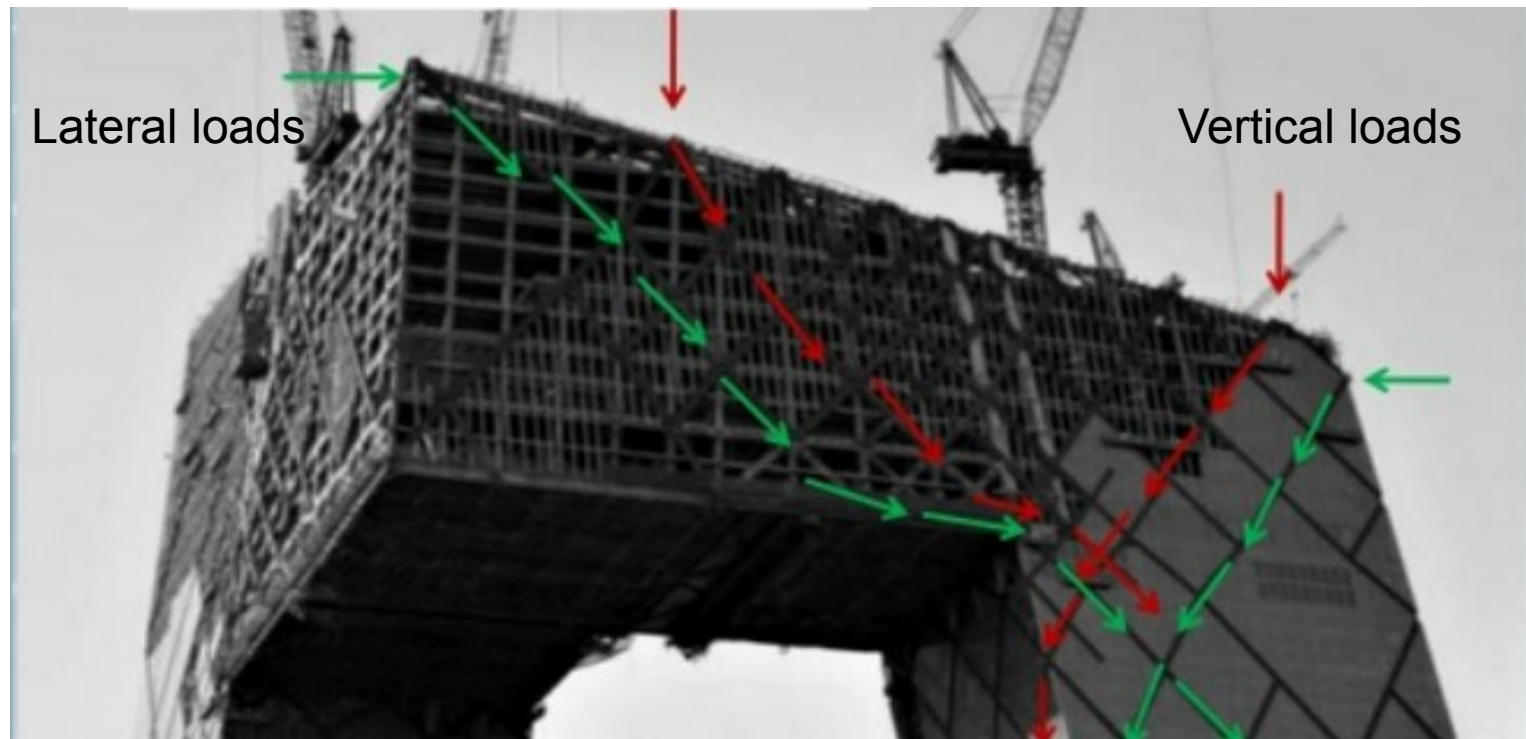


- Perimeter steel involves in bending resistance / rigidity

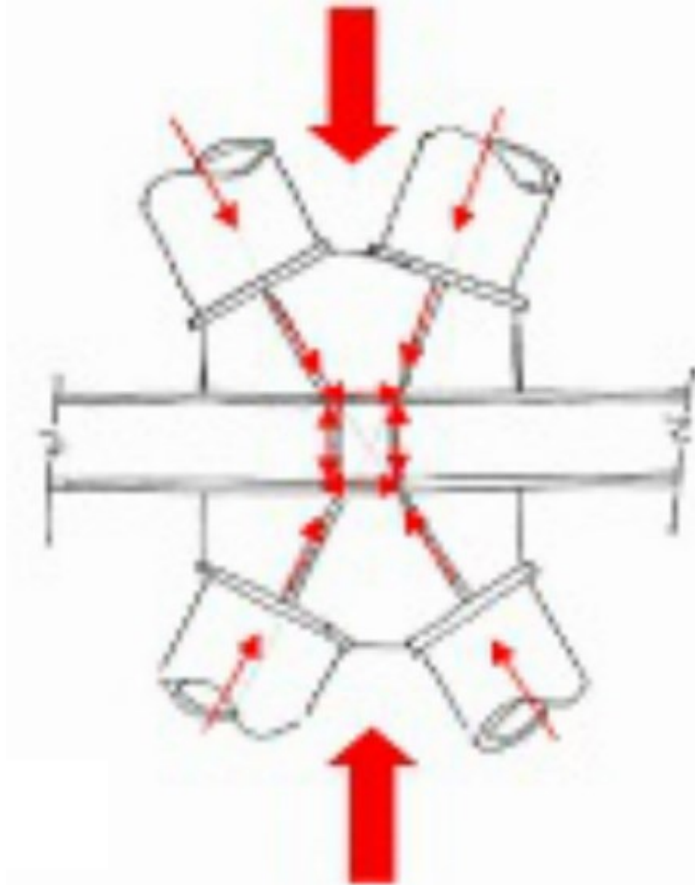


Triangulation also minimizes shear racking effects because internal axial forces are within the members.

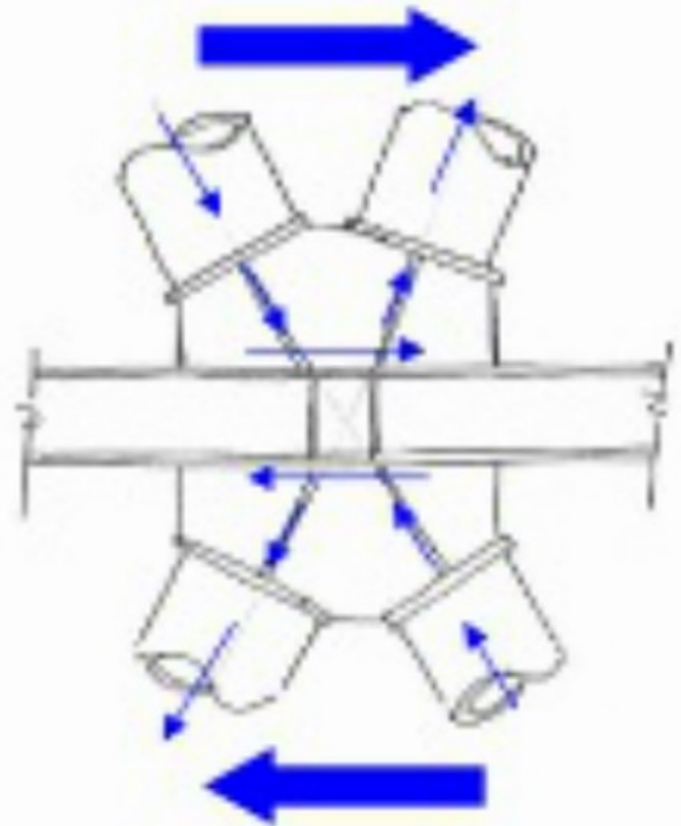
Diagonalized modules acting as inclined columns & bracing elements carry gravity & lateral load resistance.



## Diagrid force on node

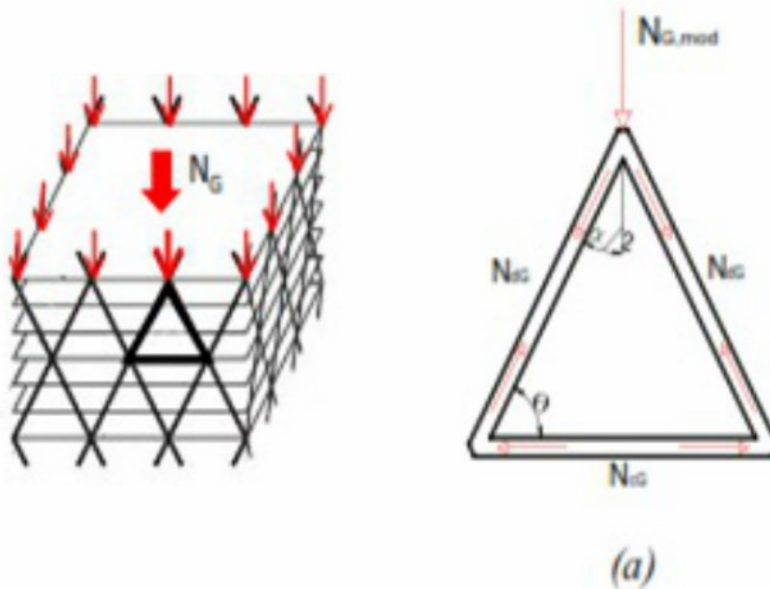


Under Vertical load



Under horizontal load

# Structural action in a diagrid module - Gravity load



$$N_{dG} = \frac{N_{G,mod}}{2\cos\left(\frac{\alpha}{2}\right)}$$

$$N_{cG} = N_{dG} \cdot \sin\left(\frac{\alpha}{2}\right)$$

Downward vertical force,  $N_G$

Diagonal in compression

Horizontal chord in tension

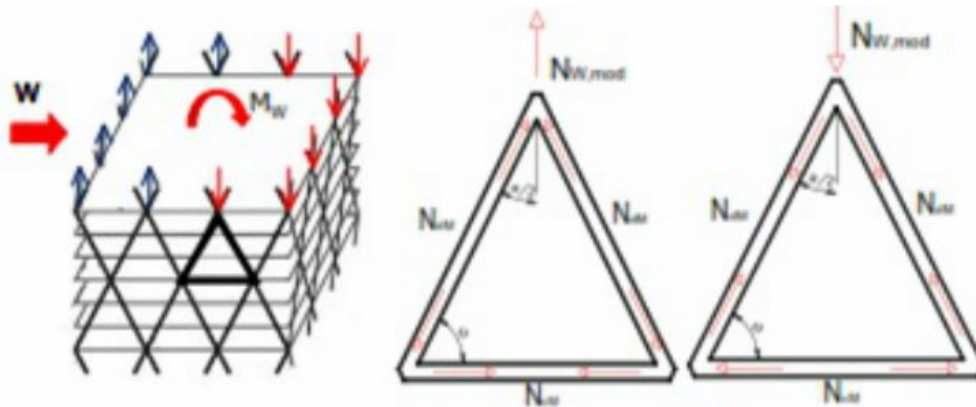
# Structural action in a diagrid module - Lateral load

Sideways horizontal force / Overturning moments ( $M_w$ ) cause vertical forces in the apex joint of the diagrid modules.

Max intensity in upward direction on windward façade. ( $N_w$ )

Max intensity in downward direction in leeward façade. ( $N_w$ )

Gradual decreasing values in modules along the sides.



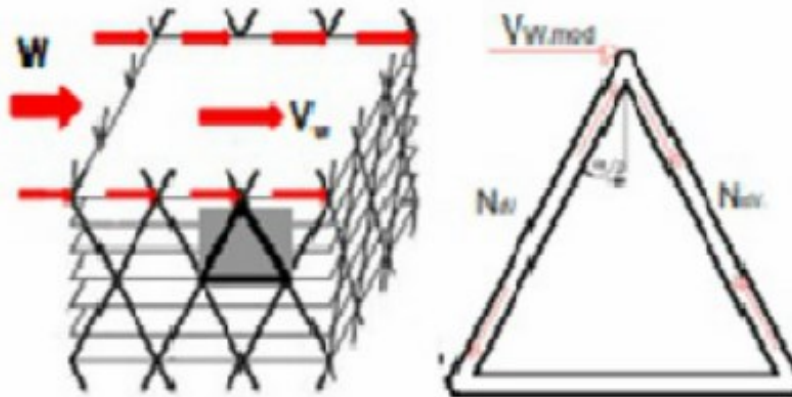
(b)

$$N_{dM} = \frac{N_{w,mod}}{2 \cos\left(\frac{\alpha}{2}\right)}$$

$$N_{cM} = N_{dM} \cdot \sin\left(\frac{\alpha}{2}\right)$$



# Structural action in a diagrid module



Global shear,  $V_w$  causes horizontal force in the apex joint of the diagrid modules,  $V_{w,mod}$ .

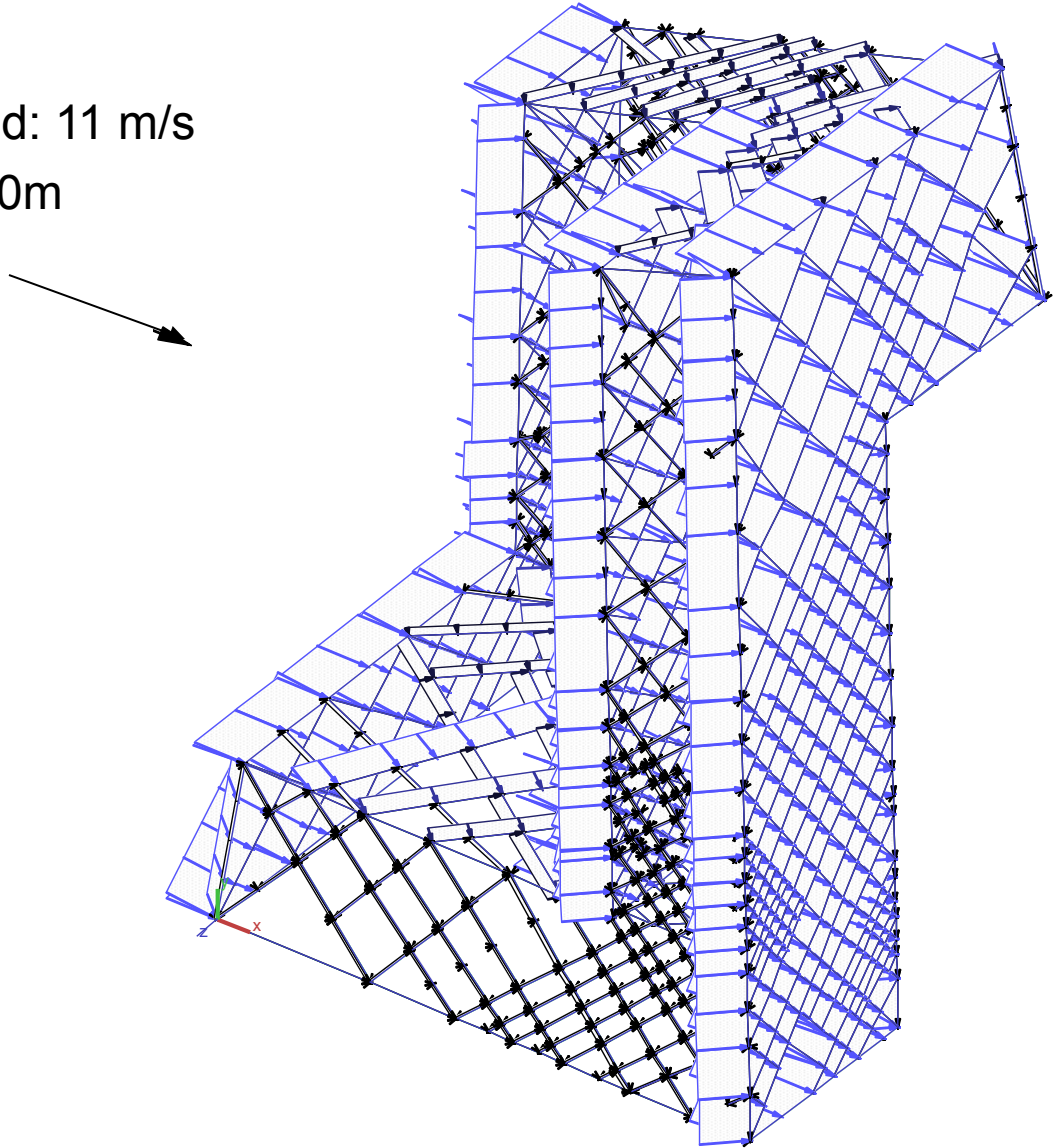
Intensity depends on the position of the module in respect to the direction of the wind.

Absorbed by the modules parallel to the load direction.

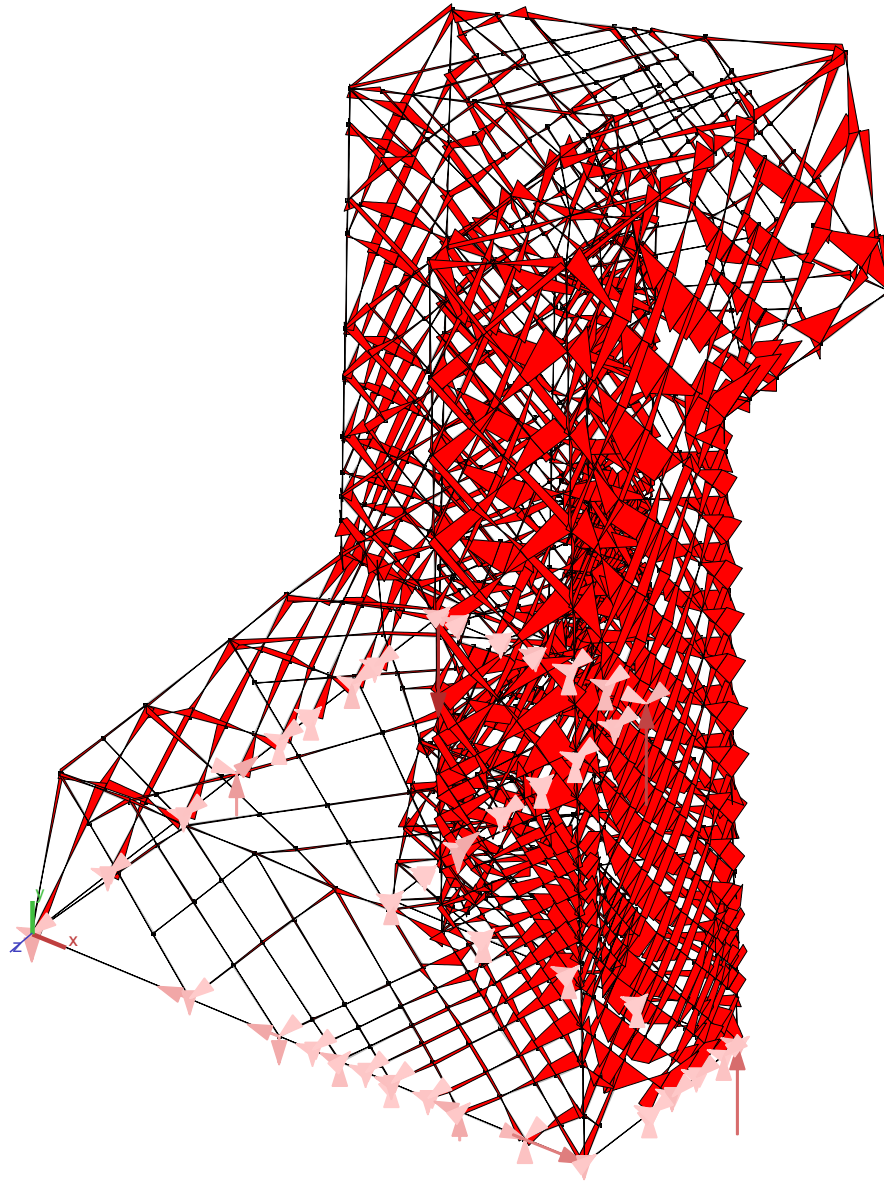
$$(c) \quad N_{dV} = \frac{V_{w,mod}}{2 \sin\left(\frac{\alpha}{2}\right)}$$

# MultiFrame-Wind Load

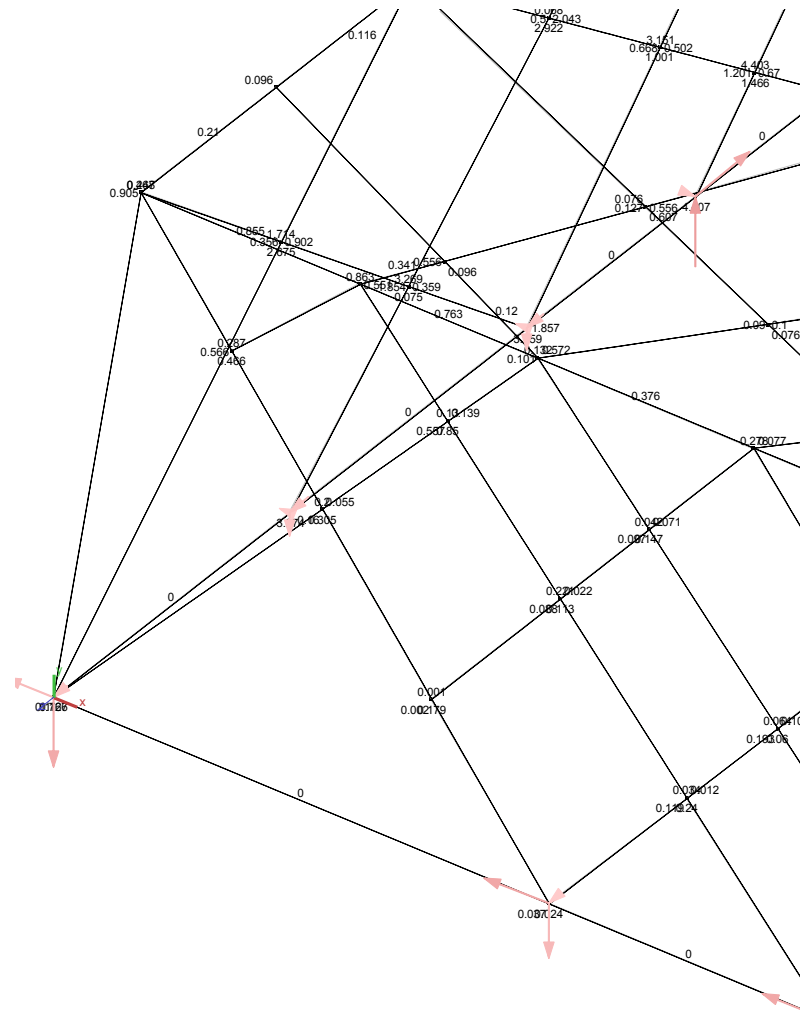
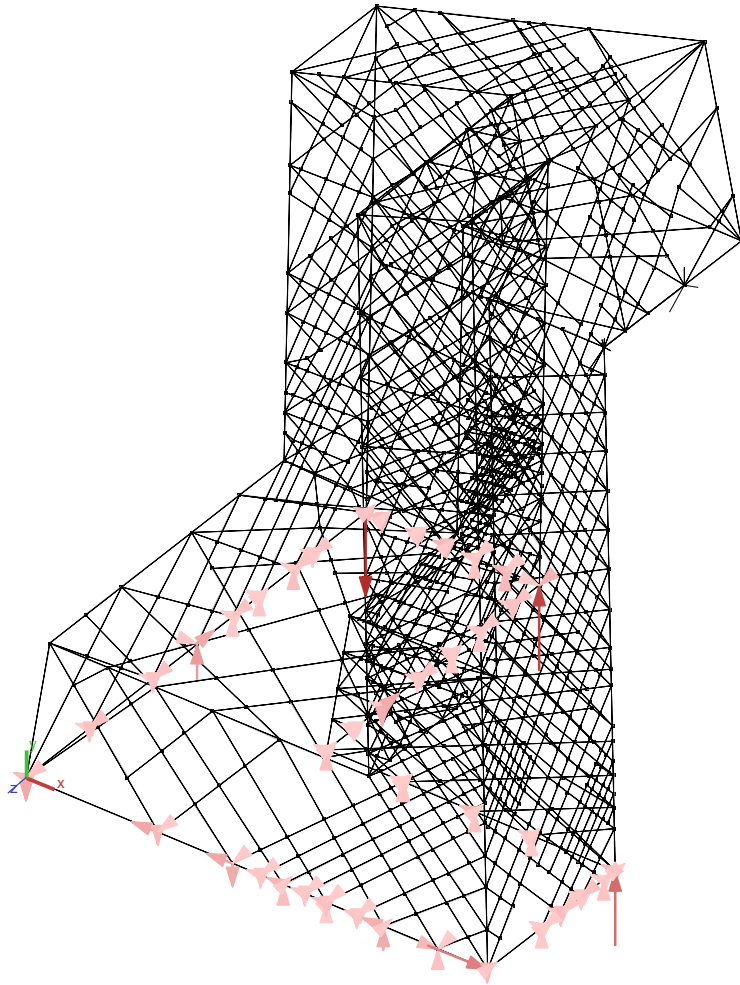
- Beijing max wind speed: 11 m/s
- Add wind load every 20m



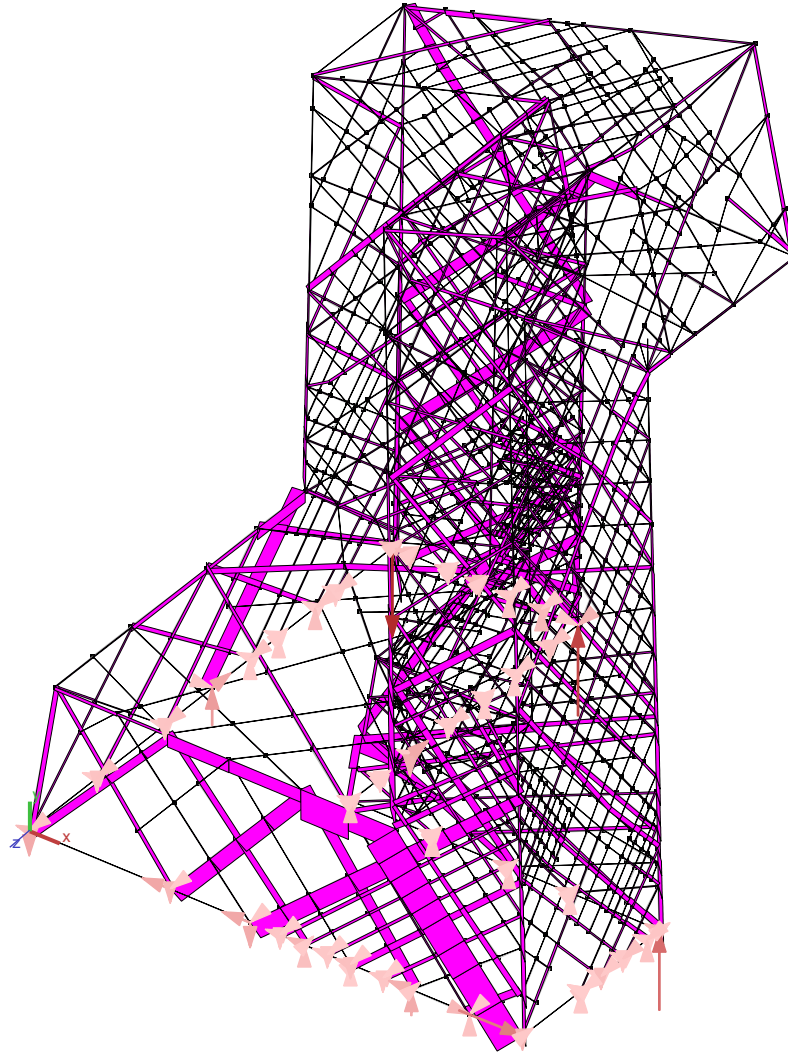
# MultiFrame- Wind Load- M



# MultiFrame- Wind Load- V

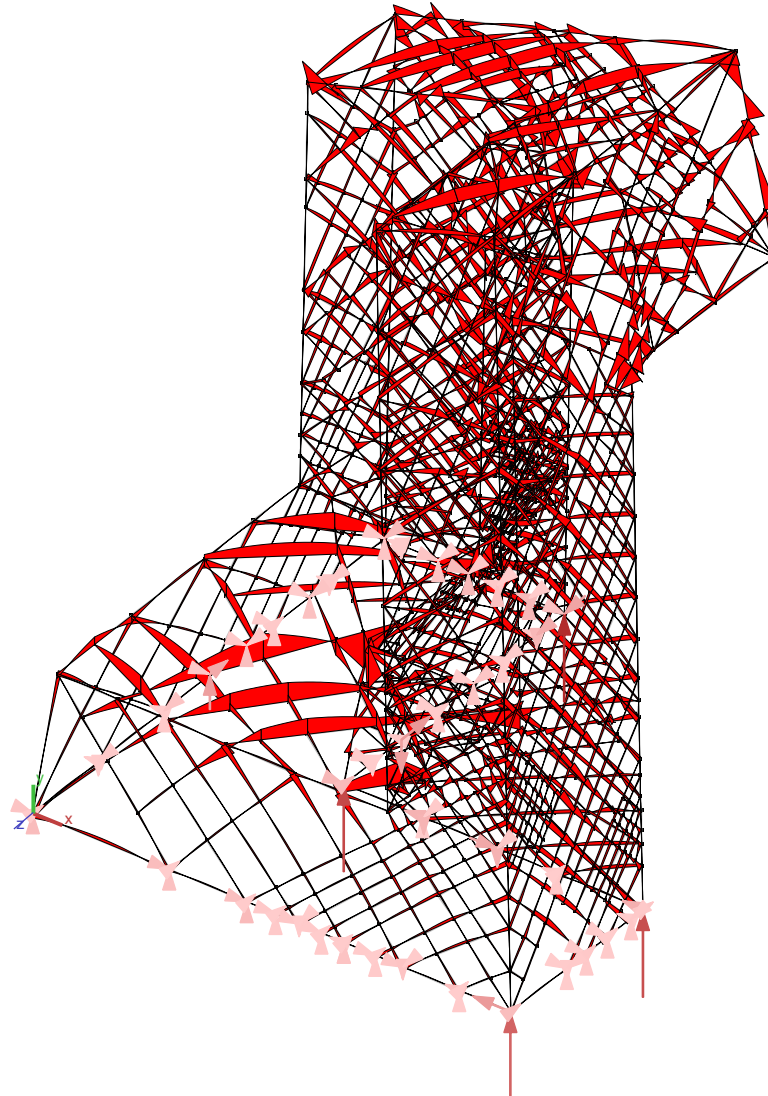


# MultiFrame- Wind Load- P

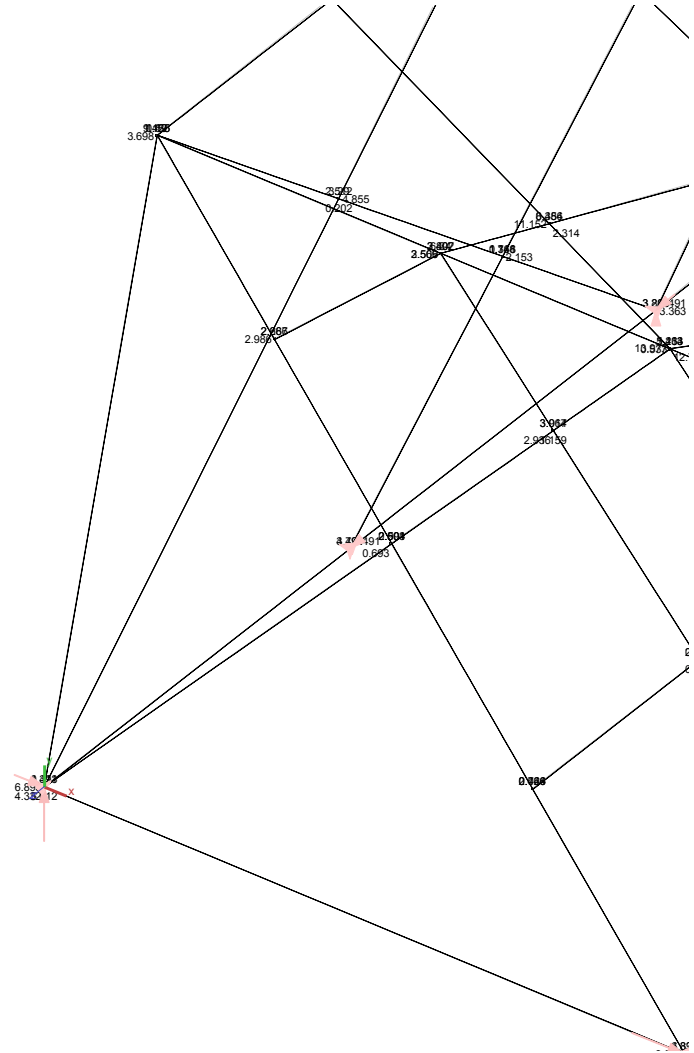
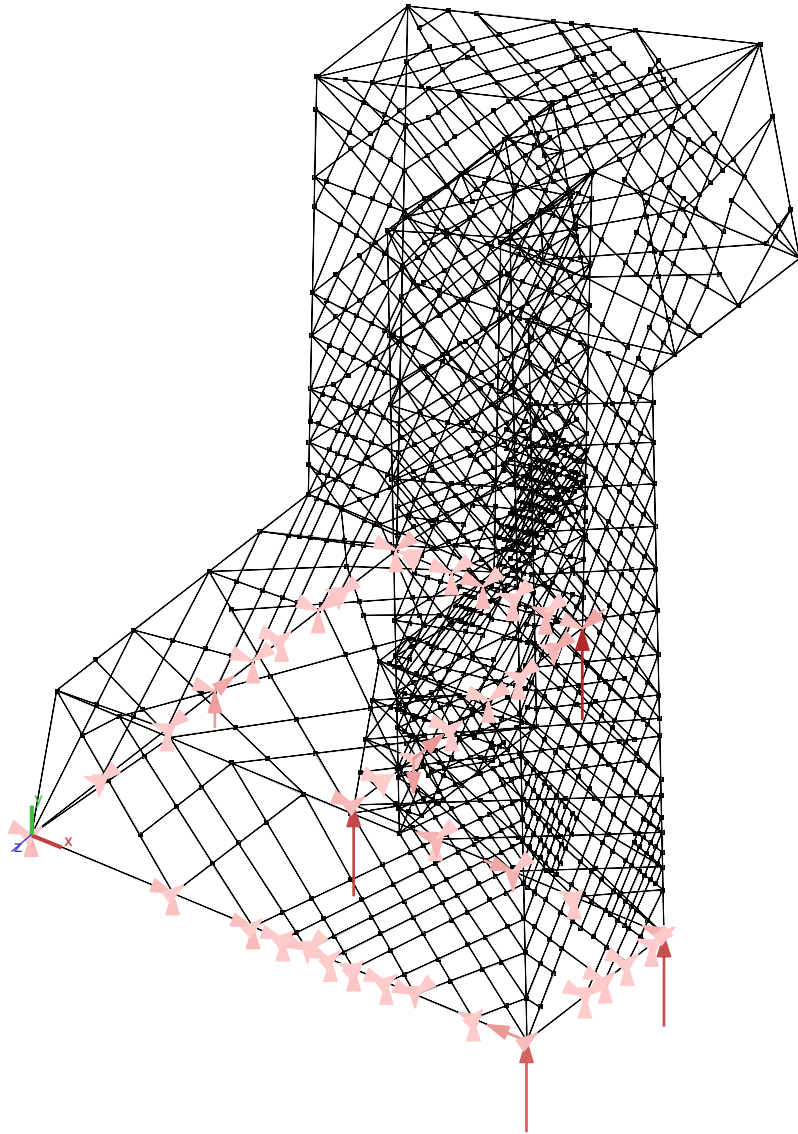




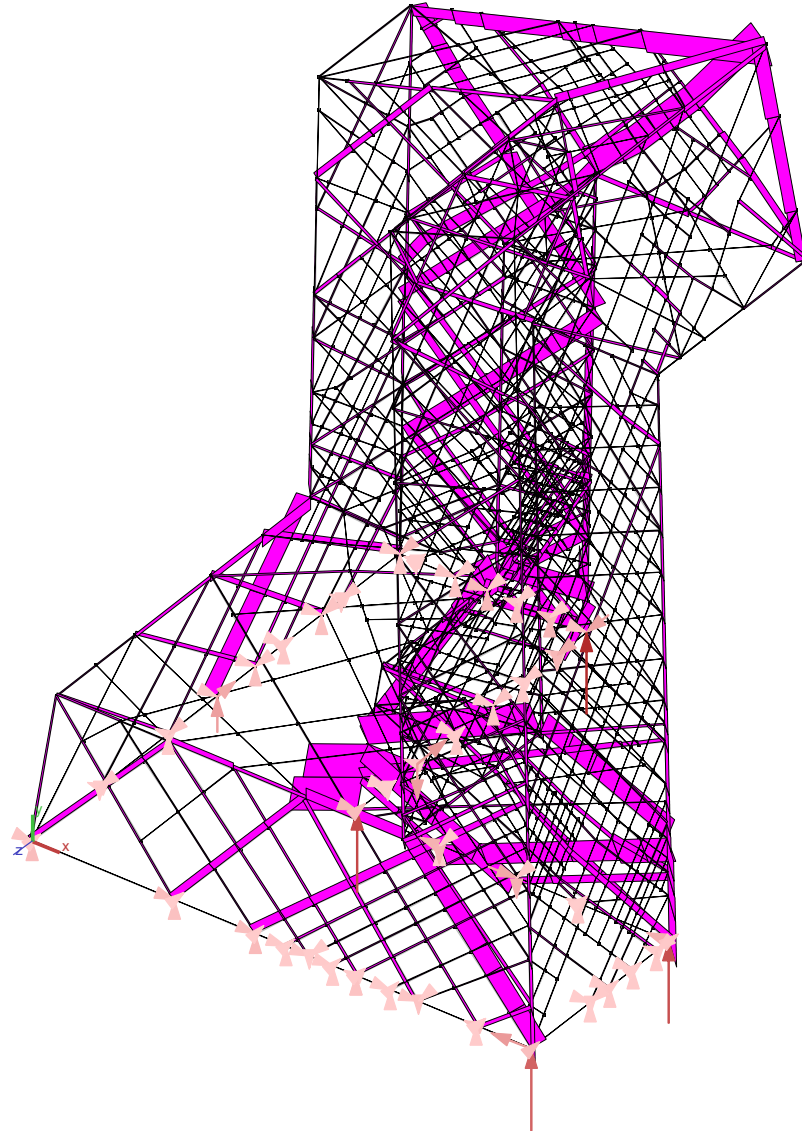
# MultiFrame- Self-Weight- M



# MultiFrame Self-Weight- V



# MultiFrame Self-Weight- P



# Bibliography

- <https://prezi.com/anmn7ckwvtj/cctv-structural-analysis/>
- CTBUH Journal | 2008 Issue III Case Study: CCTV Building - Headquarters & Cultural Center
- The Arup Journal 2/2005
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- [http://www.abeno.project-takenaka.com/abeno\\_e/saigai/sai-01.php](http://www.abeno.project-takenaka.com/abeno_e/saigai/sai-01.php)
- The CCTV foundation system.  
[http://www.360doc.com/content/10/1210/02/16546\\_76642178.shtml](http://www.360doc.com/content/10/1210/02/16546_76642178.shtml)
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Thank you!