Wind Screen Effects on Structure

Presenter:
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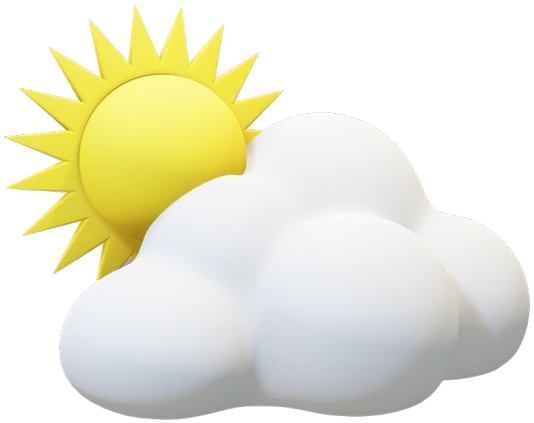
KIPCON
Engineering Consultants

Air Cooled Condenser Users Group 2018
Colorado Springs

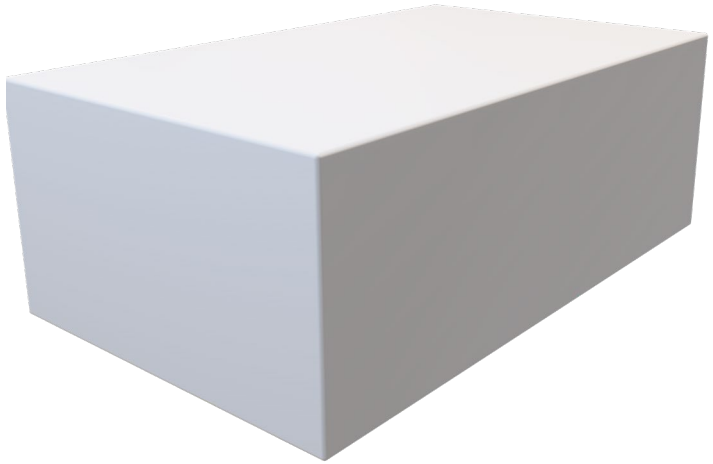
Discussion

- What is an ACC ?
- How is a Structural Review performed ?
- What are the problems ?
- What are the solutions ?
- APEX Case Study

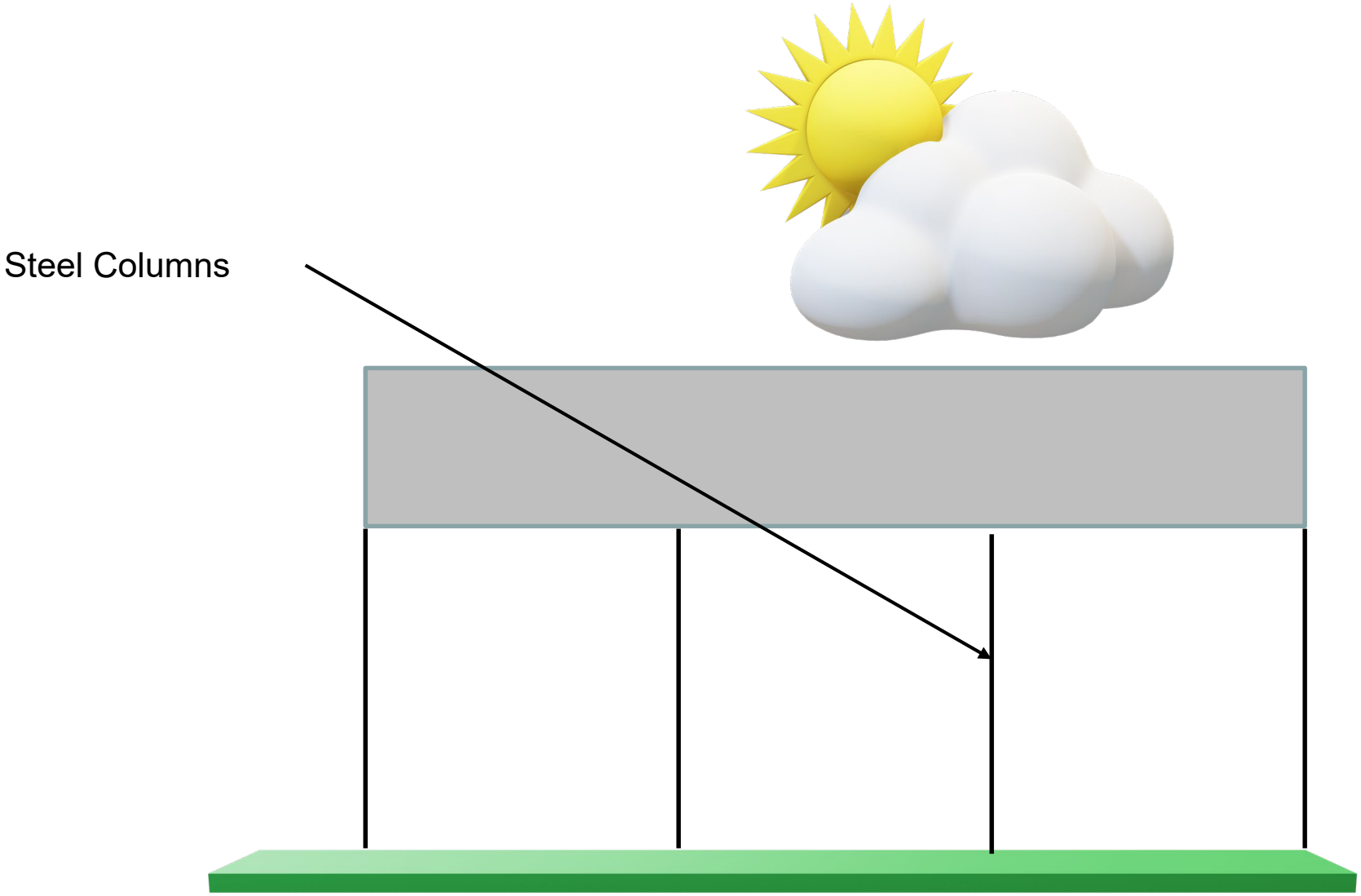
What is an ACC ?



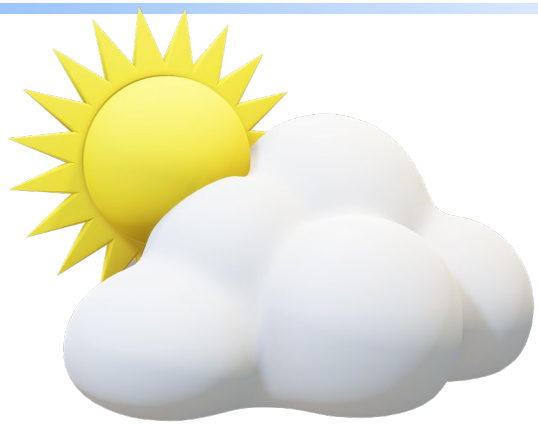
A heavy box floating in the sky!



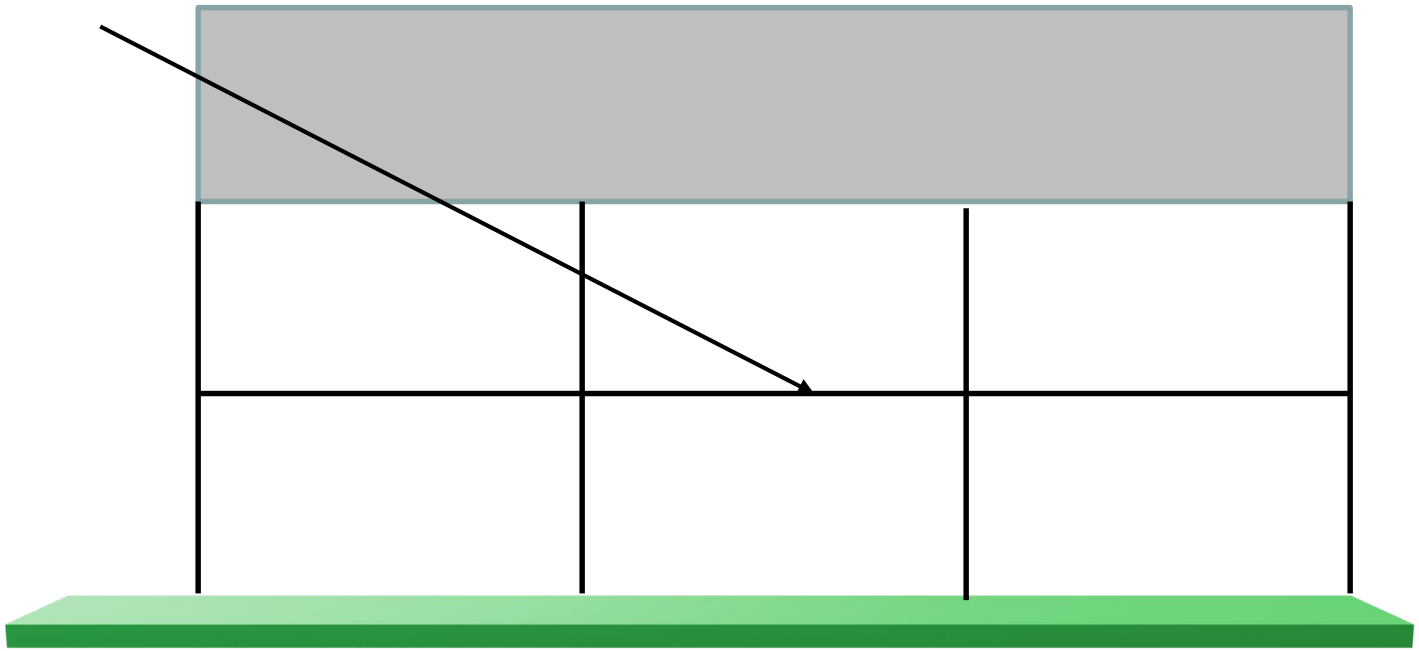
What holds it up ?



What Keeps them from buckling ?

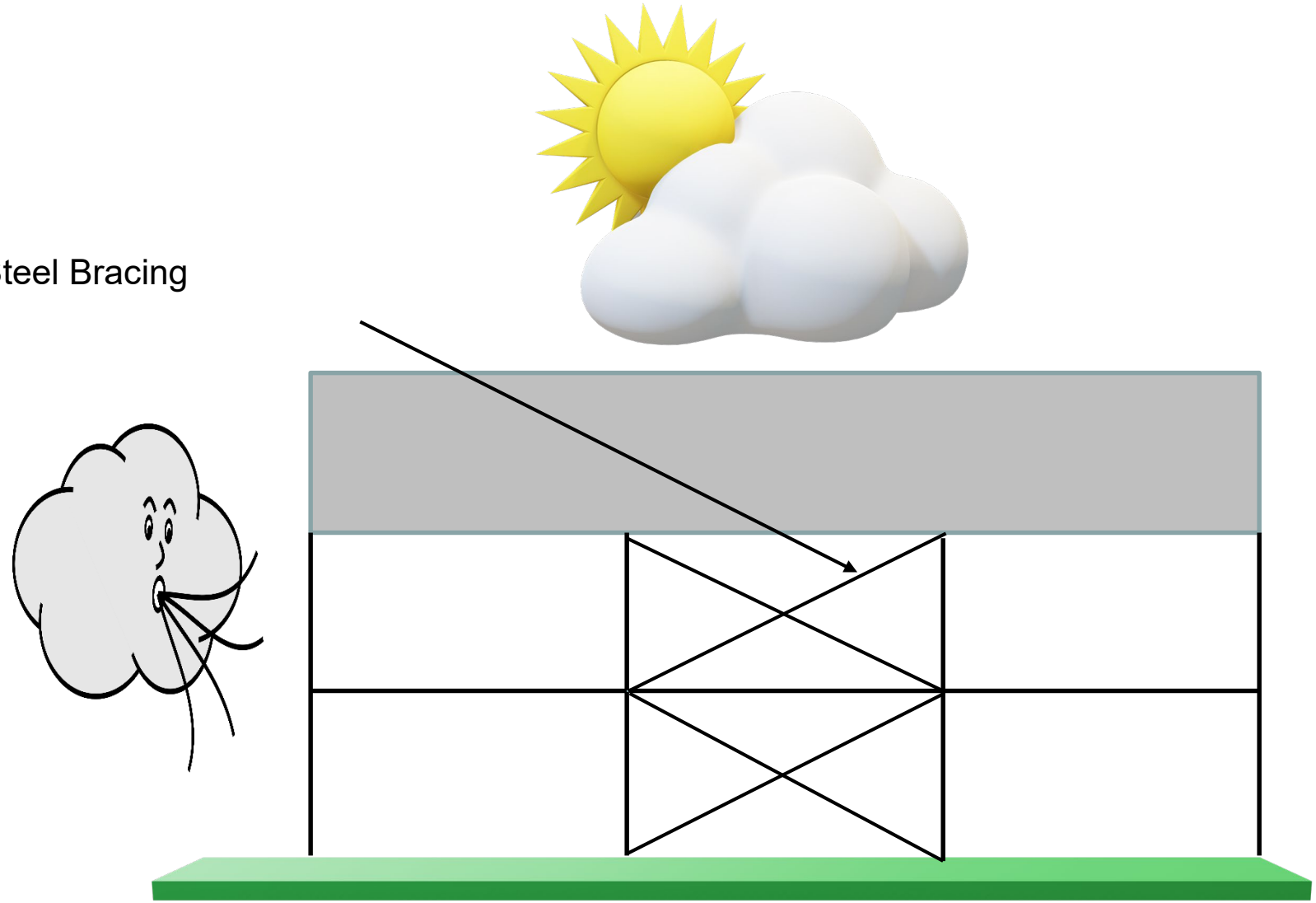


Steel struts

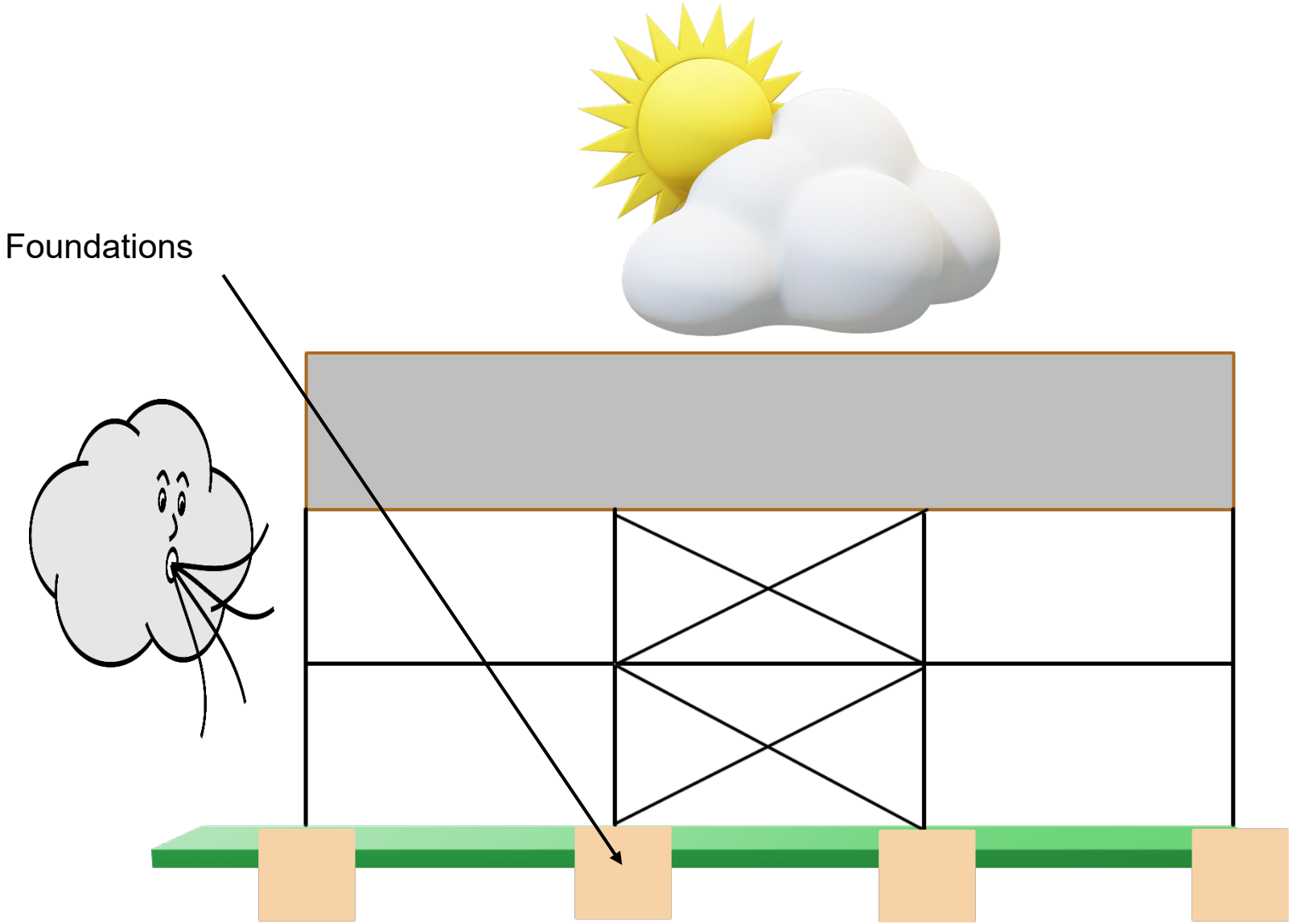


What holds it up when the wind blows ?

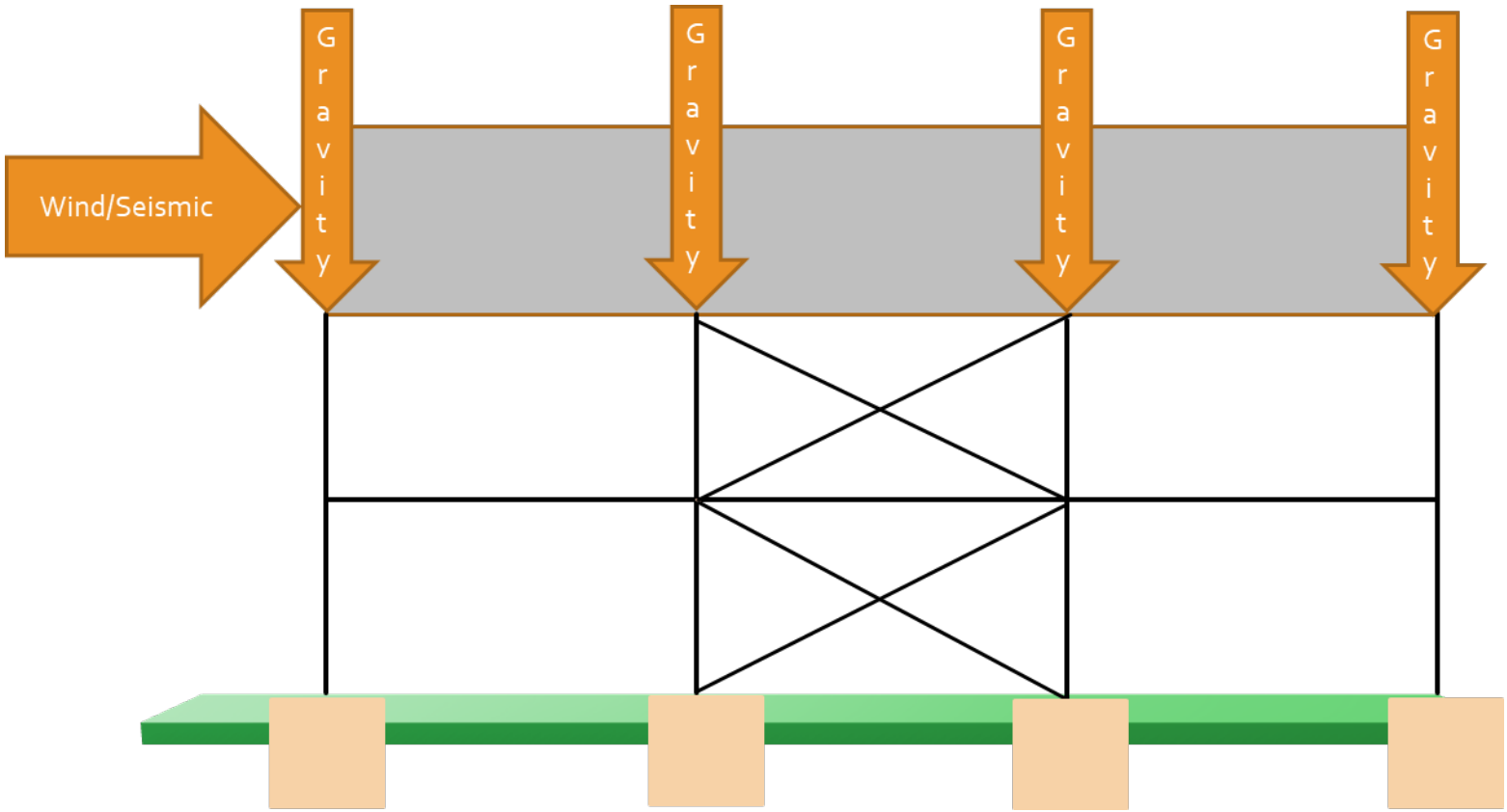
Steel Bracing



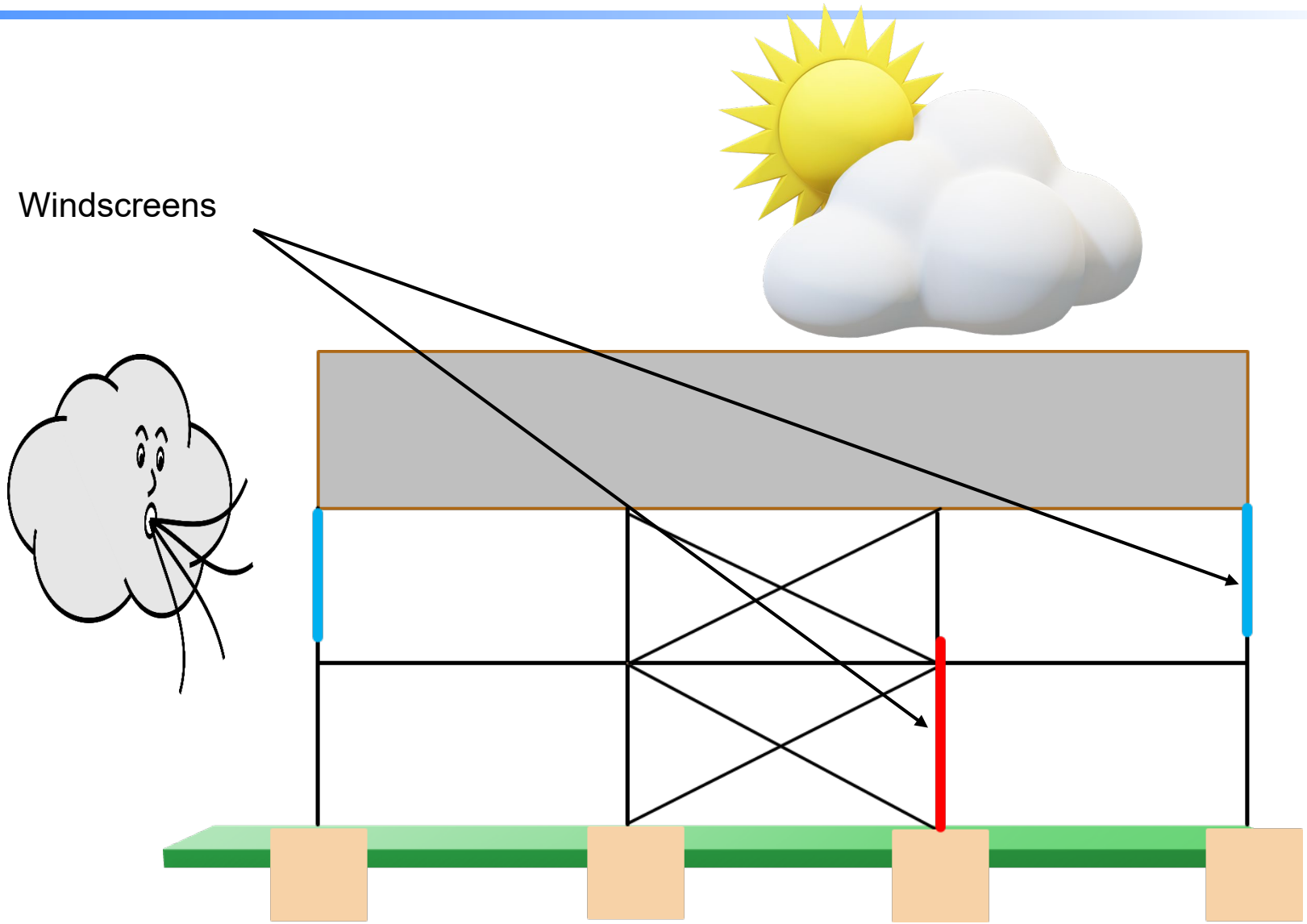
What does it all sit on ?



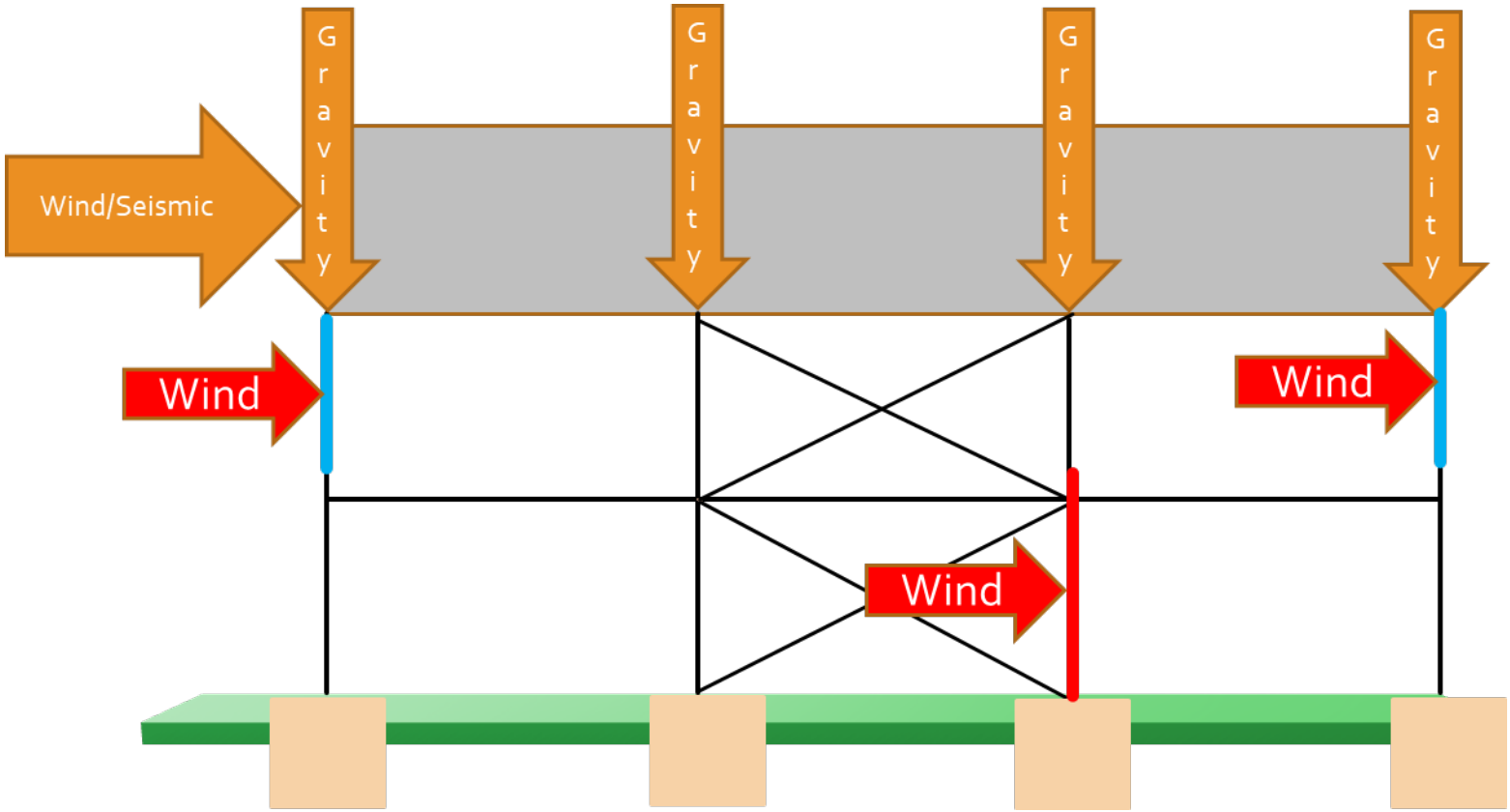
What Loads is The Structure Designed For ?



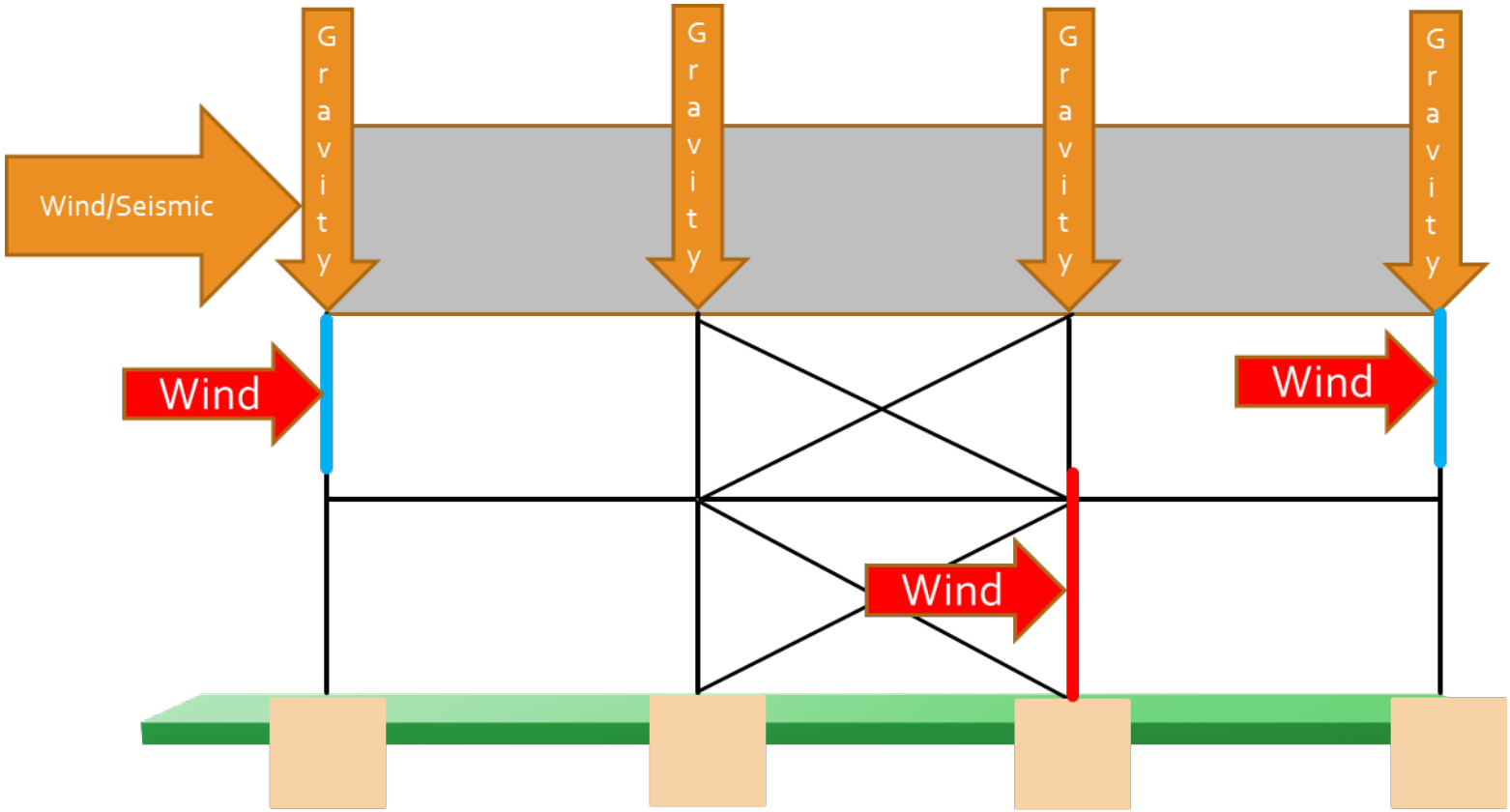
What do we add ?



What Load is Added To The Structure

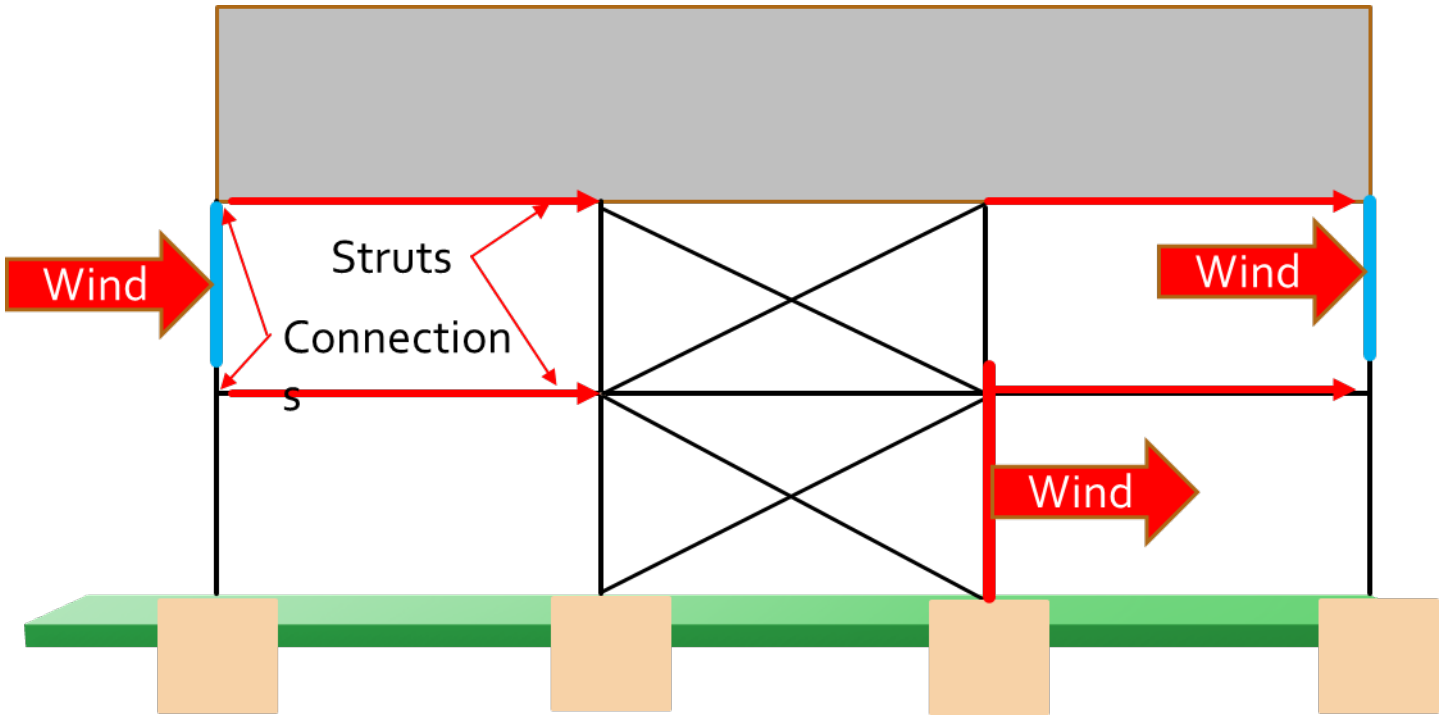


How Do These New Loads Travel Through The Structure ?



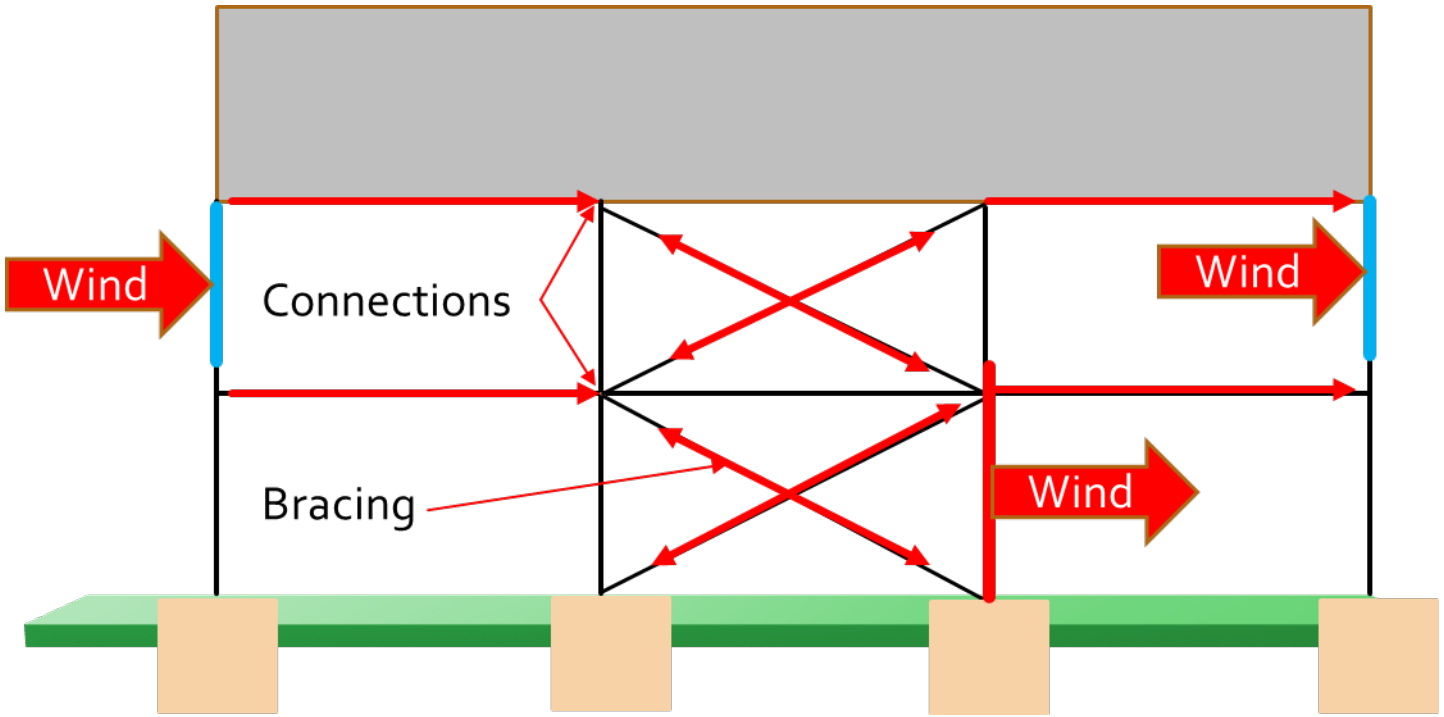
How Do These New Loads Travel Through The Structure ?

1. The Columns Go Into Bending and the Load is Transferred Through Connections to the Struts



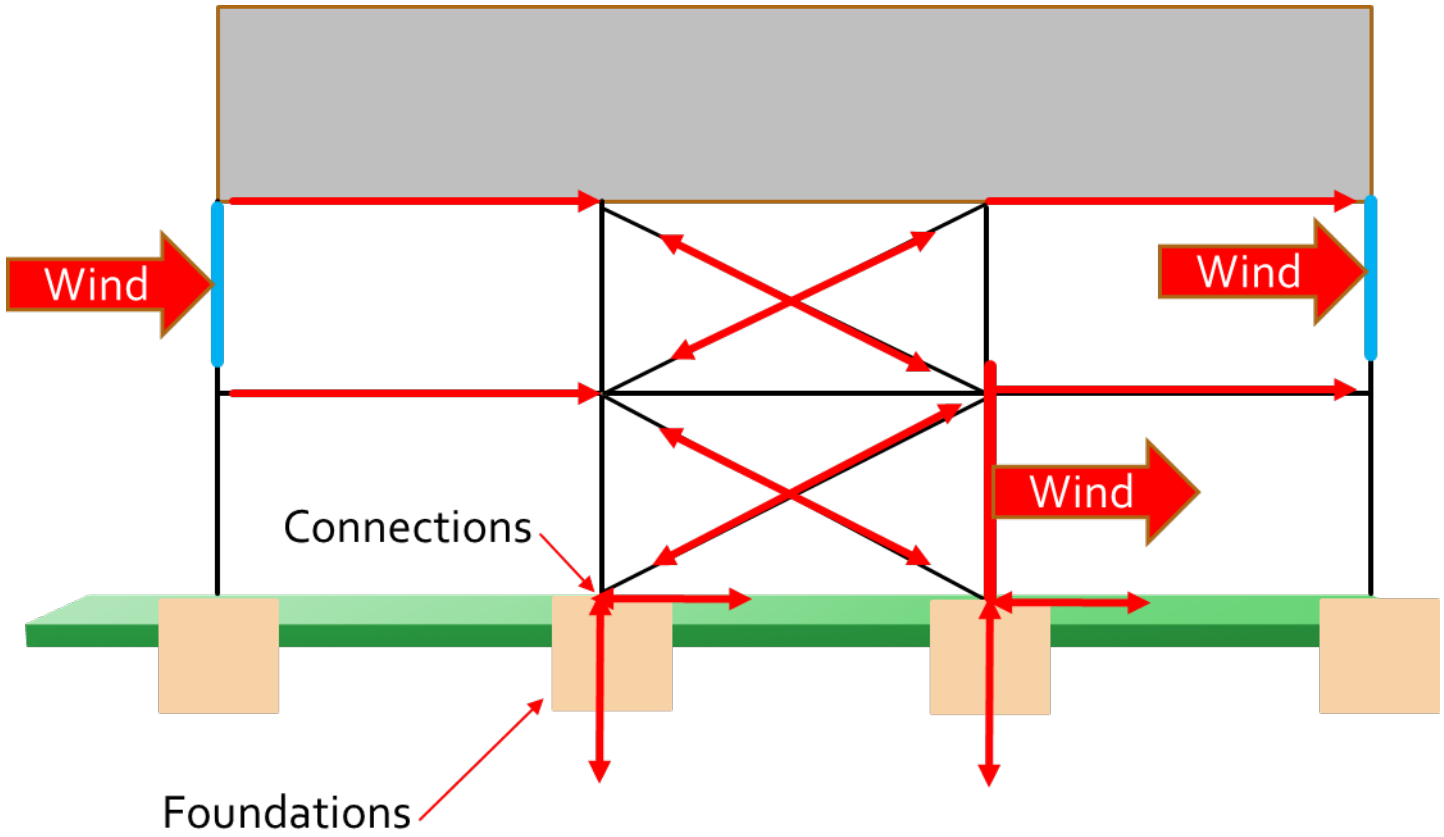
How Do These New Loads Travel Through The Structure ?

2. Load is Transferred Through Connections From the Struts Into the Bracing



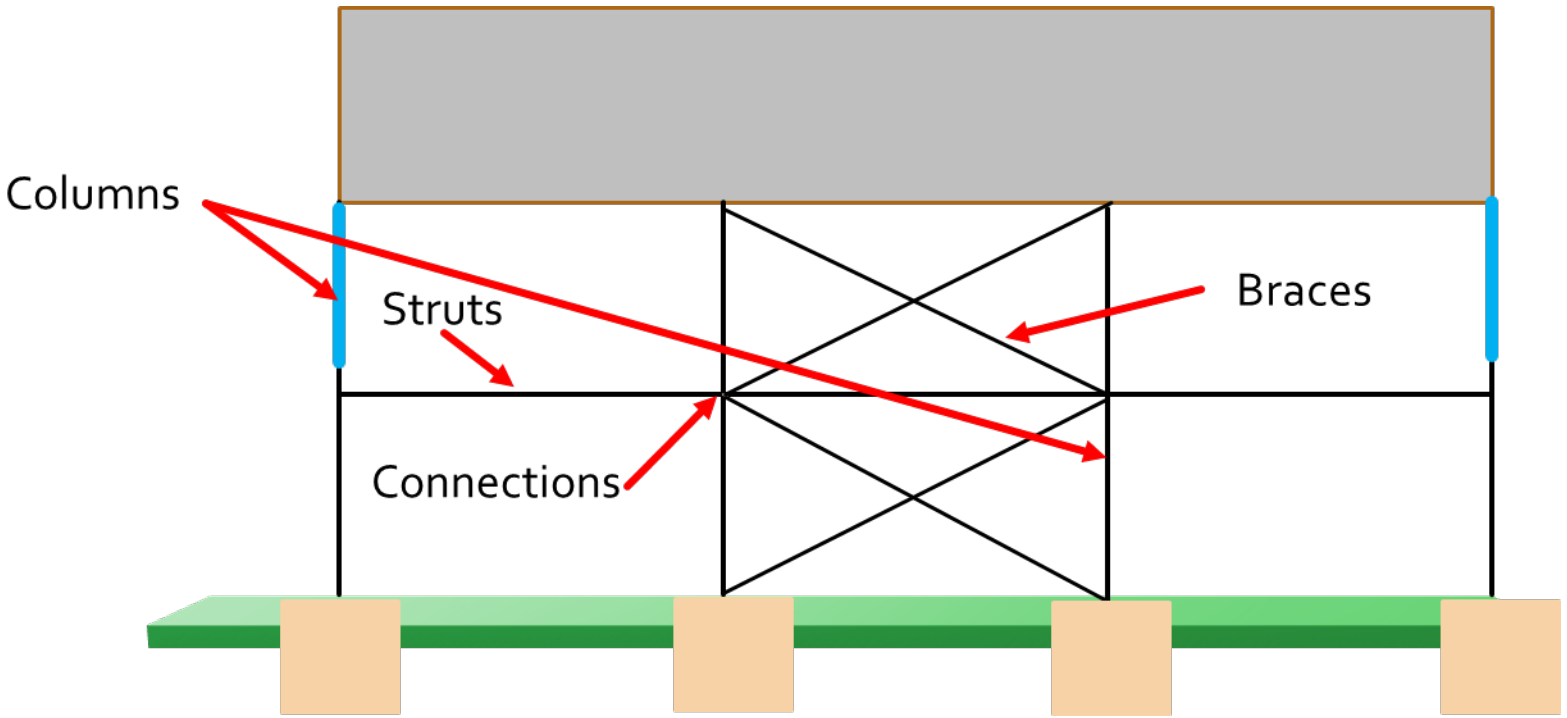
How Do These New Loads Travel Through The Structure ?

3. Load is Transferred Through Connections From the Braces Into the Foundation



Critical components

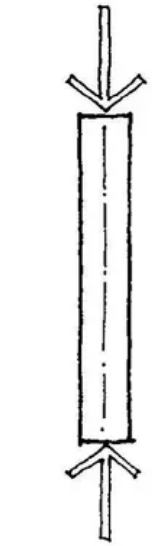
- What Parts of the Structure are Affected by the Screens and Should Be Reviewed ?



Critical components

- Most Critical Component Is the Columns Since They Only Have Minimal Wind Load.

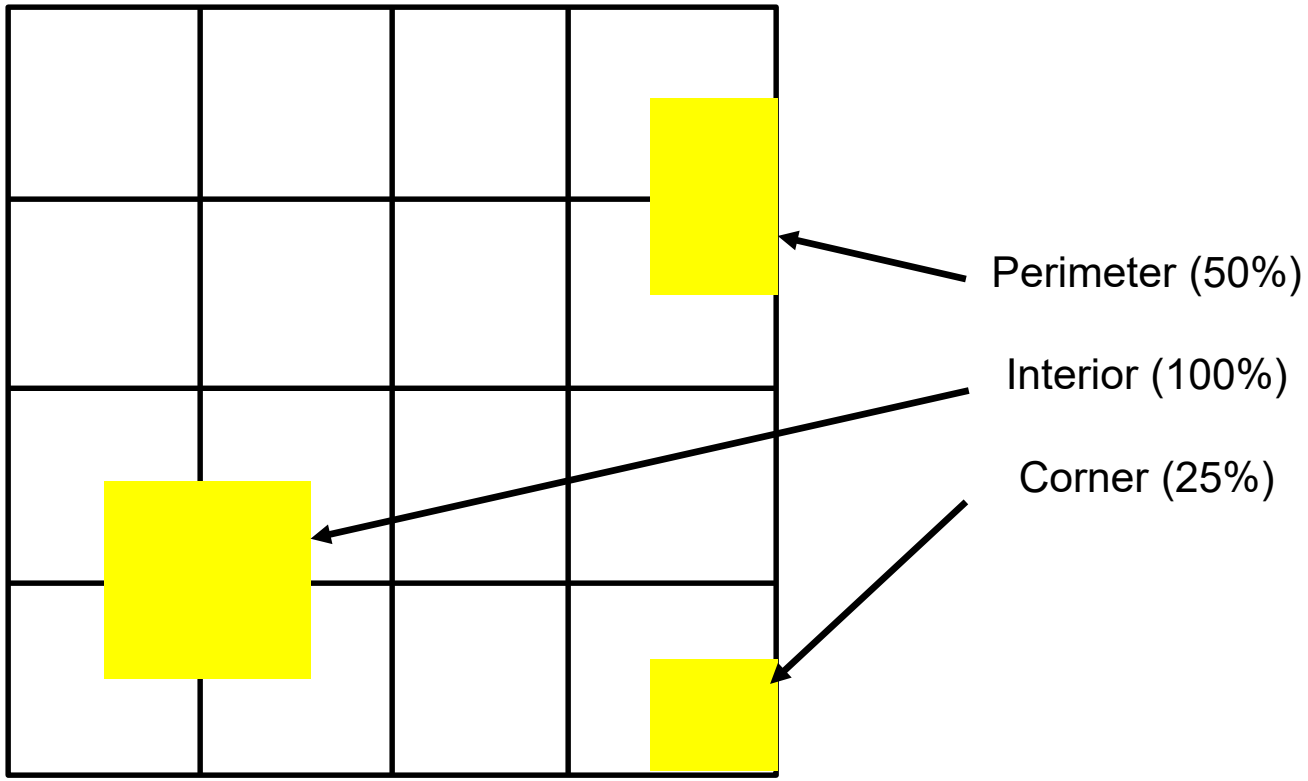
- How Do Columns Work ?
  - For an ACC Column Load is primarily axial loads caused by the weight of the ACC since there is minimal wind on columns !!



COLUMN SUPPORTING AXIAL LOAD

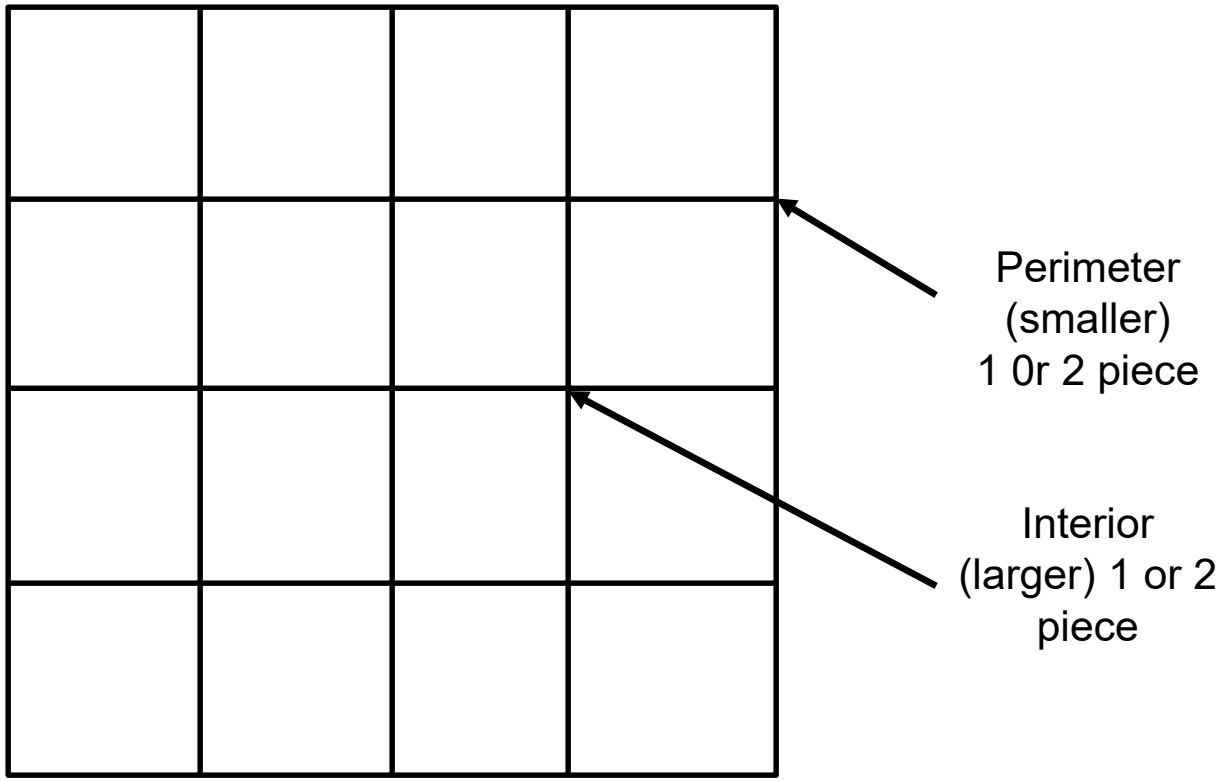
Critical components

- **Column <u>Axial</u> Loads**



Critical components

- **Typical Column Sizes**



Critical components

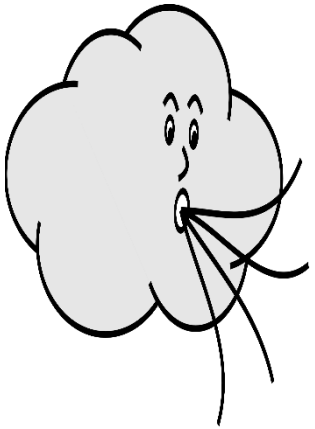
- If We Look at the Column Capacity Just from the Axial Load From the Weight of the ACC ?

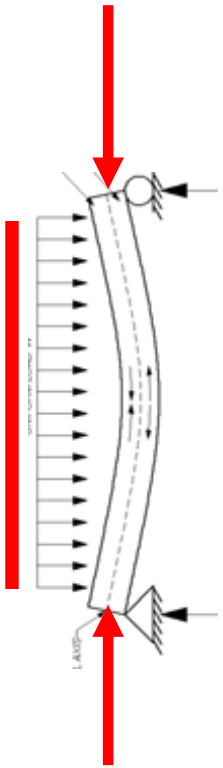
- It is Measured by %
- For example;
  - Axial load
    - → 100
    - →Column Axial Capacity = 125
    - →Capacity used 80% (100/125)

80%

What happens when the screens are added?

- When screens are installed wind load is added to column that didn't exist before.
- This results in bending stress





What happens when the screens are added?

- If We Now Just Look at the Bending Load Caused by Adding the Screens ?

- It is Measured by %
- For example;
  - Bending load
    - → 25
    - →Bending Capacity = 50
    - →Capacity used 50% (25/50)

50%

What happens when the screens are added?

- When We Now Add Them Together Creating a Problem!

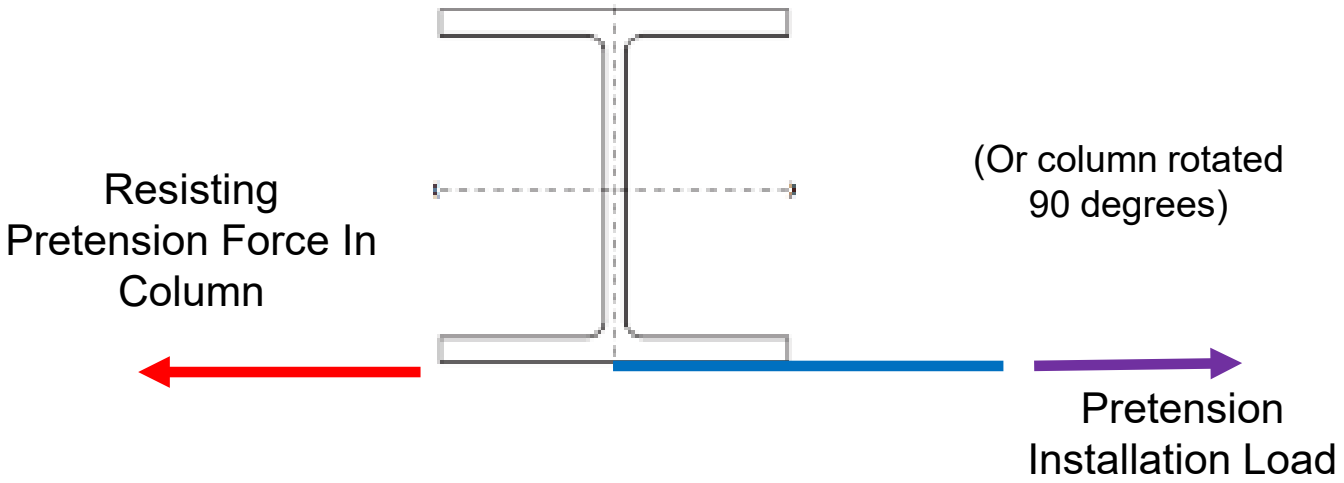
- Axial Load Capacity Used (Weight)
  80%
- Bending Capacity Used (Wind on Screens)
  50%
- **Add them together and it can Result in an**

OVERSTRESS **130%**

What are the Types of Loads From the Screens ?

Screen Load Conditions

- Load at Installation



Screen Installation at Column

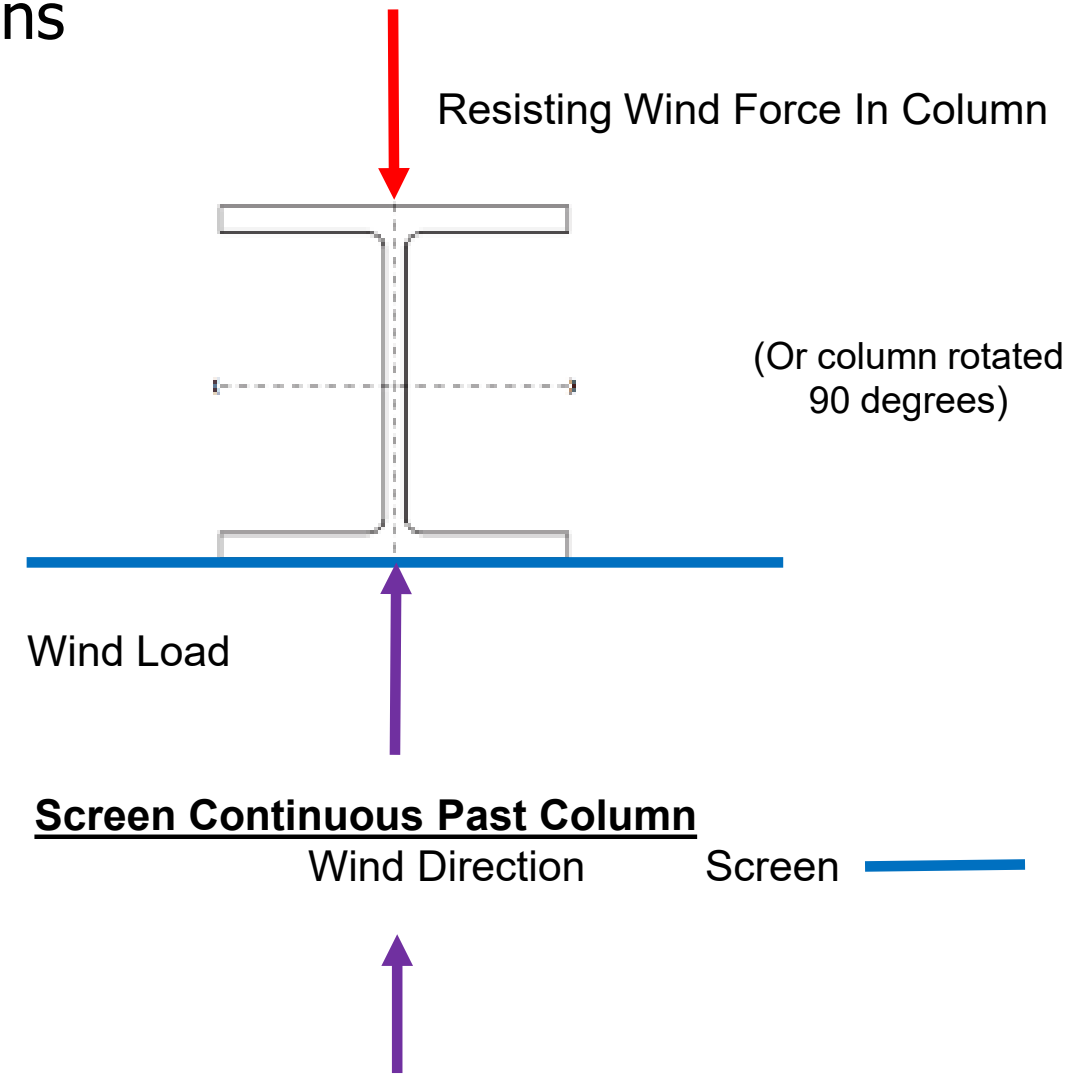
Screen

Screen Load Conditions

- Load at Installation
  - Axial (Minimal)
  - Tension Load parallel to screen
  - Note: Load offsets after installation w continuous screens

Screen Load Conditions

- Continuous Screens

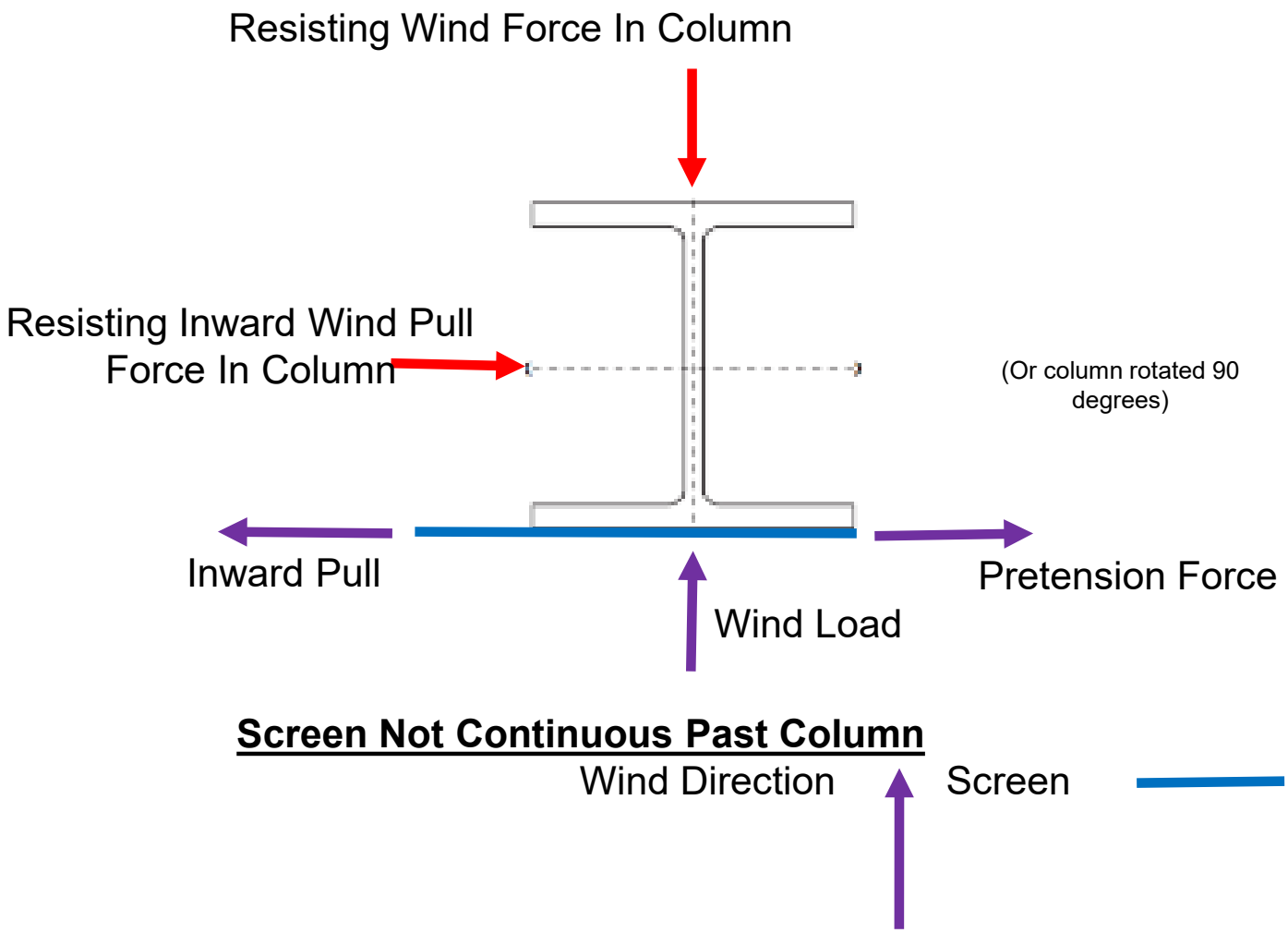


Screen Load Conditions

- Loads From Continuous Screens
  - Axial (Minimal)
  - Wind Load parallel to wind

Screen Load Conditions

- Loads from Non Continuous Screens

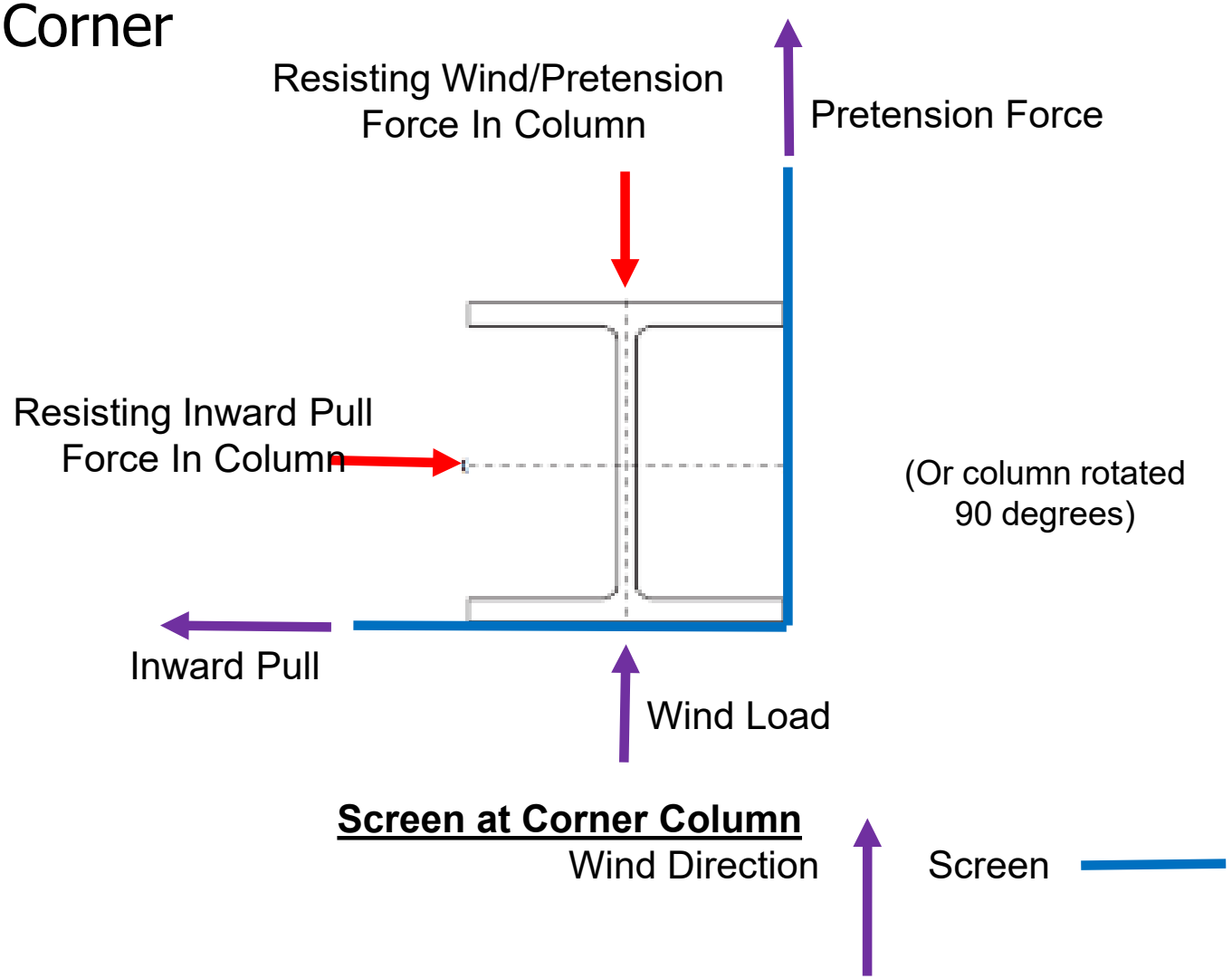


Screen Load Conditions

- Loads for Non Continuous Screens
  - Axial (Minimal)
  - Wind Load parallel to wind.
    - →Inward Pull
      - Load perpendicular to wind under wind load
      - Can be higher than parallel load !!
  - Pretension Loads (from screens)
    - →Holds screens in place with no wind

Screen Load Conditions

- Load on Corner

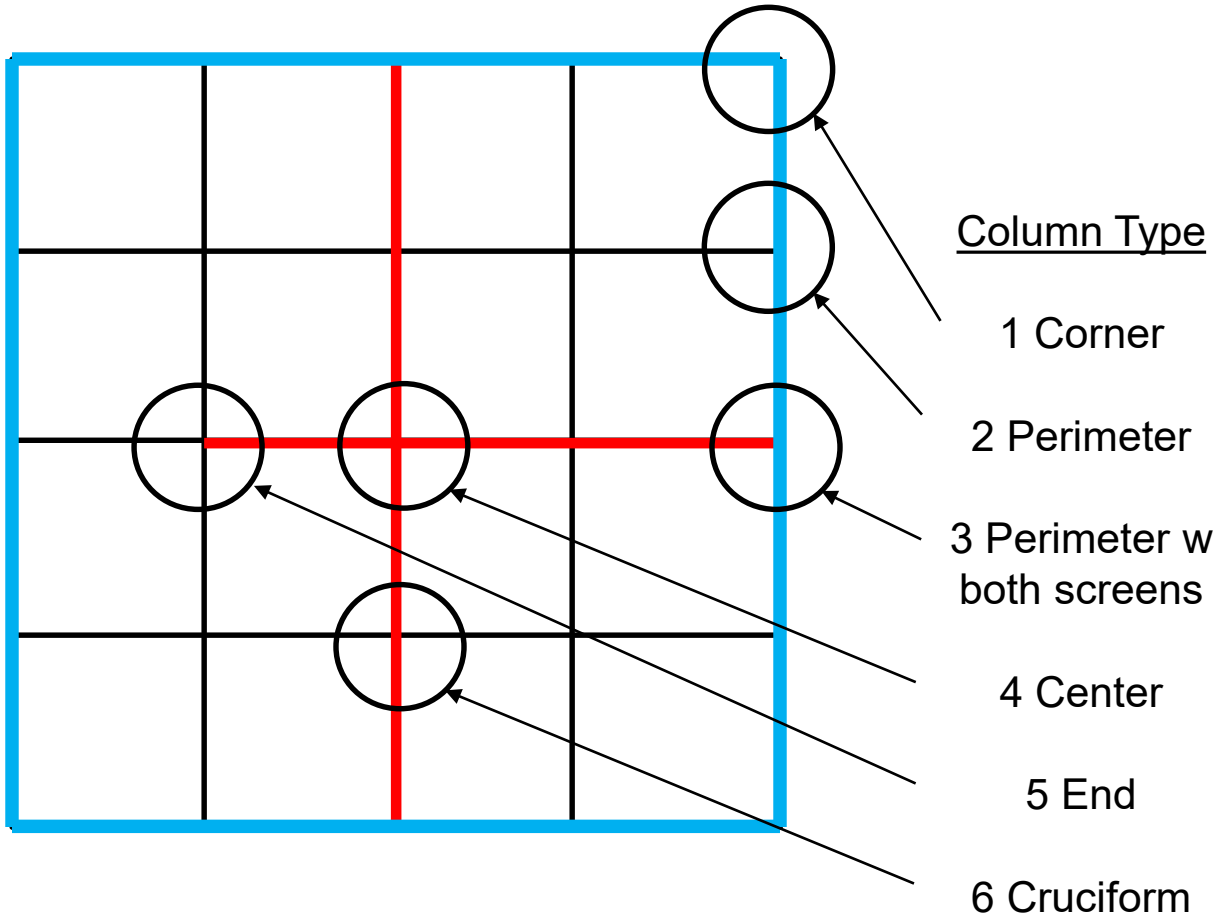


Screen Load Conditions

- Load on Corner
  - Axial (Minimal)
  - Wind Load parallel to wind.
    - →Inward Pull
      - Load perpendicular to wind under wind load
      - Can be higher than parallel load !!
  - Pretension Loads (from screens)
    - →Holds screens in place with no wind

Screen Load Conditions

- Column Type Selection Example



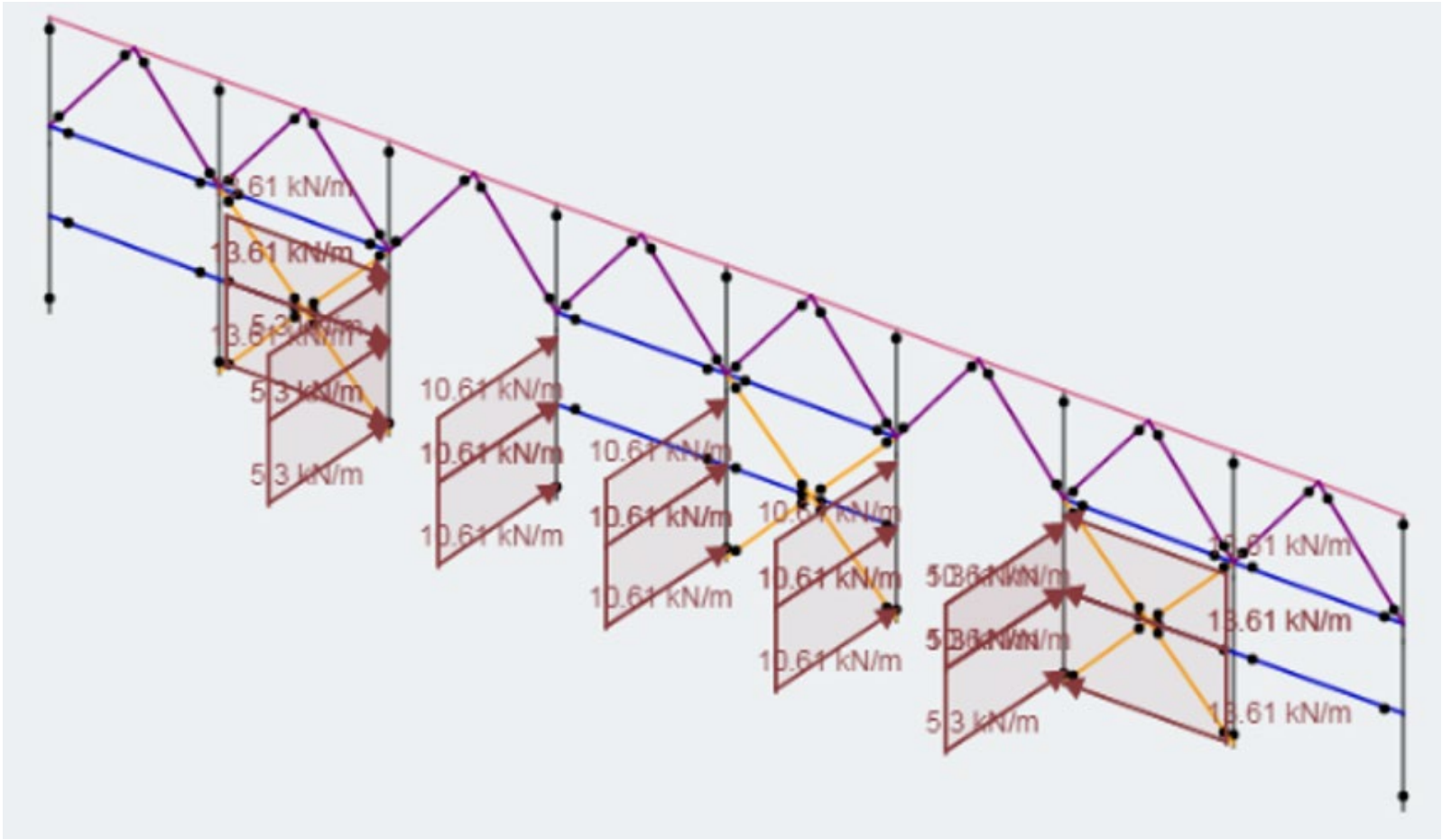
The Structural Engineering Review Process

- Review all information provided regarding existing structure as well as proposed screen layout and initial design wind load.
- Prepare sketches of structural column layout with locations of all screen. This includes:
  - Column orientation and spacing
  - Perimeter and cruciform screen locations
  - Column type (based on screen attachment and location)
  - Wind Direction

Structural Engineering Review Process

- Preparation of structural loading diagrams at all column lines in both Transverse and Longitudinal directions where there are screens being added. These diagrams show the additional wind load resulting from the addition of the screens.

Typical Loading Diagram

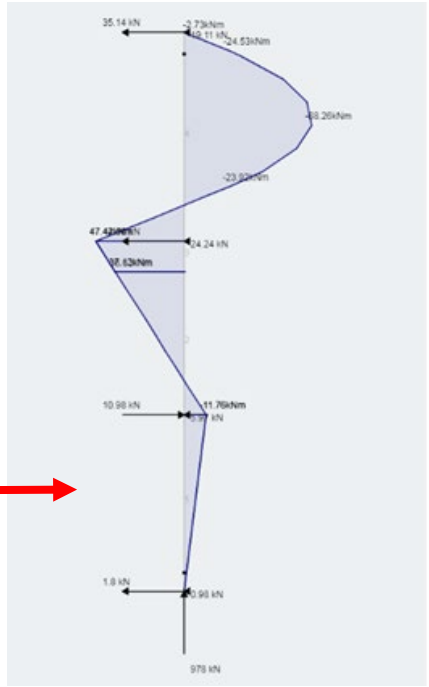


The Structural Engineering Review Process

- Preparation of computer model for each column type incorporating the existing loads as well as the new wind loads resulting in a load stress report. (example below of corner column)

Computer Load Model

Resulting Stress Analysis



The Structural Engineering Review Process

- Review Capacity of Existing Column to Support New Loads

Design Ratio

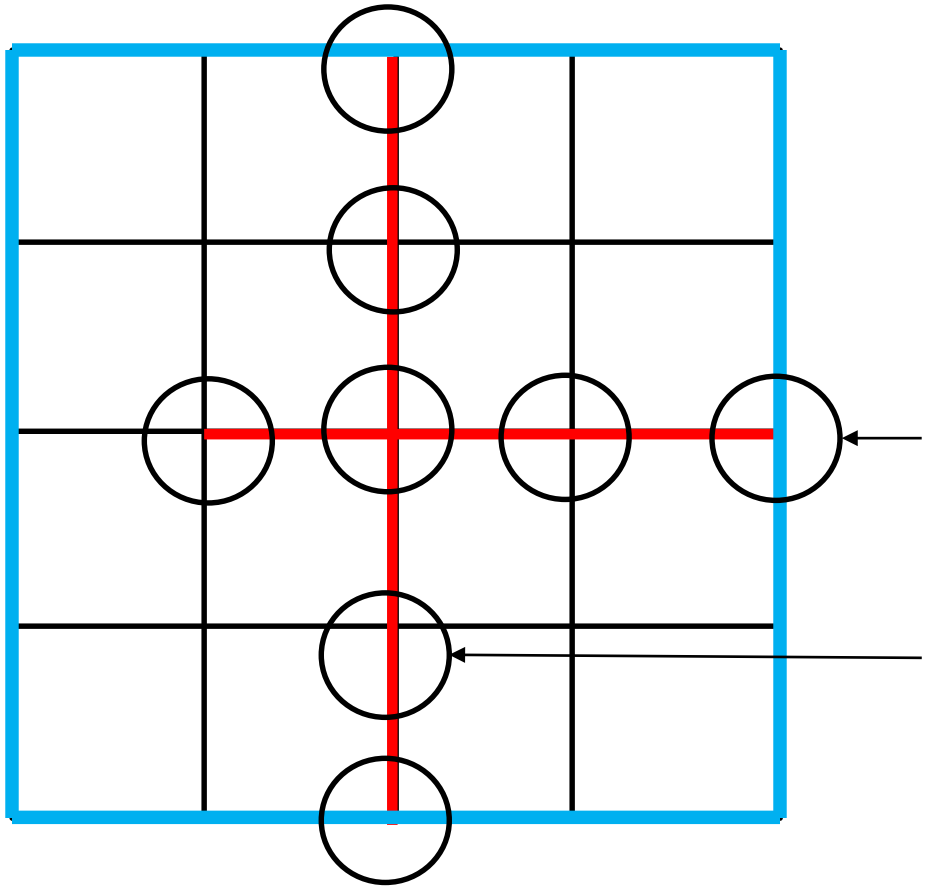
Member ID	N_{ed} / N_{Rd}	M_{zed} / $M_{zc,Rd}$	M_{yed} / $M_{yc,Rd}$	V_{yed} / $V_{ypl,Rd}$	V_{zed} / $V_{zpl,Rd}$	Combined Strength	N_{ed} / $N_{b,Rd}$	M_{zed} / $M_{b,Rd}$	Combined Buckling	KL / r	δ	Status
1	0.46	0.02	0.00	0.01	0.00	0.48	0.69	0.02	0.71	0.38	0.02	Pass
2	0.46	0.04	0.00	0.01	0.00	0.46	0.55	0.04	0.55	0.25	0.01	Pass
3	0.23	0.06	0.00	0.01	0.00	0.19	0.23	0.06	0.20	0.05	0.00	Pass
4	0.23	0.08	0.00	0.03	0.00	0.31	0.41	0.09	0.49	0.45	0.09	Pass

You want **this** Not **this**

Design Ratio

Member ID	N_{ed} / N_{Rd}	M_{zed} / $M_{zc,Rd}$	M_{yed} / $M_{yc,Rd}$	V_{yed} / $V_{ypl,Rd}$	V_{zed} / $V_{zpl,Rd}$	Combined Strength	N_{ed} / $N_{b,Rd}$	M_{zed} / $M_{b,Rd}$	Combined Buckling	KL / r	δ	Status
1	0.68	0.15	0.16	0.09	0.02	0.70	1.01	0.17	1.08	0.38	0.10	Fail
2	0.68	0.15	0.16	0.08	0.02	0.70	0.81	0.15	0.83	0.25	0.03	Pass
3	0.34	0.02	0.03	0.02	0.00	0.34	0.34	0.02	0.35	0.05	0.00	Pass
4	0.34	0.02	0.03	0.00	0.00	0.34	0.60	0.03	0.60	0.45	0.02	Pass

Typical Problem Locations



Primary Problems Occur at Cruciforms

- Interior Columns
  - Columns have minimal additional capacity for bending due to highest axial loads
  - Extended length of cruciform screens
  - Use of low permeability screens
  - Biaxial bending and axial loads at end locations (including perimeter columns) due to:
    - →Wind load
    - →Pulling force
    - →Axial/Capacity + Bending Wind/Capacity + Bending Pulling/Capacity must be less than 1.0

Primary Problems Occur at Cruciforms

- Why It Generally Doesn't Happen at Perimeter or Corner Columns?

- Perimeter Columns
  - Columns have additional capacity for bending due to due to half the cruciform column axial loads
  - Shorter length of perimeter screens
  - Use of higher permeability screens
- Corner Columns
  - Columns have additional capacity for bending due to one quarter of the cruciform column axial loads even with biaxial bending and axial loads
  - Shorter length of perimeter screens
  - Use of higher permeability screens

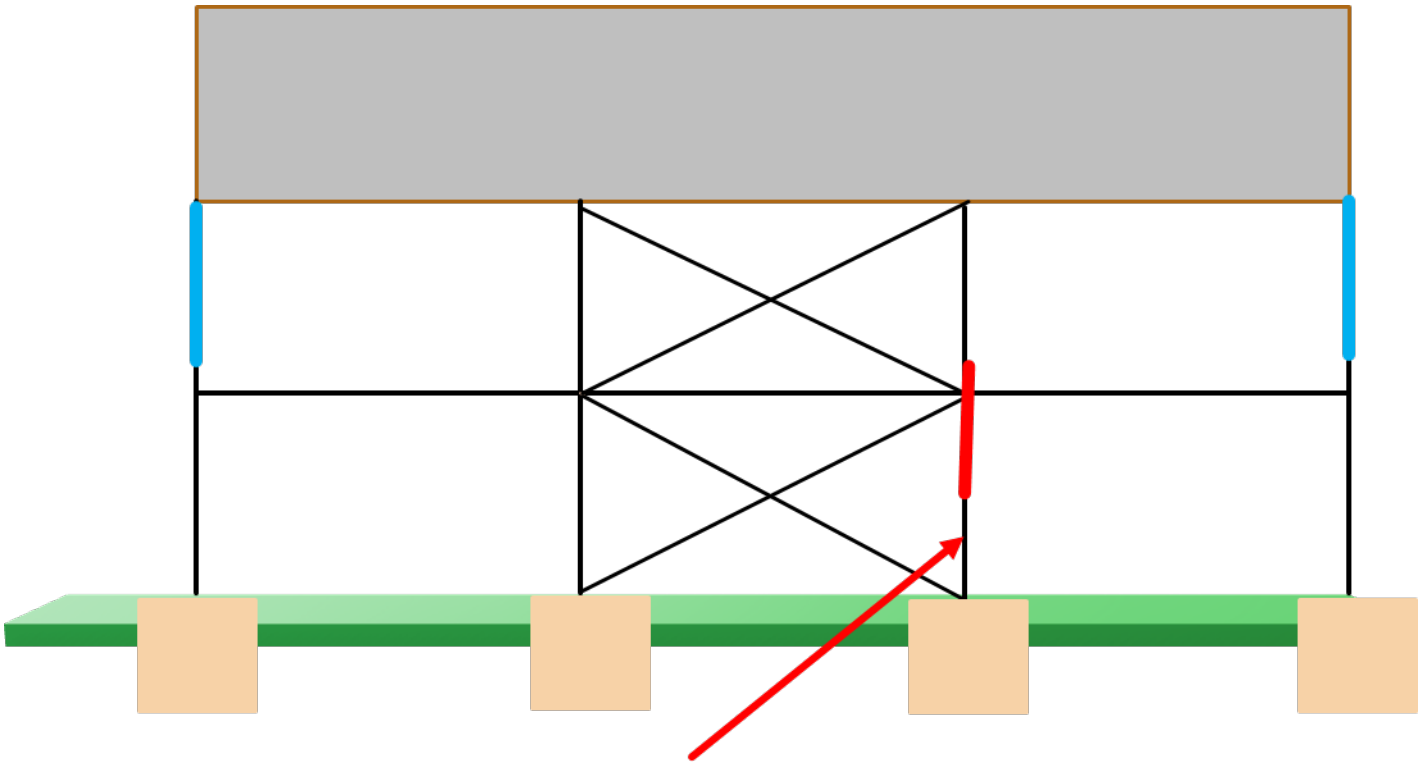
What Are the Solutions ?

- Reduce Loads From Windscreens
- Remove Loads from Columns
- Structurally Upgrade Existing Structure

- **You Must Balance the structural solution vs any loss in operational efficiency**

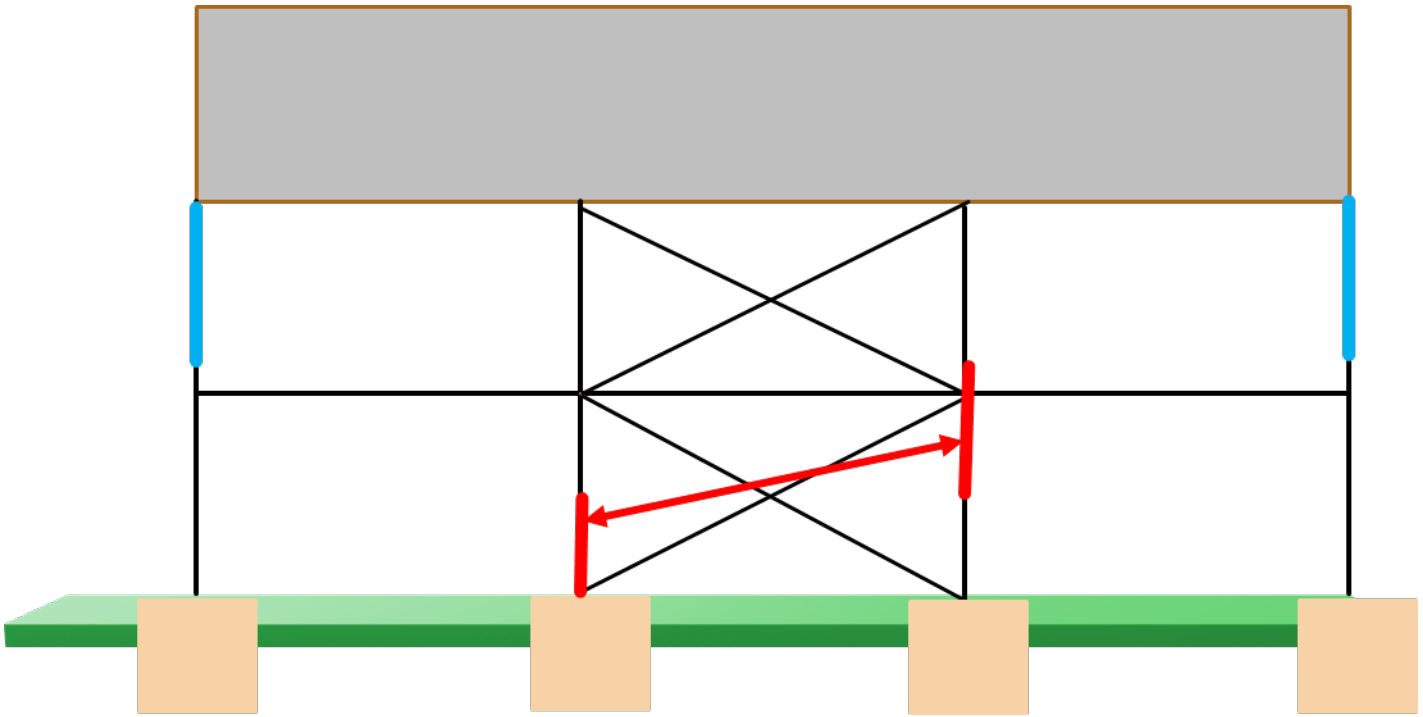
Reduce Loads From the Screens

- Reduce Extent of Screen



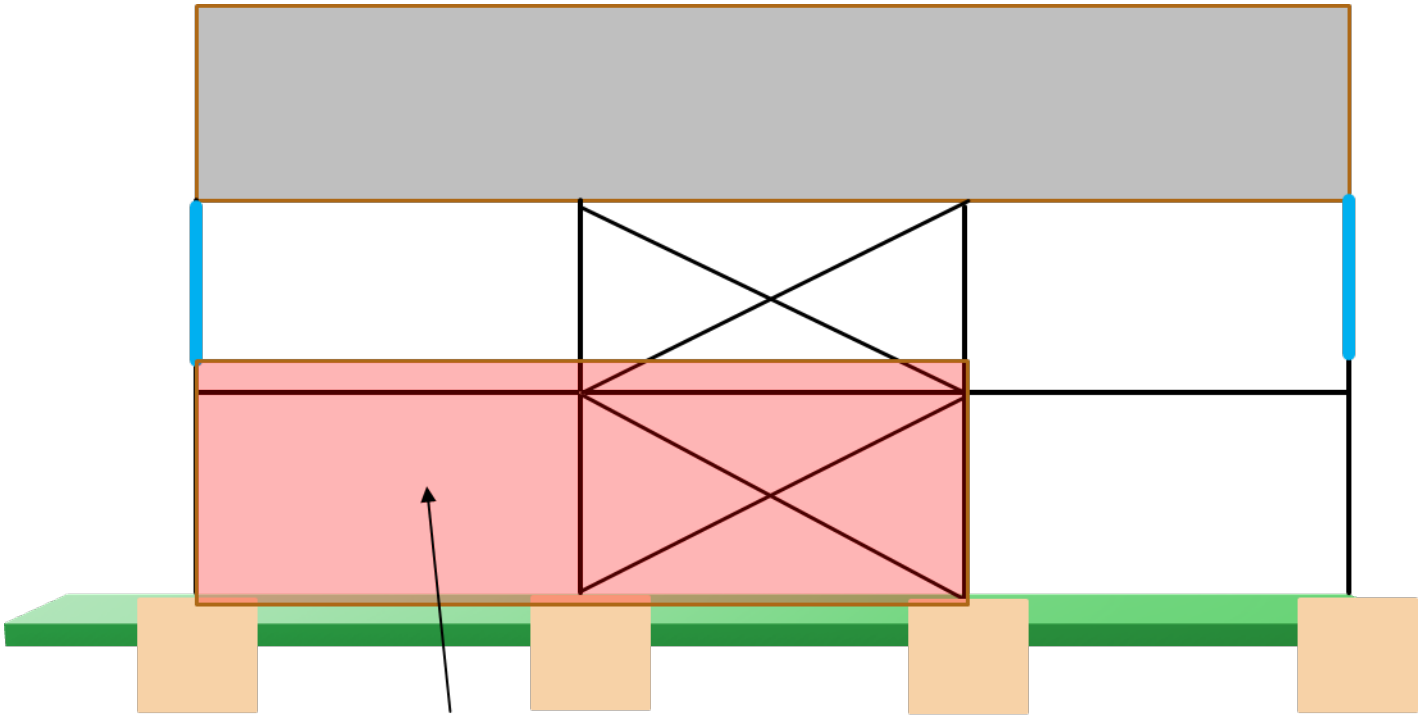
Reduce Loads From the Screens

- Stagger screens on column lines to Distribute Load



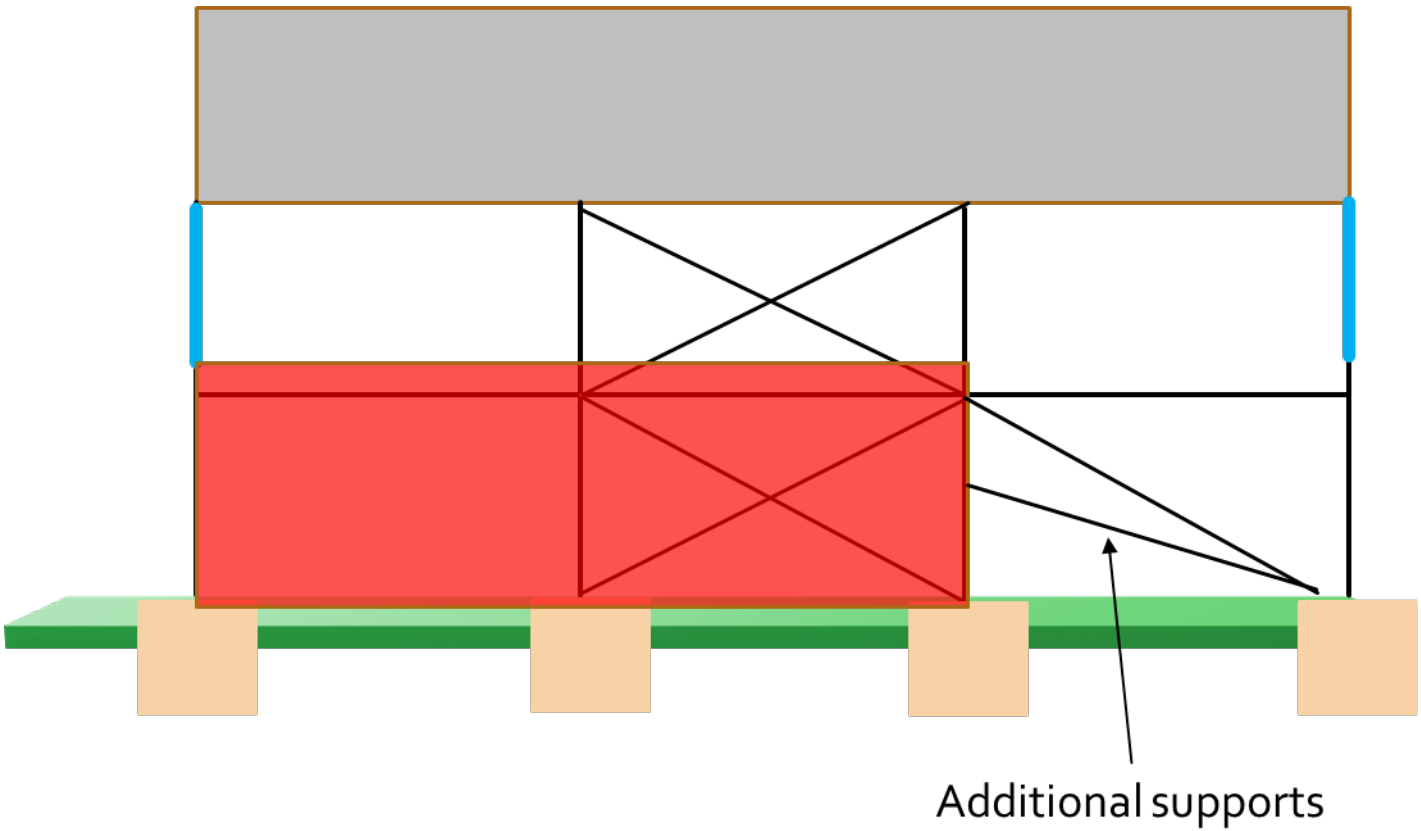
Reduce Loads From Screens

- Change type of screen



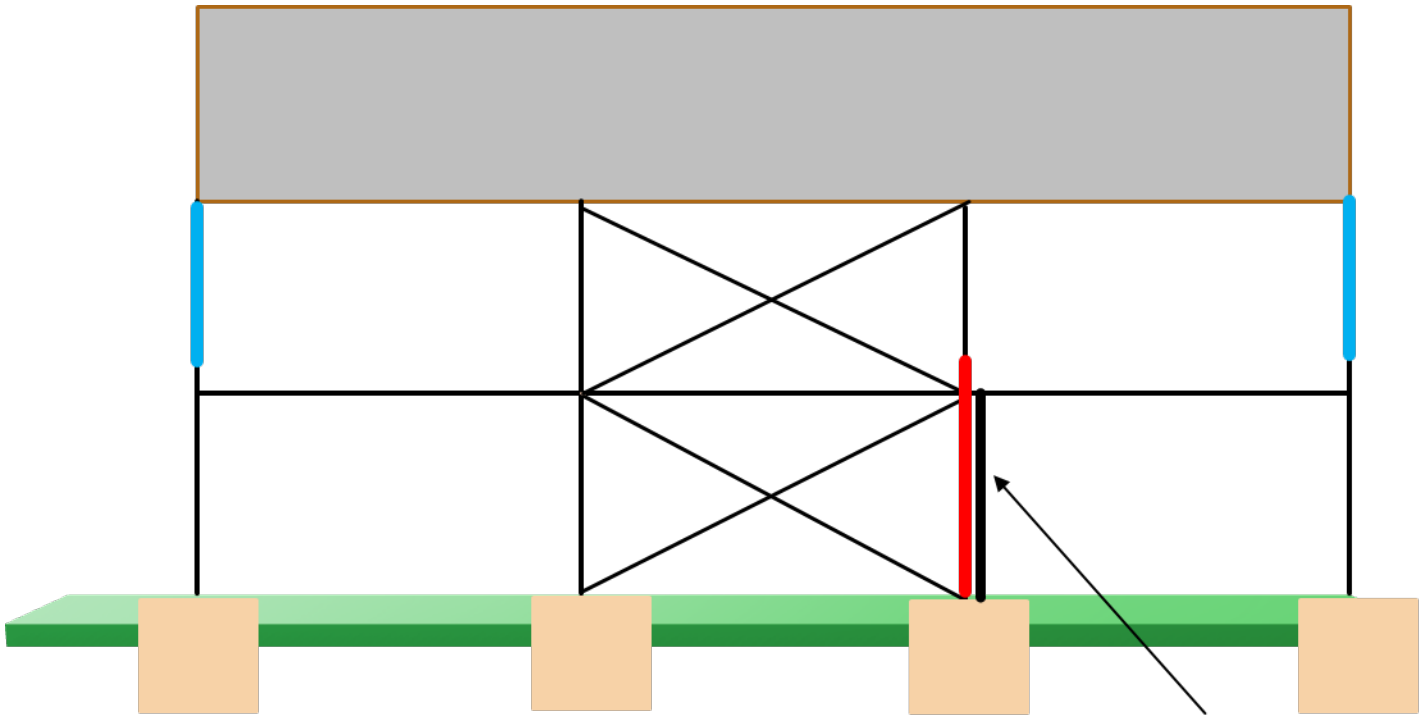
Reduce other loads

- Remove Loads From Columns



Reduce other loads

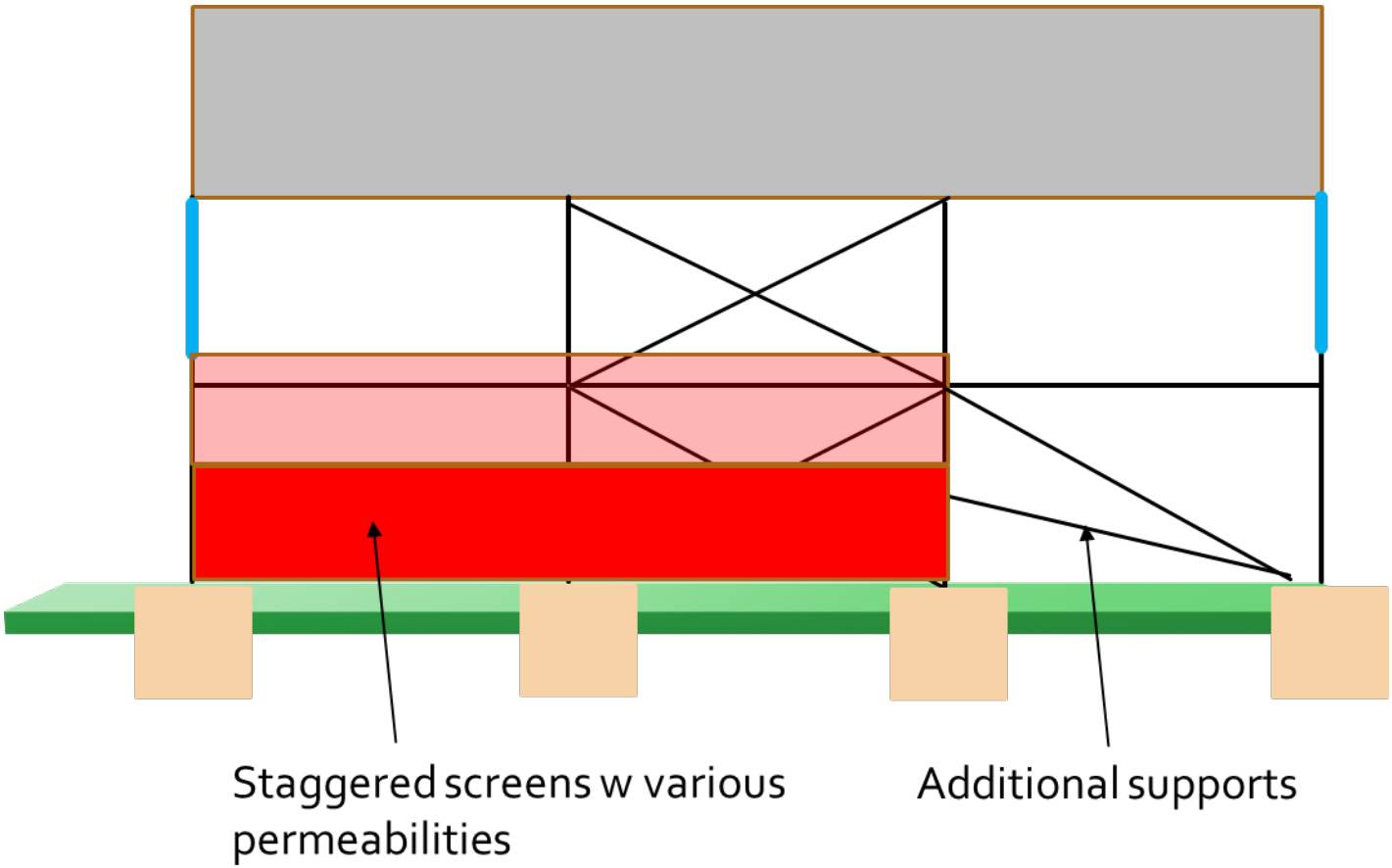
- Structural upgrade of existing structure



Add additional structure to remove bending from existing columns and transfer it directly into struts and bracing

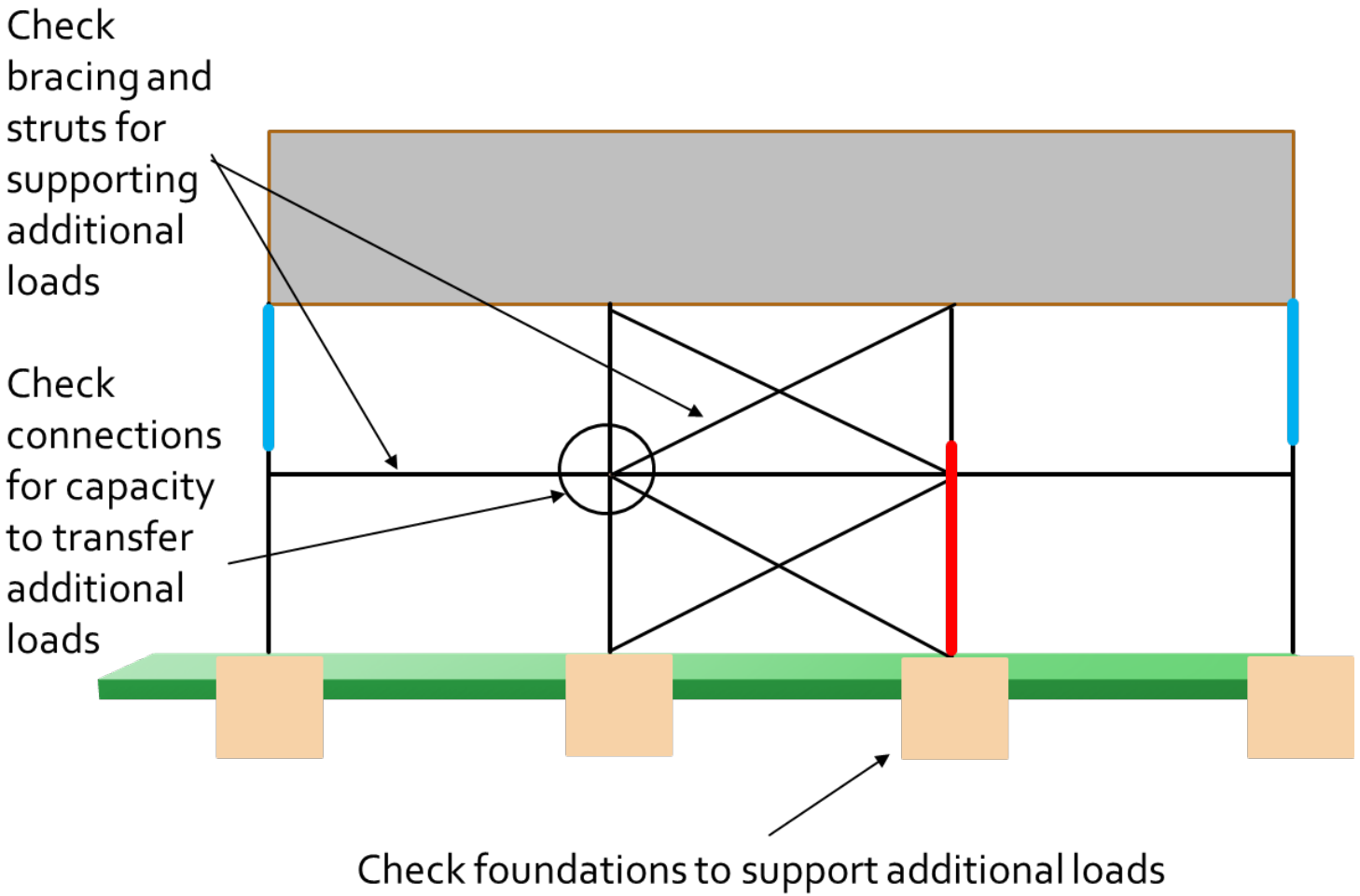
Reduce other loads

- Combinations



After Column Overstress Is Solved

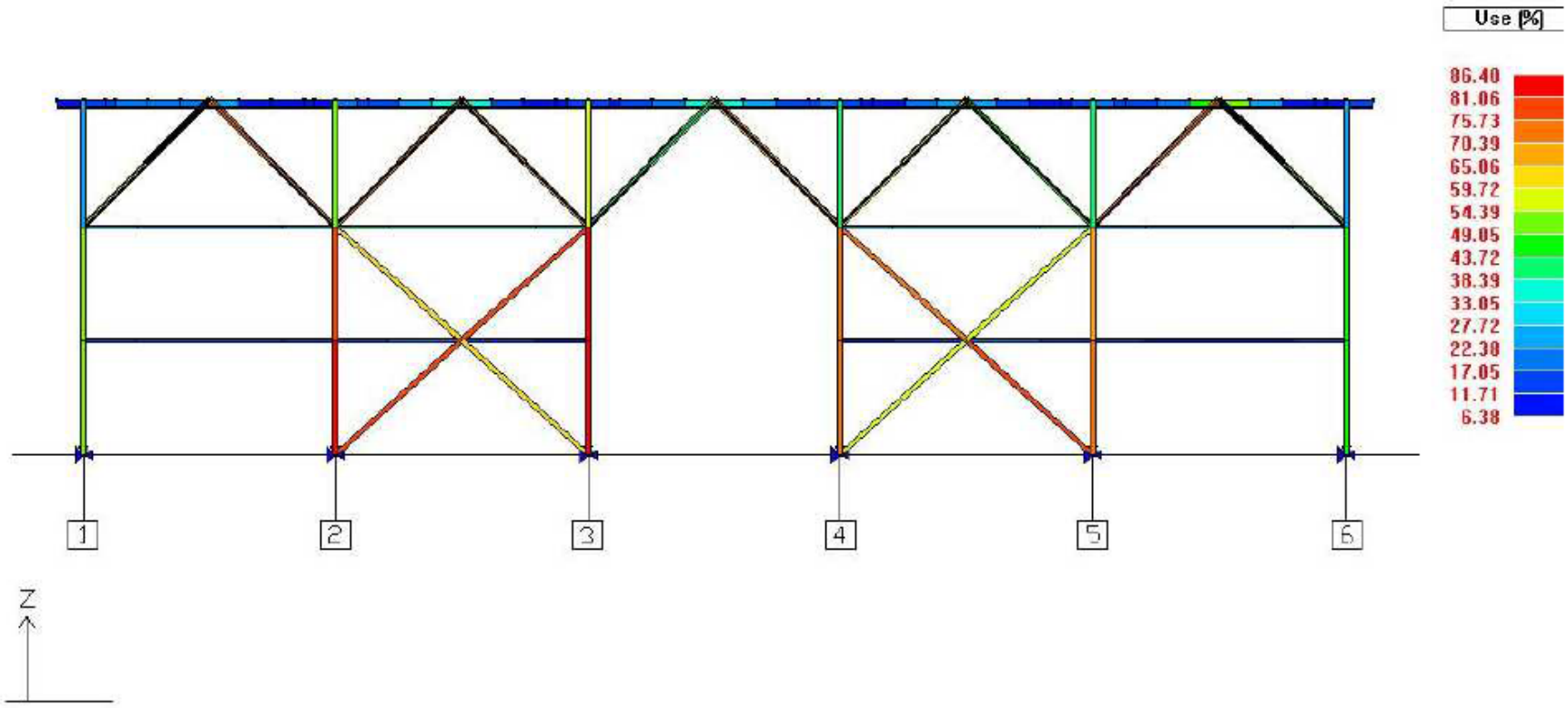
- Next Steps (typically not critical)



To Make Structural Evaluation Process Efficient

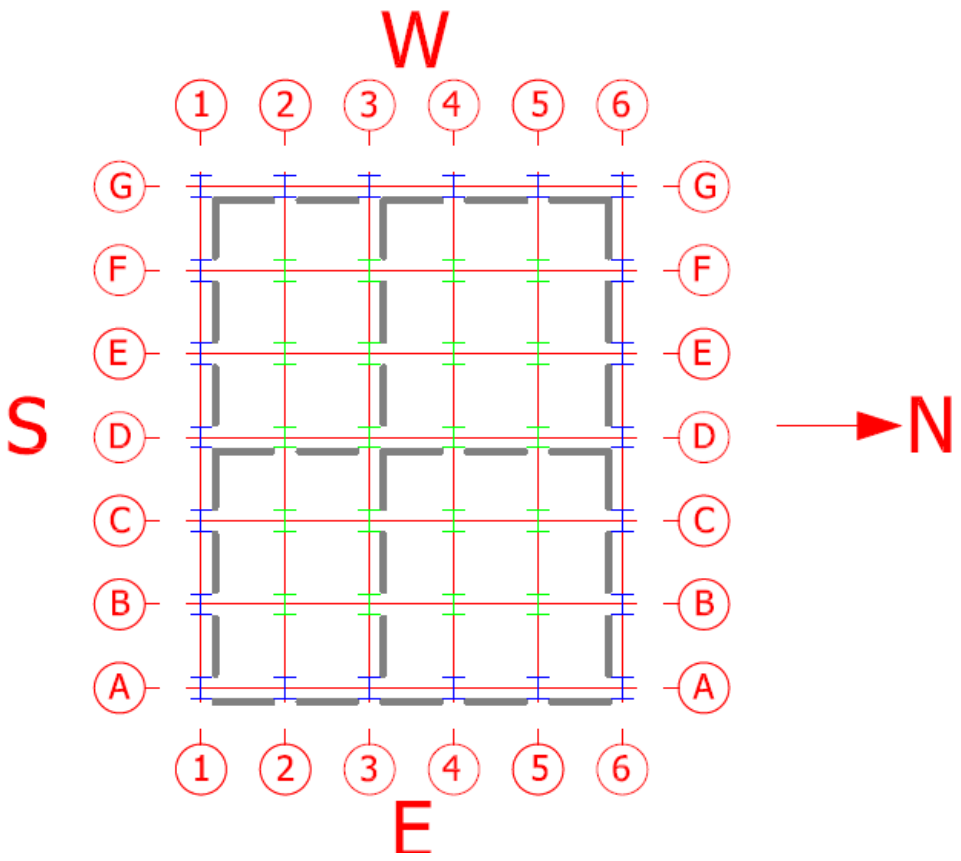
- Provide design drawings
  - Provides all structural member sizes and connections.
  - Provides steel strength
  - Provides foundation loads
- Provide structural calculations
  - Provides design wind load
  - Provides code references
  - Provides member loads
- Get agreement regarding proper edition of structural code

Example from Structural Calculations



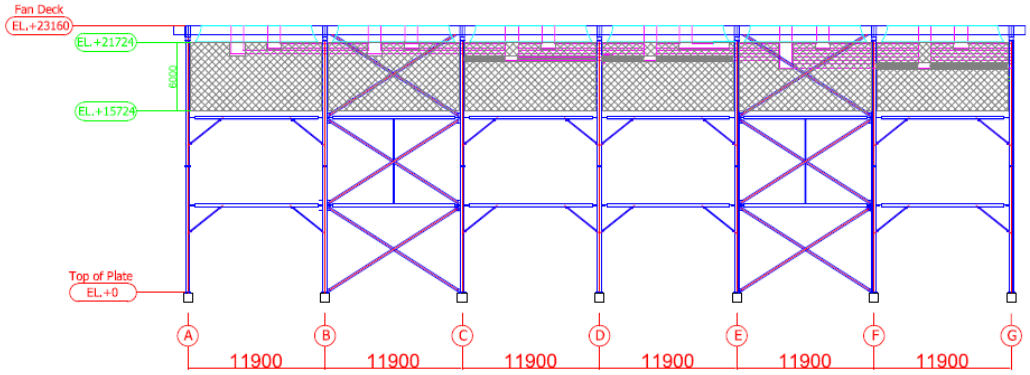
Axis F - percentage use of element capacity

APEX Generating Station



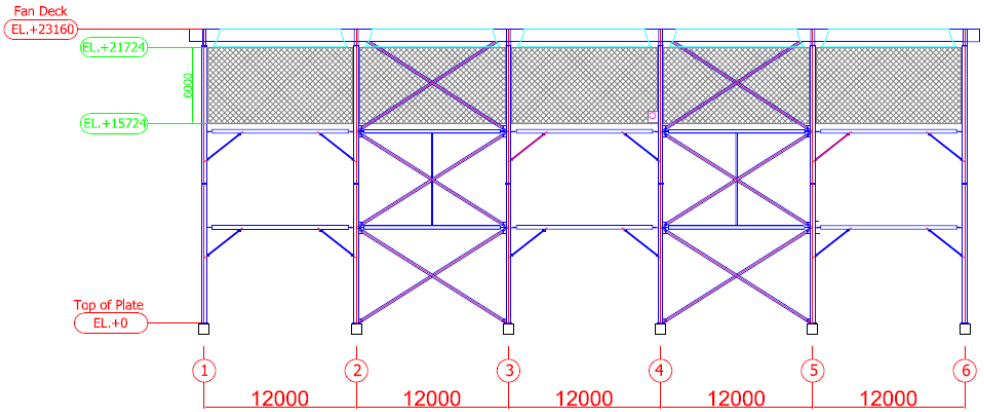
APEX Perimeter Screens

South



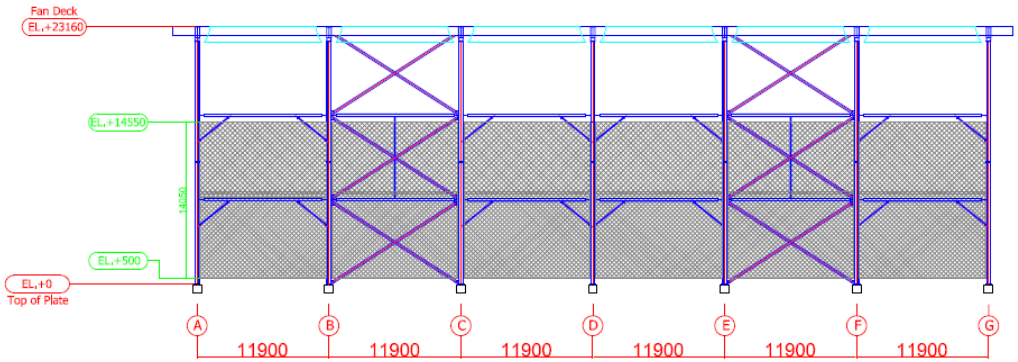
Elevation Along Column Axis 1
Inside Structure Looking South

East

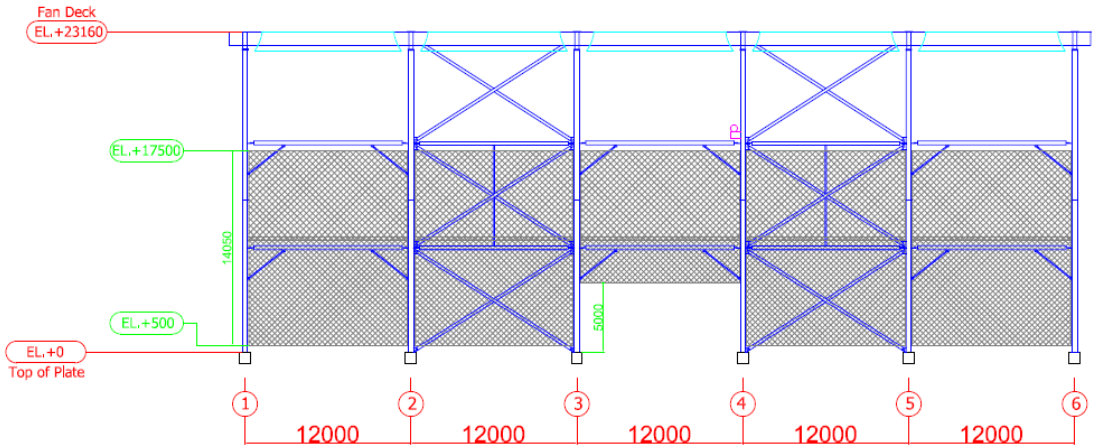


Elevation Along Column Axis A
Outside Structure Looking West

APEX Cruciform Screens



Elevation Along Column Axis 3
Inside Structure Looking South



Elevation Along Column Axis D
Inside Structure Looking East

APEX Generating Station

- Design Wind Speed
  - 90 MPH (per spec)
  - 75 MPH (Initial design)
- Initial Screens
  - Perimeter M60
  - Cruciform M75

APEX Generating Station Structural Findings

- Design Wind Speed
  - 90 MPH (per spec)
    - →NG Perimeter
    - →NG Cruciform
  - 75 MPH (Initial design)
    - →OK Perimeter except at Cruciform intersection
    - →NG Cruciform

APEX Generating Station Solution

- Design Wind Speed
  - 75 MPH
- Perimeter Screens
  - M60
- Cruciform Screens
  - M60
  - Reduce height

APEX

Perimeter M60 Screens

APEX

Cruciform M60 Screens w Bottom Elevation Raised

APEX

Wind screen effects on structure

Questions?

Presenter:
Mitch Frumkin, PE

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Engineering Consultants