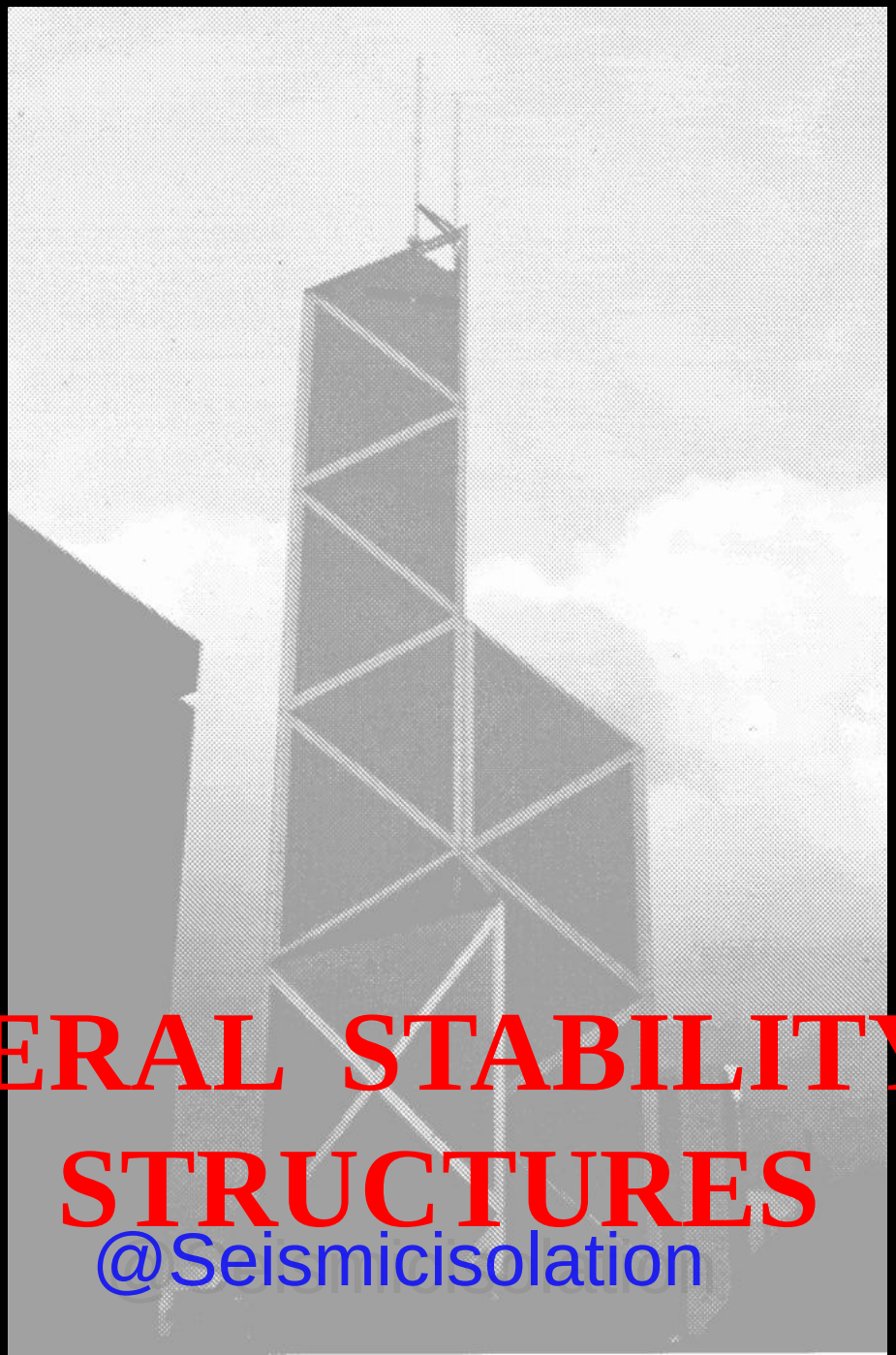
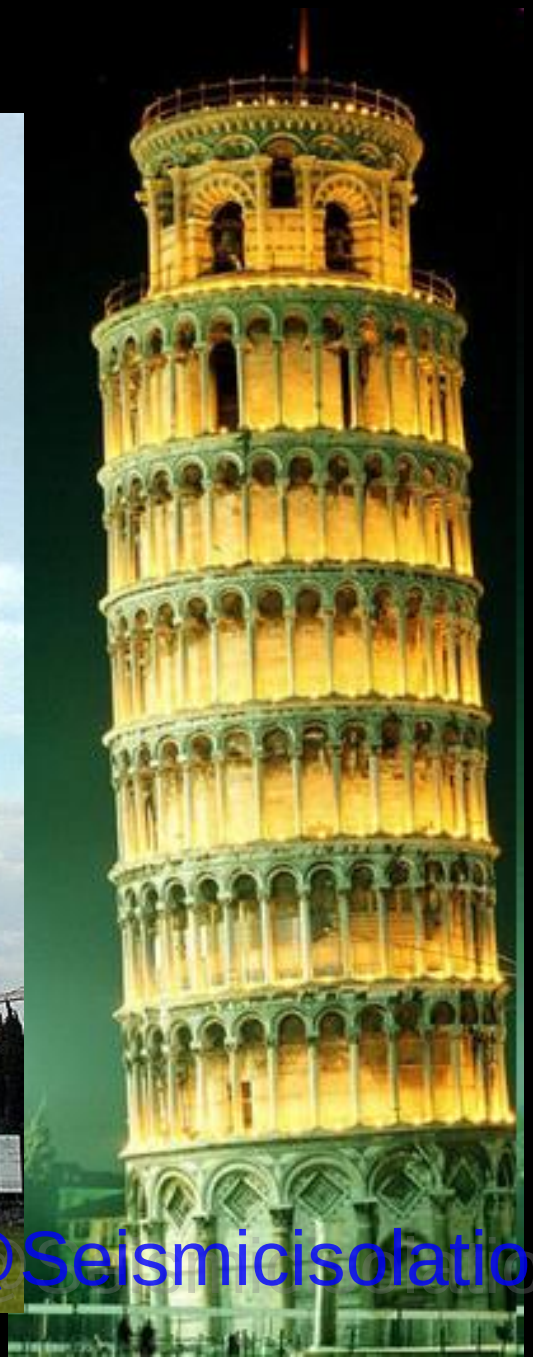


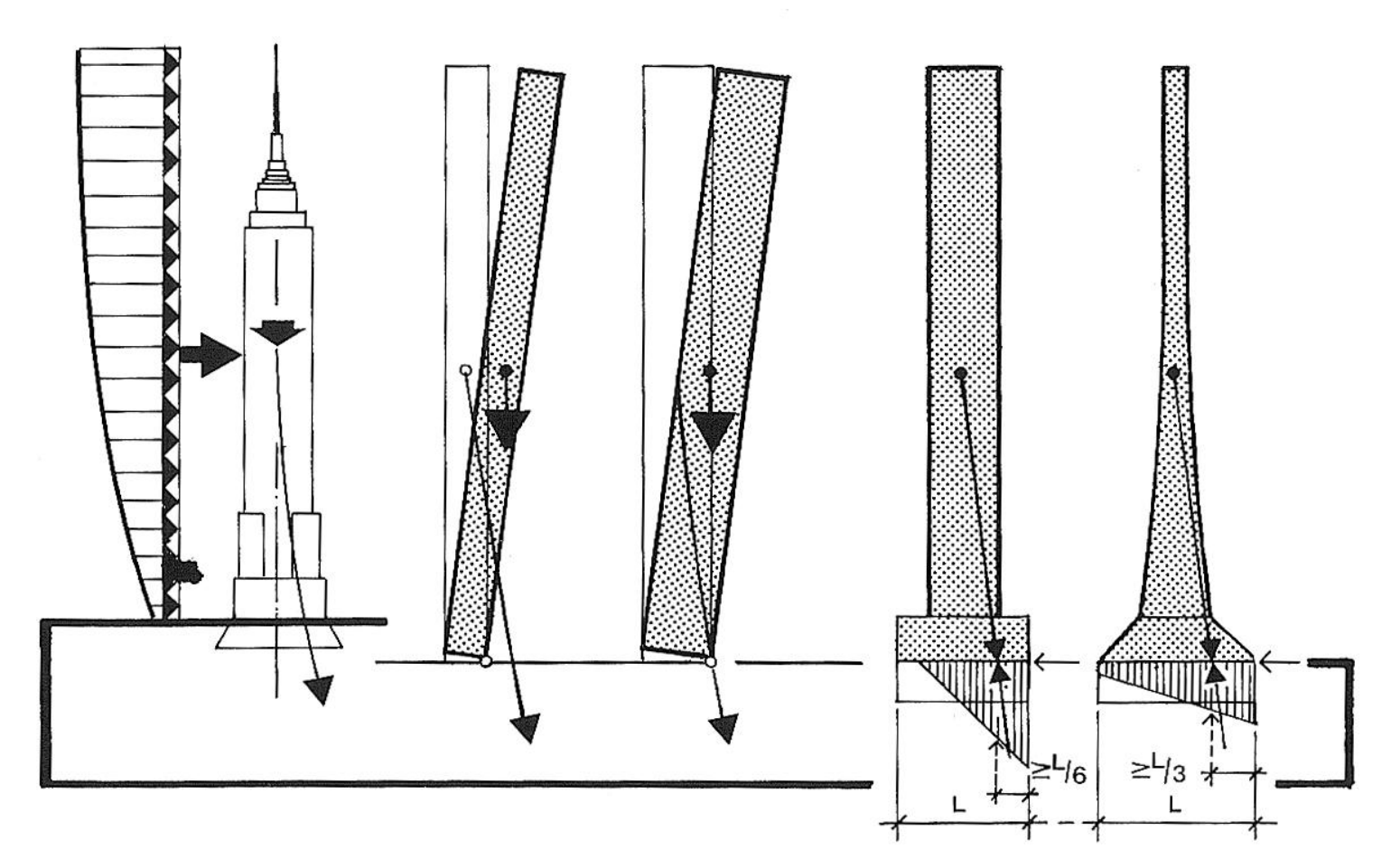
LATERAL STABILITY OF STRUCTURES

@Seismicisolation



The Leaning Tower of Pisa (54 m), Italy, 1174

@Seismicisolation



LATERAL STABILITY

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The primary lateral loads are caused by wind pressure and seismic excitation. However, lateral loads may also be generated by lateral soil pressure and liquid pressure as well as by gravity loads in cantilevering structures and irregular structures.

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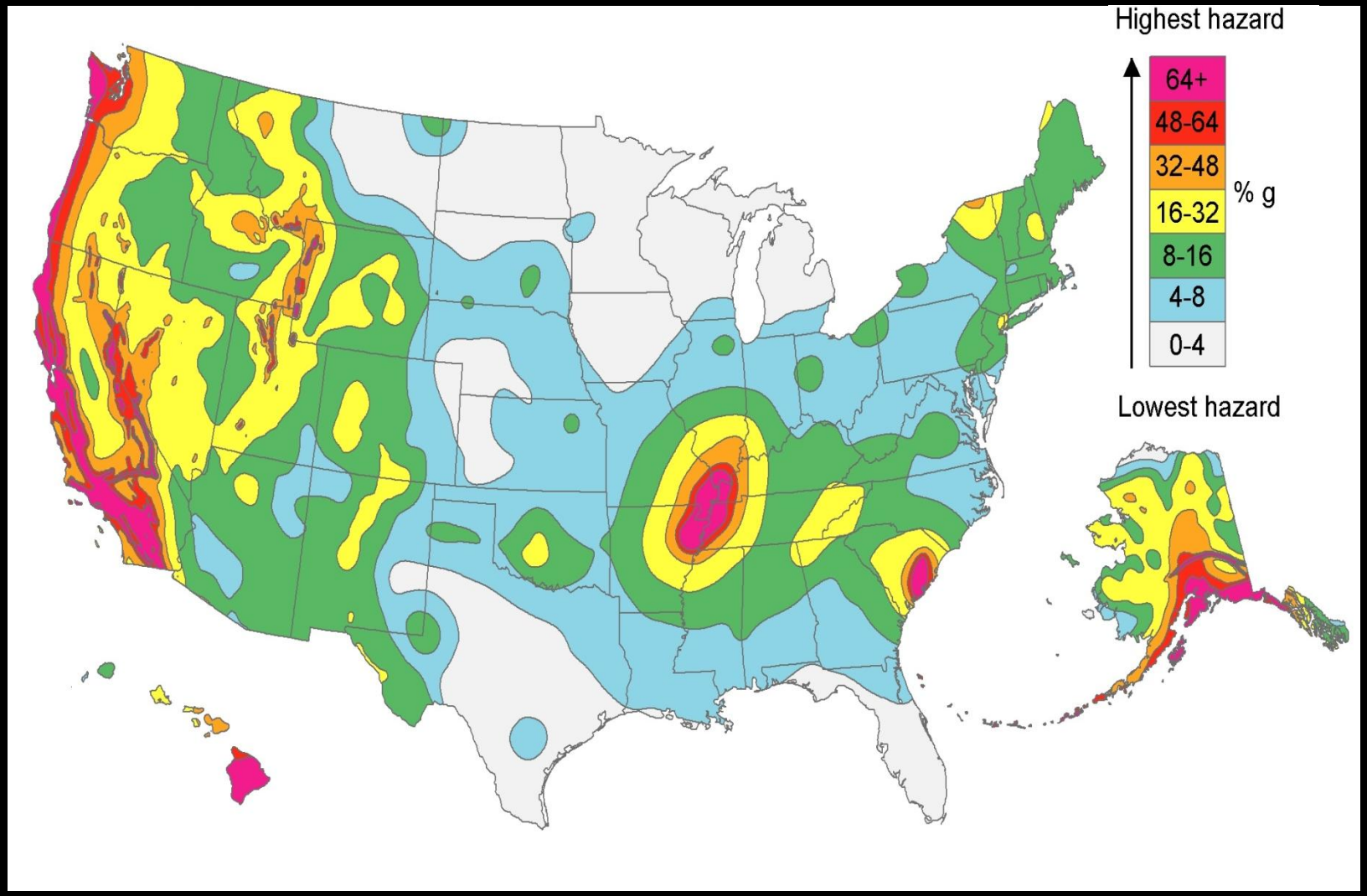

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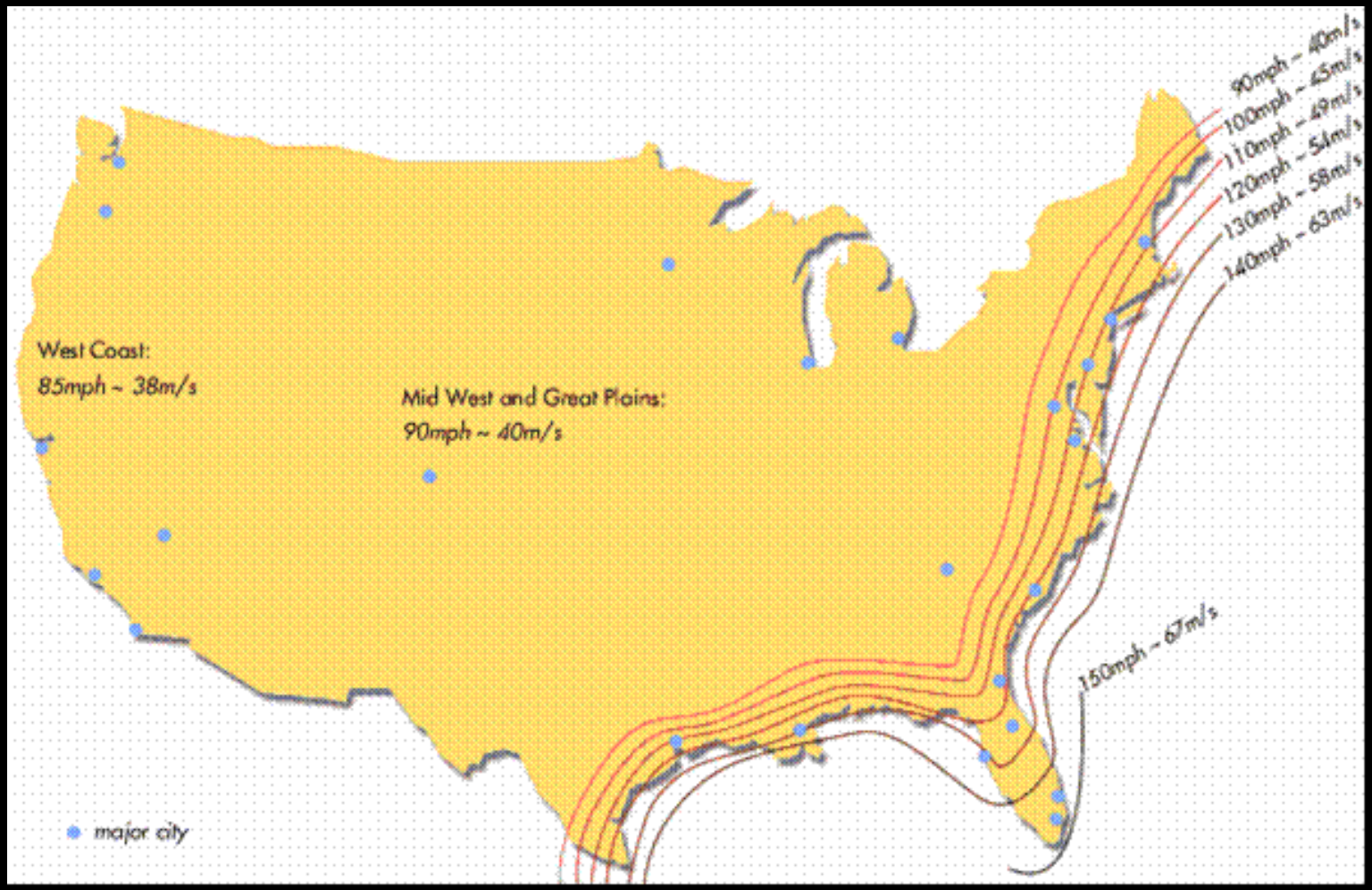

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A typical building can be visualized as consisting of

- **horizontal planes** or floors and roofs, as well as the supporting
- **vertical planes** of walls and/or frames

The horizontal planes tie the vertical planes together to achieve a box effect. In other words, floors act as **diaphragms** that connect the walls or frames in two layers.

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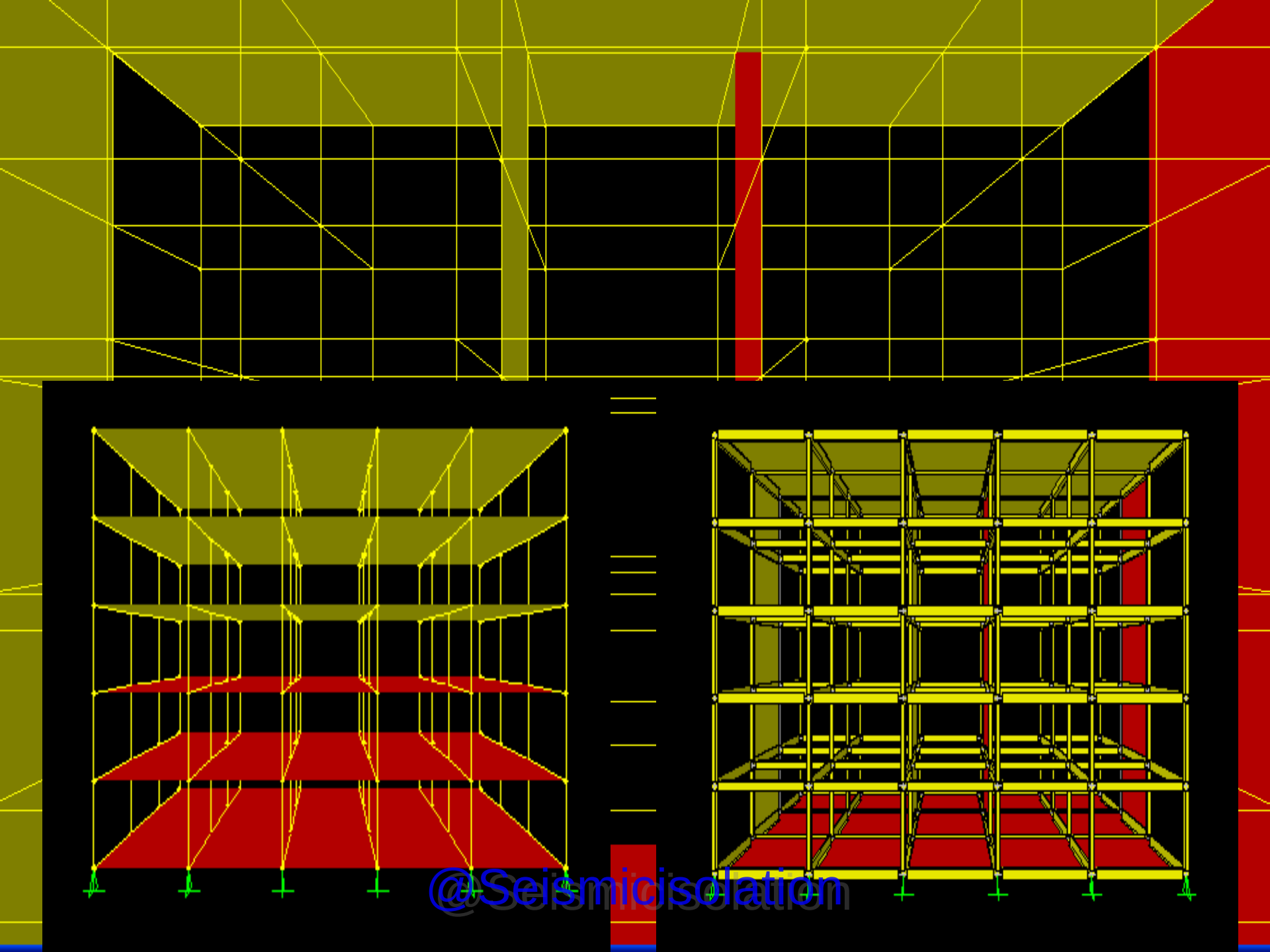
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BUILDING STRUCTURES

- GRAVITY STRUCTURES
- LATERAL-FORCE RESISTING STRUCTURES
- NON-LOADBEARING STRUCTURES

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The Behavior of Building Structure

Every building consists of the load-bearing structure and the non-load-bearing structure.

- **The main load-bearing structure**, in turn, is subdivided into the

  gravity load resisting structure, which carries only the gravity loads

  lateral load resisting structure, which supports gravity loads, but also must provide stability to the building.

  For the condition, where the lateral bracing only resists lateral forces, but does not carry gravity loads with the exception of its own weight, it is considered a *secondary structure.*

- The **non-load-bearing structure** includes the curtains, ceilings, and partitions that cover the structure and subdivide the space.

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The primary lateral loads are caused by wind pressure and seismic excitation. However, lateral loads may also be generated by lateral soil pressure and liquid pressure as well as by gravity loads in cantilevering structures and irregular structures.

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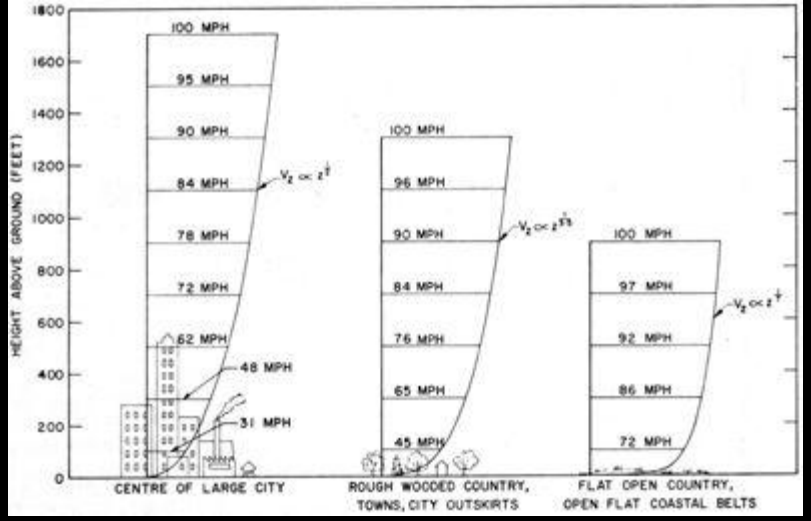
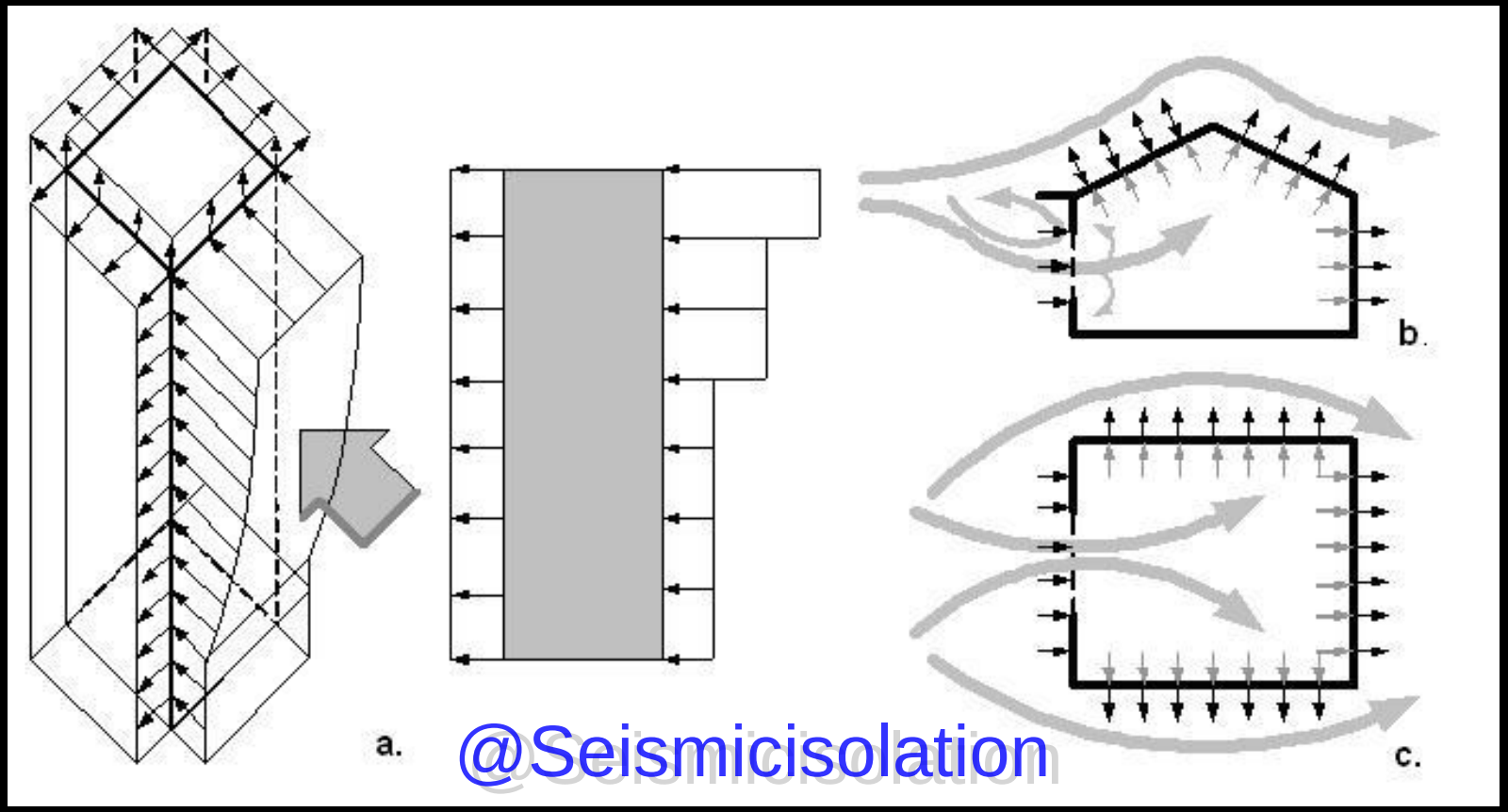
WIND PRESSURE





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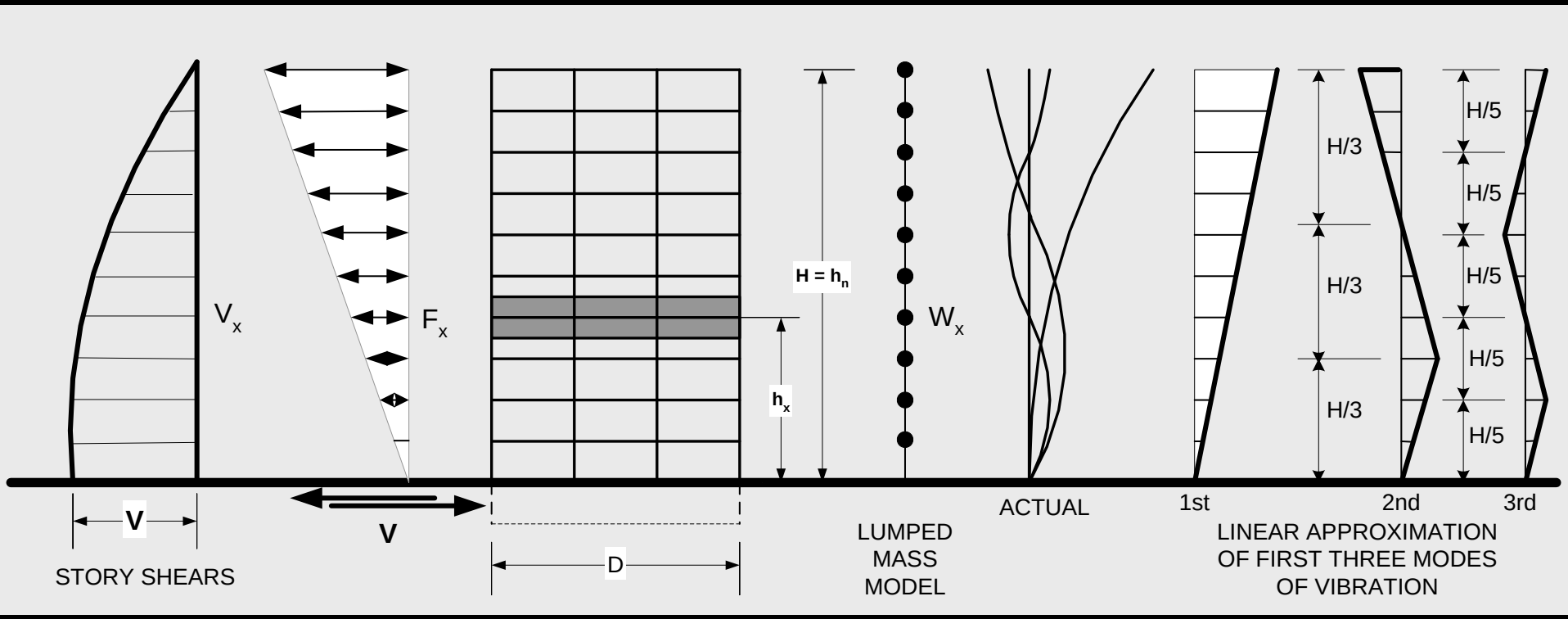

Equivalent lateral seismic load distribution

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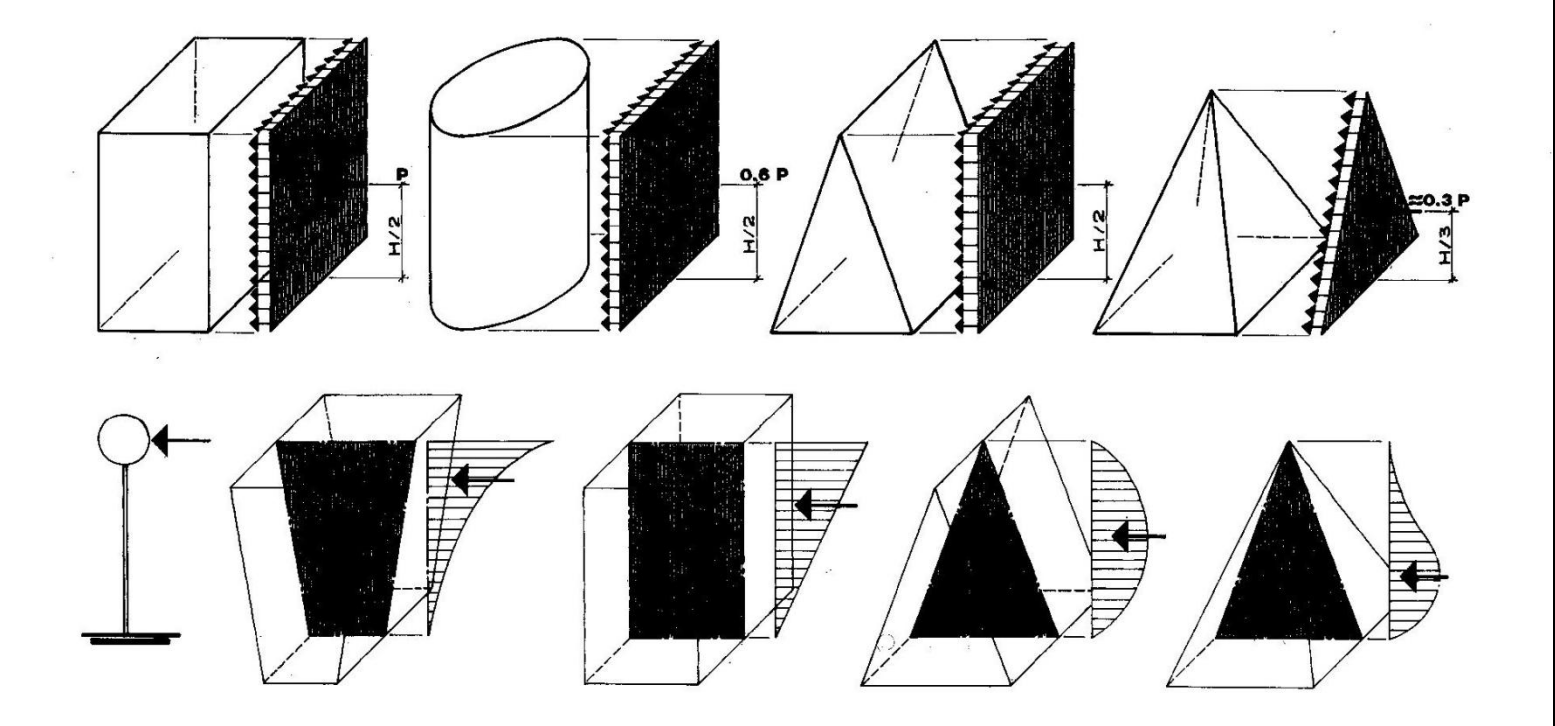
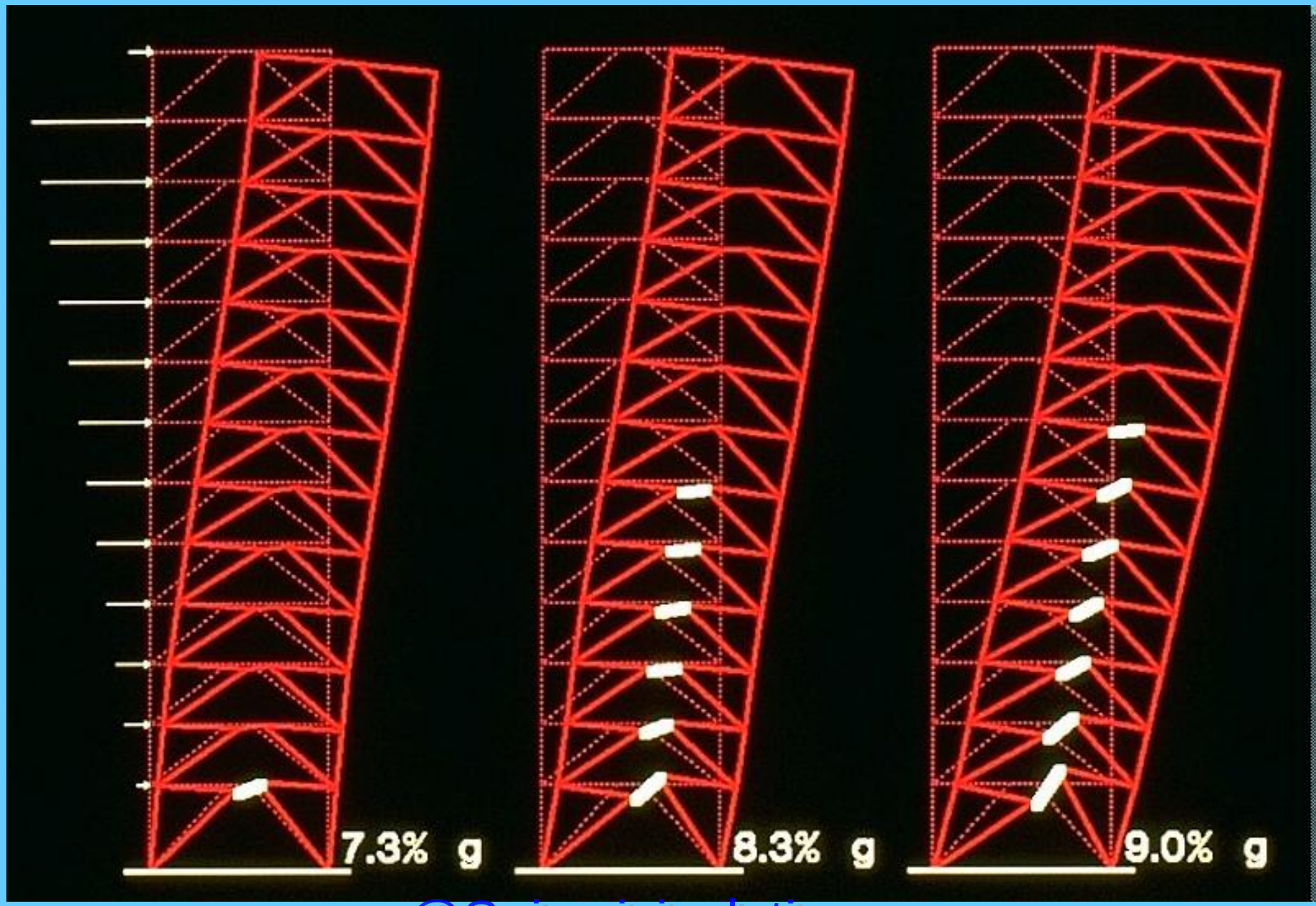


EFFECT OF BUILDING FORM ON WIND AND SEISMIC LOAD DISTRIBUTION

@Seismicisolation



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THE EFFECT OF SEISMIC INTENSITY

THE LATERAL FORCE RESISTING STRUCTURE

The lateral-load resisting structure of a building can be subdivided into horizontal and vertical structure subsystems.

- **The horizontal structure systems**. called ***diaphragms***, resist horizontal forces induced by wind or earthquake and transfer these forces to the vertical systems, which then take the forces to the ground. **DIAPHRAGMS** are like large beams (usually horizontal beams). **Diaphragms typically act like large simply supported beams spanning between vertical systems.**

- **Vertical structure systems** typically act like large cantilevers spanning vertically out of the ground. Common vertical structure systems that are frameworks and walls.

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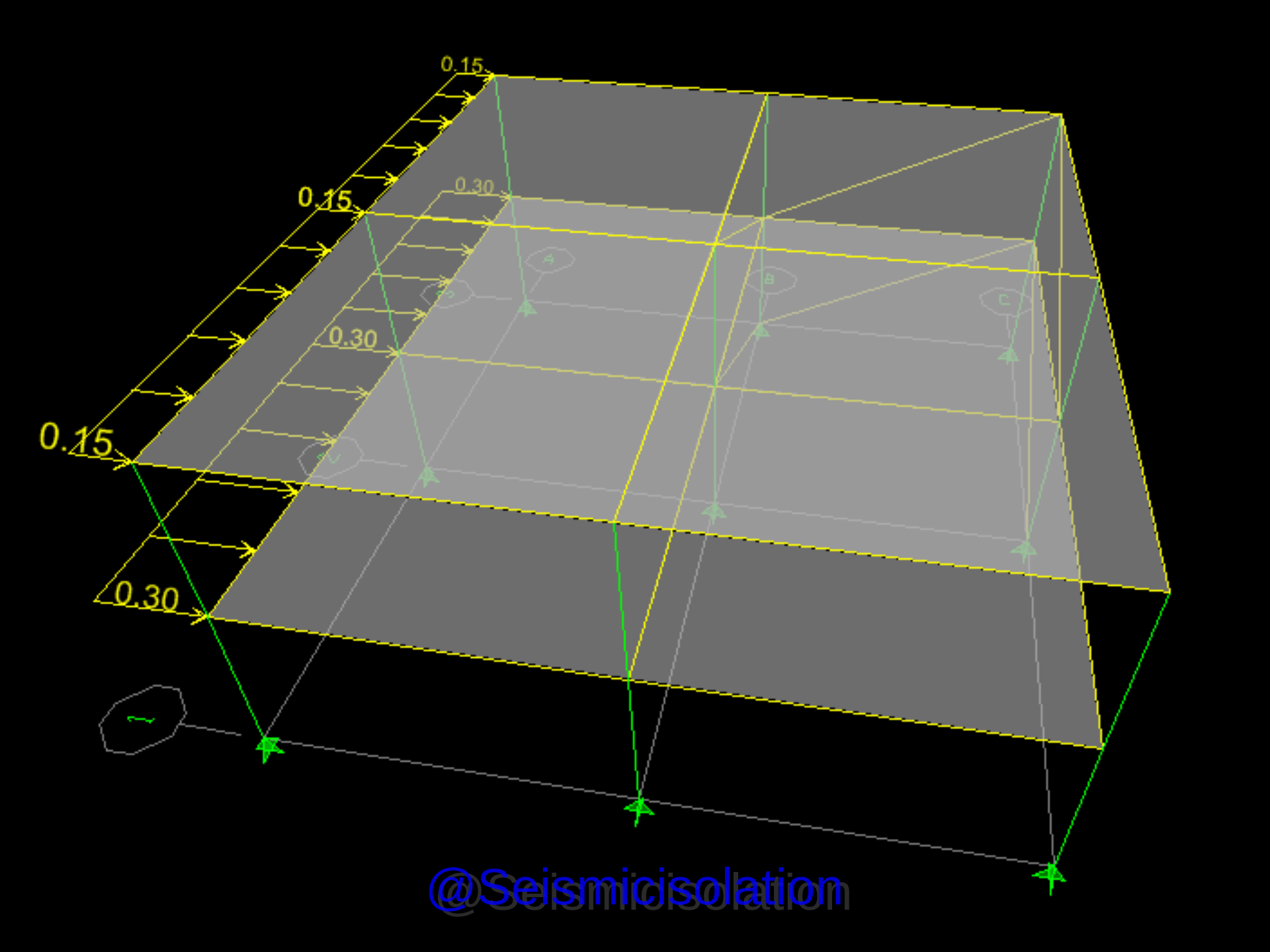
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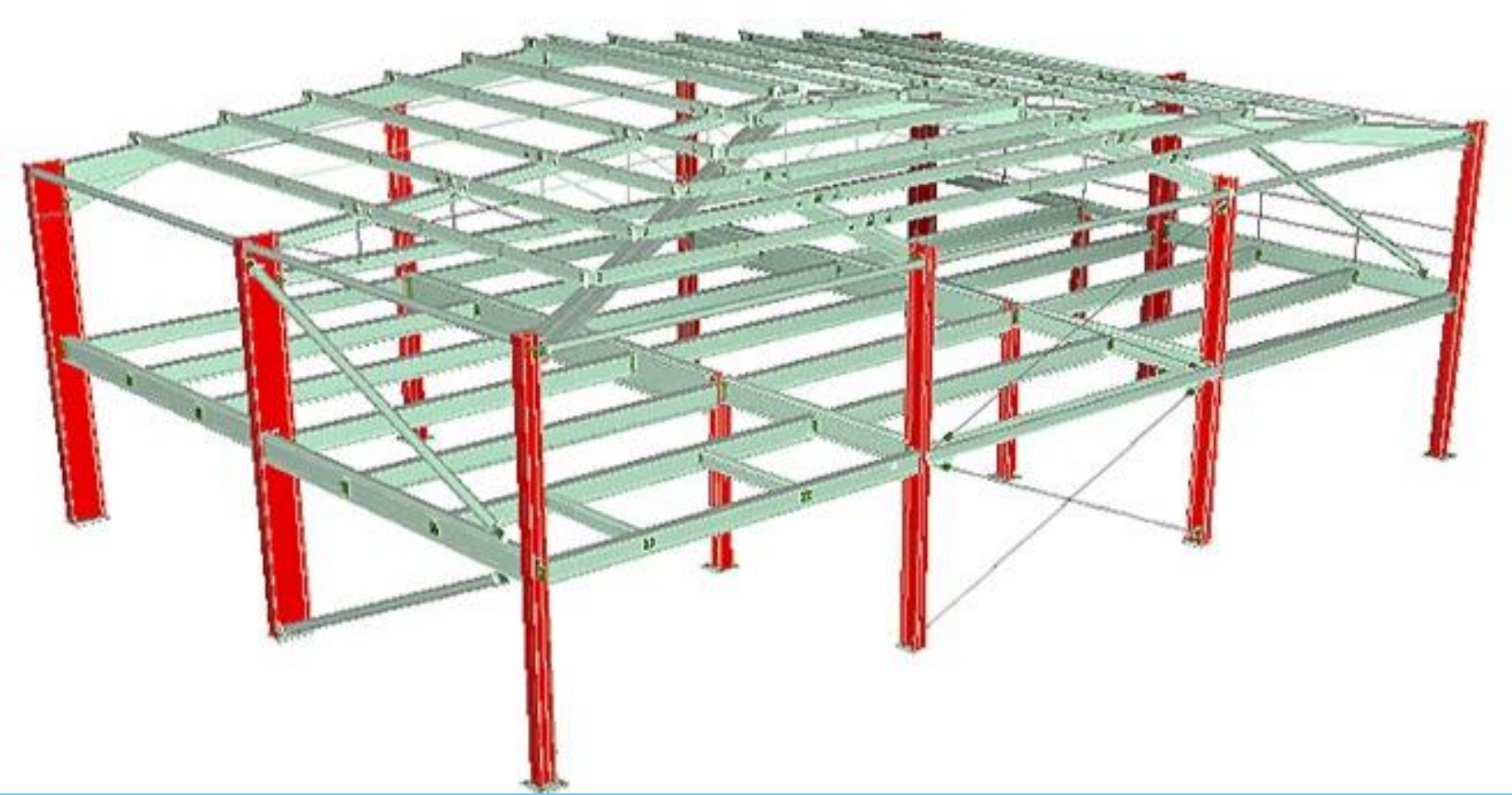

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We may distinguish between the following basic types of vertical, lateral-force resisting structures,

- **Moment-resisting frames**
- **Braced frames**
- **Shear walls**
- **Combinations of above** (e.g. dual systems)

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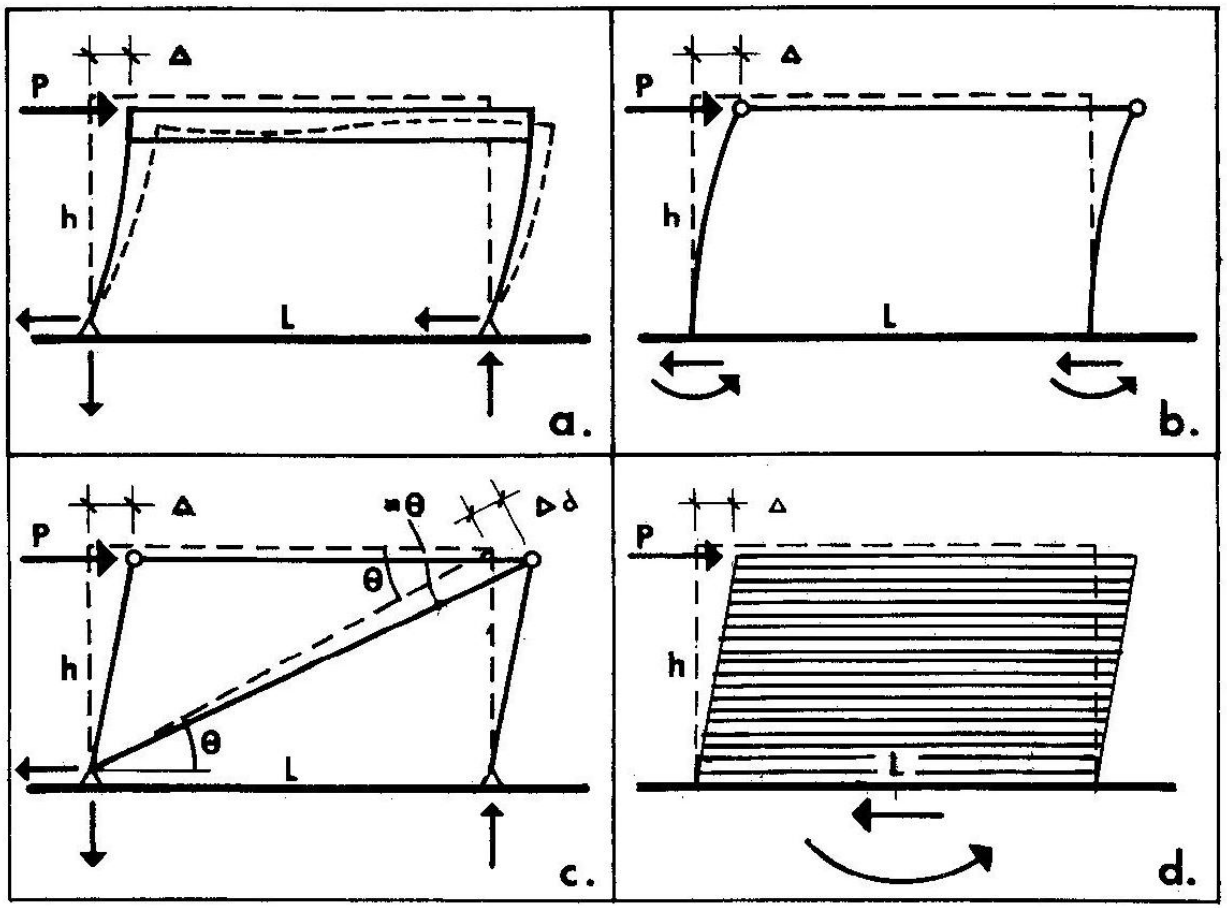

BASIC LATERAL FORCE RESISTING STRUCTURE TYPES

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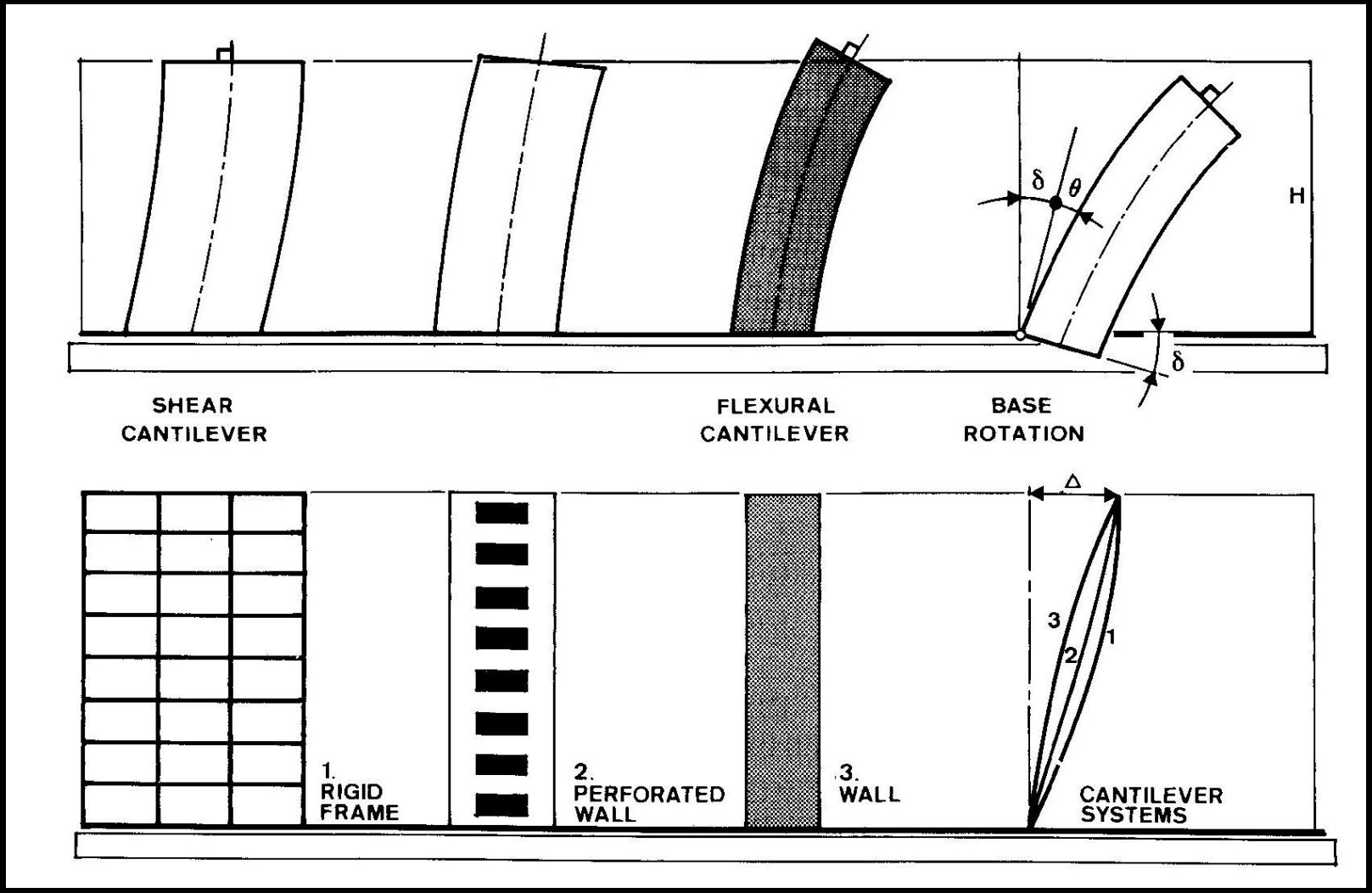

Effect of structure type on cantilever action

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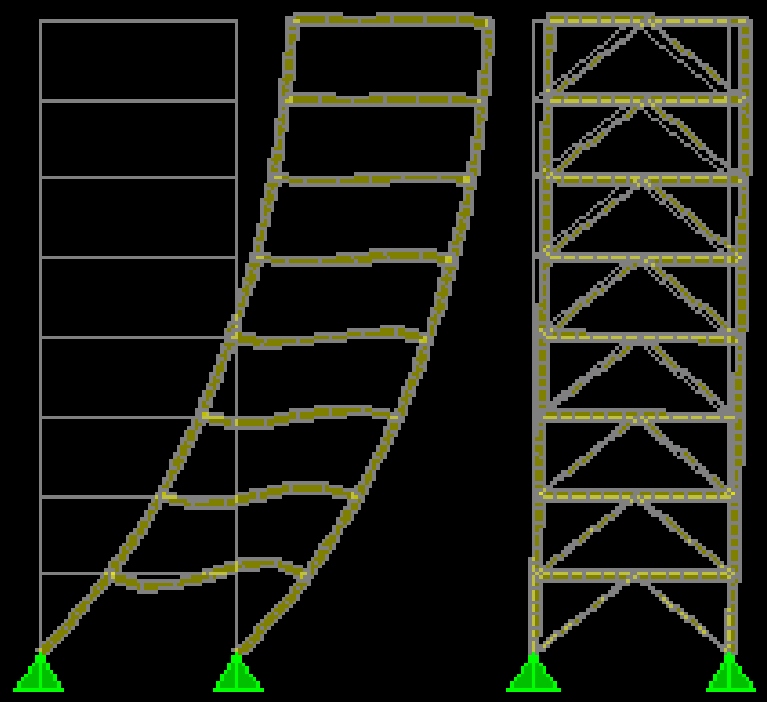

Of these structure systems is the frame the most flexible structure. It is quite apparent from that bracing the flexible rigid frame results in extensive reduction of the lateral building sway. A frame braced by trussing or shear walls is a relatively stiff structure as compared to the frame, where the lateral deflection depends on the rigidity of beam-column and slab joints.

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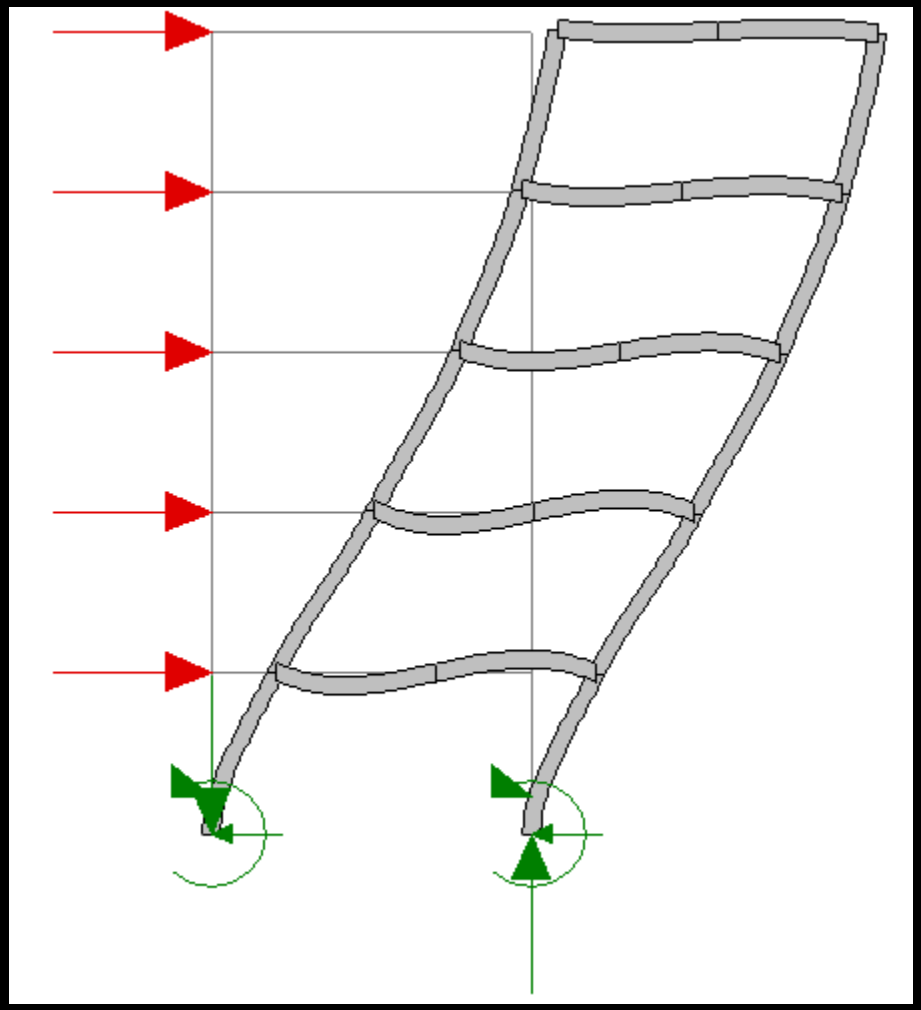

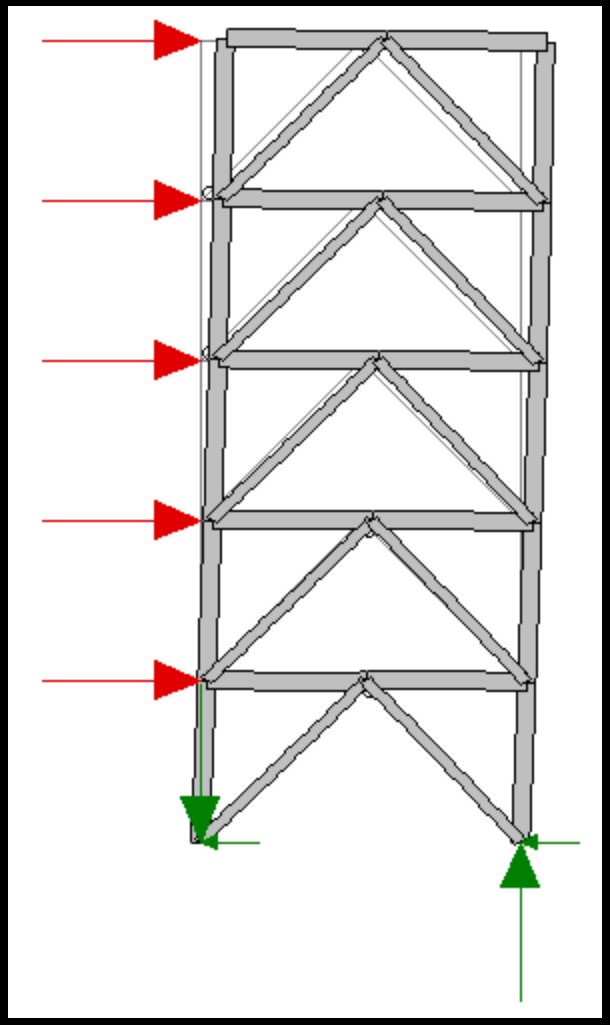

RIGID FRAME vs. BRACED FRAME

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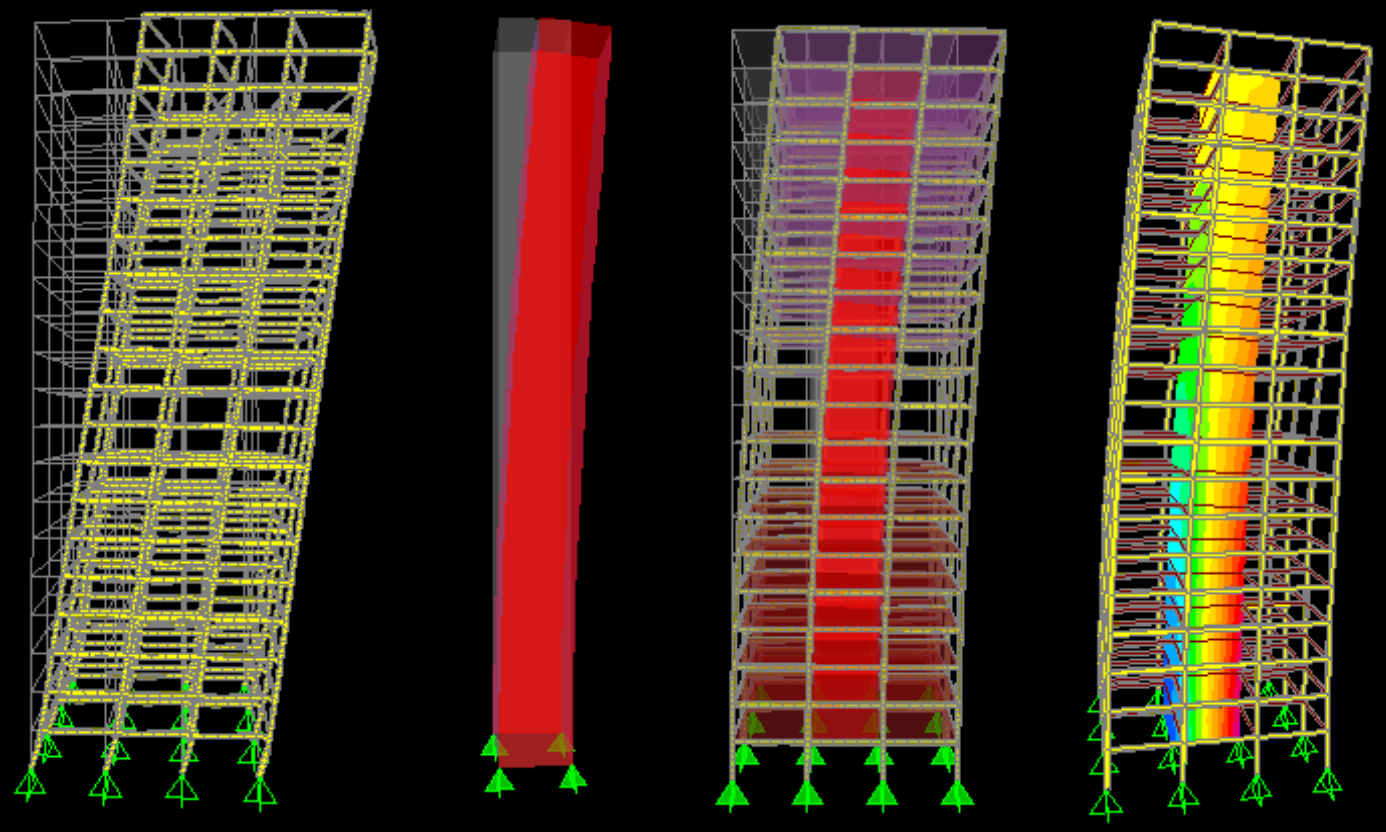

Rigid Frame Shear Core Interaction

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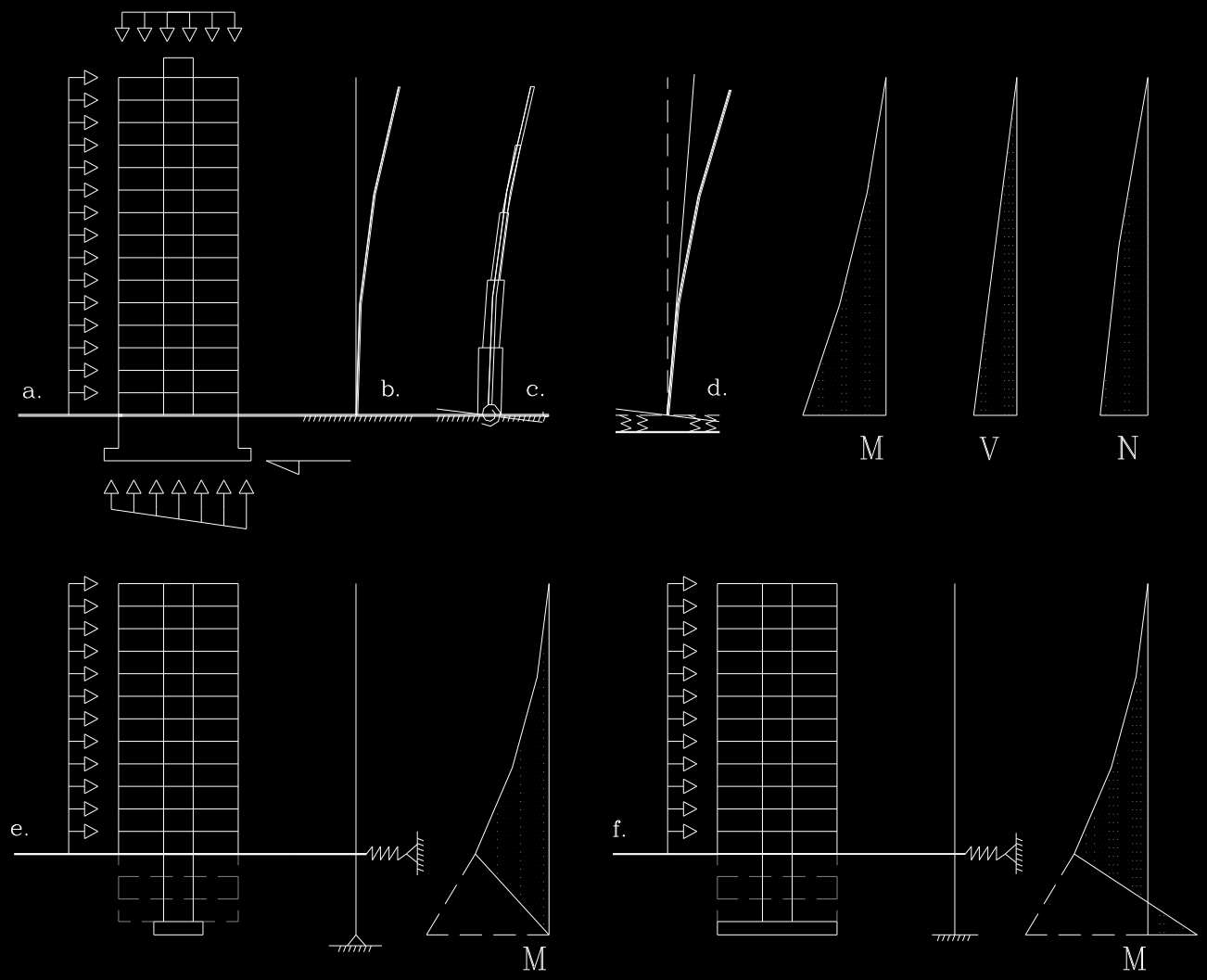

The Building Response to Load Action

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The classification for **common** high-rise building structure systems is as follows, taking into account special framing types when ductility considerations for seismic design must be considered:

BEARING WALL SYSTEMS

Reinforced or plain concrete shear walls (ordinary, special)
Reinforced or plain masonry shear walls (ordinary, special)
Light frame walls with shear panels
Steel-braced frames in light frame construction
Prestressed masonry shear walls (ordinary, special)
etc.

BUILDING FRAME SYSTEMS

Steel eccentrically braced frames with moment or hinged beam-column connections
Concentrically braced frames (ordinary, special)
Reinforced or plain concrete shear walls (ordinary, special)
Composite eccentrically braced frames
Ordinary composite braced frames
Composite steel plate shear walls
Light frame walls with shear panels
Reinforced or plain masonry shear walls (ordinary, special)
Prestressed masonry shear walls (ordinary, special)
etc.

MOMENT-RESISTING FRAME SYSTEMS

Steel moment frames (ordinary, special)
Reinforced concrete moment frames (special, ordinary)
Composite moment frames (ordinary, special)
Composite partially restrained moment frames
Special steel truss moment frames
Masonry wall frames
etc.

DUAL SYSTEMS WITH MOMENT FRAMES

Combination of the above

INVERTED PENDULUM SYSTEMS

Cantilevered column systems
Steel moment frames (ordinary, special)
Special reinforced concrete moment frames
etc.

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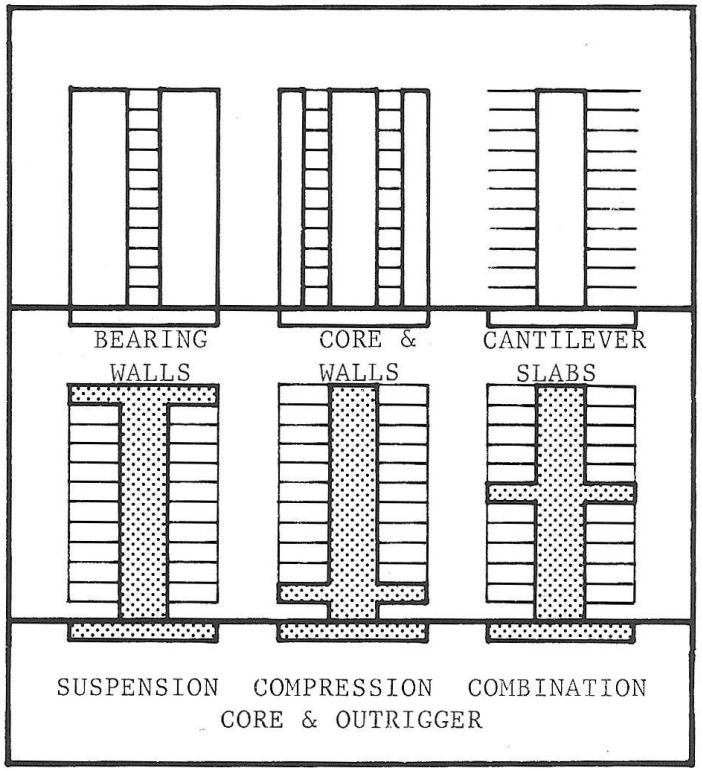

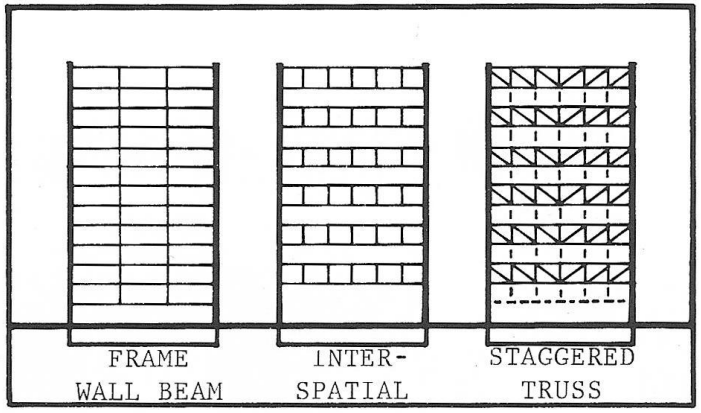

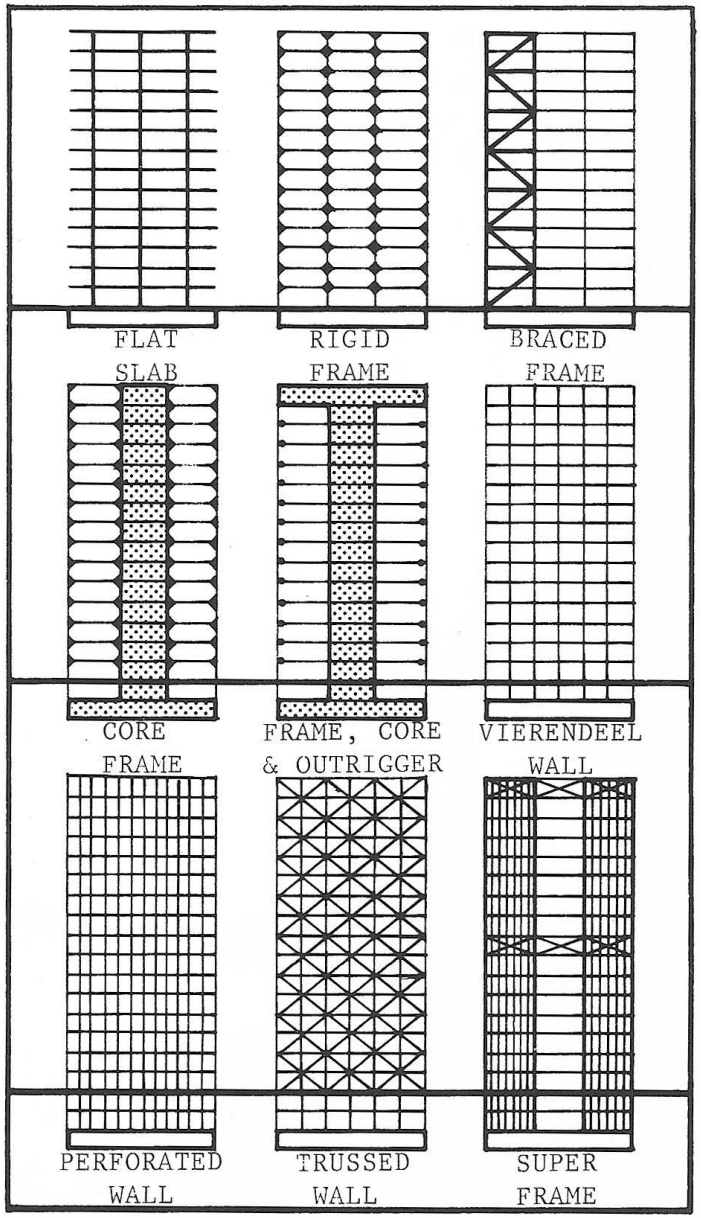

VERTICAL BUILDING STRUCTURE SYSTEMS 1

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Braced Frames have much better **strength** and **stiffness**. Bracing is a much effective than rigid joints at resisting racking deformation of the frame. Efficient and economical braced frames use less material and have simpler connections than moment-resisting frames. Compact braced frames can lead to lower floor-to-floor heights, which can be an important economic factor in tall buildings, or in a region where there are height limits. Visual braces can be used as a strong visual element. Obstructive. Braces can interfere with architectural requirements for doors, windows, and open floor area. Braced frames have **low ductility** characteristics under cyclic loading, which is important for seismic design. **Brace buckling** is not a good energy dissipation mechanism (not such bad news for wind design).

Moment Frames provide a great deal of flexibility in planning: no braces. They can have **good ductility**, if detailed properly (Special Moment Resisting Space Frame = SMRF = "smurf"). The performance is very sensitive to the detailing and workmanship at connections. The bad aspect of **moment frames** are expensive lots of material plus labor-intensive connections. **Low stiffness** (large deflections) can lead to high non-structural damage in earthquakes (i.e. undamaged structure will all glass broken and finishes cracked). The 1994 Northridge earthquake revealed unforeseen problems with conventional details and weld procedures.

Eccentric Braced Frames combine properties of moment and braced frames; braces provide stiffness in elastic range, links control strength and provide ductility.

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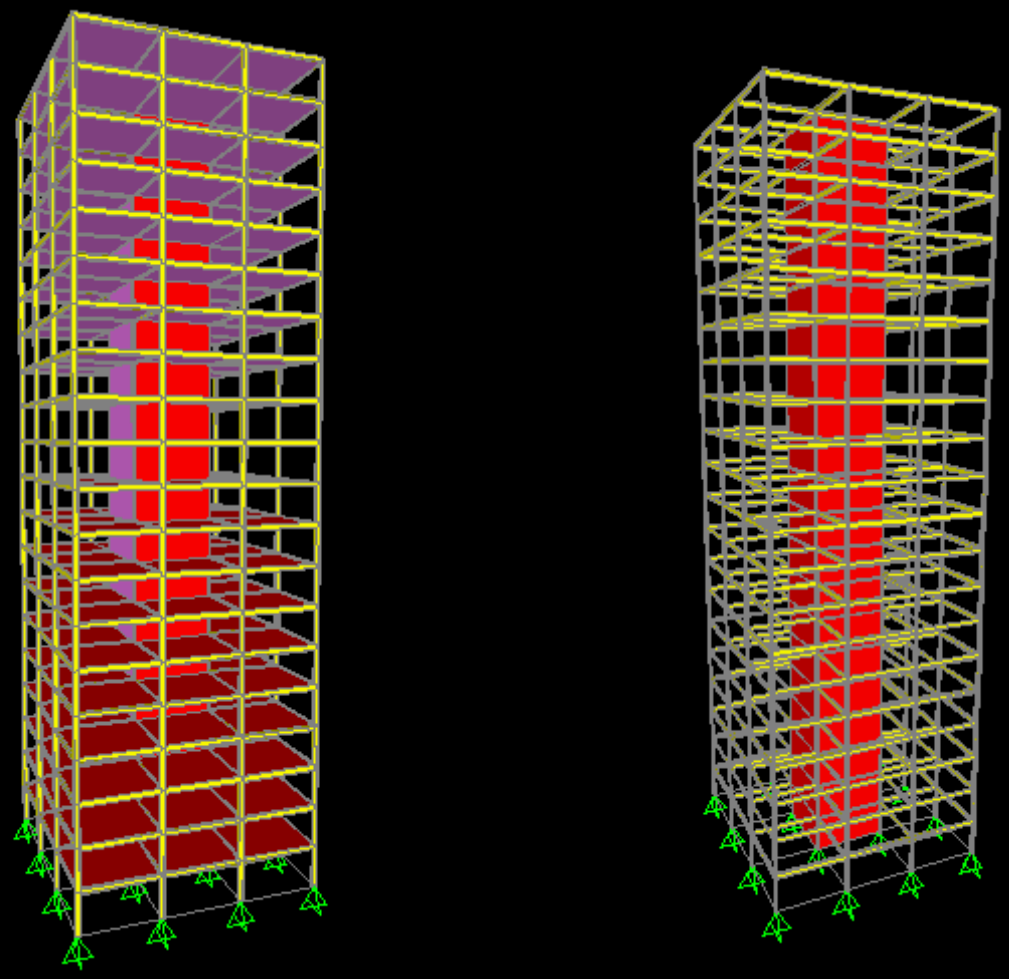

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the Dee and Charles Wyly Theater, Dallas, 2009, Joshua Prince-Ramus and Rem Koolhaas

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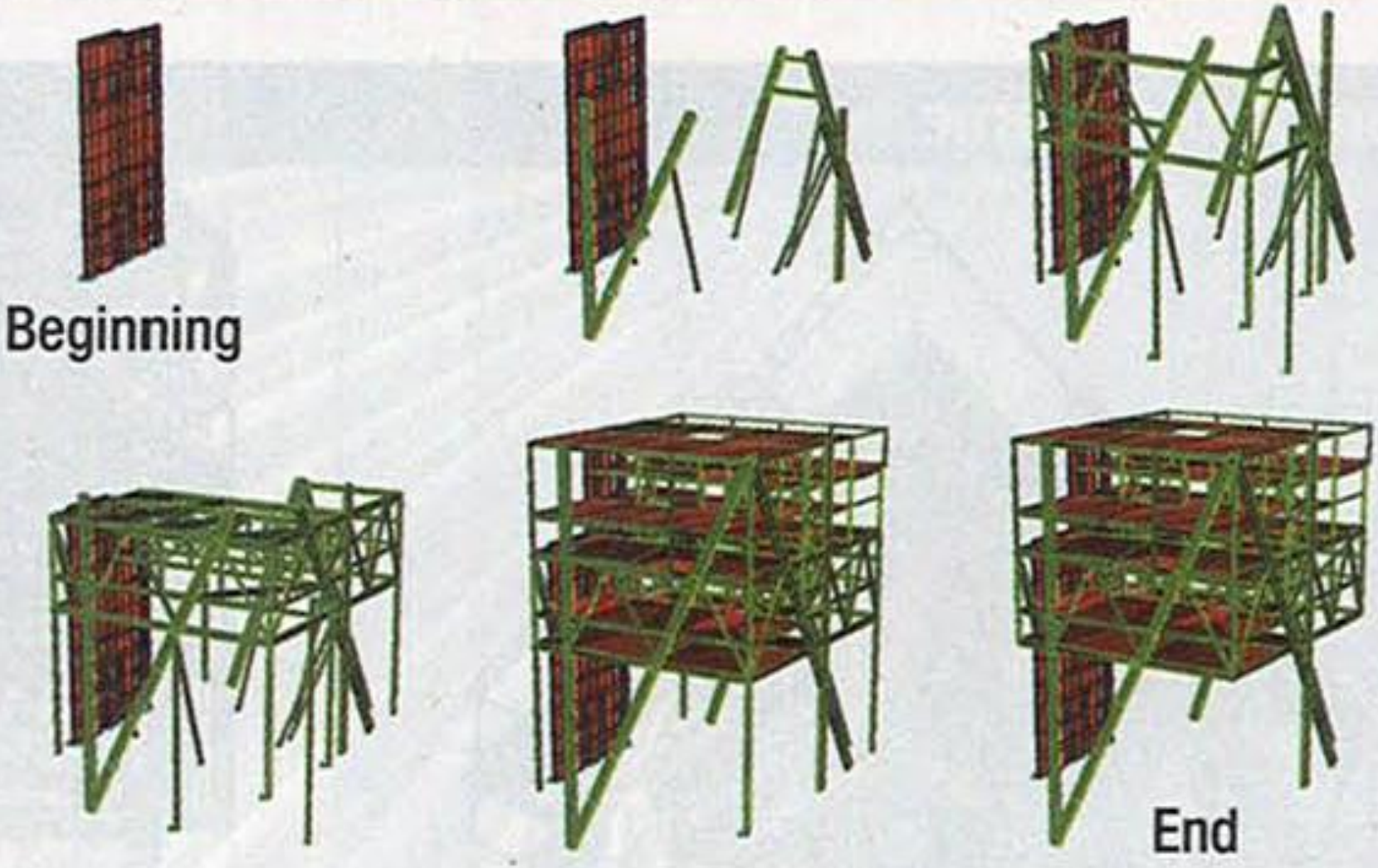
Gravity-Defying Structure



Builders divided construction of the high-rise theater's main structure, a steel bird cage on concrete stilts, into 22 stages for analysis because the frame did not support itself during construction.

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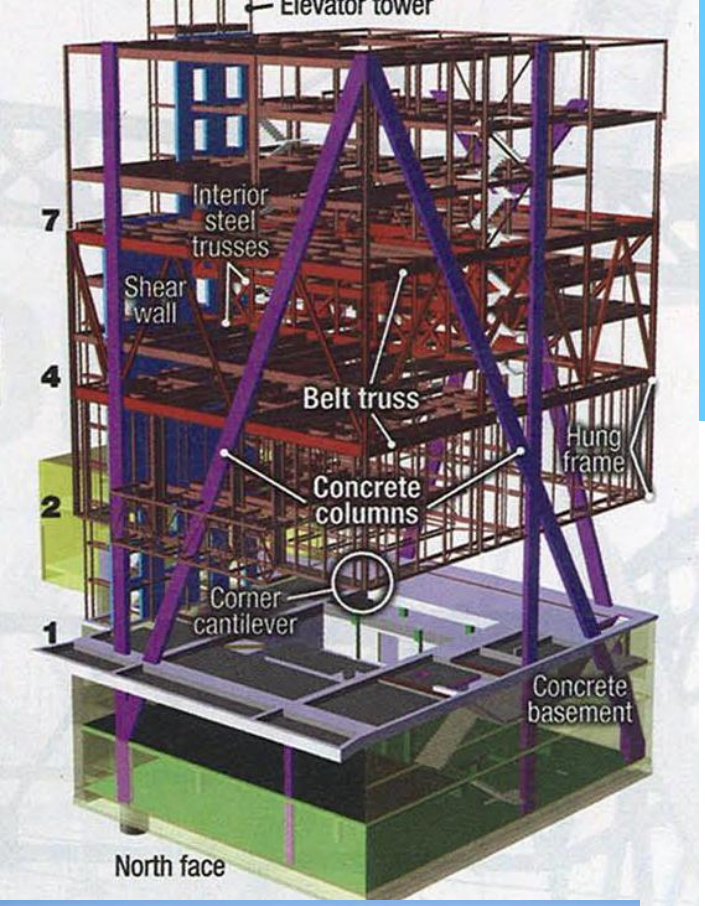

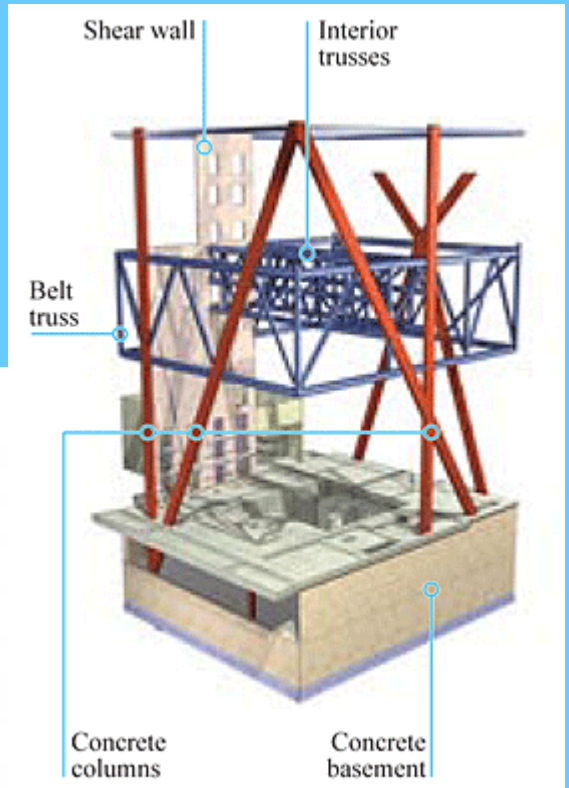

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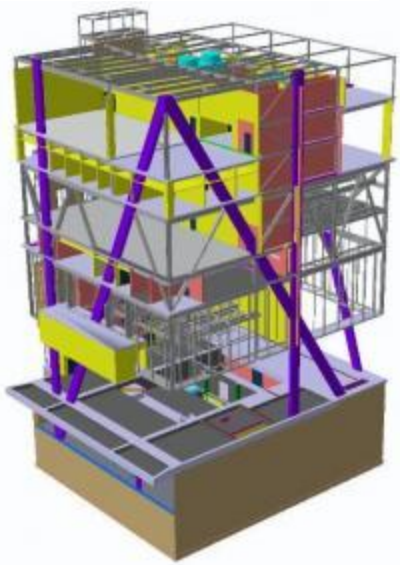

Completed Frame

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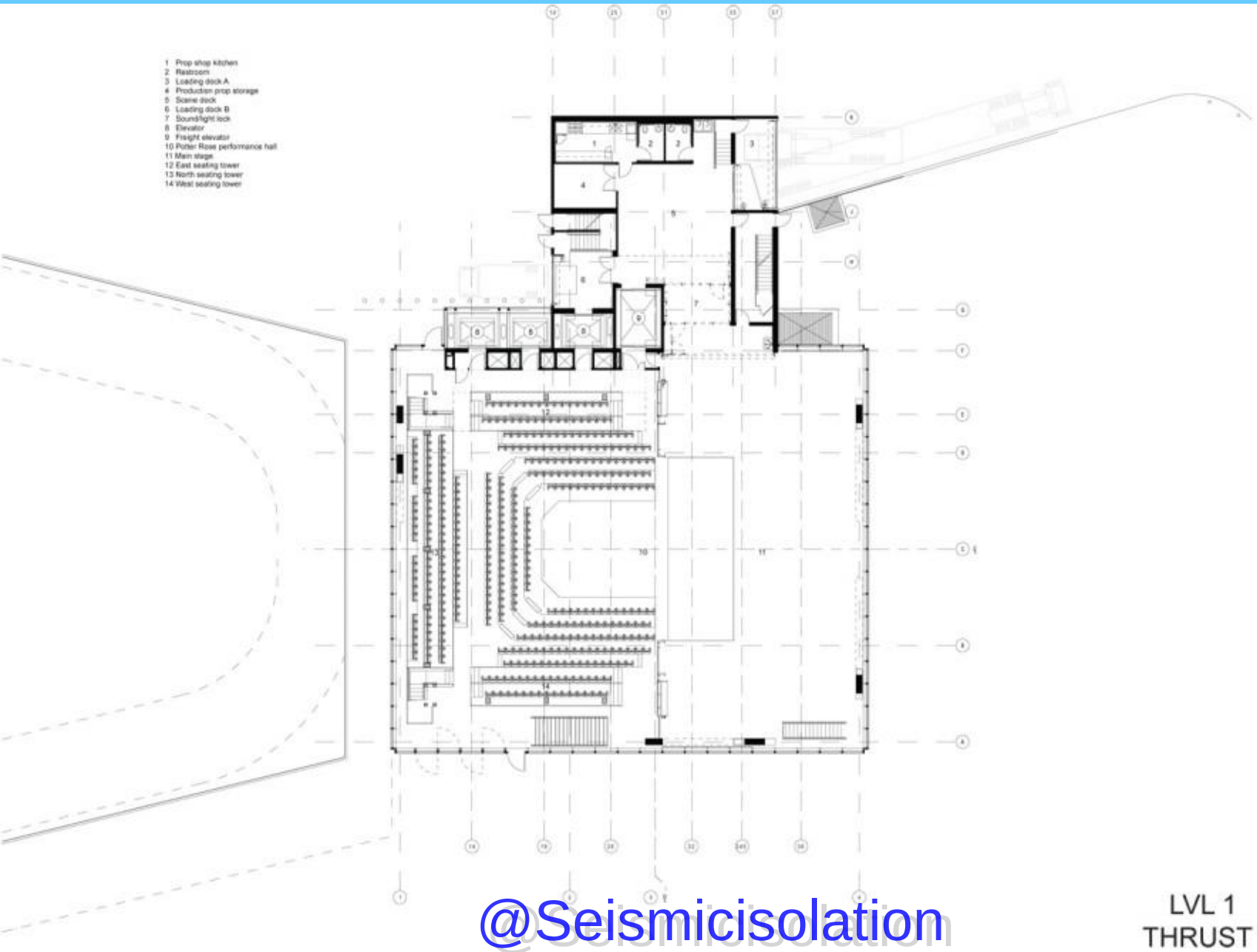

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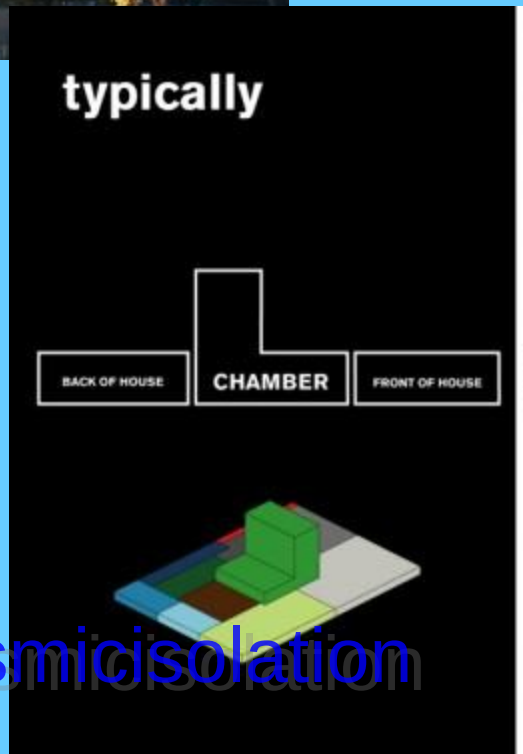

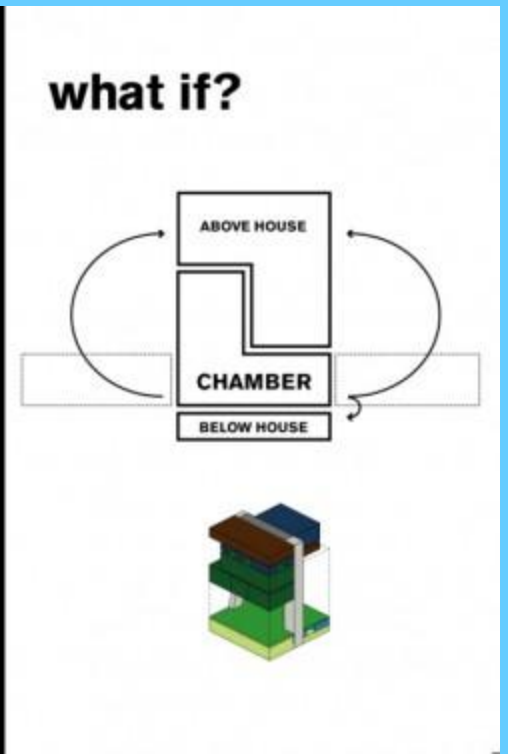

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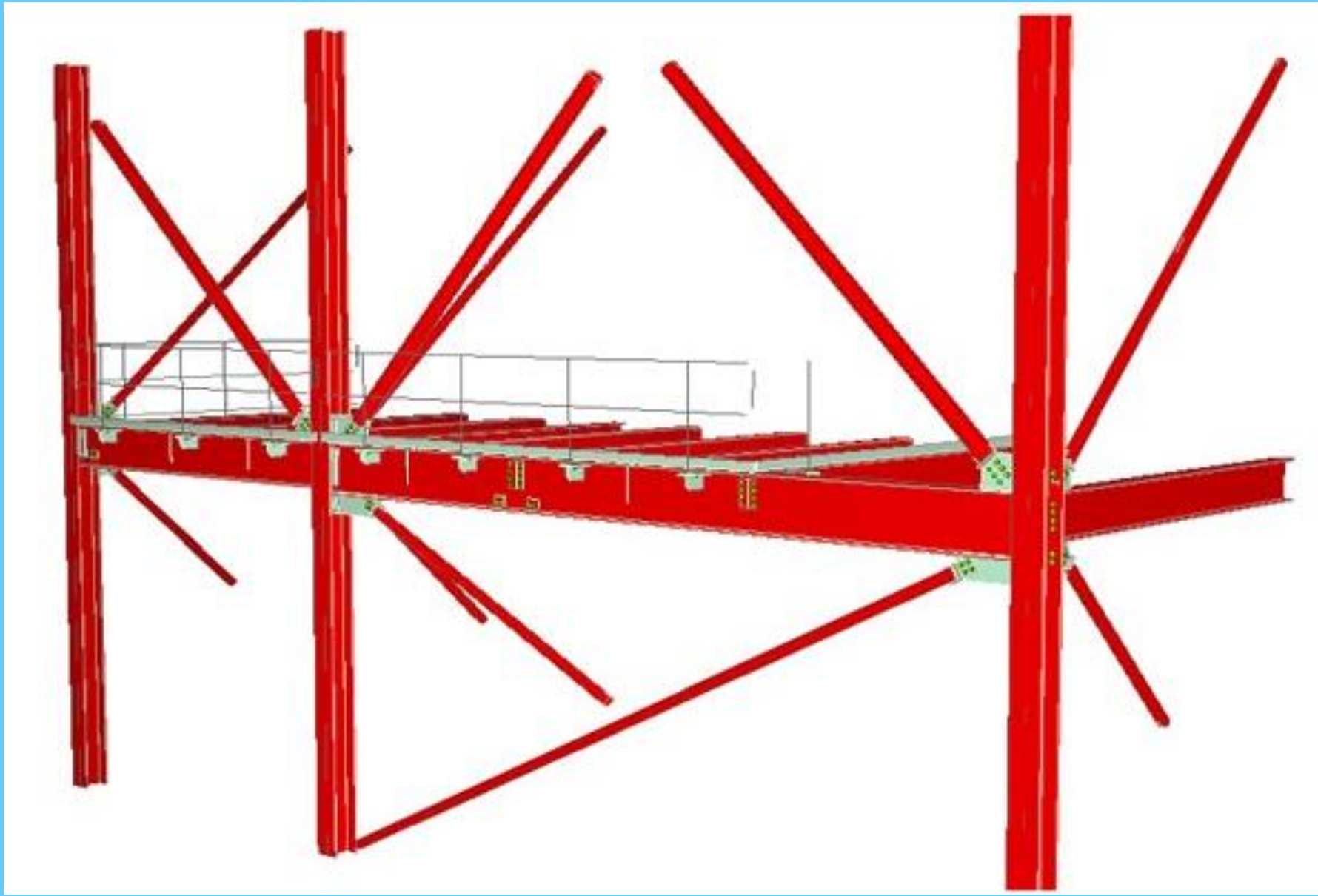

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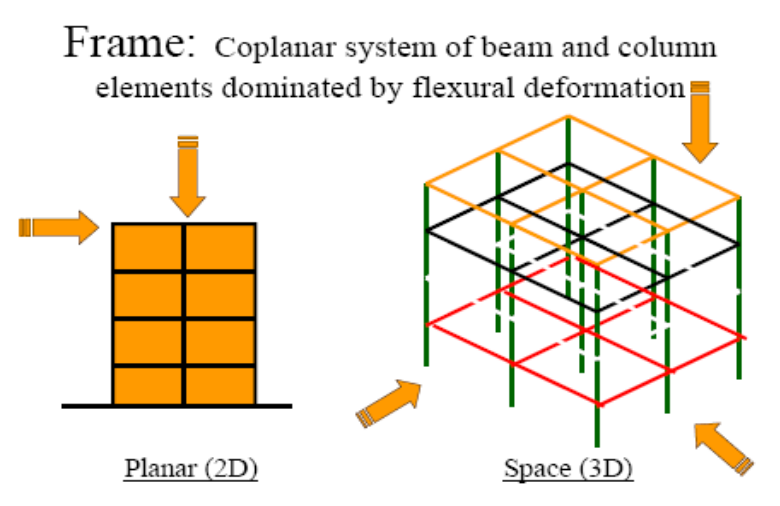
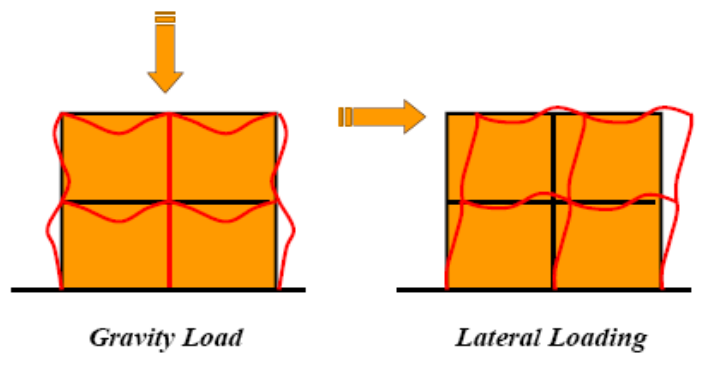
Frame Systems
IBC 2000

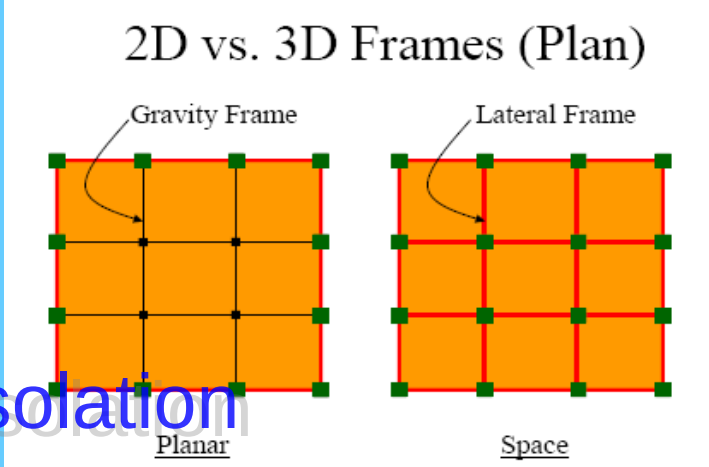
- Building Frame
  - Complete space frame systems providing support for gravity loads and seismic resistance is provided by shear walls or braced frames
- Dual Frame
  - Complete space frame systems providing support for gravity loads and seismic resistance is provided by the space frame and shear walls or braced frames
- Space Frame
  - Members that are capable of supporting gravity loads and also provide resistance to seismic forces

Moment Frame Systems
IBC 2000

- Ordinary (OMF)
  - Members and joints are capable of resisting forces by flexure as well as along the member axis
- Intermediate (IMF)
  - Members and joints are capable of resisting forces by flexure as well as along the member axis with some extra detailing requirements for ductility
- Special (SMF)
  - Members and joints are capable of resisting forces by flexure as well as along the member axis with special detailing requirement for ductility







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Frame Advantages

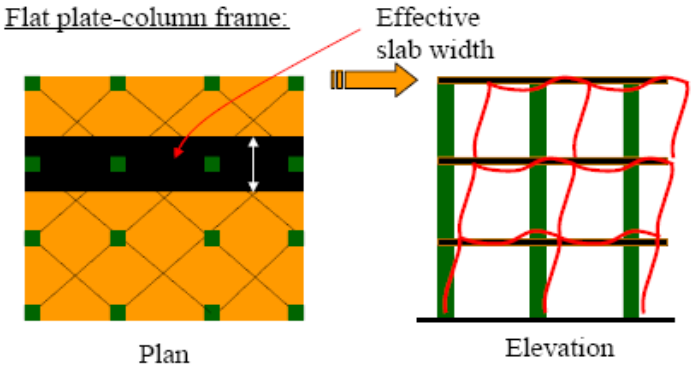
- Optimum use of floor space, ie. optimal for office bldgs, retail, parking structures where open space is required.
- Relatively simple and experienced construction process
- Generally economical for low-to mid-rise construction (less than about 20 stories)
- In Houston, most frames are made of reinforced concrete.

Frame Disadvantages

- Generally, frames are flexible structures and lateral deflections generally control the design process for buildings with greater than about 4 stories. Note that concrete frame are about 8 times stiffer than steel frames of the same strength.
- Span lengths are limited with using normal reinforced concrete (generally less than about 40 ft, but up to about 50 ft). Span lengths can be increased by using prestressed concrete.

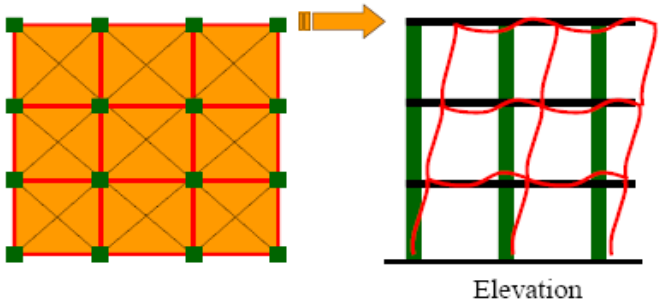
Frame Lateral Load Systems

Flat plate-column frame:



Frame Lateral Load Systems

Beam-column frame:



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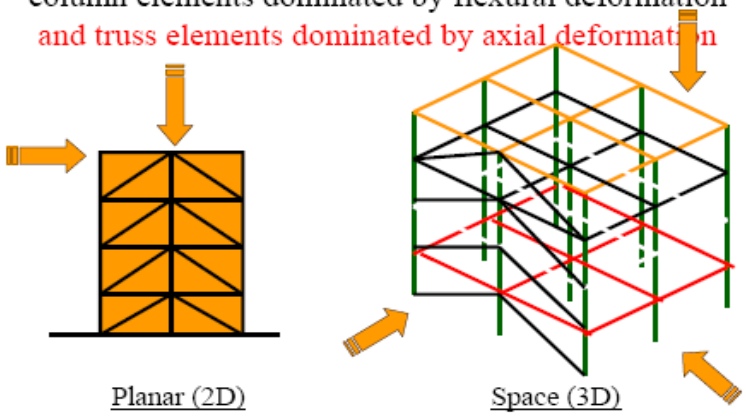
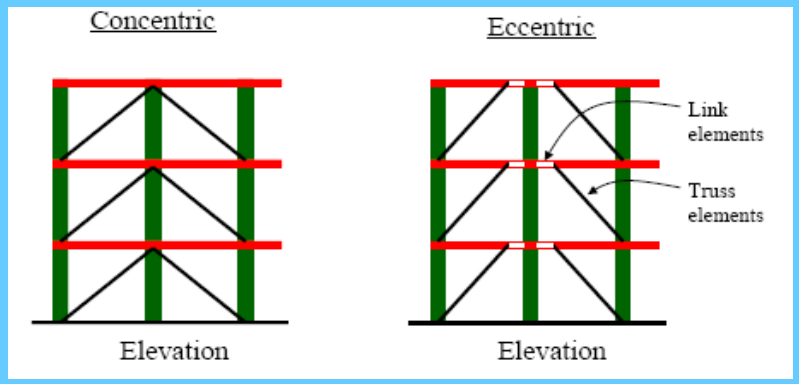
Braced Frame: Coplanar system of beam and column elements dominated by flexural deformation and truss elements dominated by axial deformation



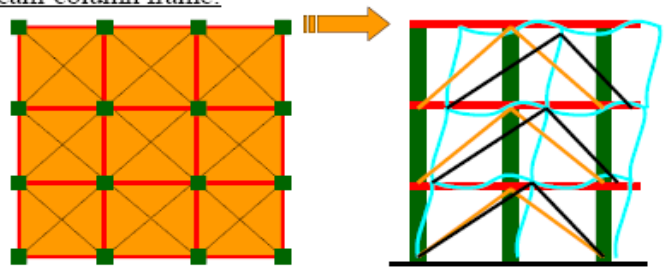


Braced Frame Advantages

- Much stiffer and stronger lateral load system when compared with frame systems
- Optimum use of floor space. Most braced frames are on the building perimeter or near elevator stairwell
- Generally economical for low-rise construction (less than about 5 stories)
- Eccentricity braced frames have superior seismic resistance due to very ductile link elements (fuses)

Concentrically Braced Frames

Beam-column frame:



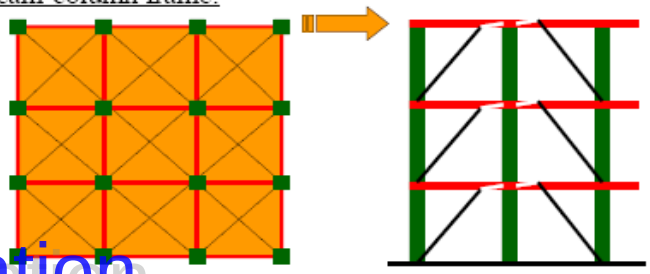
Note: Deformations are a function of axial stiffness in truss elements

Frame Disadvantages

- Architectural constraints. Sometimes braces must be hidden and other times can be visualized as part of the architectural scheme.

Eccentrically Braced Frames

Beam-column frame:



Note: Deformations are a function of shear stiffness in link elements

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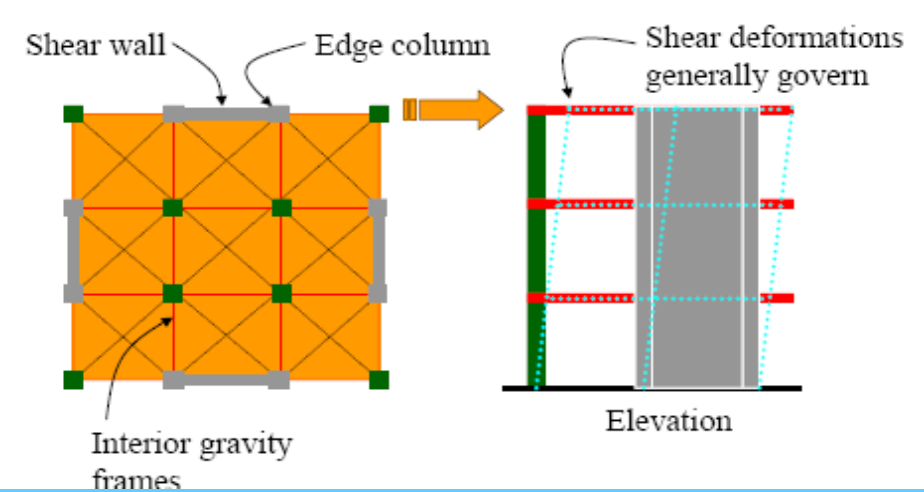
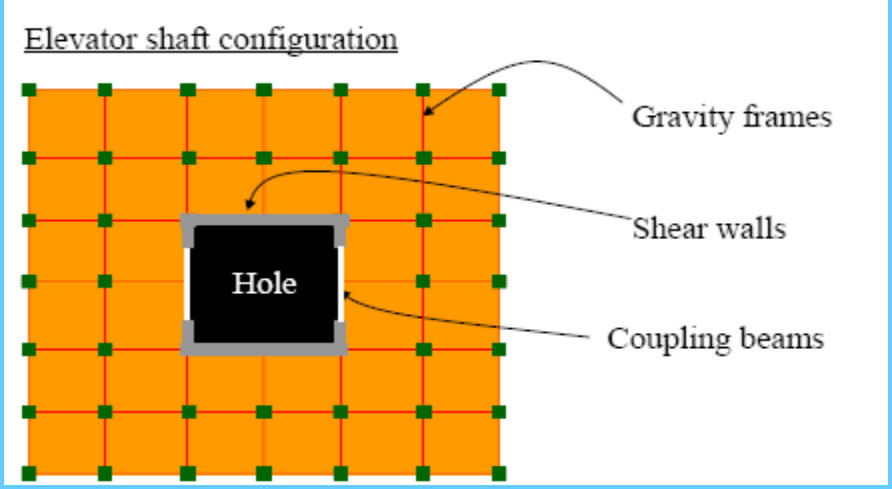
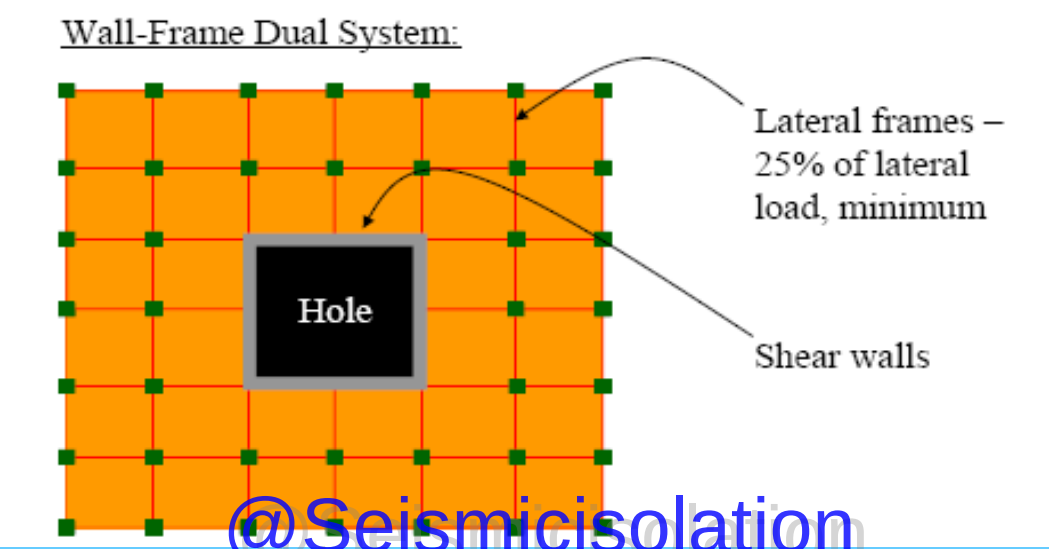
SHEAR WALL LATERAL LOAD SYSTEMS





DUAL LATERAL LOAD SYSTEMS



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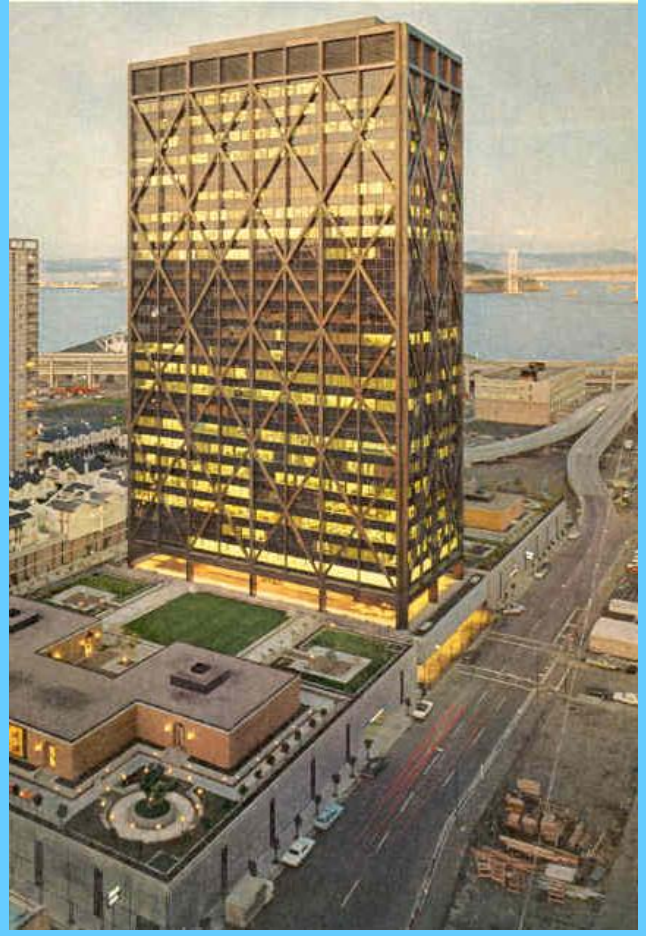


Alcoa Building (6 stories), San Francisco, 1967, SOM

@Seismicisolation

Proposal for the new World Trade Center in New York (2002), Rafael Vinoly

@Seismicisolation

Turmhaus am Kant-Dreieck mit Wetterfahne aus Blech, Berlin, Josef Paul Kleinhues, 1994

@Seismicisolation

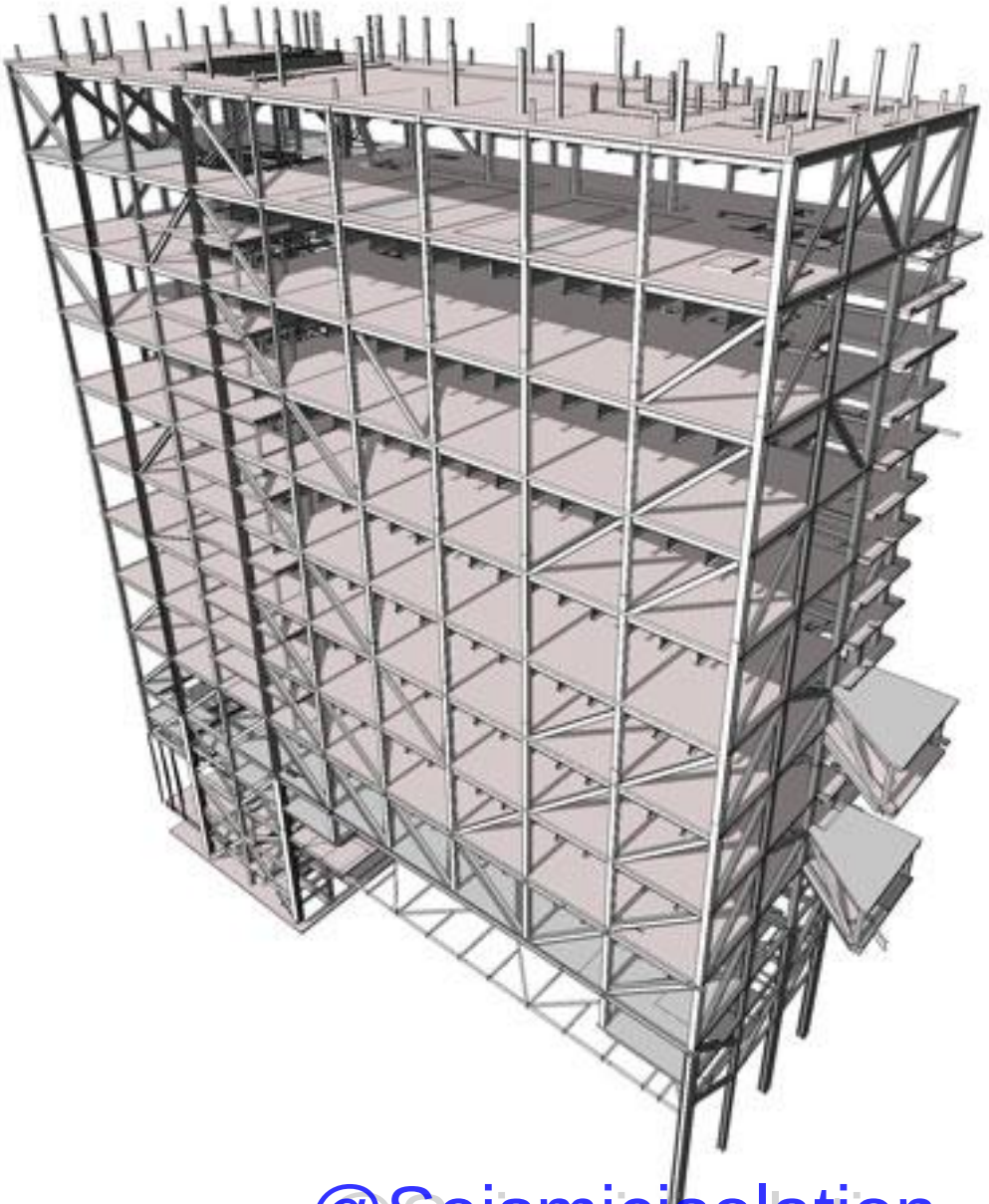
Chulalongkorn University, Bangkok, Thailand

@Seismicisolation

Interdisciplinary Building, Columbia University, New York, 2009, Rafael Moneo + Arup

@Seismicisolation

@Seismicisolation



@Seismicisolation

Fort School, *Mumbai, India*, 2005,
Chris Lee & Kapil Gupta

@Seismicisolation

Expansion Printing Office, Berlin, 1997, BHHS & Partner

@Seismicisolation

@Seismicisolation

House (World War 2 bunker),
Aachen, Germany

@Seismicisolation

Dormitory of Nanjing University,
Zhang Lei Arch., Nanjing University, Research Center of Architecture

@Seismicisolation

@Seismicisolation

Triangle building,
Friedrichstr/ Mauerstr.

Berlin, 1996, Josef Paul Kleihues

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The two large one-bay frames at each end of the building are designed to resist the lateral forces applied in the direction indicated.

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Sainsbury Centre for Visual Arts, Norwich, UK, 1978, Norman Foster

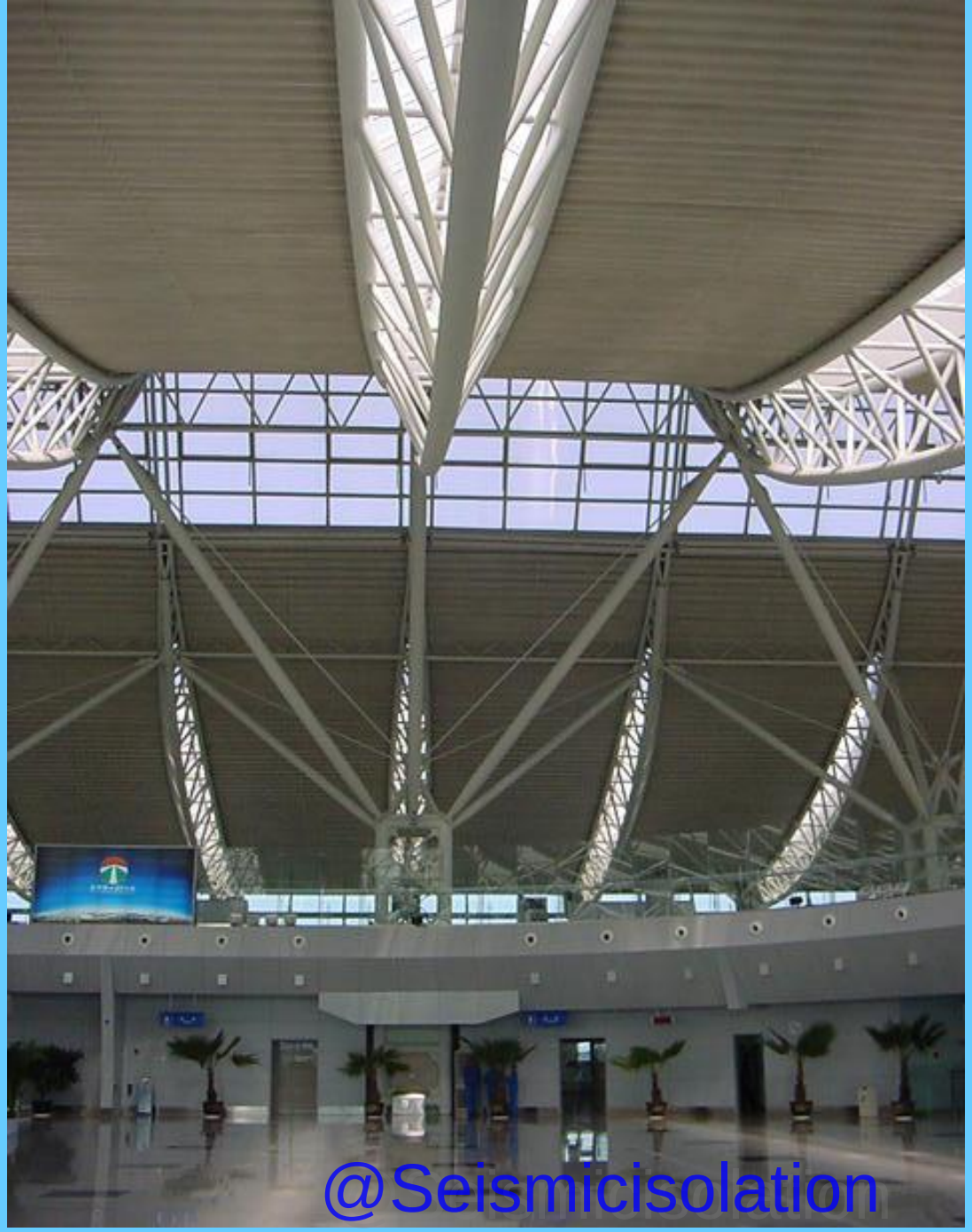
@Seismicisolation

The Reliance Control Electronic Plant, Swindon, UK, 1966, Team 4 (Foster/Rogers), Tony Hunt: first high-tech building

@Seismicisolation

Shenyang Taoxian International Airport, 2001,
Huilai Yao architect

@Seismicisolation

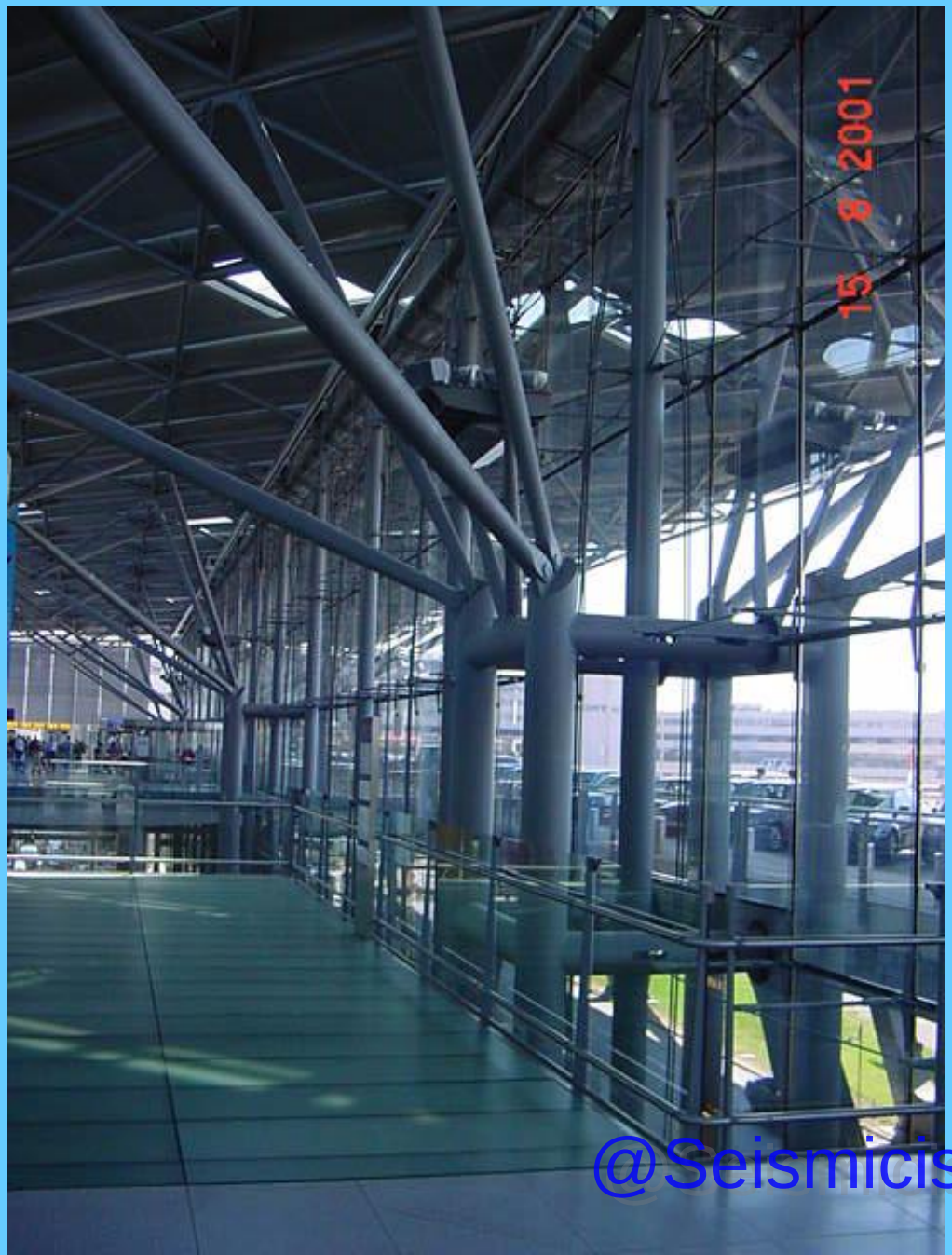


Shenyang Airport

@Seismicisolation

Ningbo Air terminal

@Seismicisolation



Cologne/Bonn Airport, Germany, 2000, Helmut Jahn Arch., Ove Arup USA Struct. Eng

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@Seismicisolation

Beijing Airport, Terminal 2,1999

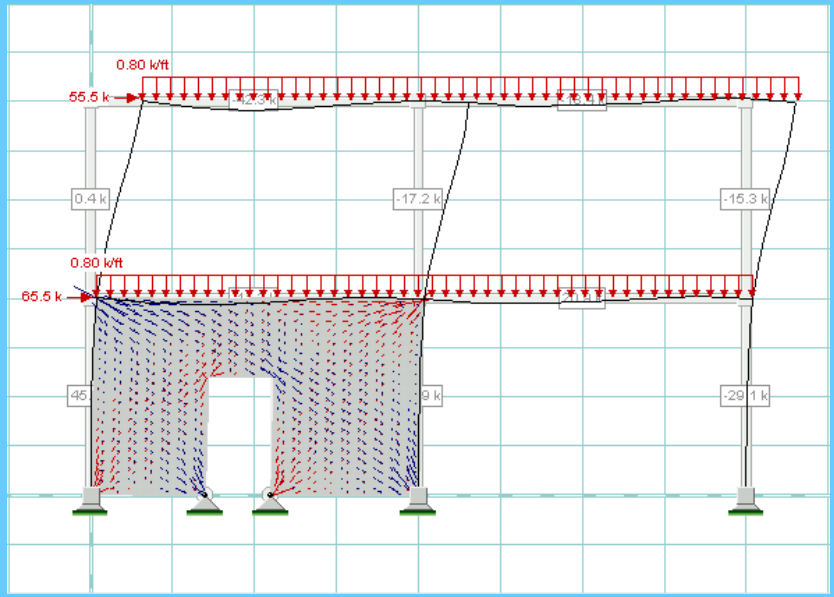
@Seismicisolation

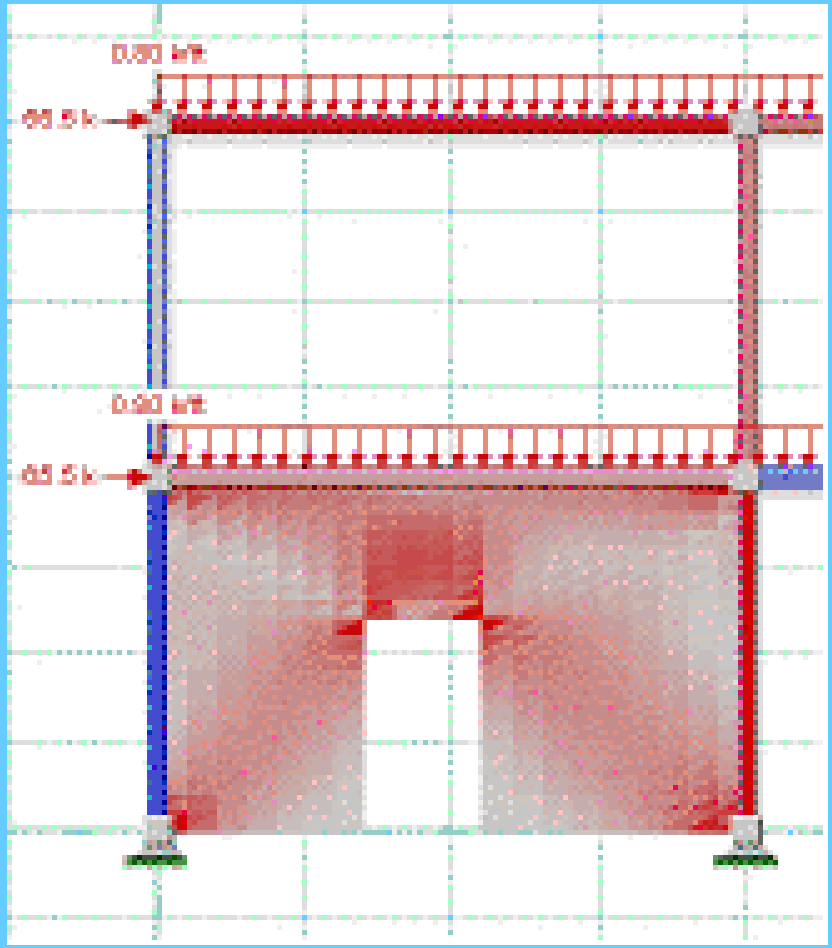
Alan House, Los Angeles, 2007, Neil Denari (NMDA)

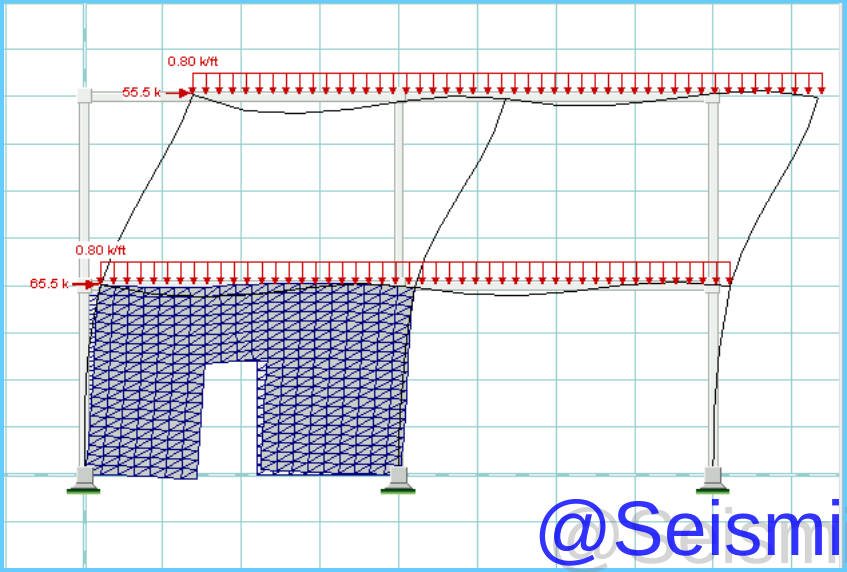
@Seismicisolation

@Seismicisolation

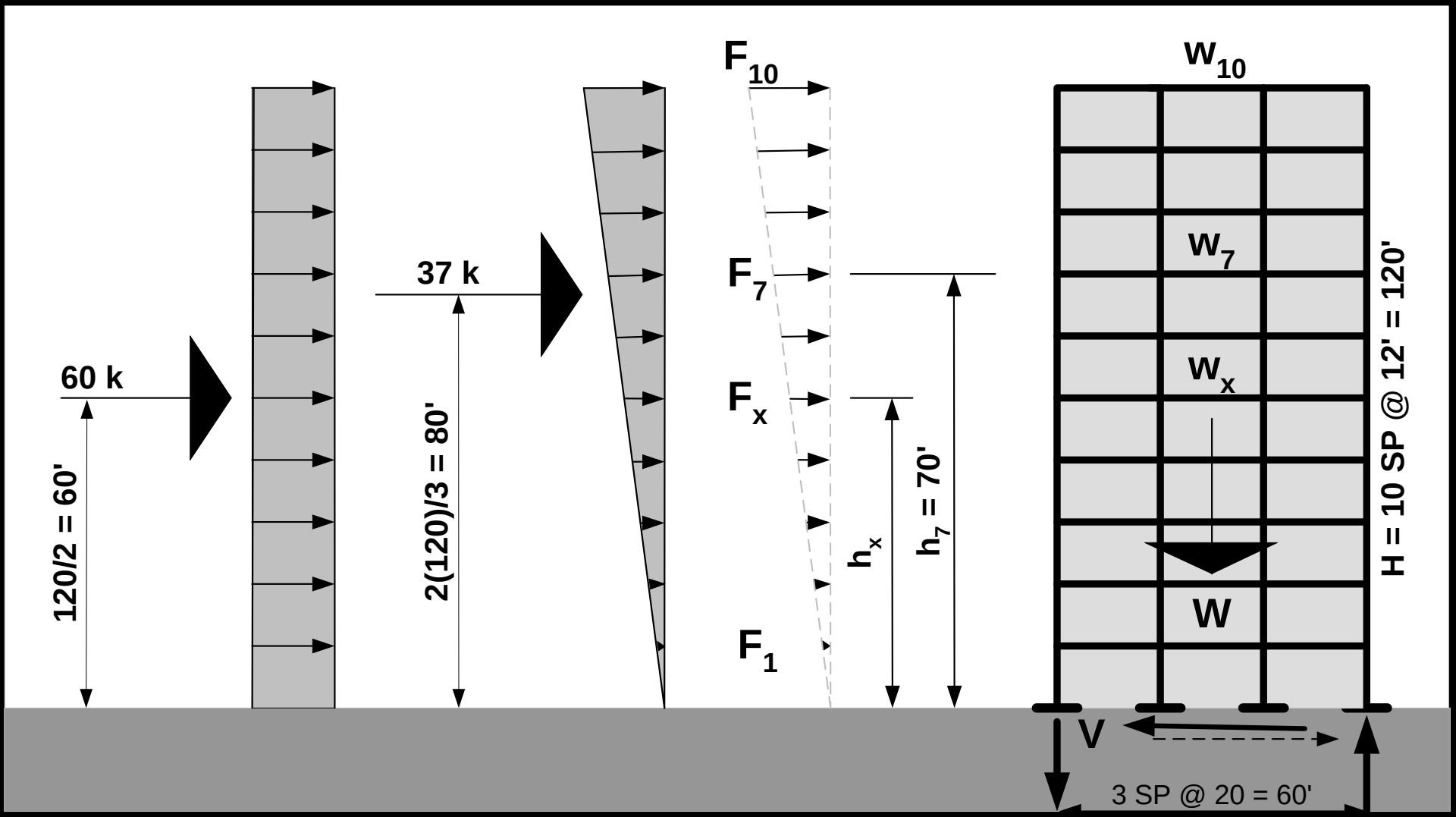
Market Bangkok, Thailand
@Seismicisolation





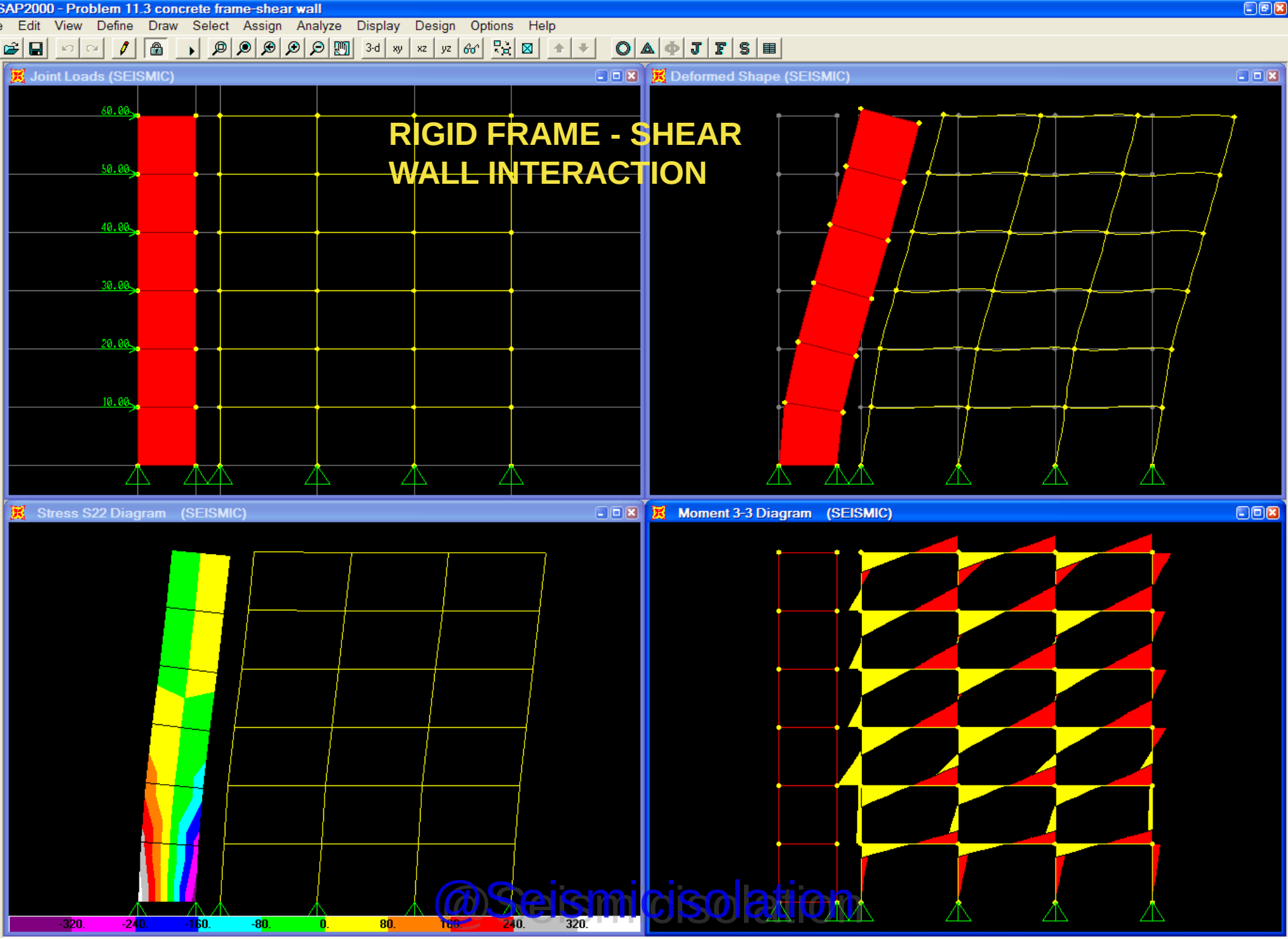


@Seismicisolation



Multi-Bay, Multi-Story Rigid Frame

@Seismicisolation


SAP2000 - Problem 11.3 concrete frame-shear wall
Edit View Define Draw Select Assign Analyze Display Design Options Help
Joint Loads (SEISMIC)
60.00
50.00
40.00
30.00
20.00
10.00
RIGID FRAME - SHEAR WALL INTERACTION
Deformed Shape (SEISMIC)
Stress S22 Diagram (SEISMIC)
-320. -240. -160. -80. 0. 80. 160. 240. 320.
Moment 3-3 Diagram (SEISMIC)
@Seismicisolation
Click on any Frame Element for detailed diagram
Kip-ft

SAP2000 - Problem 11.3 concrete frame-shear wall

Edit View Define Draw Select Assign Analyze Display Design Options Help

X-Z Plane @ Y=0

Axial Force Diagram (SELFWEI)

Stress S22 Diagram (SELFWEI)

Moment 3-3 Diagram (SELFWEI)

CONCRETE FRAME - SHEAR WALL INTERACTION

@Seismicisolation

Click on any Shell Element for detailed diagram

Kip-in

start SAP2000 - Proble... Microsoft PowerP... 8:43 PM

SAP2000 - Example concr.wall hinged steel steel frame

Edit View Define Draw Select Assign Analyze Display Design Options Help

Frame Span Loads (DL)

Joint Loads (EQ)

Deformed Shape (DL)

Deformed Shape (EQ)

HINGED STEEL FRAME
BRACED BY CONCRETE
SHEAR WALL

@Seismicisolation

Click on any joint for displacement values

Start Animation

Kip-ft

SAP2000 - Example concr.wall hinged steel steel frame

Edit View Define Draw Select Assign Analyze Display Design Options Help

X-Z Plane @ Y=0

Moment 3-3 Diagram (COMB1)

Restraint Reactions (COMB1)

Axial Force Diagram (COMB1)

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Click on any Joint for reaction values

Kip-ft

start Appendix C, SAP2... Ch.11doc, Floor a... Microsoft PowerP... SAP2000 - Examp... 10:18 AM

SAP2000 - Example concr.wall hinged steel steel frame

Edit View Define Draw Select Assign Analyze Display Design Options Help

Stress S22 Diagram (EQ)

-112. -84. -56. -28. 0. 28. 56. 84. 112.

Stress S12 Diagram (EQ)

-11.0 -5.5 0.0 5.5 11.0 16.5 22.0 27.5 33.0

Steel P-M Interaction Ratios (AISC-ASD89)

0.0 0.5 0.7 0.9 1.0

3-D View

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View

Kip-ft

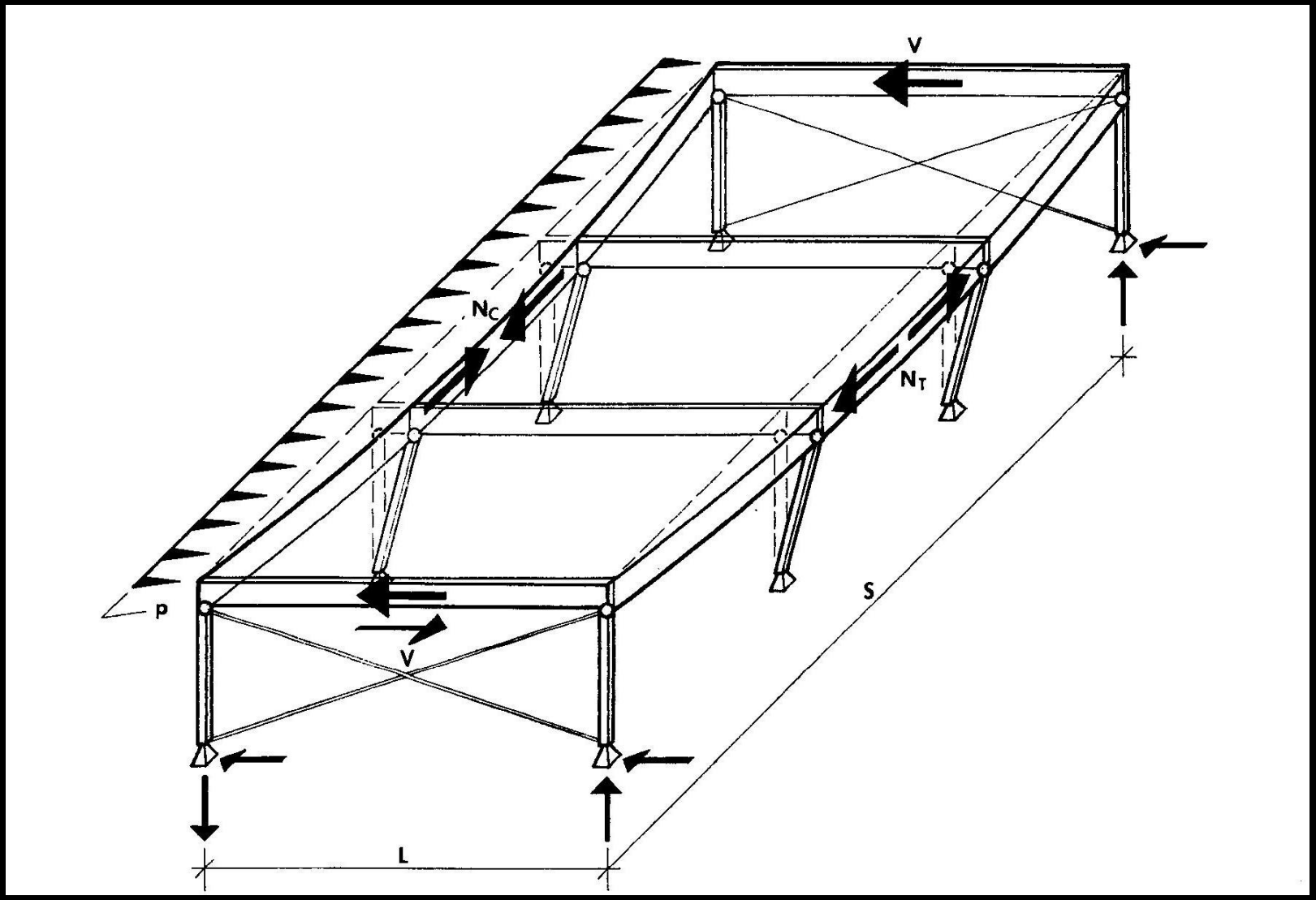
DIAPHRAGM ACTION OF TYPICAL HORIZONTAL BUILDING PLANES

The horizontal forces are transmitted along the floor and roof planes, which act as deep beams, called **diaphragms** that span between the **vertical lateral-force-resisting structures** as indicated in the next slide. As the lateral wind forces strike the building façade, curtain panels are assumed to act similar to one-way slabs spanning vertically between the floor spandrel beams, from where the lateral loads, in turn, are carried along the floor diaphragms and distributed to the lateral-force resisting structural systems.

The layout of the vertical lateral-force resisting systems can take many different forms, (see next slide) varying from symmetrical to asymmetrical arrangements, or range from a minimum of three planar structures to a maximum of a cellular wall subdivision as for bearing wall apartment buildings. The resisting system may be located within the building as a single spatial core unit or as separate planes.

In a **symmetrical building** with regular arrangement of vertical structures, where the line of action of the resultant of the applied loads passes through the **center of resistance**, the structure deflects equally in a purely **translational manner**. **Asymmetry** in buildings is caused by geometry (e.g. Fig. 11.1B), stiffness, and mass distribution; here, the applied **resultant load does not act through the center of resistance**. **The floor diaphragms not only translate, but also rotate in the direction of the lateral load action.**

@Seismicisolation



DIAPHRAGM ACTION OF ROOF

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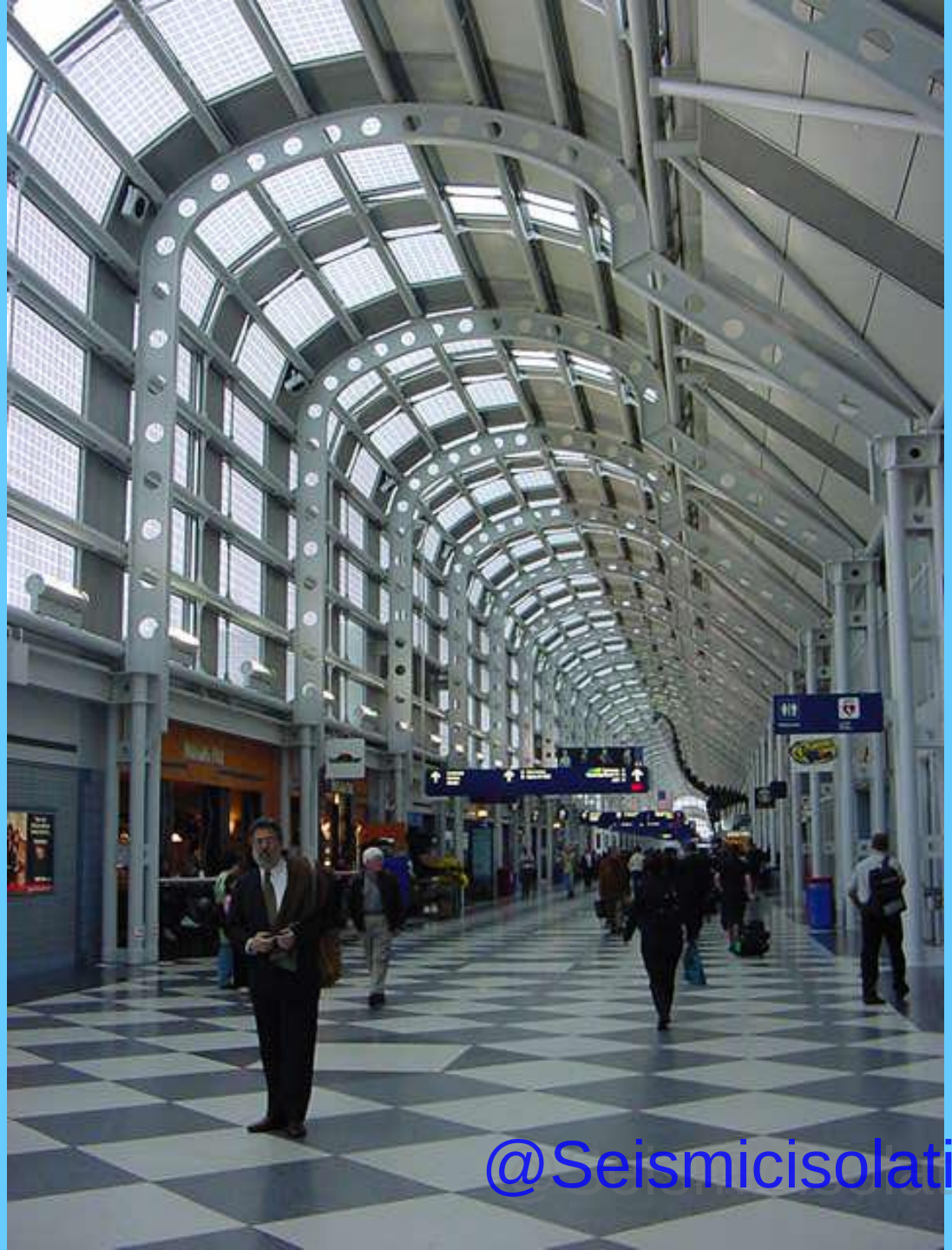

United Airlines Terminal at O'Hare Airport, Chicago, 1987, H. Jahn

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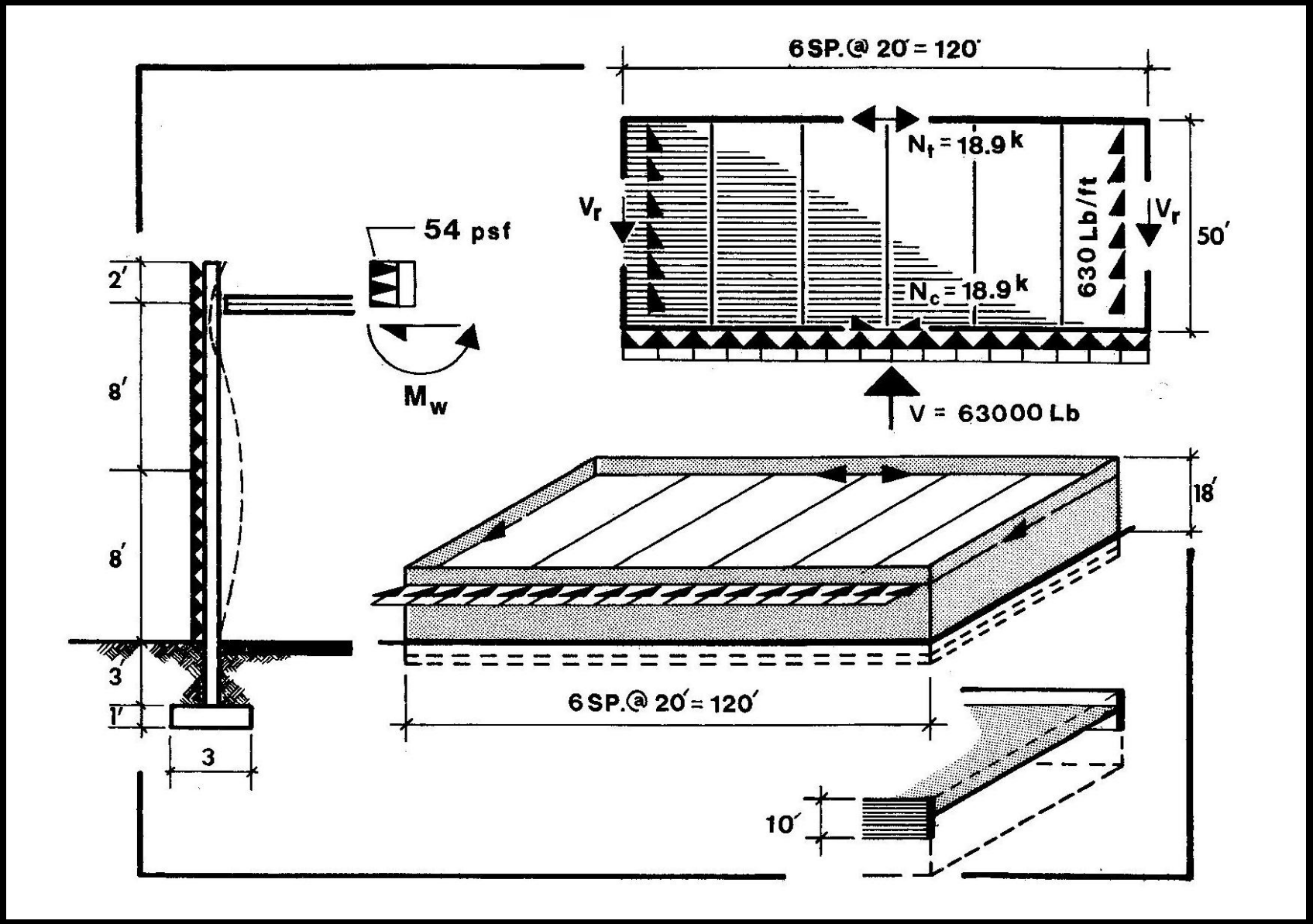
@Seismicisolation

@Seismicisolation

Atrium, Germanisches Museum, Nuremberg, Germany



EXAMPLE OF ROOF DIAPHRAGM ACTION

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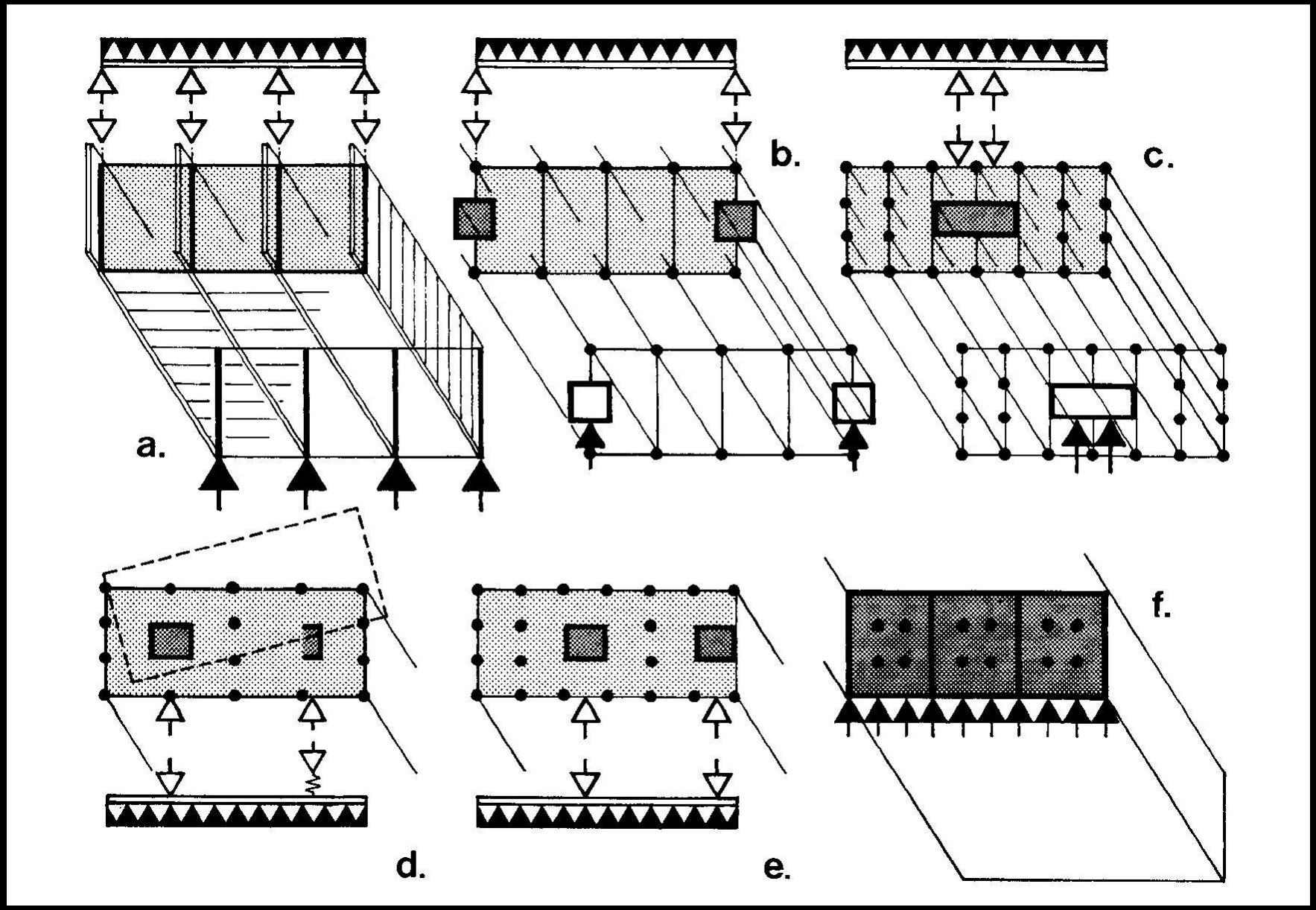

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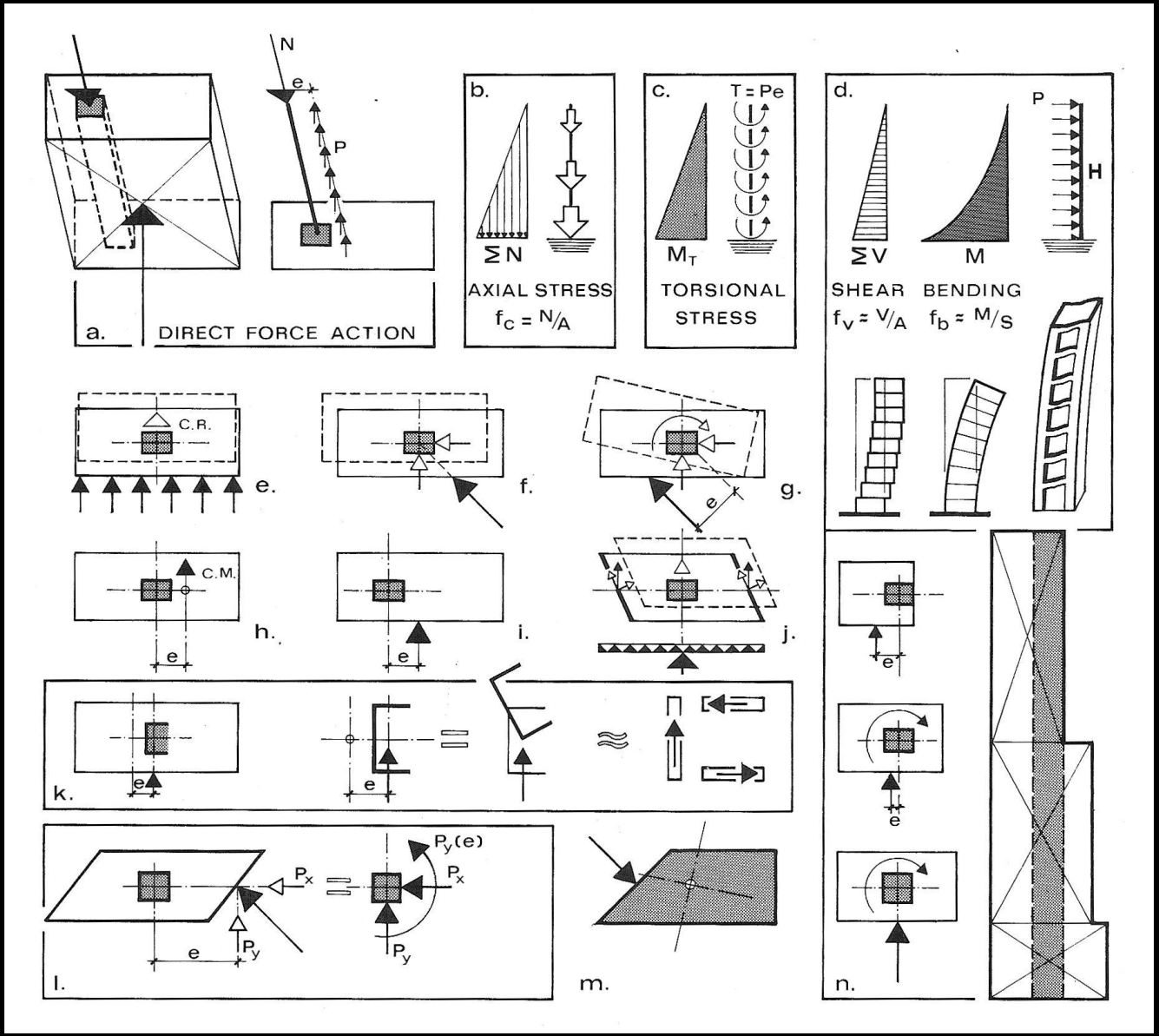
HORIZONTAL FORCE FLOW



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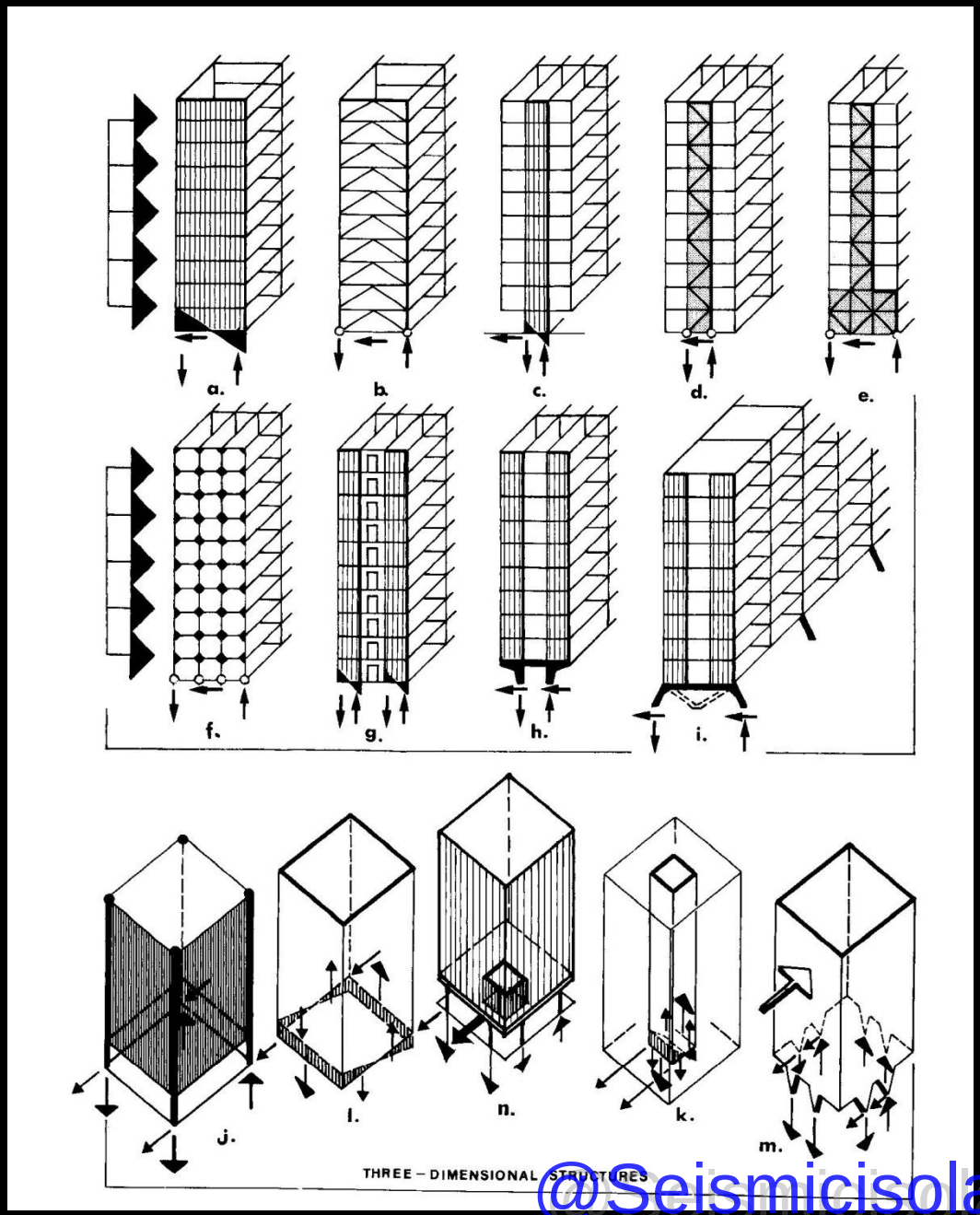
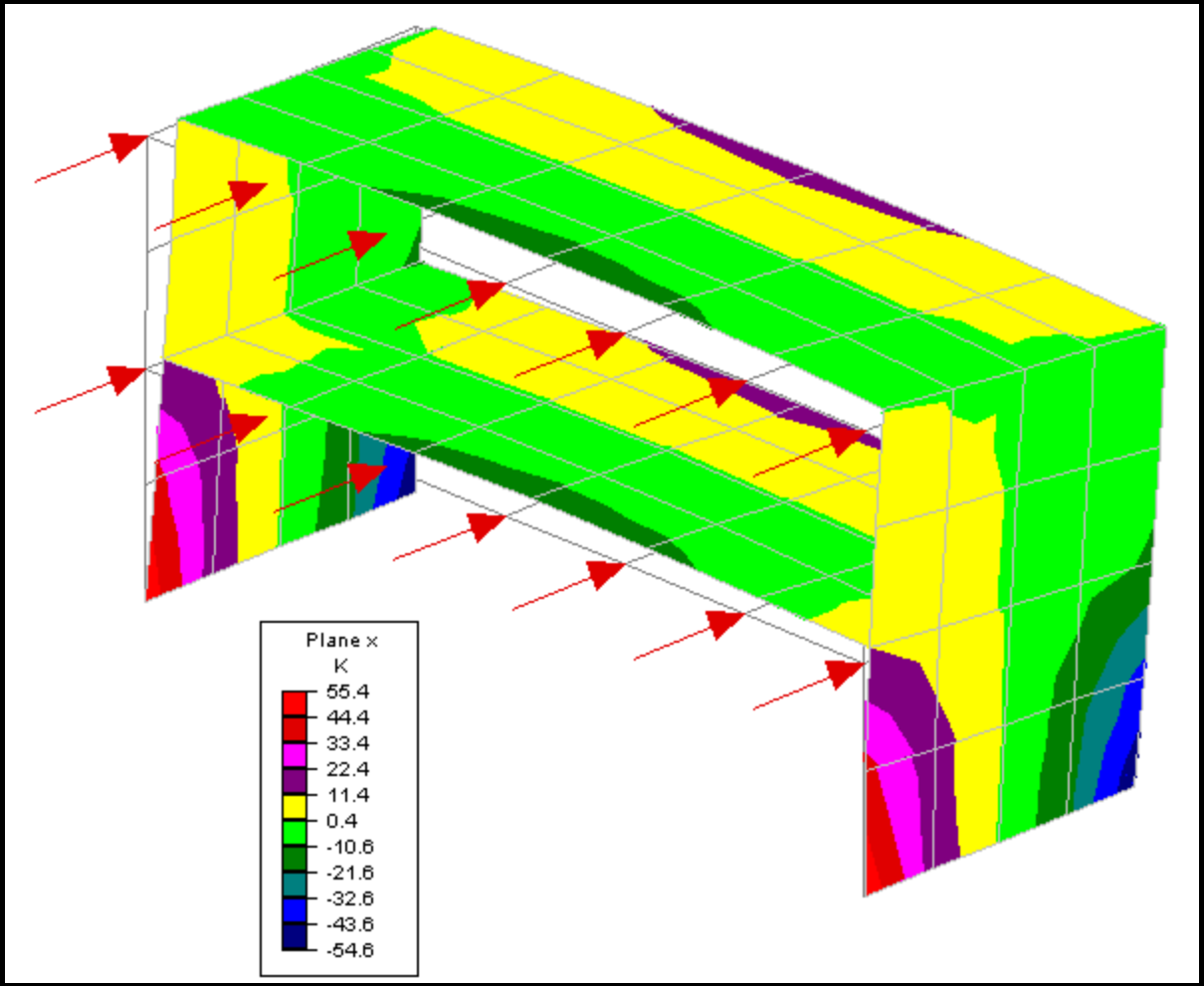
BUILDING RESPONSE TO LATERAL FORCE ACTION



Resistance of various structure systems to overturning

@Seismicisolation



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SAP2000 - Ex. 11.1a parallel walls with roof dia

Edit View Define Draw Select Assign Analyze Display Design Options Help

Joint Loads (WINDX)

Stress S22 Diagram (WINDX)

-5.60 -4.20 -2.80 -1.40 0.00 1.40 2.80 4.20 5.60

Deformed Shape (WINDX)

Deformed Shape (WINDX)

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View

lb-in

start Book Ch.11doc, Floor a... Adobe Photoshop Microsoft PowerP... SAP2000 - Ex. 11.... 11:03 AM

The lateral force distribution does not only depend on the location of the resisting structures in the building but also on their stiffness, as well as the stiffness of the diaphragms. For the purpose of preliminary investigation, **floor structures for buildings are treated generally as rigid diaphragms** with the exception of the following situations, where they may be treated as **flexible diaphragms** for preliminary design purposes**.**

- **Closely spaced shear walls** in relatively narrow buildings are stiffer in comparison to the floor diaphragms.
- For **low-rise buildings**, the floor or roof diaphragms are often more flexible than the supporting shear walls (e.g. light wood-framed construction).
- Floor diaphragms in long, narrow buildings with deep beam proportions of greater than say 3:1 that span large distances across the building.
- Floor diaphragms that are weakened by cutouts and openings, unless they are braced.
- **Wood and metal deck** (without concrete fill) roofs as well as prefabricated floor systems without cast-in-place topping are to be treated as flexible, unless the diaphragm is braced to allow truss action.

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- **RIGID DIAPRAGMS: rigid diaphragm action can be modeled by using,**

Rigid plane with constraints of floor joints

RIGID PLANES, that is **constraints** of floor joints, where a *diaphragm constraint* causes all of its constrained joints to move together as a planar diaphragm (i.e. **truly rigid membrane**) preventing in plane relative displacements of the nodes at each floor, that is all constrained joints are connected to each other by links that are rigid in the plane, but do not affect out-of-plane (plate) bending. All floor beams are absorbed into the stiffness of the rigid plane.
Use the following procedure in **SAP**: Use the following procedure in **ETABS**: select, for instance, all columns in plan view, then from the *Assign* menu choose *Joint* and then click on *Rigid Diaphragm,* then change diaphragm name *D1* if you want to, then click *OK*

Rigid floor membranes

RIGID MEMBRANE can be approximated for typical concrete floor slabs and concrete-topped steel deck where the diaphragm is significantly stiffer than the vertical lateral-force resisting structure such as for frame construction.
.
DIAGONAL BRACING of floor framing provides a large stiffness in plane of the diaphragm.

- **FLEXIBLE DIAPHRAGM MEMBRANES**

In a wall building with parallel floor diaphragms, the concrete floor diaphragms behave as deformable membranes and not as rigid floors. This action is best demonstrated in *Fig. 11.7* using a single story bearing wall building with parallel walls and a concrete roof structure; notice how the ***flexible diaphragm*** *action of the roof is expressed by the deformed structure.*
Flexible diaphragm action also applies to plywood diaphragms, where the diaphragm is very flexible relative to the supporting vertical structure

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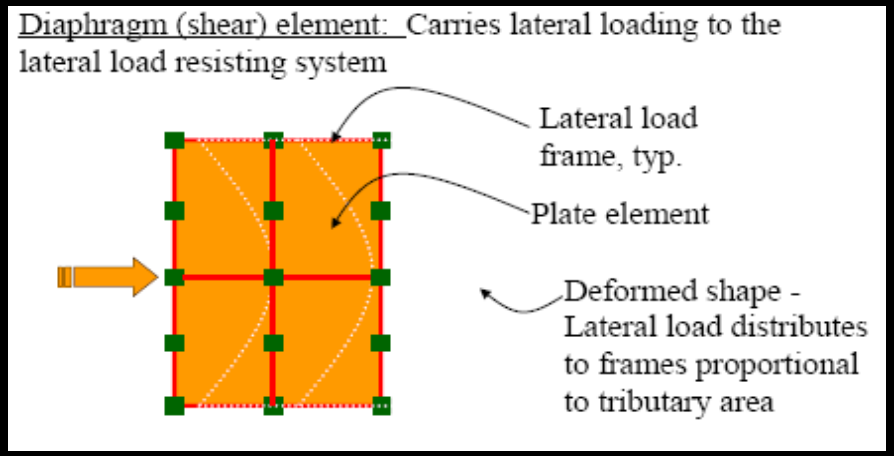
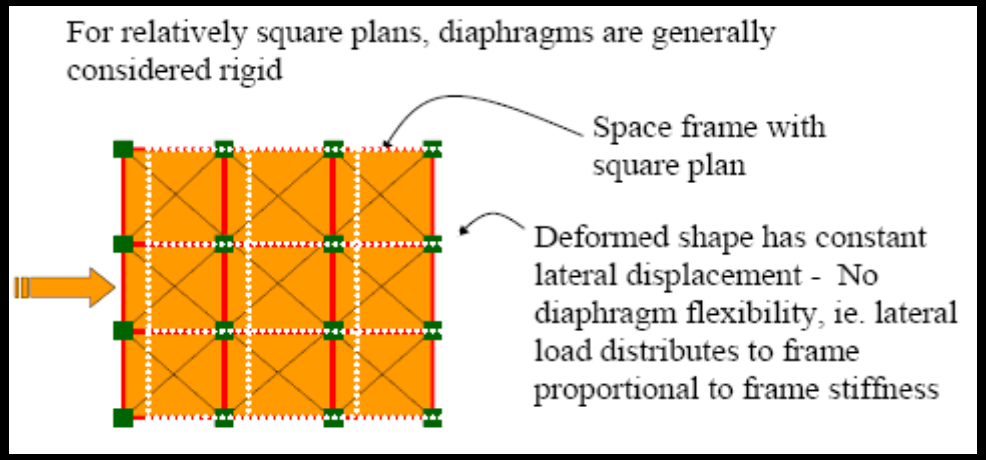
FRAME LATERAL LOAD SYSTEMS





Floor Diaphragm Flexibility

- Can be a concern with exterior braced frames or shear wall systems that have a rectangular floor plan
- Special design considerations must be followed
- According to IBC 2000, lateral forces get distributed to the lateral force resisting system
  - Proportional to the frame stiffness for rigid diaphragms
  - Proportional to the tributary mass that each frame carries for flexible diaphragms

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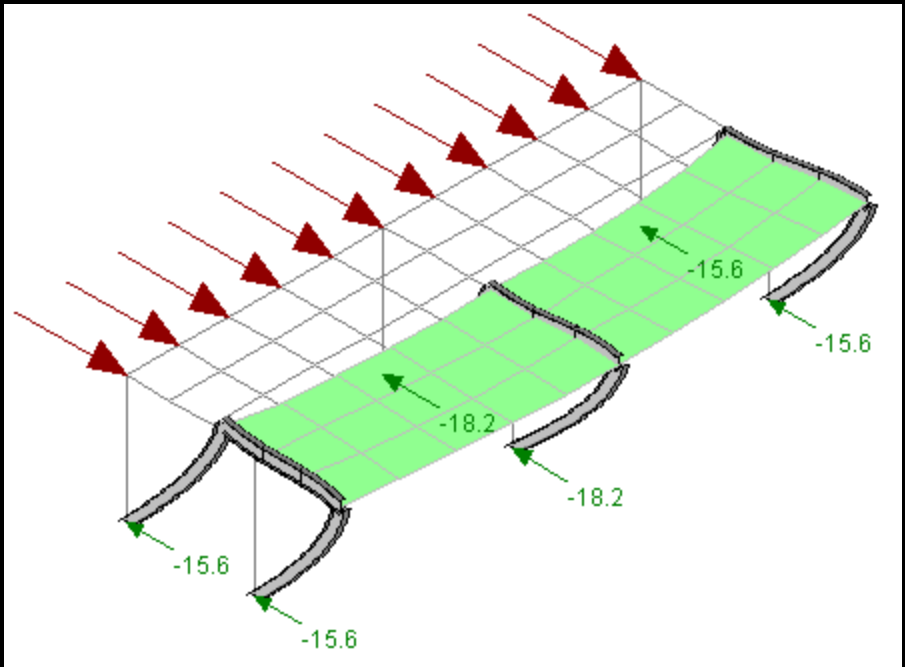

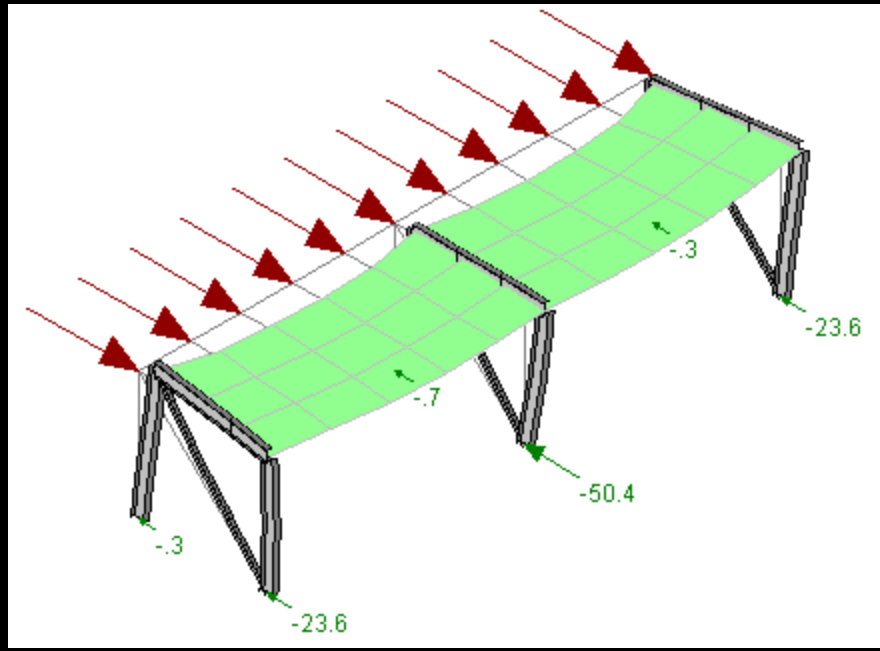

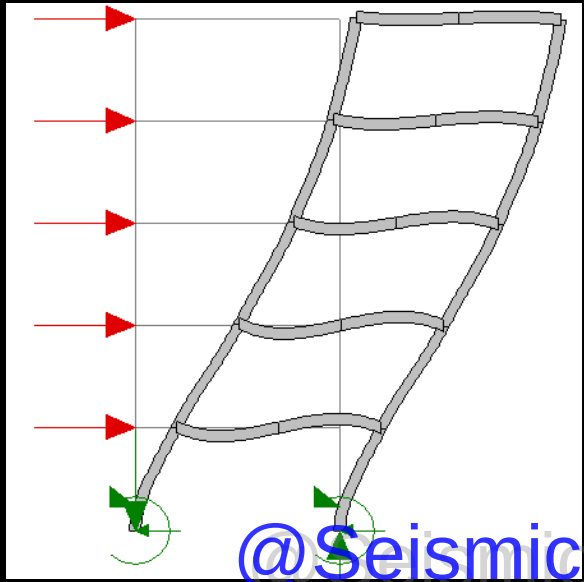

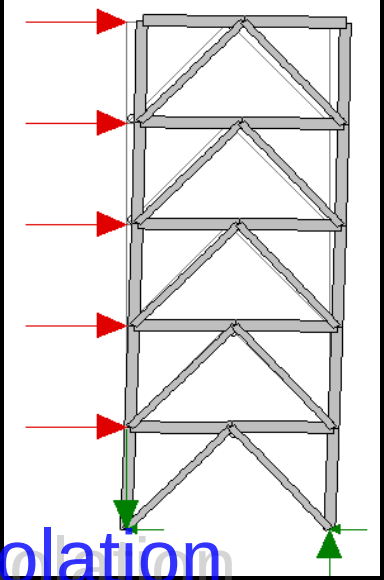

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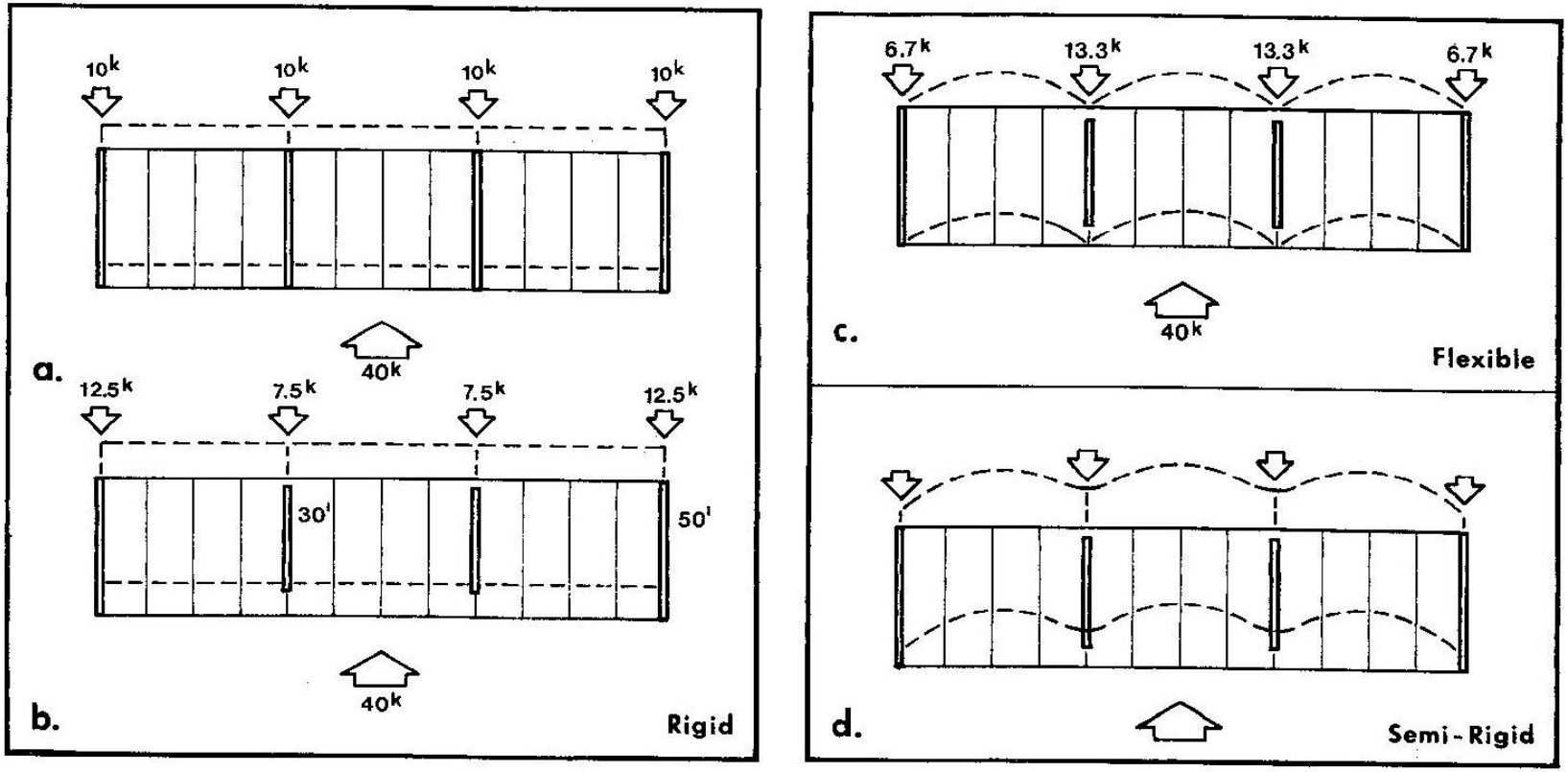

rigid vs. flexible diaphragm action vs. indeterminate force distribution

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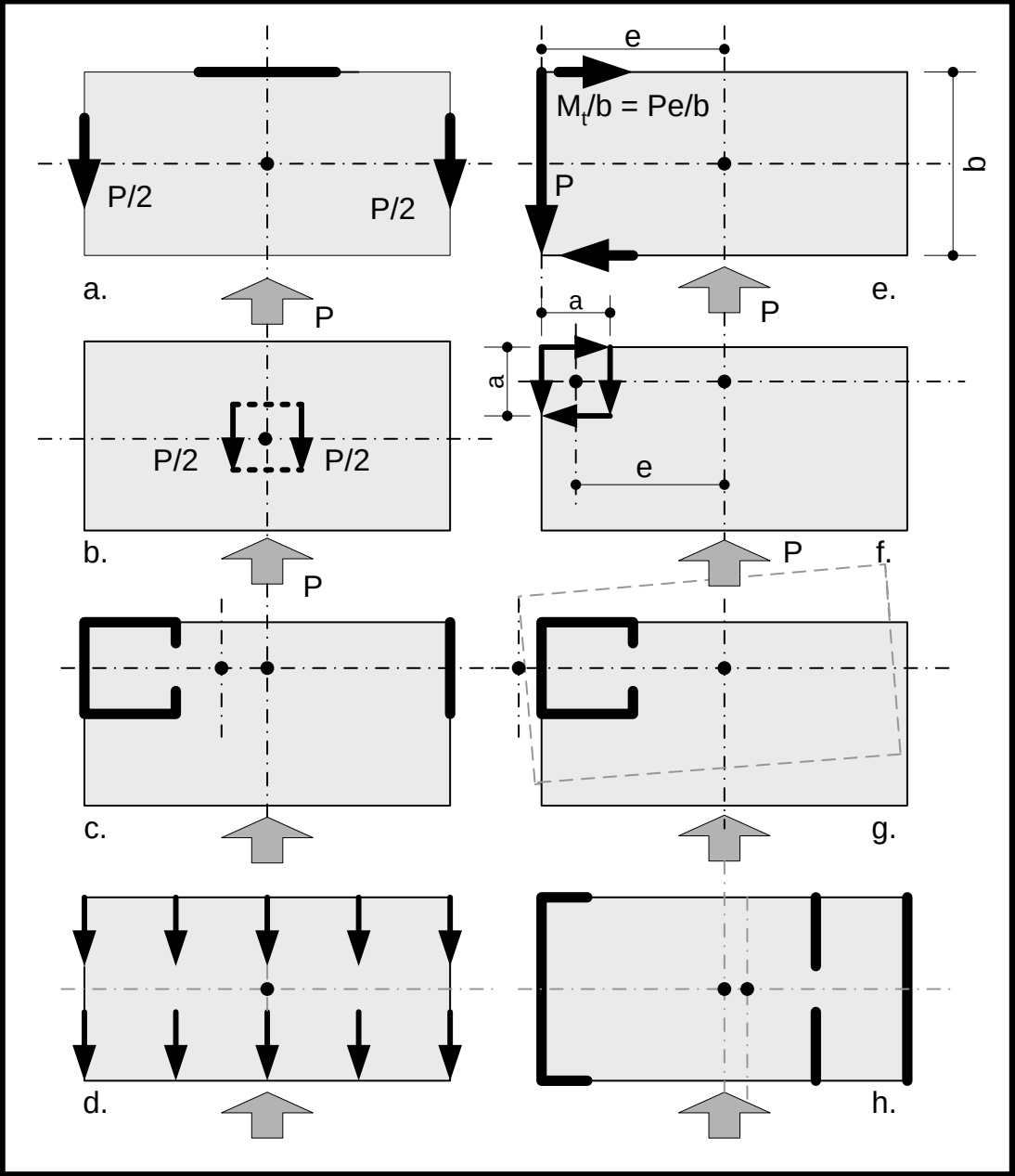

ARRANGEMENT OF LATERAL FORCE RESISTING STRUCTURES

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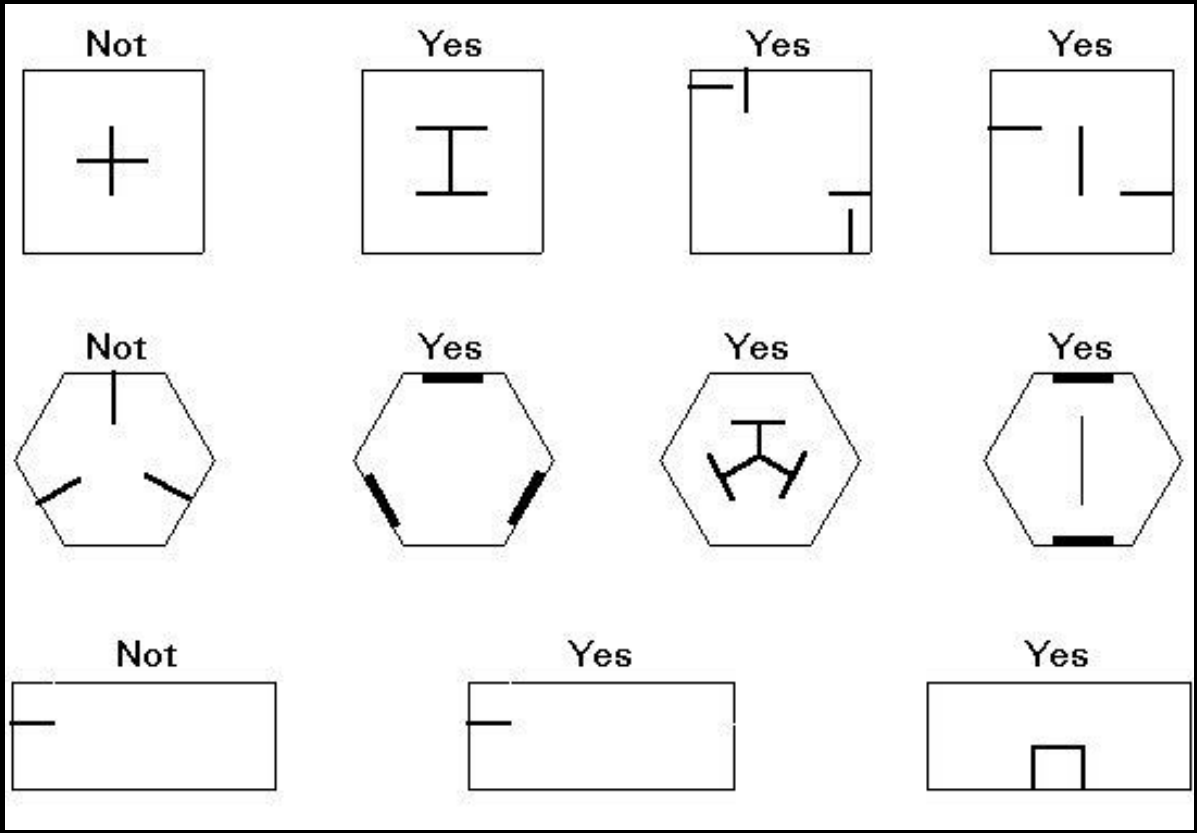
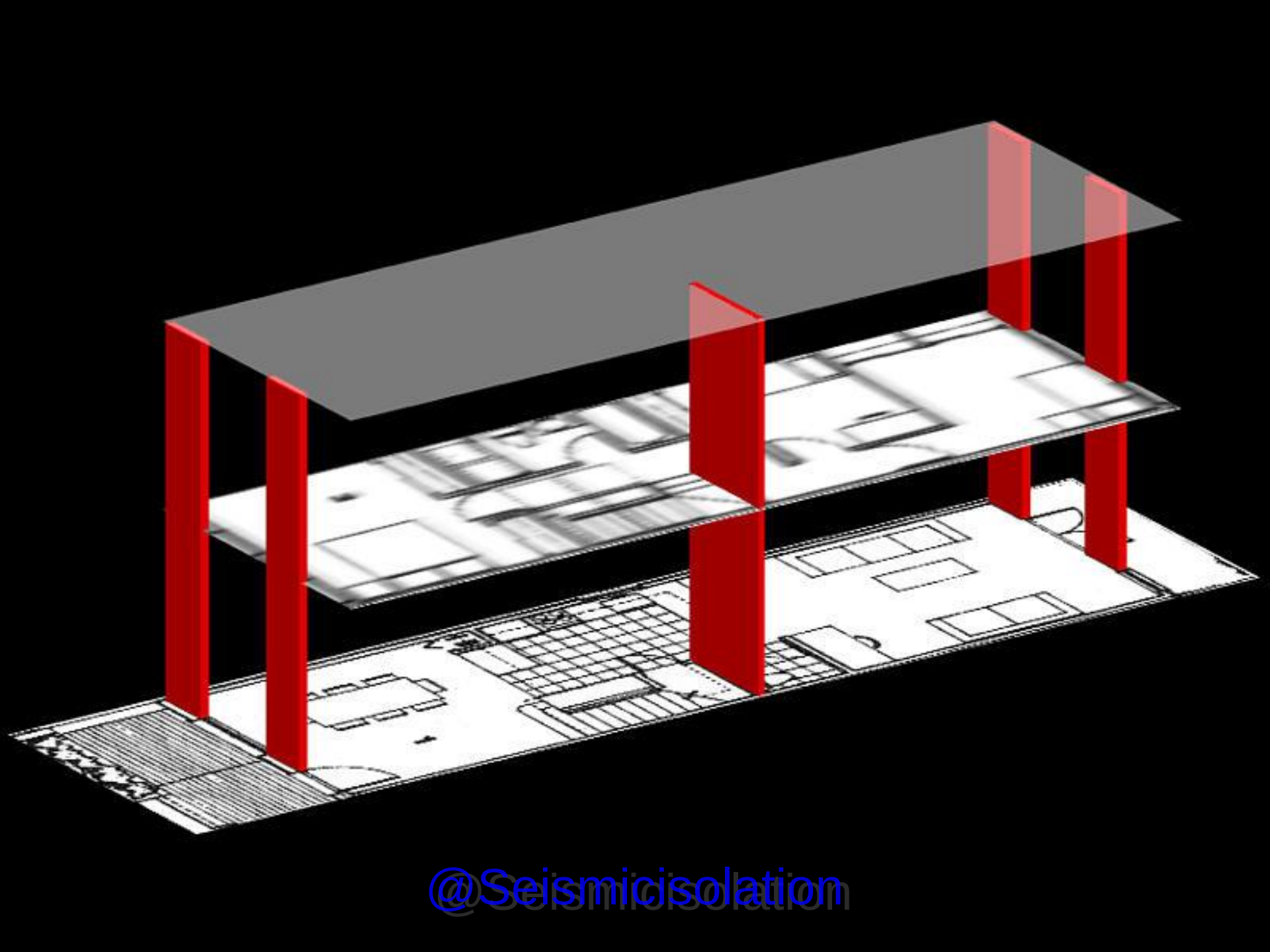


Different locations of bracing systems

@Seismicisolation



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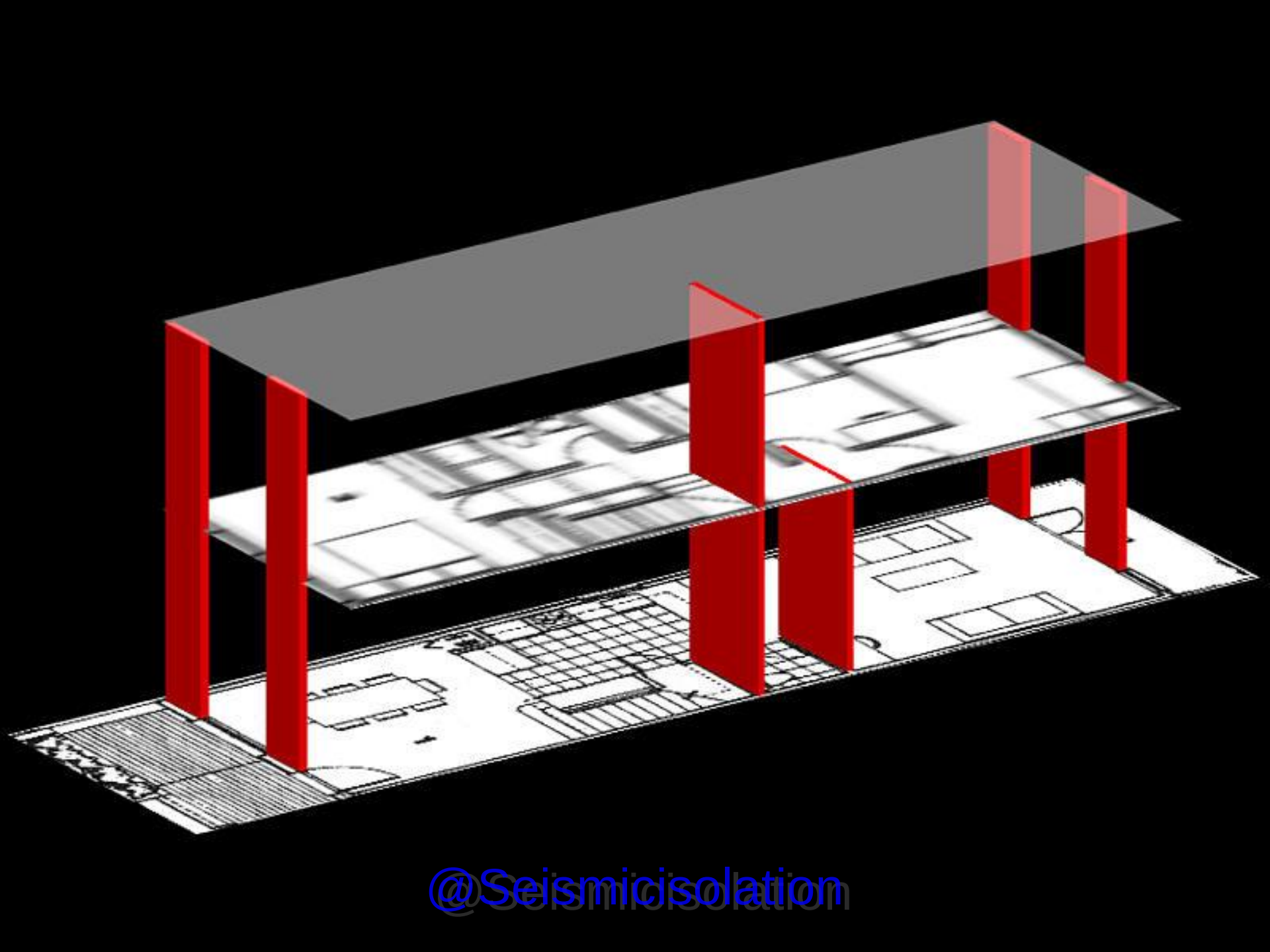

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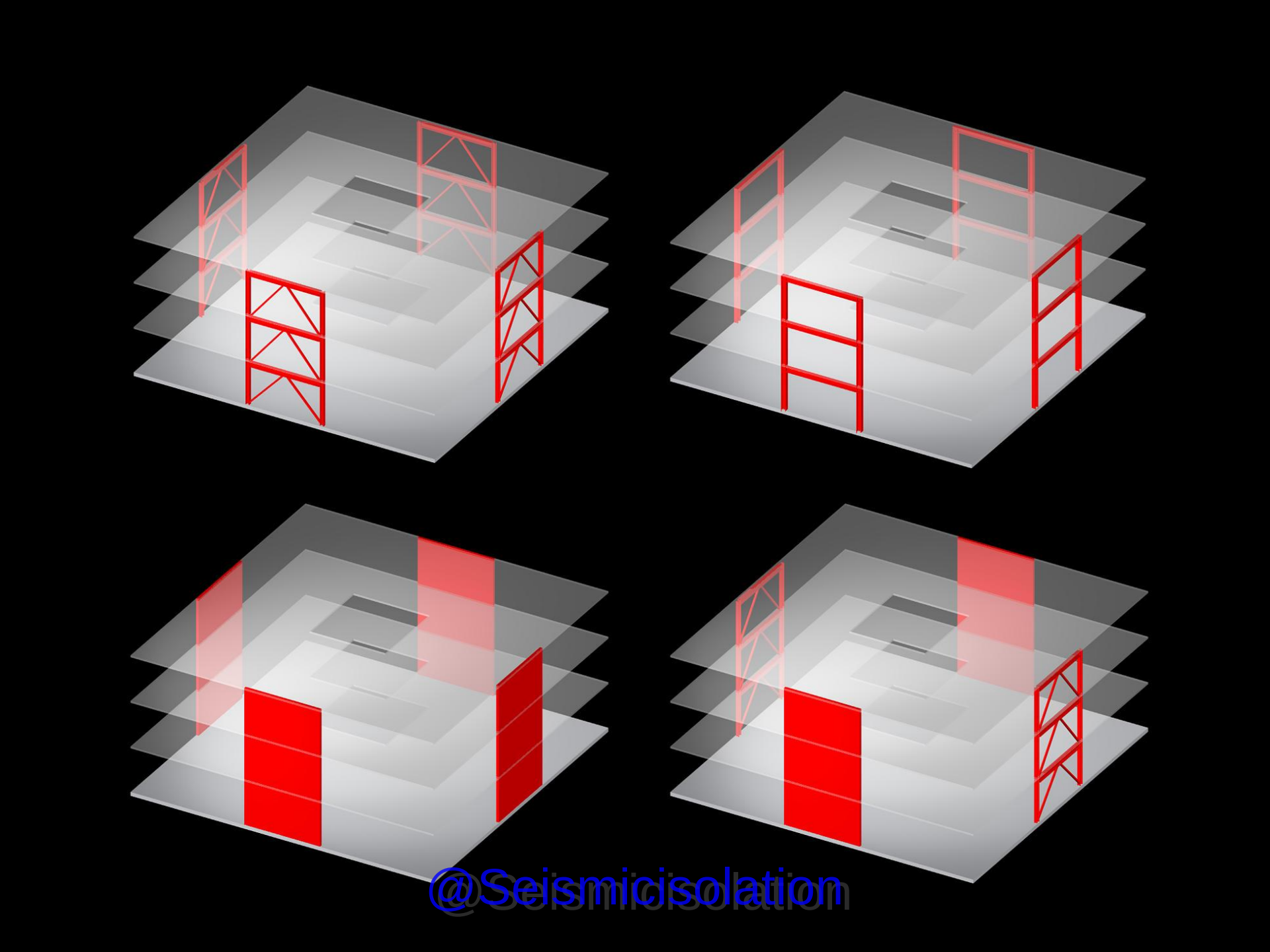
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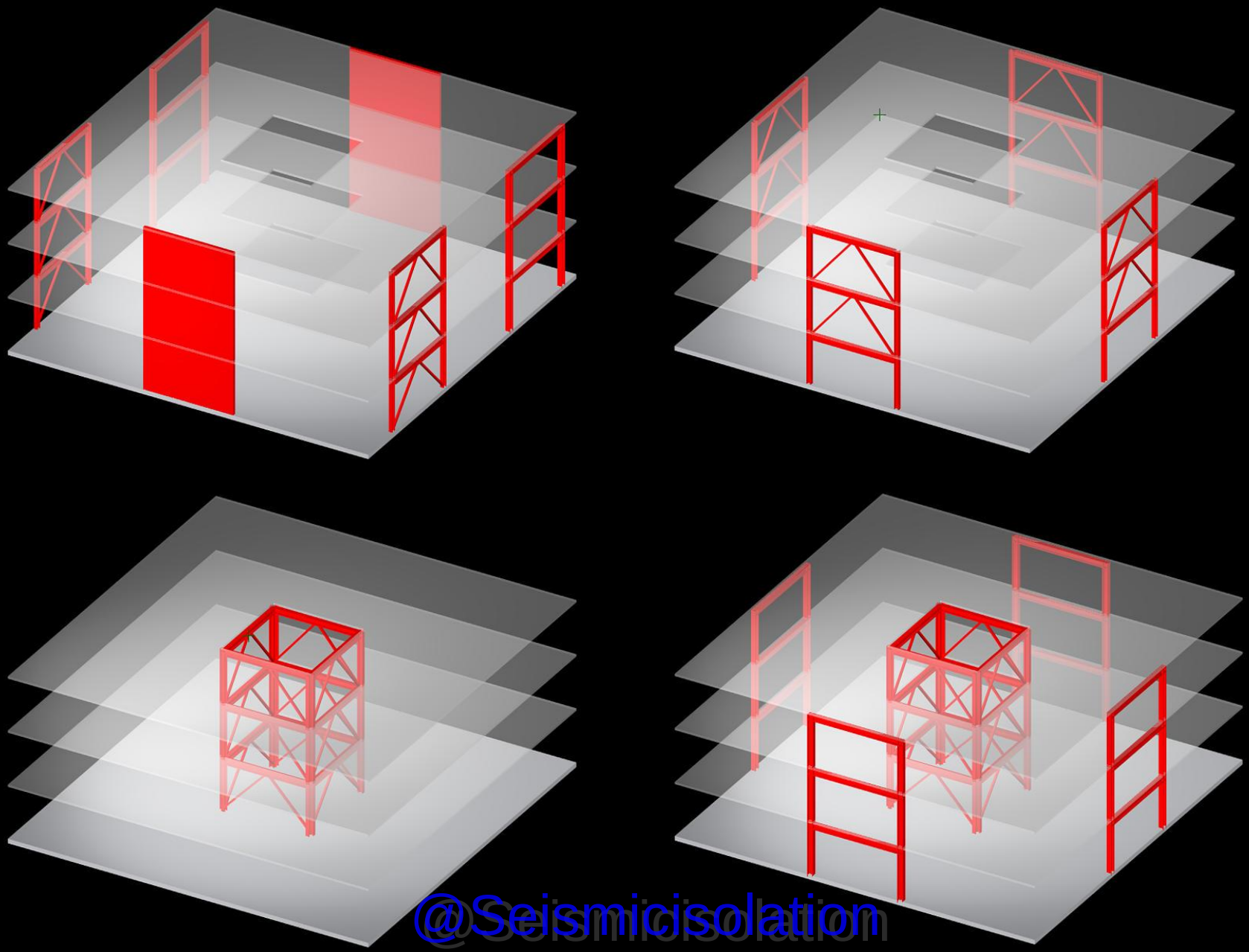

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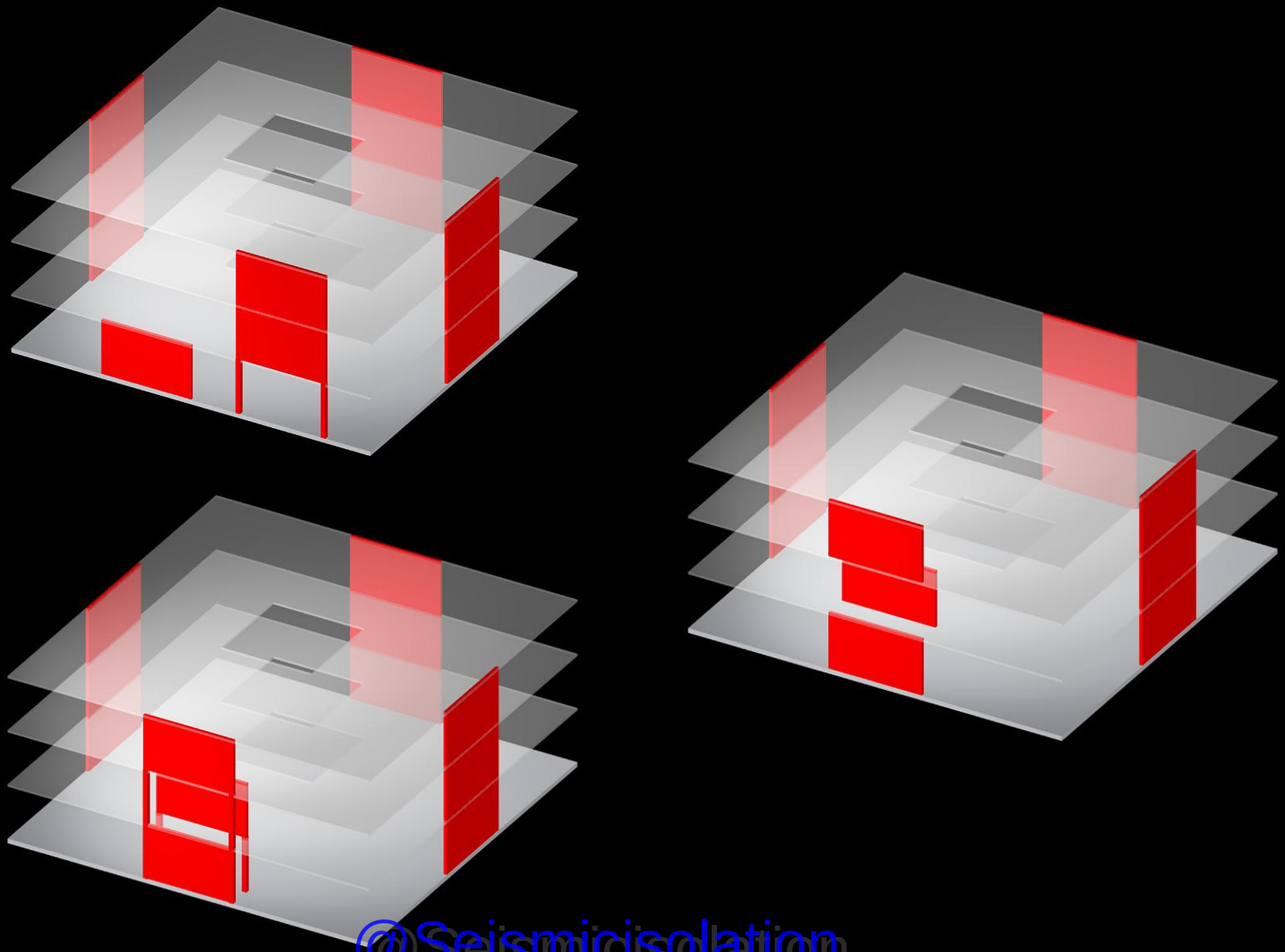

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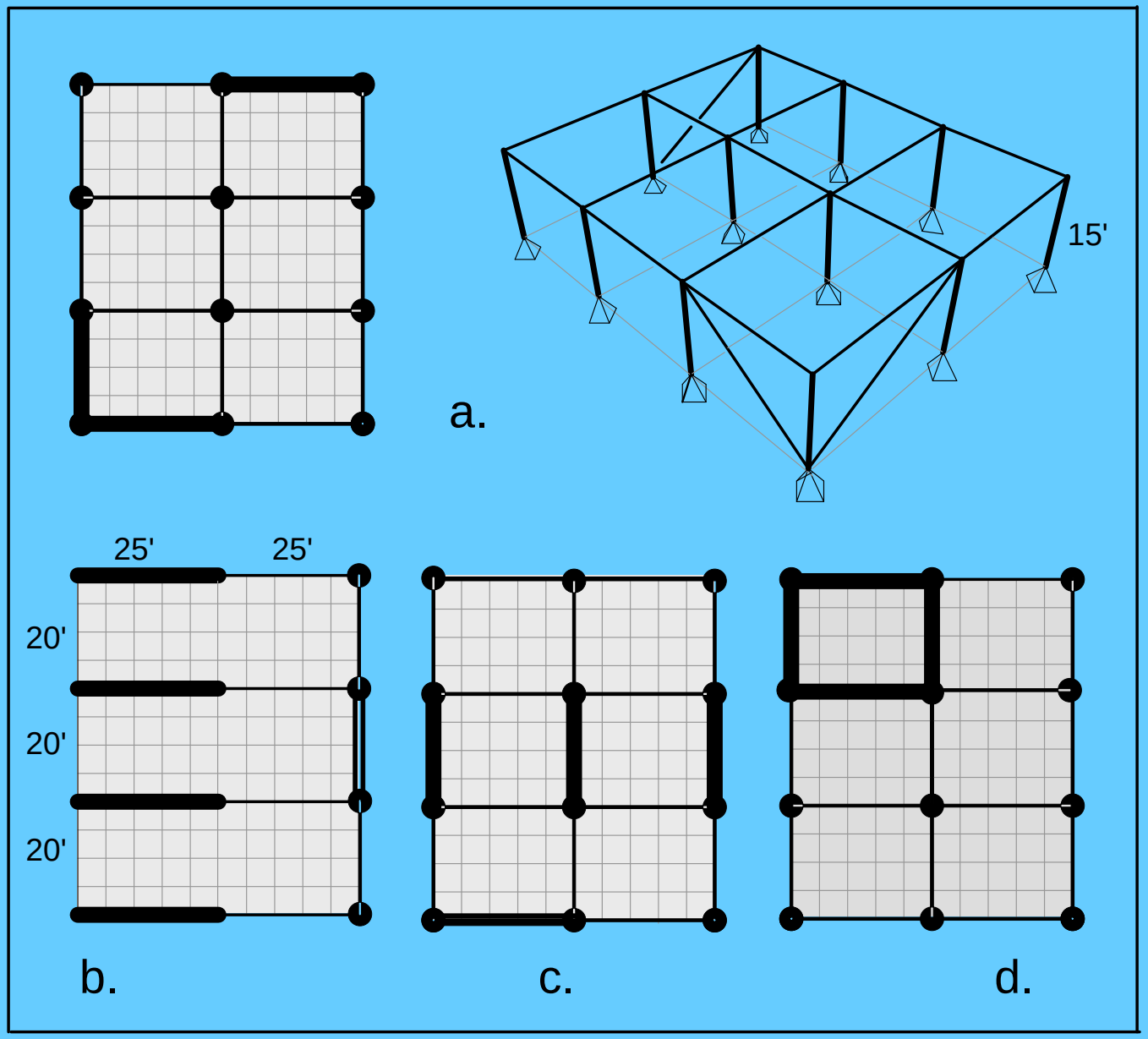

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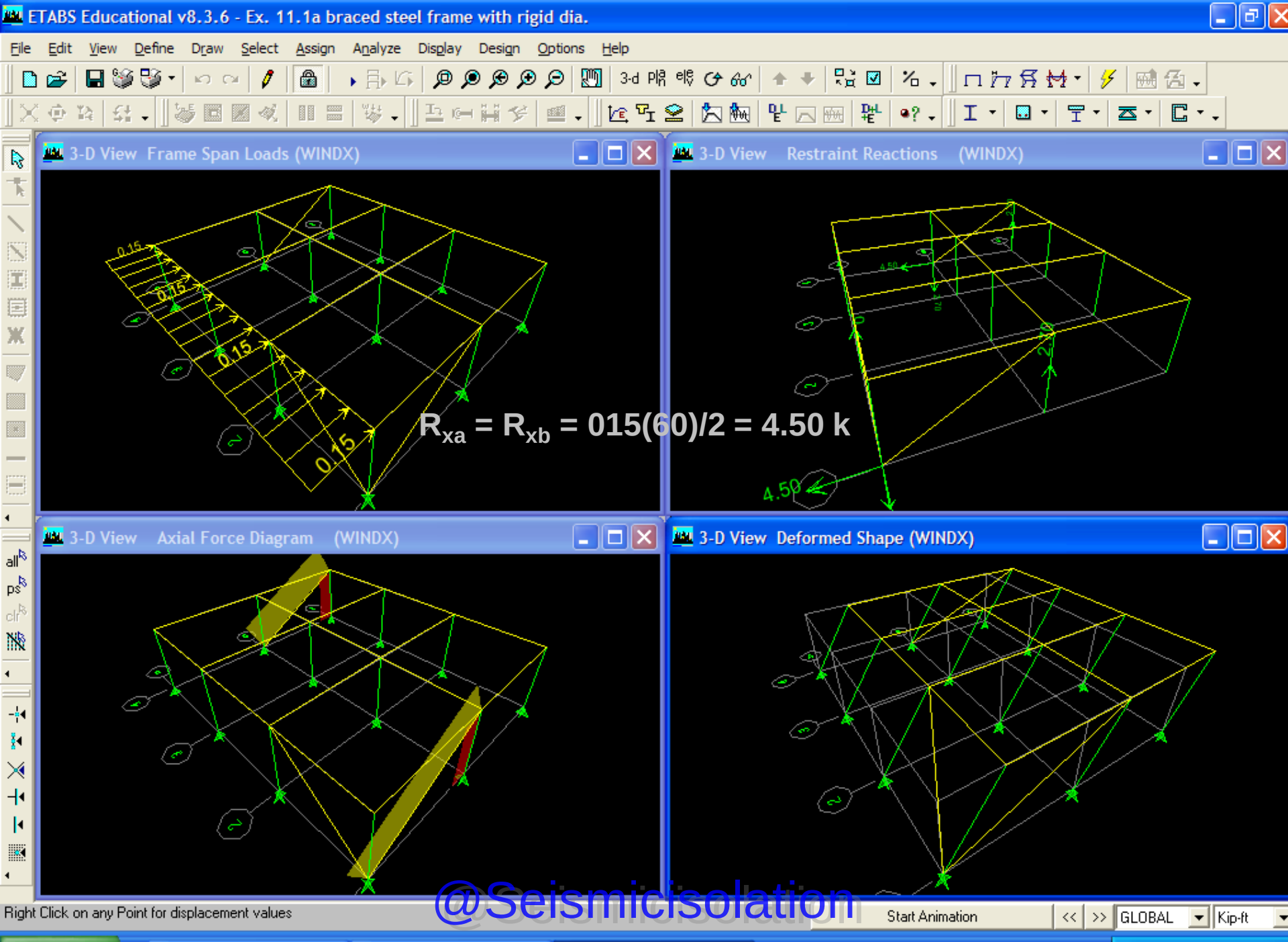

ETABS Educational v8.3.6 - Ex. 11.1a braced steel frame with rigid dia.
File Edit View Define Draw Select Assign Analyze Display Design Options Help
3-D View Frame Span Loads (WINDX)
0.15
0.15
0.15
0.15
$R_{xa} = R_{xb} = 015(60)/2 = 4.50$ k
3-D View Restraint Reactions (WINDX)
4.50
4.50
3-D View Axial Force Diagram (WINDX)
3-D View Deformed Shape (WINDX)
Right Click on any Point for displacement values
Start Animation
GLOBAL
Kip-ft
@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.1 braced stee frame with wind load

File Edit View Define Draw Select Assign Analyze Display Design Options Help

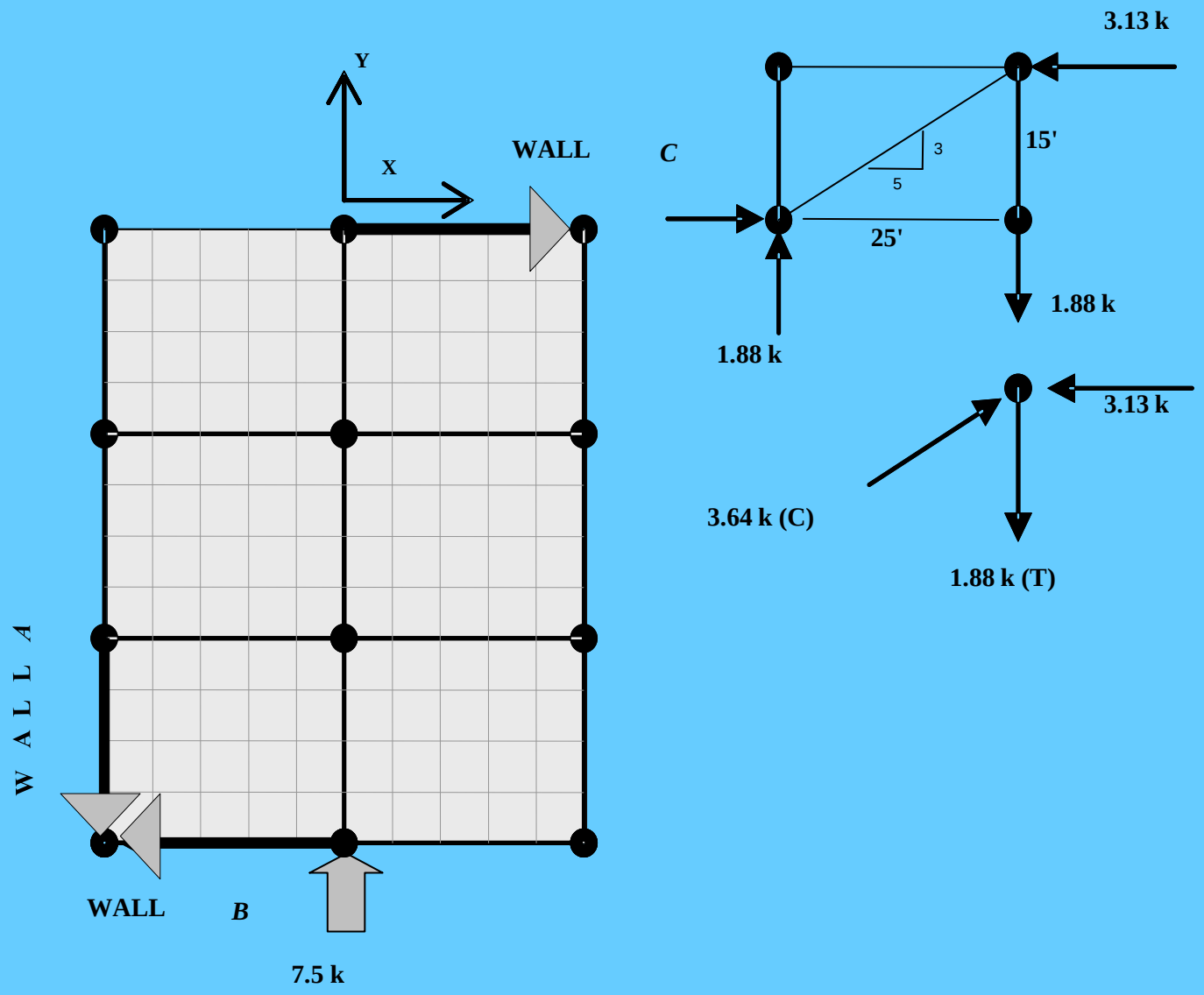
3-D View Moment 2-2 Diagram (WINDX)

3-D View Axial Force Diagram (WINDX)

Right Click on any Line for detailed diagram

GLOBAL Kip-ft

@Seismicisolation



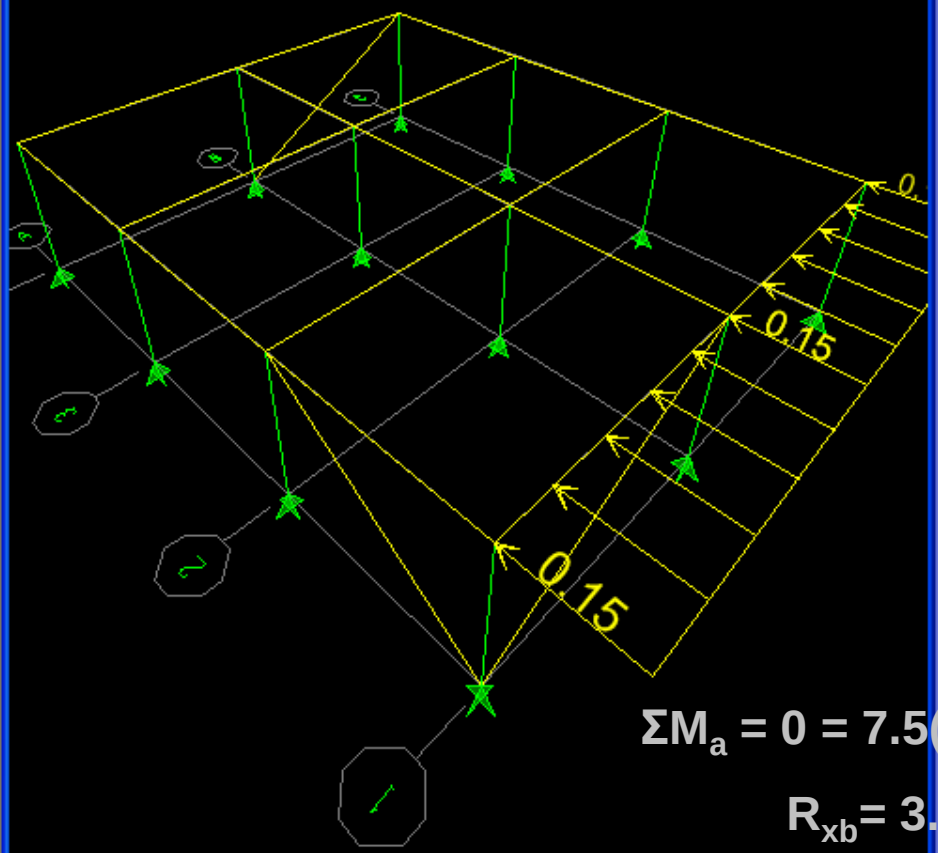
@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.1 braced stee frame with wind load

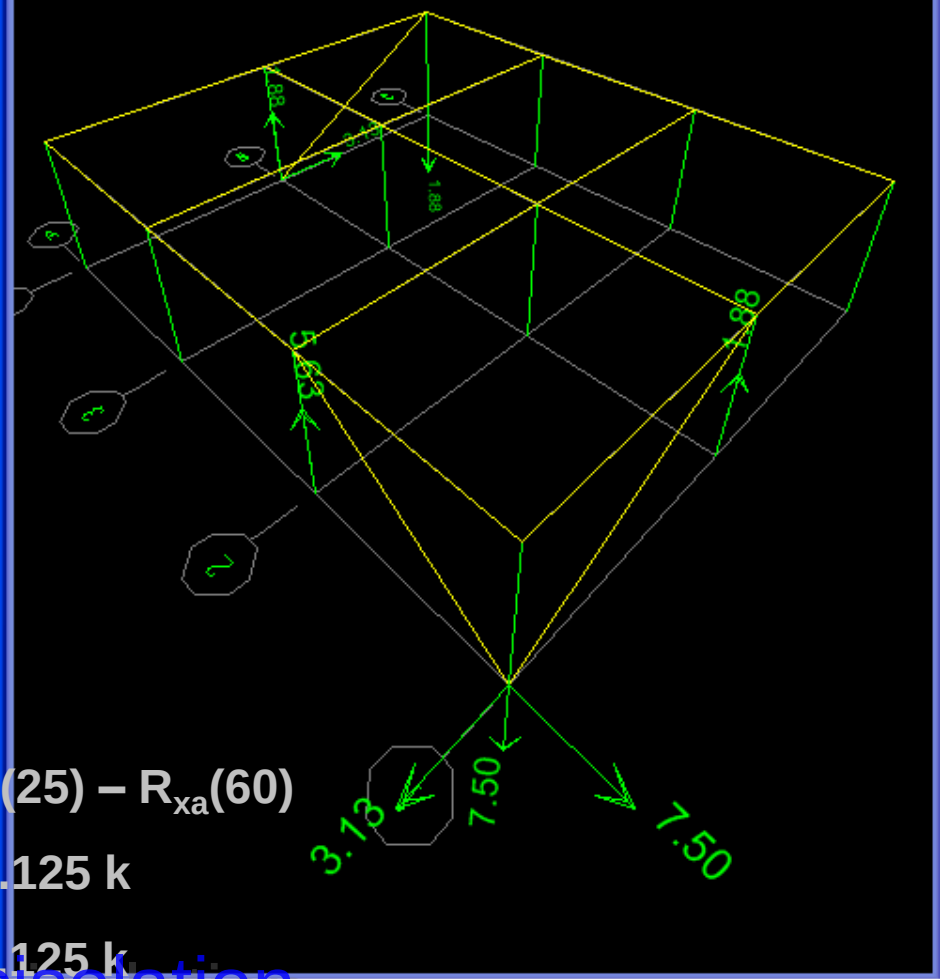
File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Frame Span Loads (WINDY)

$R_{ya} = 0.15(50) = 7.50$ k



3-D View Restraint Reactions (WINDY)



$\Sigma M_a = 0 = 7.5(25) - R_{xa}(60)$

$R_{xb} = 3.125$ k

$R_{xa} = 3.125$ k

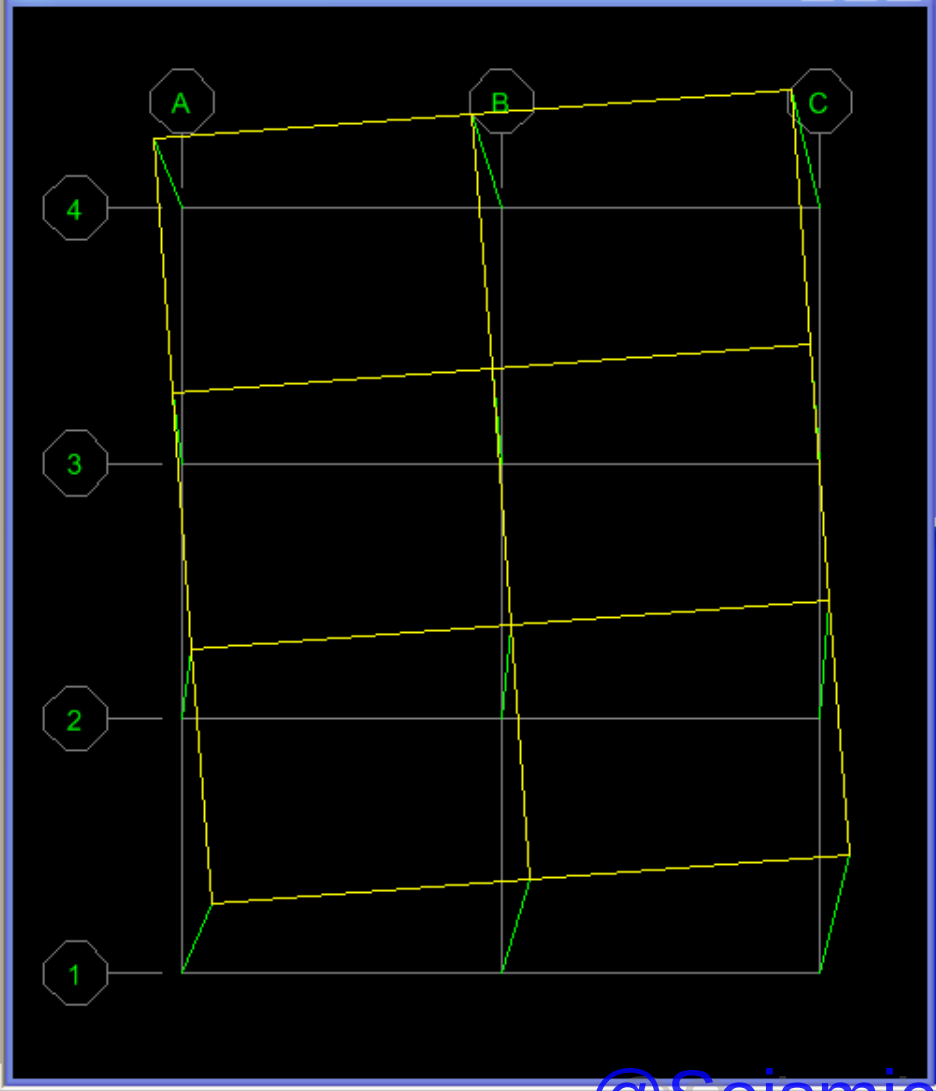
@Seismicisolation

3-D View Inactive GLOBAL Kip-ft

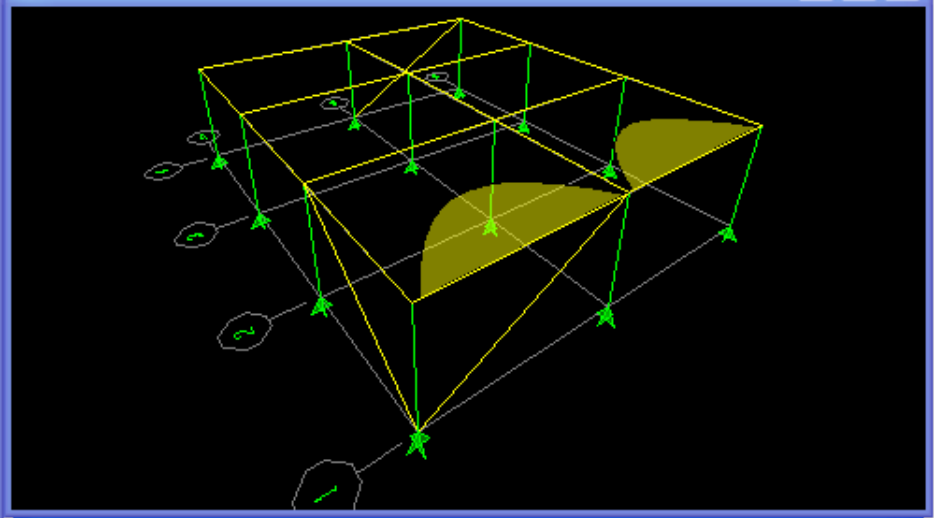
ETABS Educational v8.3.6 - Ex. 11.1 braced stee frame with wind load

File Edit View Define Draw Select Assign Analyze Display Design Options Help

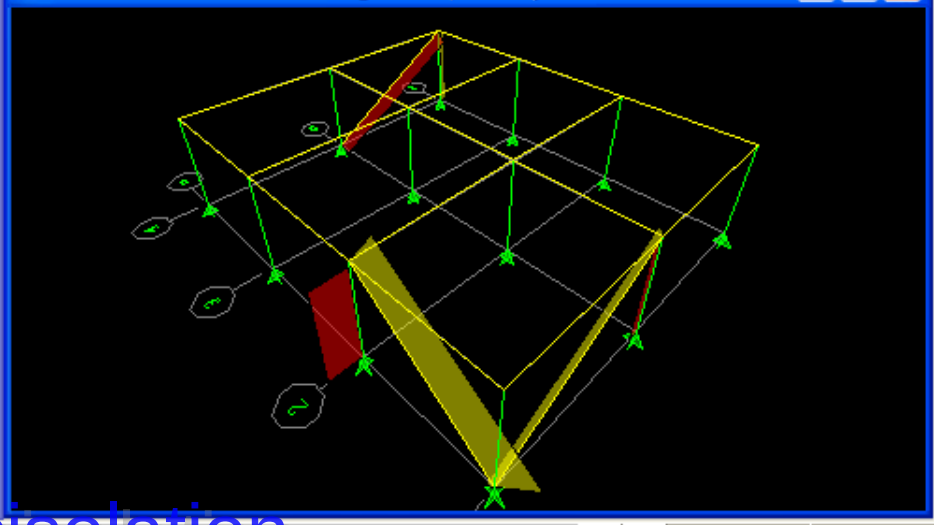
Plan View - STORY1 - Elevation 15 Deformed Shape (WINDY)



3-D View Moment 2-2 Diagram (WINDY)



3-D View Axial Force Diagram (WINDY)



Right Click on any Line for detailed diagram

@Seismicisolation

GLOBAL Kip-ft

ETABS Educational v8.3.6 - Ex. 11.1a braced steel frame with rigid dia.

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Frame Span Loads (WINDY)

0.15

0.15

0.15

3-D View Restraint Reactions (WINDY)

3.12

7.50

7.50

3-D View Axial Force Diagram (WINDY)

Plan View - STORY1 - Elevation 15 Stress S22 Diagram (W...

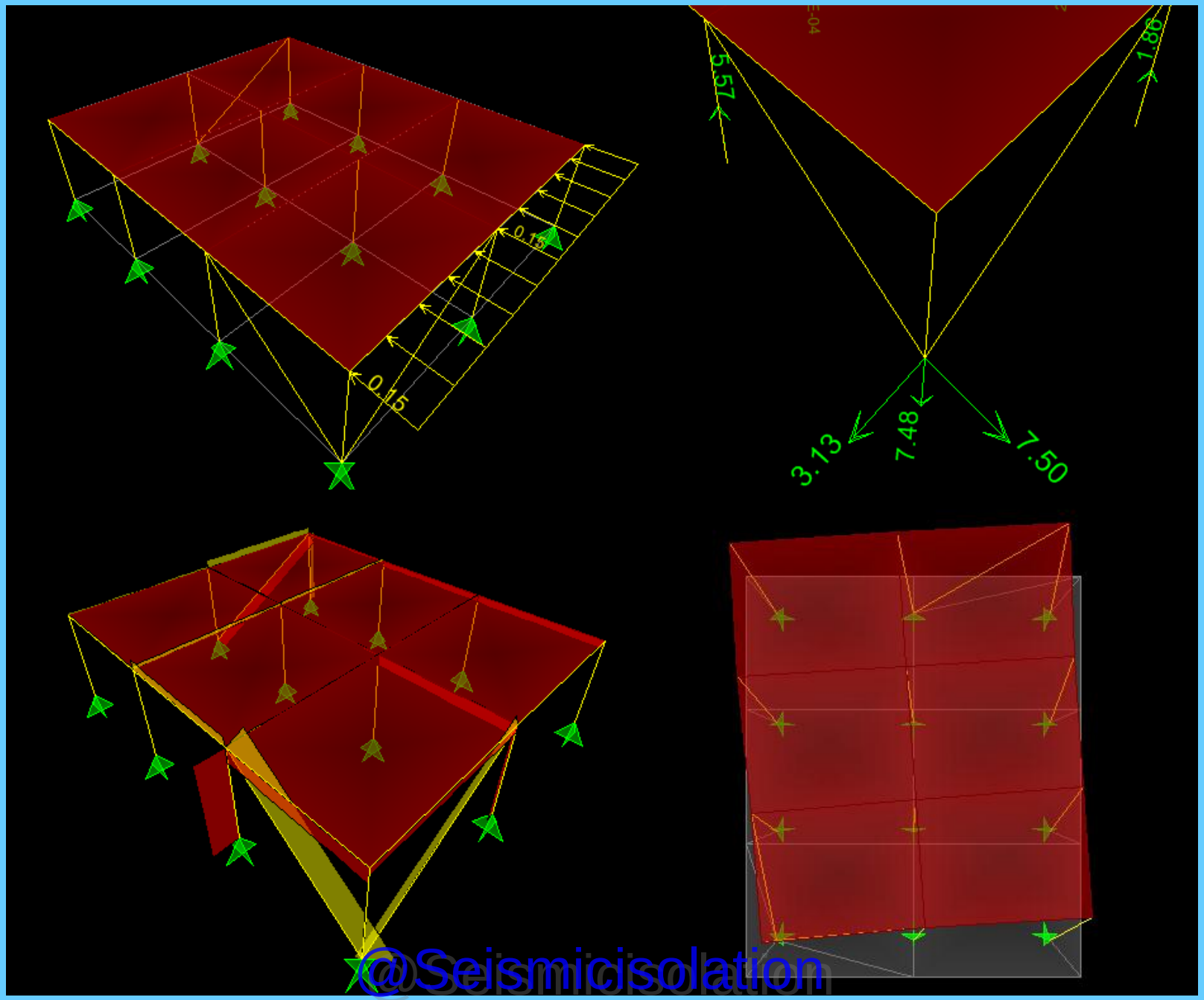
-595. -510. -425. -340. -255. -170. -85. 0. 85. 170. 255. 340. 425. 510. E-3

Right Click on any Point for reaction values

GLOBAL

Kip-ft

@Seismicisolation



@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.1 concrete frame with shear walls

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Frame Span Loads (WINDY)

3-D View Restraint Reactions (WINDY)

3-D View Stress S11 Diagram (WINDY)

-200. -160. -120. -80. -40. 0. 40. 80. 120. 160. 200. 240. 280. 320.E-3

Plan View - STORY1 - Elevation 15 Deformed Shape (WINDY)

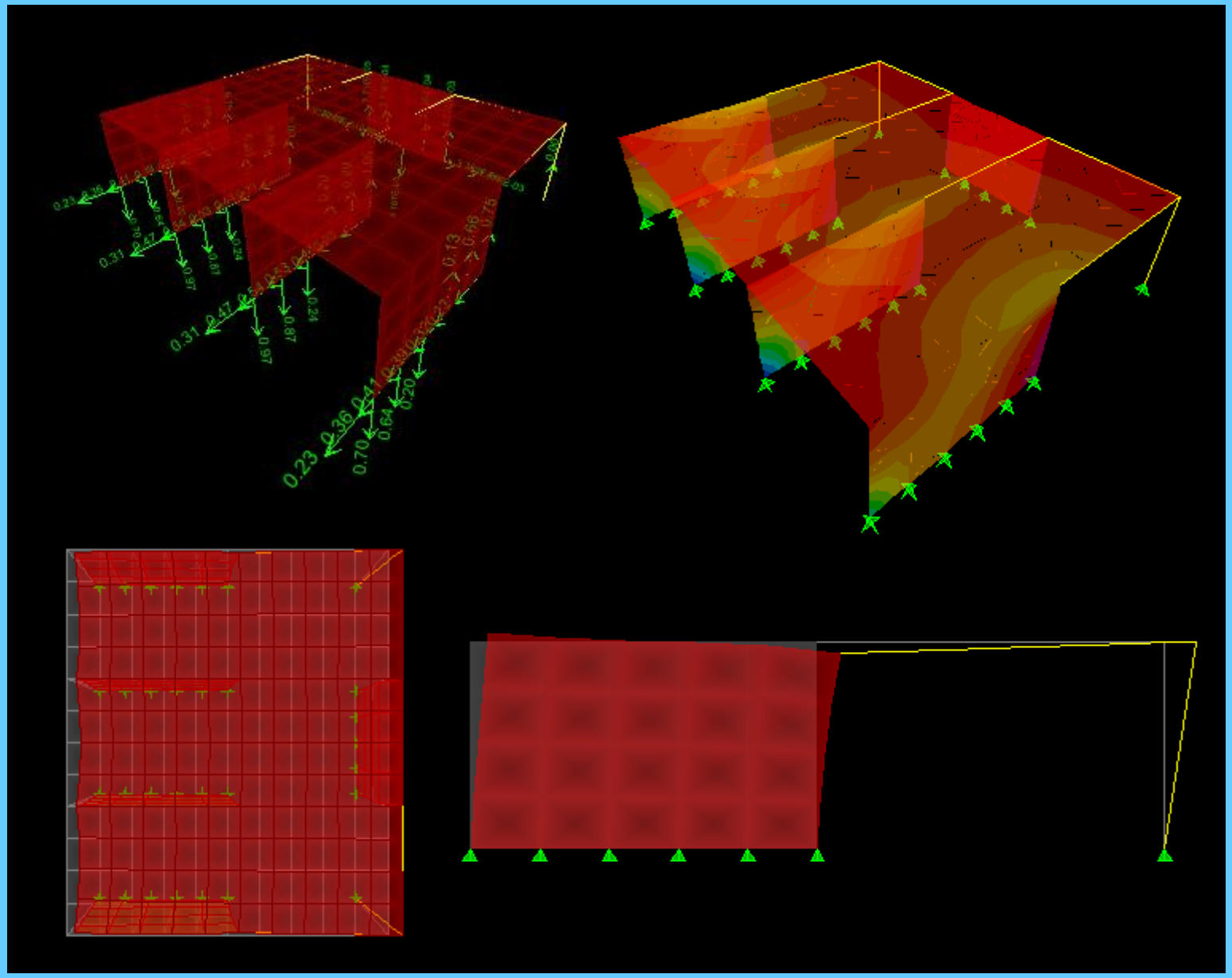
Right Click on any Point for displacement values

Start Animation

GLOBAL

Kip-ft

@Seismicisolation



@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.1 concrete wall structure

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Deformed Shape (WINDX)

3-D View Restraint Reactions (WINDX)

3-D View Stress S22 Diagram (WINDX)

-2.10 -1.75 -1.40 -1.05 -0.70 -0.35 0.00 0.35 0.70 1.05 1.40 1.75 2.10 2.45E-3

3-D View of STORY1 Stress S22 Diagram (WINDX)

-2.10 -1.75 -1.40 -1.05 -0.70 -0.35 0.00 0.35 0.70 1.05 1.40 1.75 2.10 2.45E-3

MIN=-0.002, MAX=0.002, Right Click on any Shell Element for detailed diagram

GLOBAL Kip-in

@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.1 concrete wall structure

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View

3-D View Frame Span Loads (WINDX)

0.15

0.15

0.15

0.15

3-D View Axial Force Diagram (WINDX)

3-D View Moment 2-2 Diagram (WINDX)

@Seismicisolation

3-D View

Inactive GLOBAL Kip-ft

SAP2000 - Ex. 11.1a parallel walls with roof dia

File Edit View Define Draw Select Assign Analyze Display Design Options Help

Shell Uniform GLOBAL-X (WINDX)

3.00 3.00 3.00 3.00 3.00 3.00

Restraint Reactions (WINDX)

1885.40 1172.96 1363.38 1527.84 1181.77 649.53

Stress S22 Diagram (WINDX)

-320. -240. -160. -80. 0. 80. 160. 240. 320.

Deformed Shape (WINDX)

@Seismicisolation

SAP2000 - Ex. 11.1c membrane diaphragms

Edit View Define Draw Select Assign Analyze Display Design Options Help

Deformed Shape (WINDY)

Restraint Reactions (WINDY)

Axial Force Diagram (WINDY)

Stress S22 Diagram (WINDY)

-420. -350. -280. -210. -140. -70. 0. 70. 140. E-3

@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.3a rigid diaphragm on braced frames

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Restraint Reactions (WINDY)

3-D View Deformed Shape (WINDY)

Right Click on any Point for displacement values

Start Animation

Sunday, February 22, 2004

@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.3a rigid diaphragm on braced frames

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Restraint Reactions (WINDY)

3-D View Stress S22 Diagram (WINDY)

-1.92 -1.76 -1.60 -1.44 -1.28 -1.12 -0.96 -0.80 -0.64 -0.48 -0.32 -0.16 0.00 0.16E-

MIN=-0.002, MAX=2.226E-04, Right Click on any Shell Element for detailed diagram

GLOBAL Kip-in

@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.3b concrete slab on braced frames

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View

3-D View

@Seismicisolation

3-D View

Inactive

Monday, February 23, 2004

ETABS Educational v8.3.6 - Ex. 11.1c diaphragm with unfilled deck on shear walls

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Restraint Reactions (WINDY)

3-D View Stress S22 Diagram (WINDY)

-60.0 -54.0 -48.0 -42.0 -36.0 -30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0E-

MIN=-0.062, MAX=0.018, Right Click on any Shell Element for detailed diagram

GLOBAL Kip-in

@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.4 concrete slab on braced frames

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Restraint Reactions (WINDY)

3-D View Stress S22 Diagram (WINDY)

-2.09 -1.90 -1.71 -1.52 -1.33 -1.14 -0.95 -0.76 -0.57 -0.38 -0.19 0.00 0.19 0.38E-3

MIN=-0.002, MAX=3.963E-04, Right Click on any Shell Element for detailed diagram

GLOBAL Kip-in

@Seismicisolation

ETABS Educational v8.3.6 - Ex. 11.4 eccentric braced core. EDB

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Restraint Reactions (WINDY)

3-D View Stress S22 Diagram (WINDY)

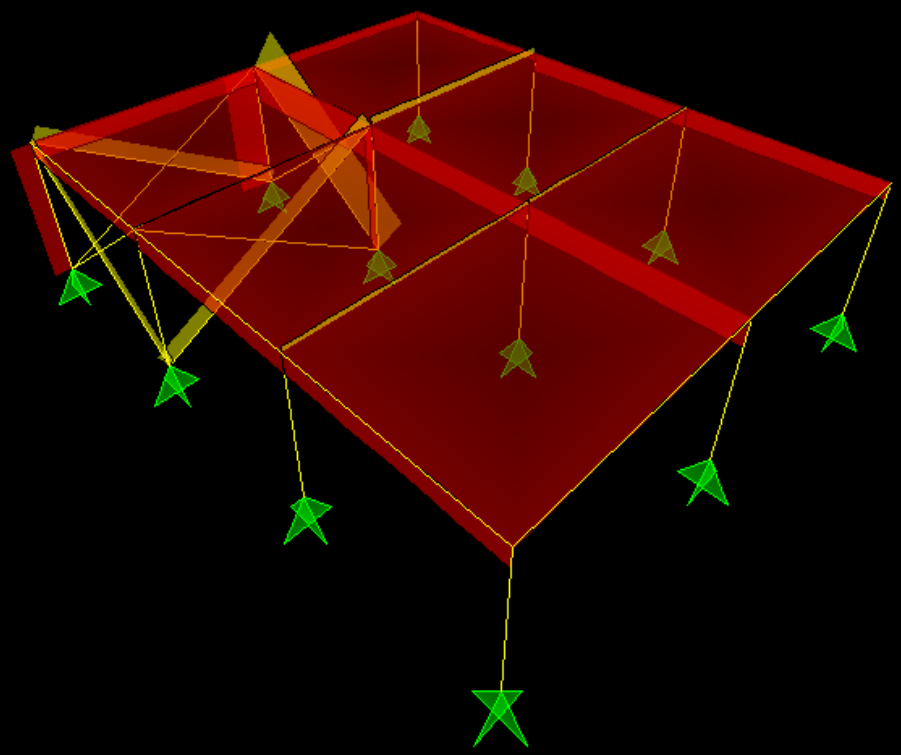
-3.00 -2.75 -2.50 -2.25 -2.00 -1.75 -1.50 -1.25 -1.00 -0.75 -0.50 -0.25 0.00 0.25E-3

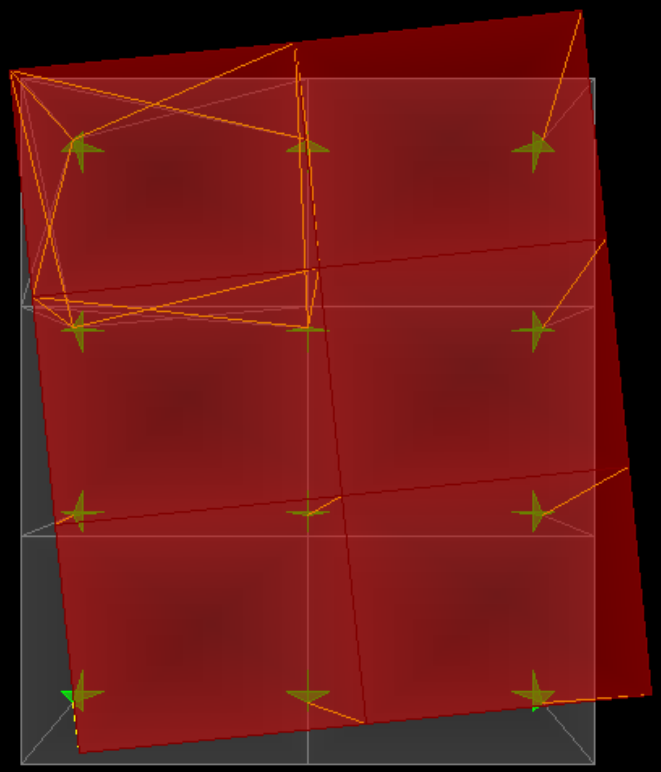
More Buttons

AX=2.889E-04, Right Click on any Shell Element for detailed diagram

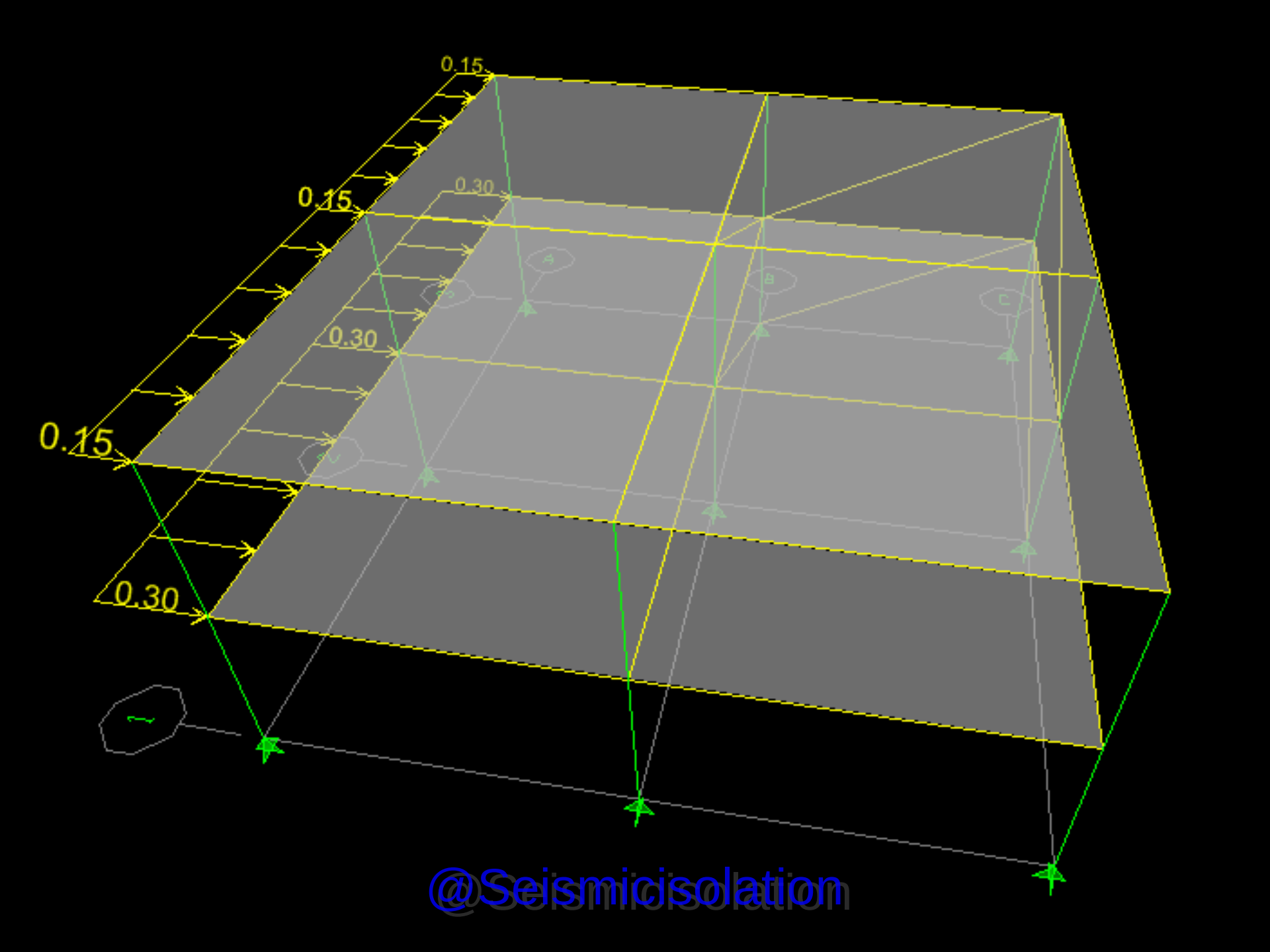
GLOBAL Kip-in

@Seismicisolation





@Seismicisolation


0.15
0.15
0.30
0.30
0.15
0.30
@Seismicisolation

ETABS Educational v8.3.6 - Probl. 11.1b laterally braced building frame

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View

3-D View Frame Span Loads (W)

0.30

0.15

0.30

3-D View Axial Force Diagram (W)

3-D View Stress S22 Diagram (W)

-2.42 -2.20 -1.98 -1.76 -1.54 -1.32 -1.10 -0.88 -0.66 -0.44 -0.22 0.00 0.22 0.44

MIN=-2.607, MAX=0.360, Right Click on any Shell Element for detailed diagram

GLOBAL Kip-ft

@Seismicisolation

ETABS Educational v8.3.6 - Probl. 11.1b laterally braced building frame

File Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View Restraint Reactions (W)

3-D View Frame Span Loads (W)

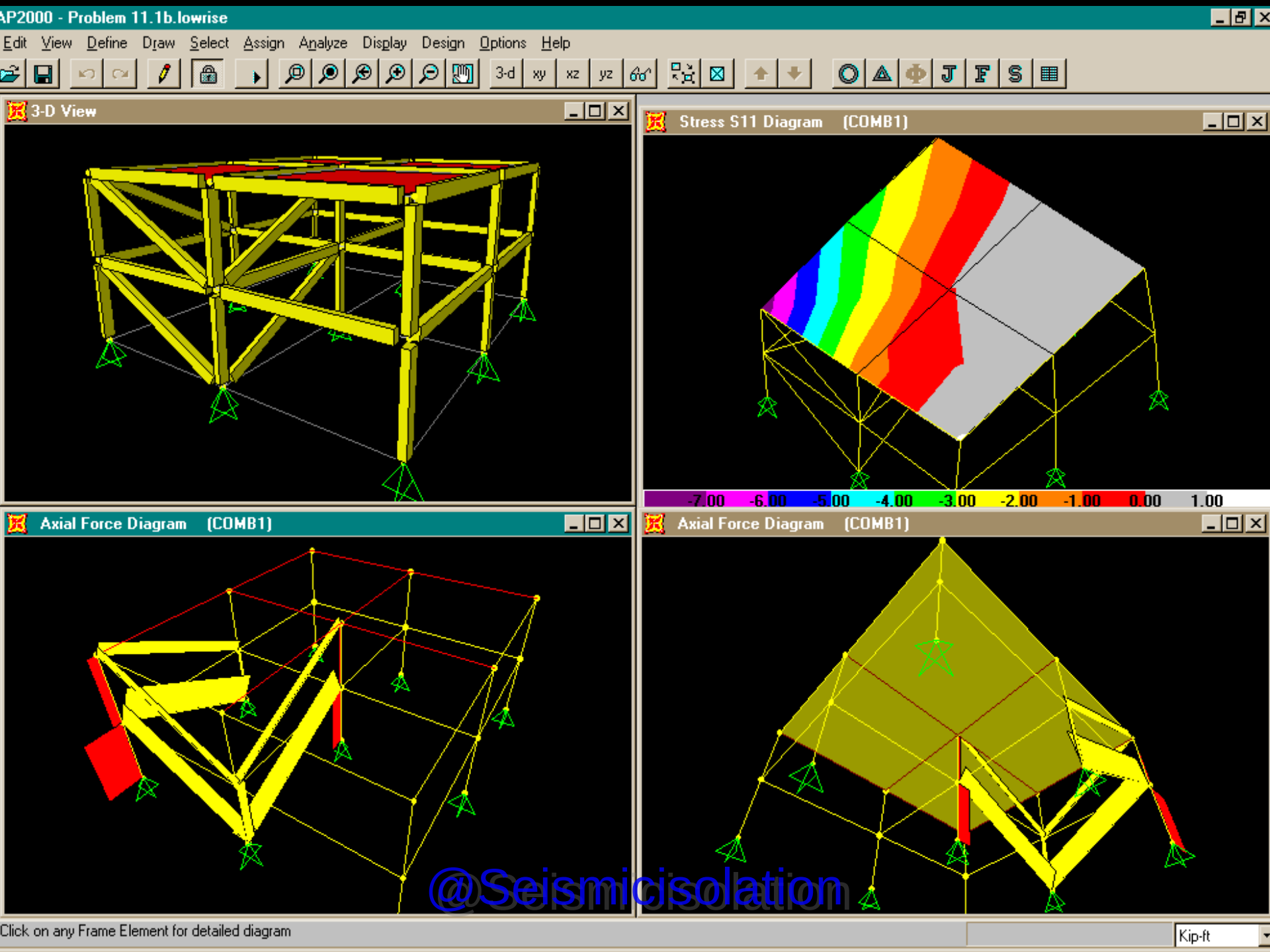
3-D View Moment 2-2 Diagram (W)

@Seismicisolation

Right Click on any Point for reaction values

Click here to begin

GLOBAL Kip-in



@Seismicisolation

SAP2000 - Problem 11.2 diaphragm bldg

Edit View Define Draw Select Assign Analyze Display Design Options Help

Frame Span Loads (SPANDREL)

300.00

300.00

300.00

Deformed Shape (COMB1)

Stress S11 Diagram (COMB1)

-7.00 -6.00 -5.00 -4.00 -3.00 -2.00 -1.00 0.00 1.00 E+3

Deformed Shape (COMB1)

@Seismicisolation

Click on any Shell Element for detailed diagram

Start Animation

lb-ft

SAP2000 - Problem 11.2 diaphragm bldg

Edit View Define Draw Select Assign Analyze Display Design Options Help

3-D View

Axial Force Diagram (COMB1)

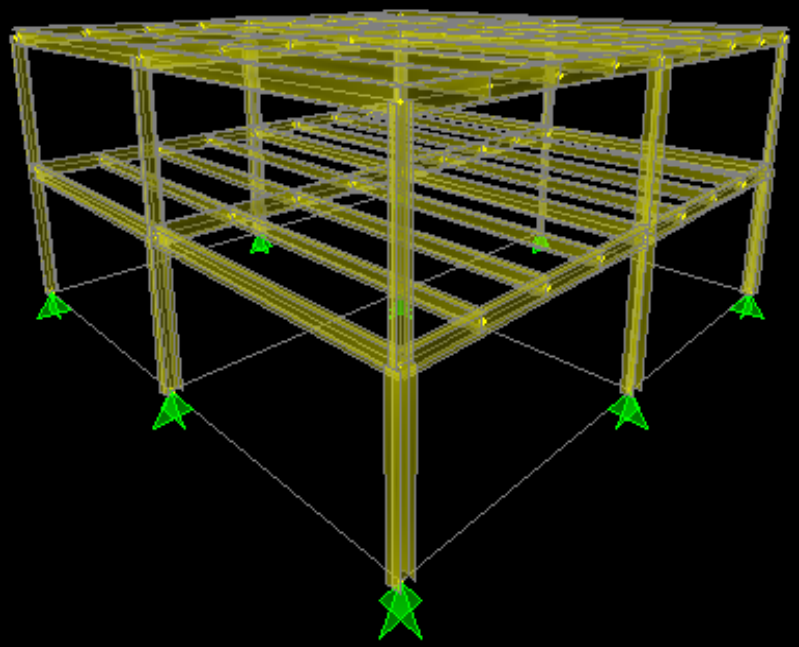
Restraint Reactions (COMB1)

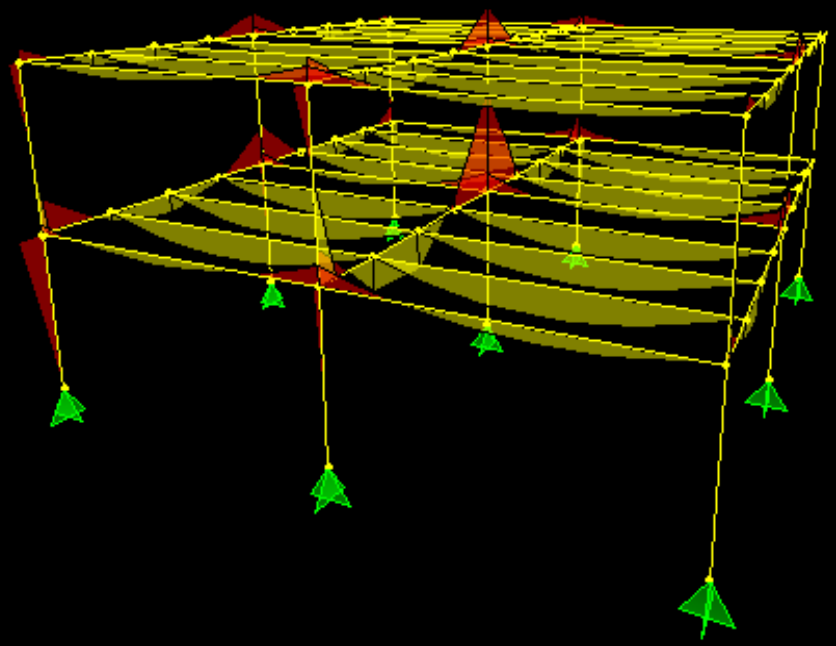
Axial Force Diagram (COMB1)

@Seismicisolation

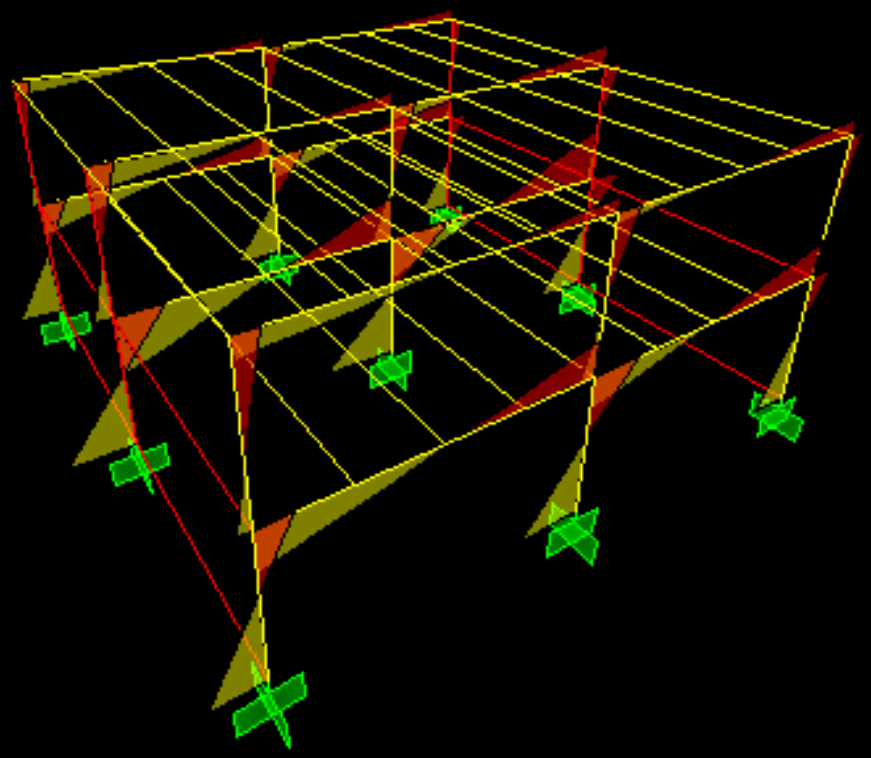
nts, 1 Frames selected

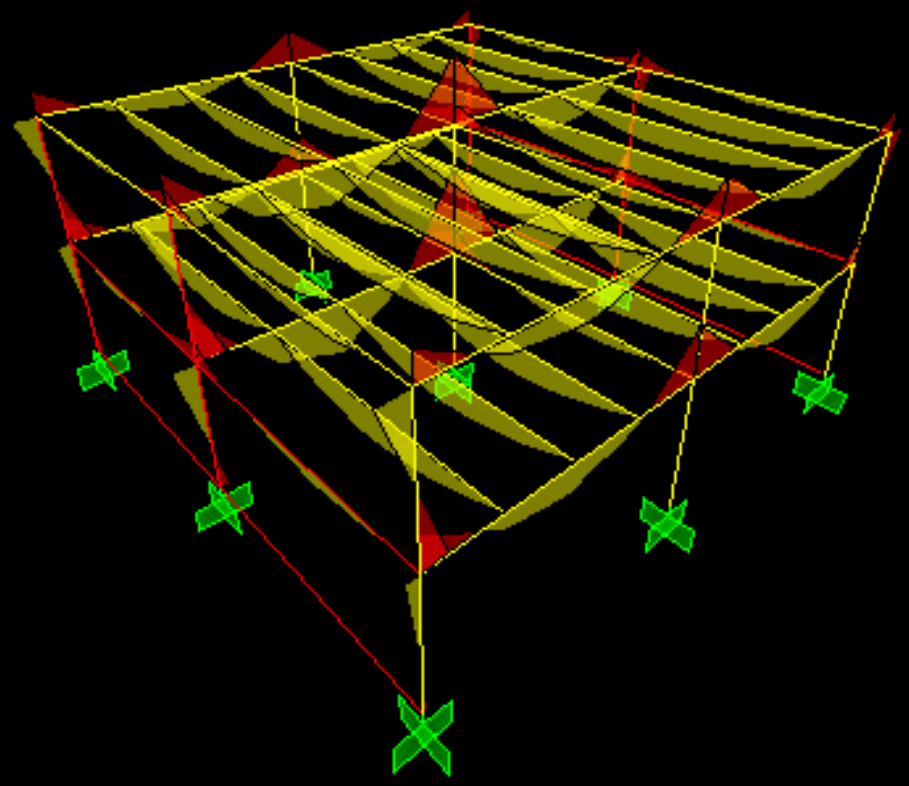
lb-ft





@Seismicisolation

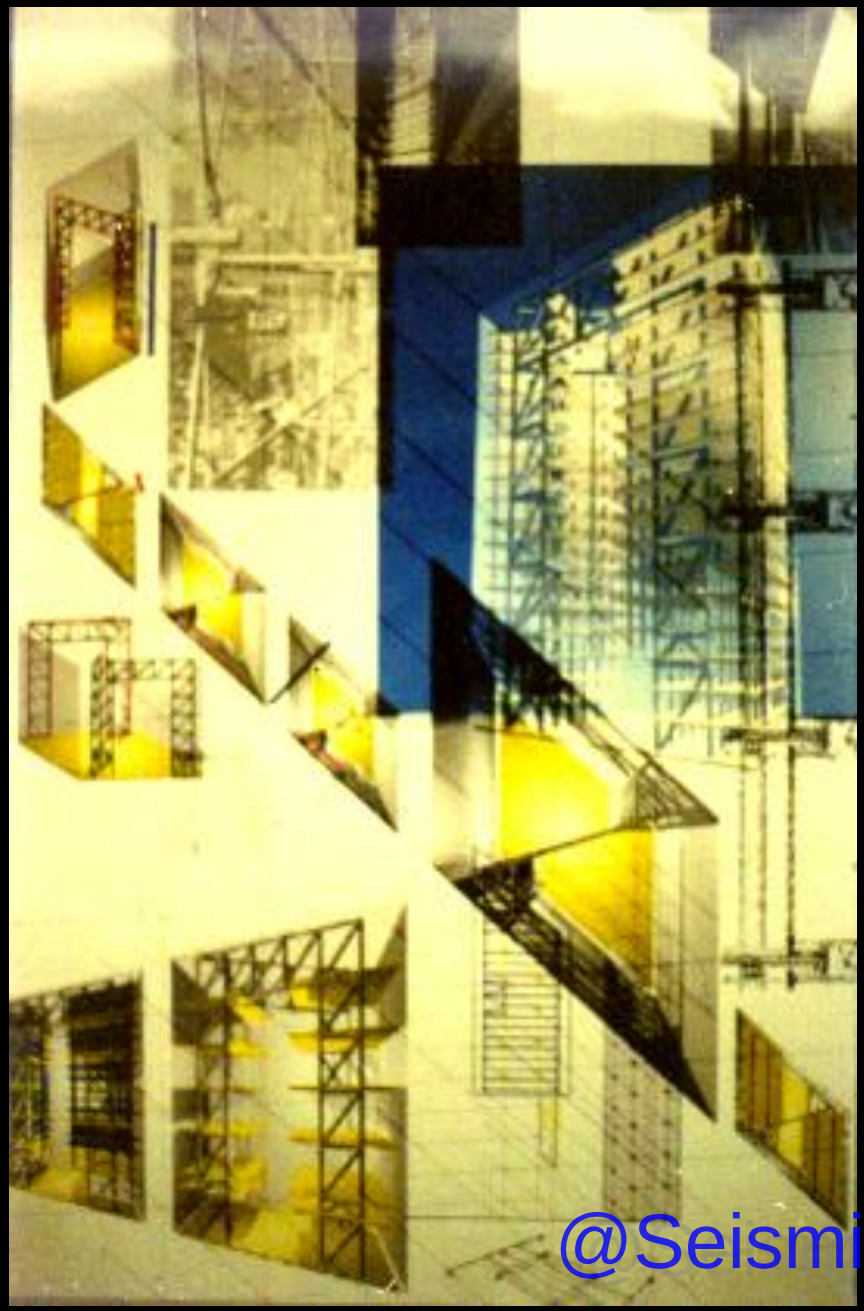


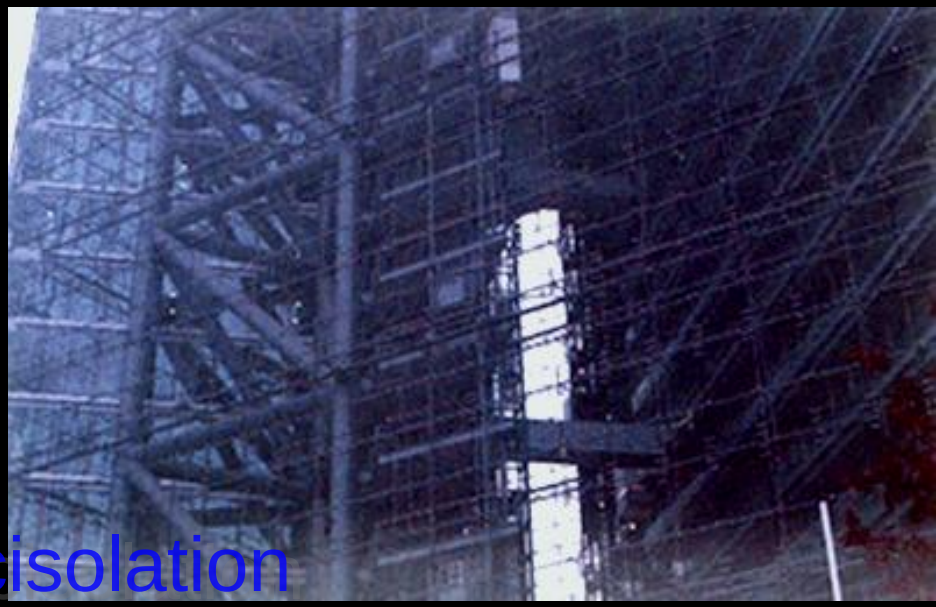


@Seismicisolation

Duesseldorf City Gate,
Duesseldorf, Germany, 1997,
H. Petzinka + Fink Arch

@Seismicisolation

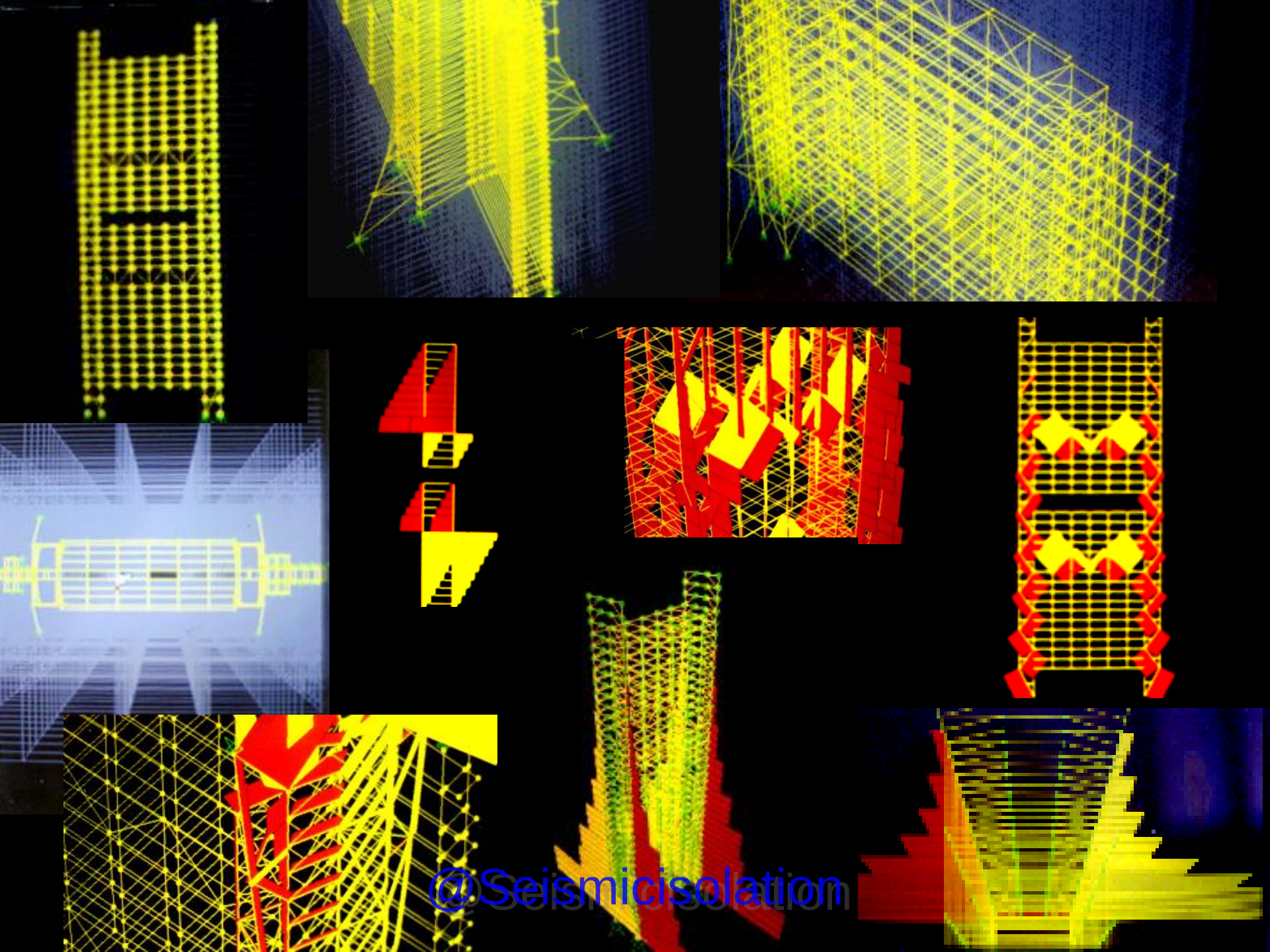




@Seismicisolation

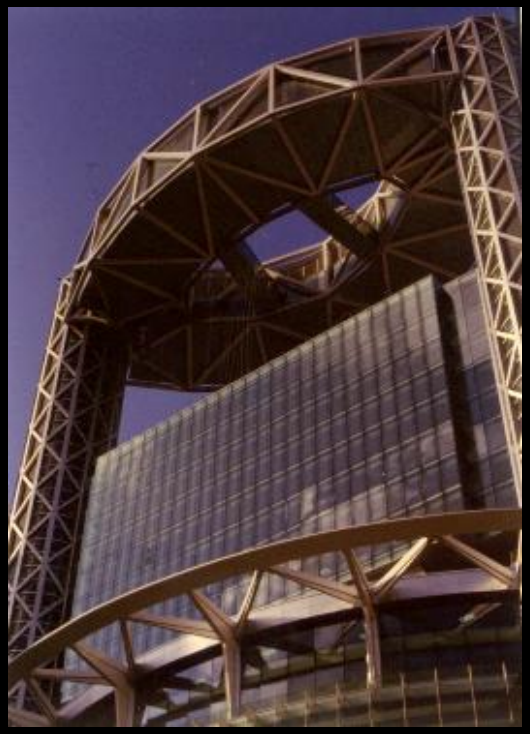
Seoul Broadcasting Center, Seoul, 2003, Richard Rogers Arch. And Buro Happold Struct. Eng

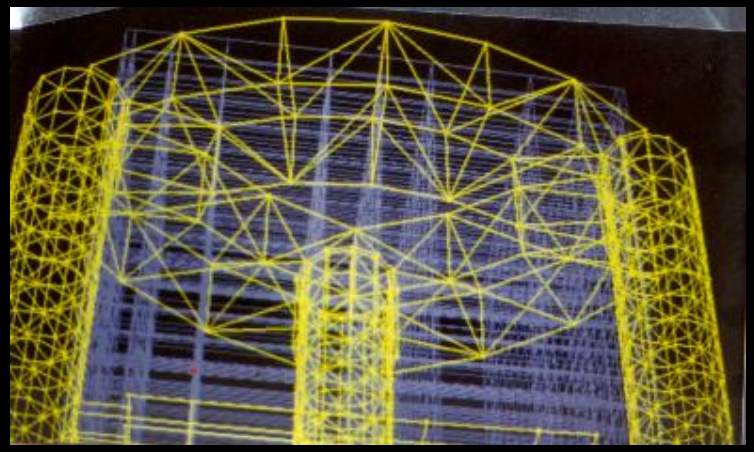
@Seismicisolation

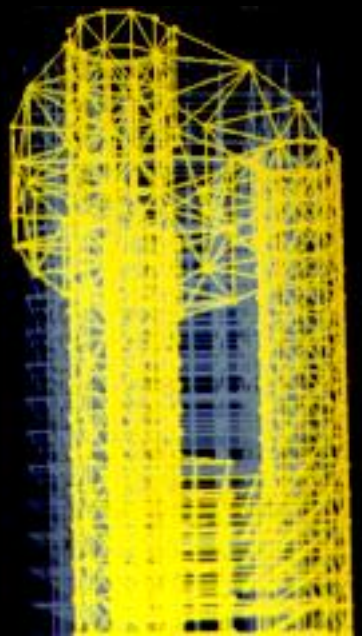

@Seismicisolation

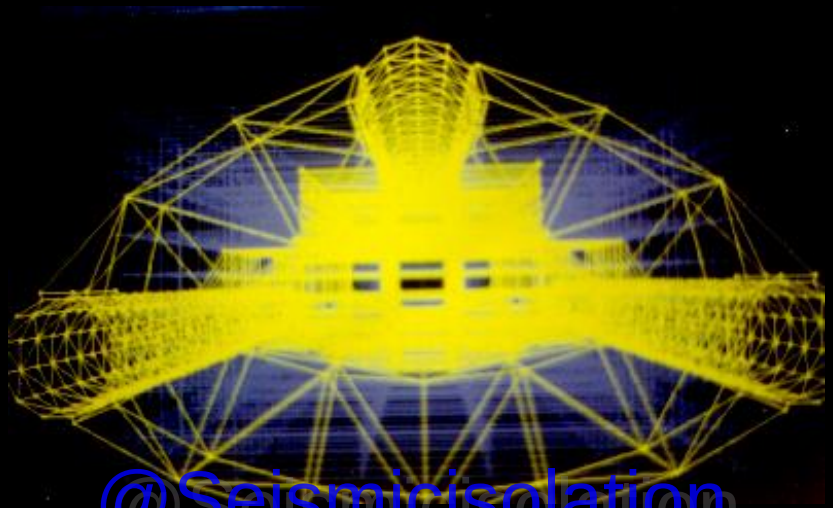
Samsung Samsung Jongro Tower, Seoul, 1999, Rafael Vinoly

@Seismicisolation









@Seismicisolation