Design of Seismic-Resistant Steel Building Structures

Brief Overview

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with the support of the
American Institute of Steel Construction.

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- Earthquake Effects on Structures
- Performance of Steel Buildings in Past Earthquakes
- Importance of Ductility
- Design Earthquake Forces: ASCE-7
- Steel Seismic Load Resisting Systems
- AISC Seismic Provisions

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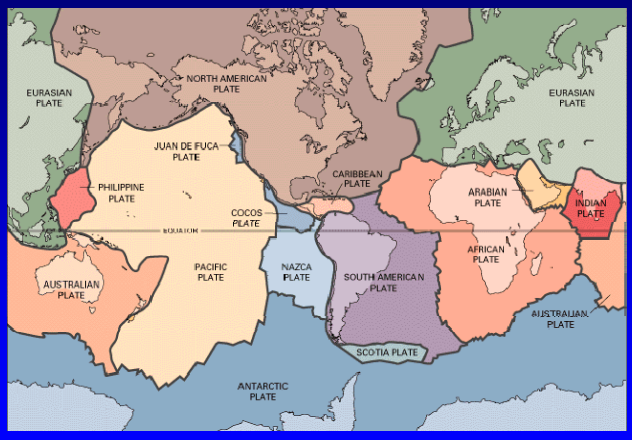

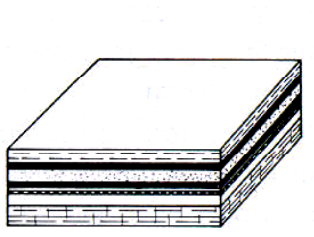

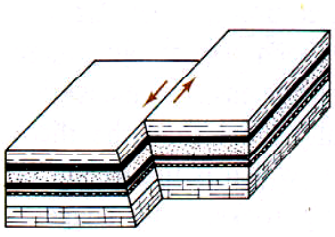

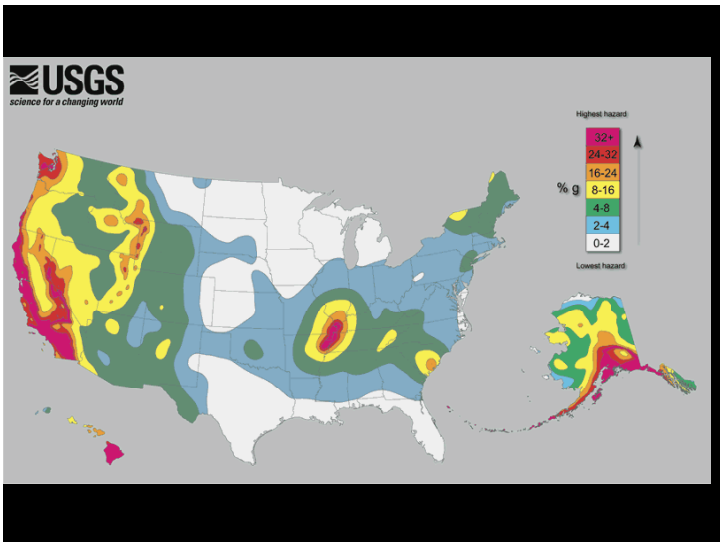

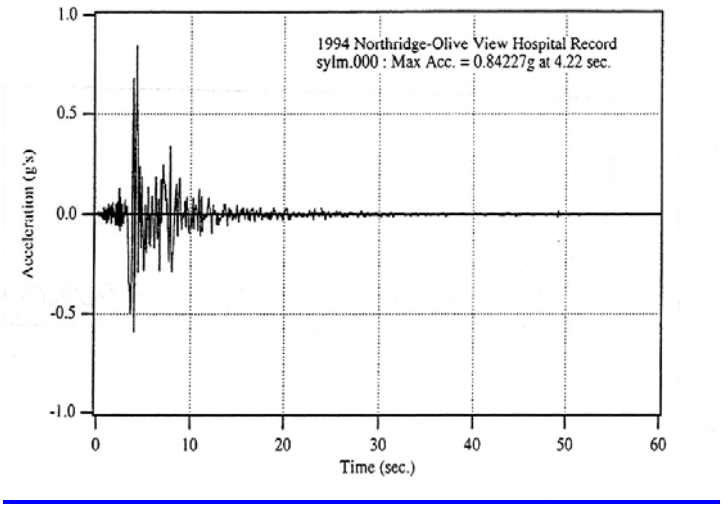

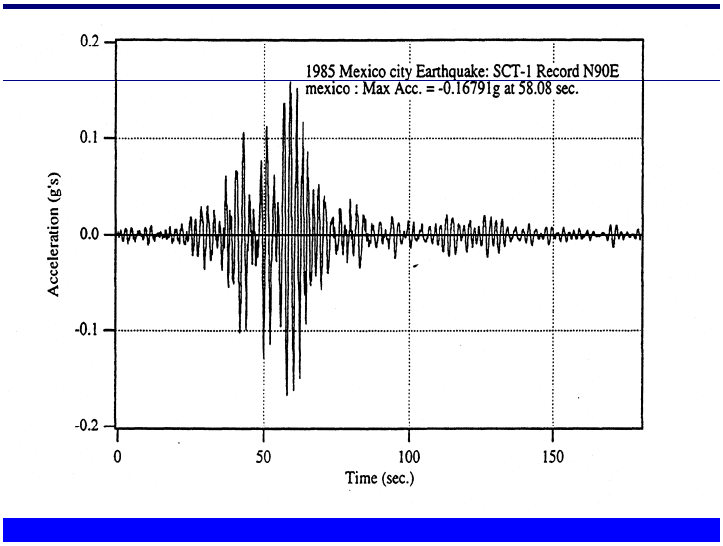

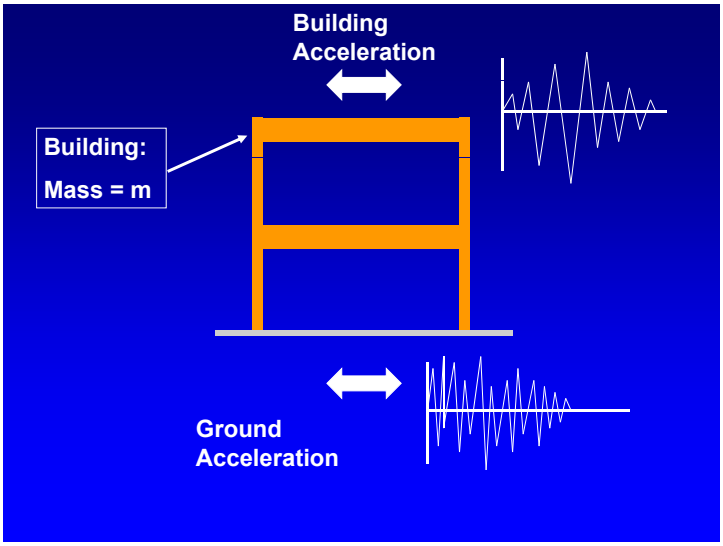

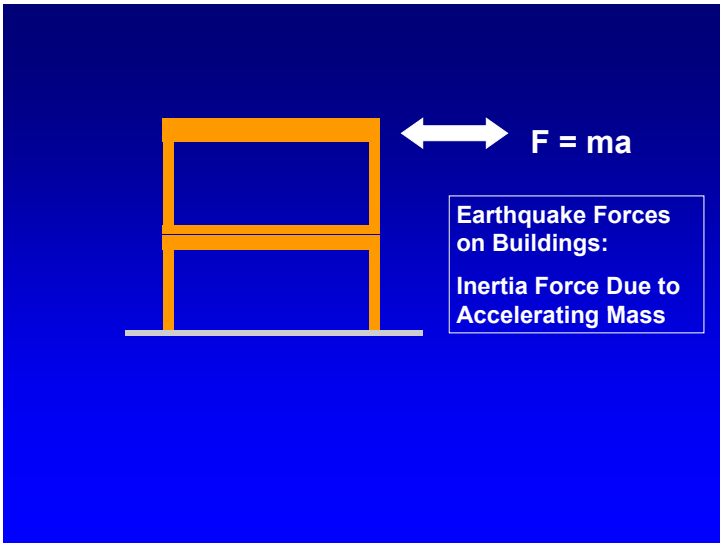

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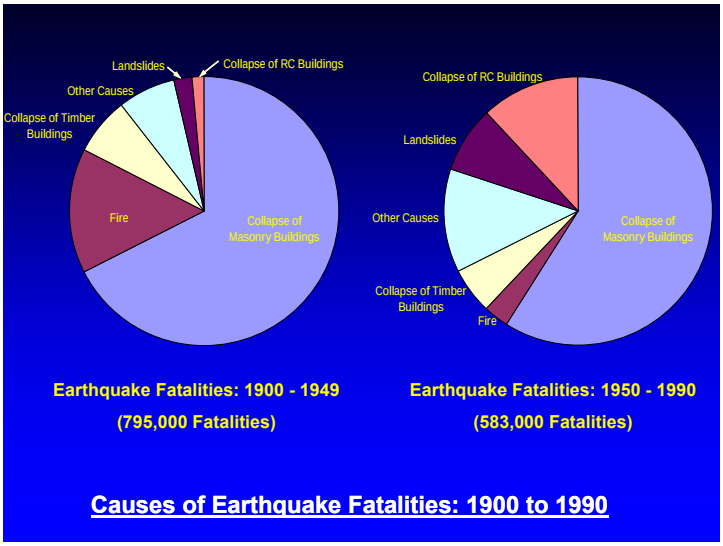
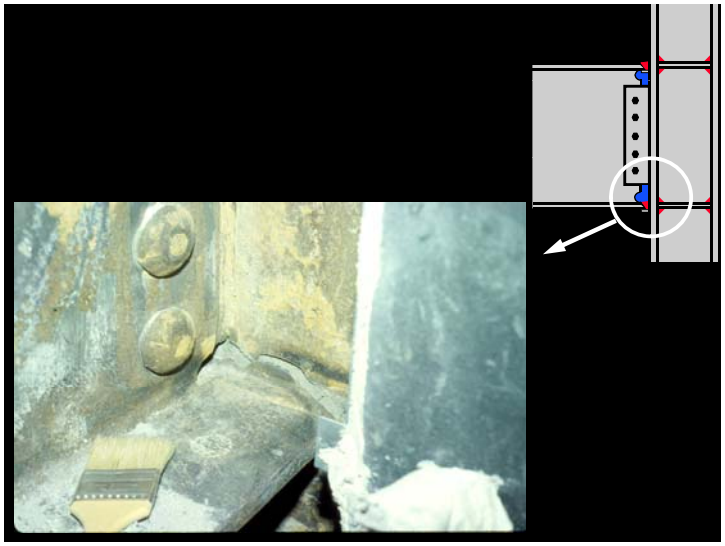
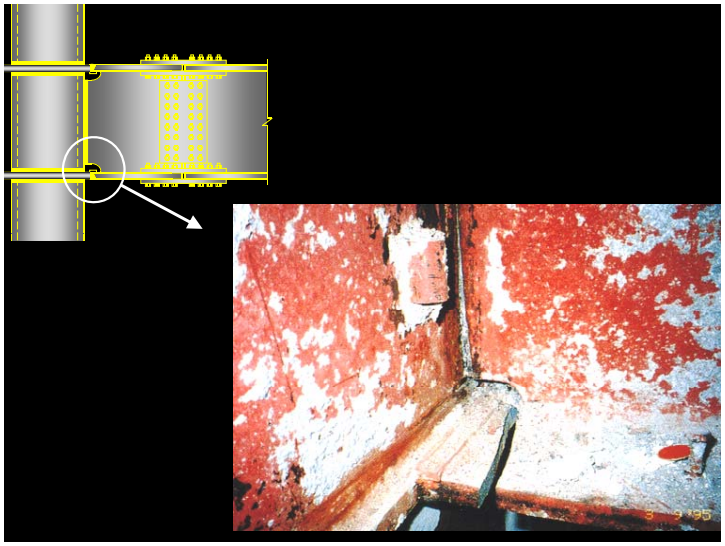

Landslides
Collapse of RC Buildings
Other Causes
Collapse of Timber Buildings
Fire
Collapse of Masonry Buildings
Earthquake Fatalities: 1900 - 1949
(795,000 Fatalities)
Collapse of RC Buildings
Landslides
Other Causes
Collapse of Masonry Buildings
Collapse of Timber Buildings
Fire
Earthquake Fatalities: 1950 - 1990
(583,000 Fatalities)
Causes of Earthquake Fatalities: 1900 to 1990





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Conventional Building Code Philosophy for Earthquake-Resistant Design

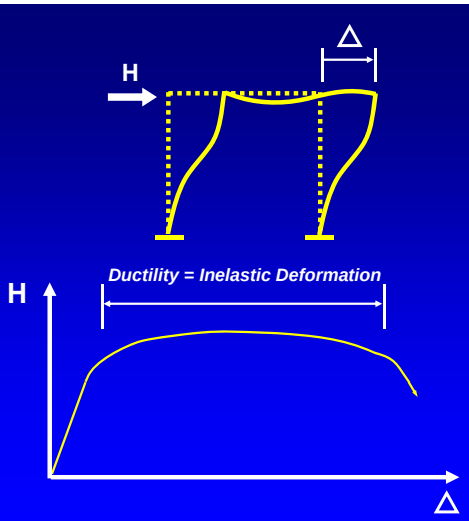
Objective: Prevent collapse in the extreme earthquake likely to occur at a building site.

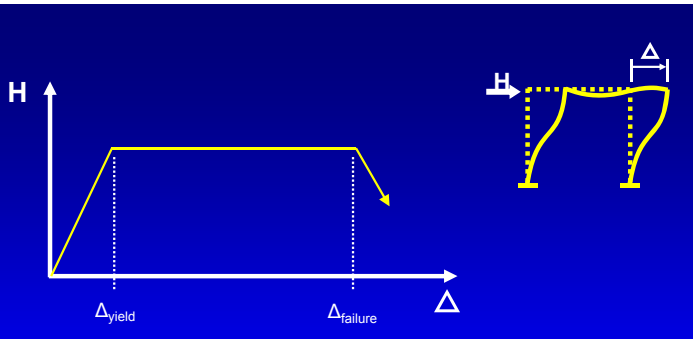
Objectives are not to:

- limit damage
- maintain function
- provide for easy repair

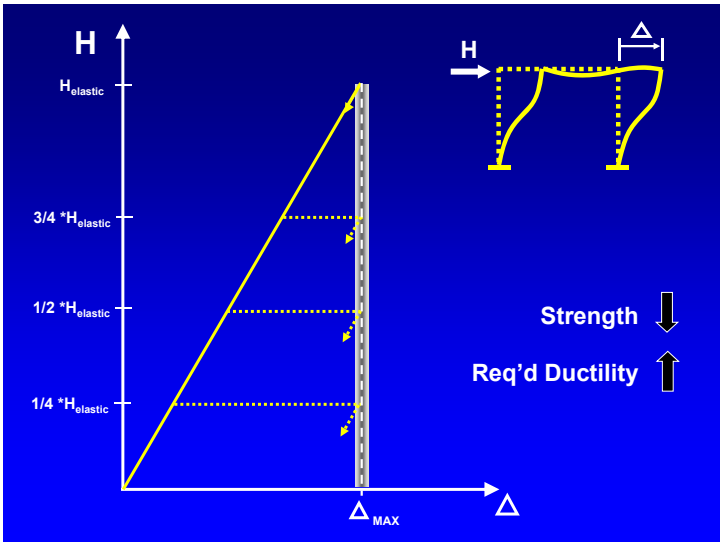
To Survive Strong Earthquake without Collapse:

Design for Ductile Behavior



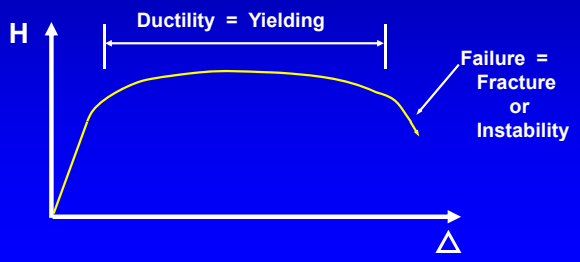


Ductility Factor $\mu = \frac{\Delta_{failure}}{\Delta_{yield}}$



Ductility in Steel Structures: *Yielding*

Nonductile Failure Modes: *Fracture or Instability*



Developing Ductile Behavior:

- Choose frame elements ("fuses") that will yield in an earthquake.
- Detail "fuses" to sustain large inelastic deformations prior to the onset of fracture or instability (i.e. , detail fuses for ductility).
- Design all other frame elements to be stronger than the fuses, i.e., design all other frame elements to develop the plastic capacity of the fuses.

Key Elements of Seismic-Resistant Design

Required Lateral Strength

ASCE-7:

Minimum Design Loads for Buildings and Other Structures

Detailing for Ductility

AISC:

Seismic Provisions for Structural Steel Buildings

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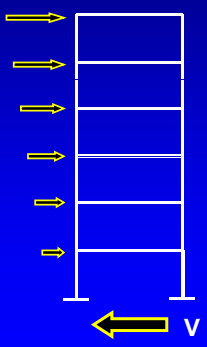
Design EQ Loads – Total Lateral Force per ASCE 7-05:

$$V = C_s W$$

V = total design lateral force or shear at base of structure

W = effective seismic weight of building

C_S = seismic response coefficient



Design EQ Loads – Total Lateral Force per ASCE 7-05:

$$V = C_S W$$

$$C_S = \frac{S_{DS}}{\left(\frac{R}{I}\right)} \le \begin{cases} \dfrac{S_{D1}}{T\left(\frac{R}{I}\right)} & \text{for } T \le T_L \\ \dfrac{S_{D1} T_L}{T^2\left(\frac{R}{I}\right)} & \text{for } T > T_L \end{cases}$$

S_{DS} = design spectral acceleration at short periods

S_{D1} = design spectral acceleration at 1-second period

I = importance factor

T = fundamental period of building

T_L = long period transition period

R = response modification coefficient

R factors for Selected Steel Systems (ASCE 7):

SMF	(*Special Moment Resisting Frames*):	R = 8
IMF	(*Intermediate Moment Resisting Frames*):	R = 4.5
OMF	(*Ordinary Moment Resisting Frames*):	R = 3.5
EBF	(*Eccentrically Braced Frames*):	R = 8 or 7
SCBF	(*Special Concentrically Braced Frames*):	R = 6
OCBF	(*Ordinary Concentrically Braced Frames*):	R = 3.25
BRBF	(*Buckling Restrained Braced Frame*):	R = 8 or 7
SPSW	(*Special Plate Shear Walls*):	R = 7
Undetailed Steel Systems in Seismic Design Categories A, B or C (AISC Seismic Provisions not needed)		R = 3

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Seismic Load Resisting Systems for Steel Buildings

- Moment Resisting Frames
- Concentrically Braced Frames
- Eccentrically Braced Frames
- Buckling Restrained Braced Frames
- Special Plate Shear Walls

MOMENT RESISTING FRAME (MRF)

Beams and columns with moment resisting connections; resist lateral forces by flexure and shear in beams and columns - i.e. by frame action.

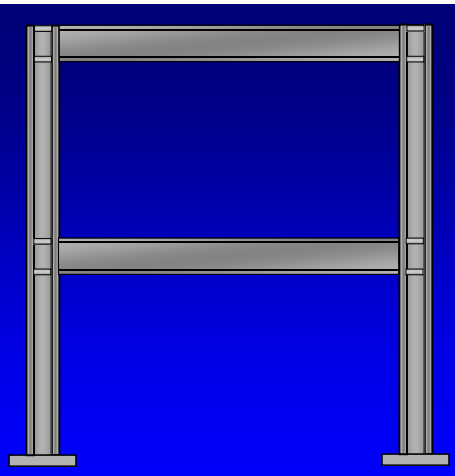
Develop ductility primarily by flexural yielding of the beams:

Advantages

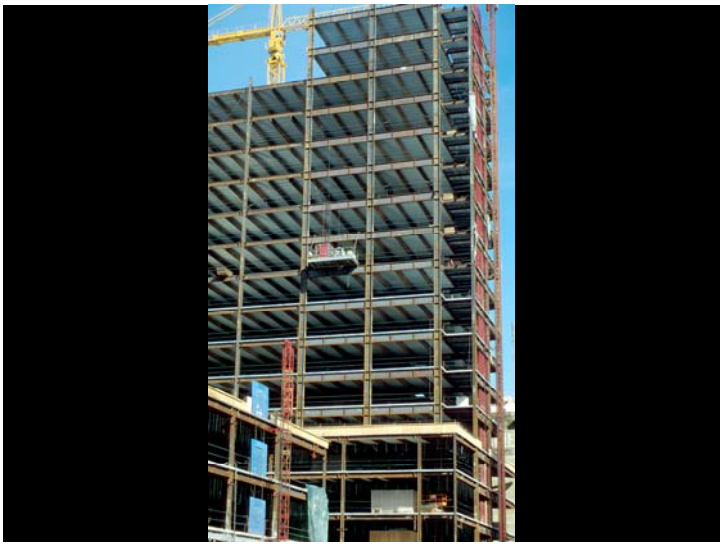
- Architectural Versatility
- High Ductility and Safety

Disadvantages

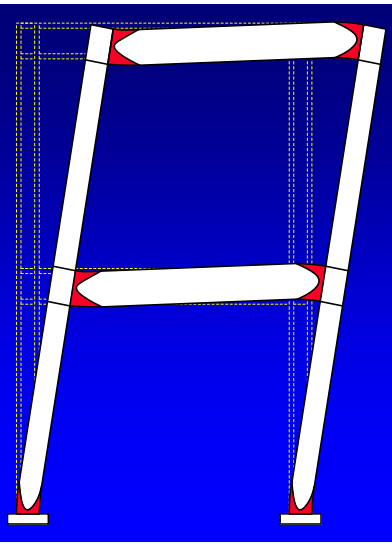
- Low Elastic Stiffness



Moment Resisting Frame



Inelastic Response of a Steel Moment Resisting Frame



Concentrically Braced Frames (CBFs)

Beams, columns and braces arranged to form a vertical truss.
Resist lateral earthquake forces by truss action.

Develop ductility through inelastic action in braces.

- braces yield in tension
- braces buckle in compression

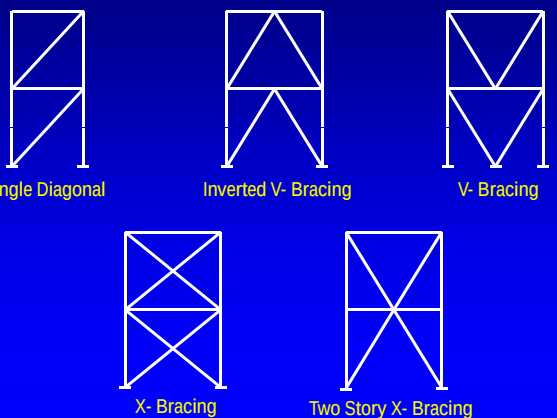
Advantages

- high elastic stiffness

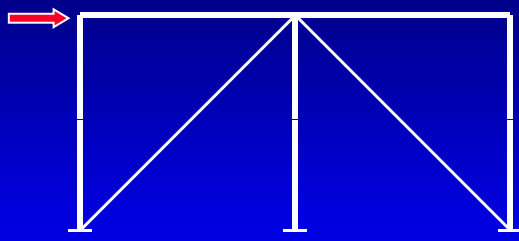
Disadvantages

- less ductile than other systems (SMFs, EBFs, BRBFs)
- reduced architectural versatility

Types of CBFs



Inelastic Response of CBFs under Earthquake Loading



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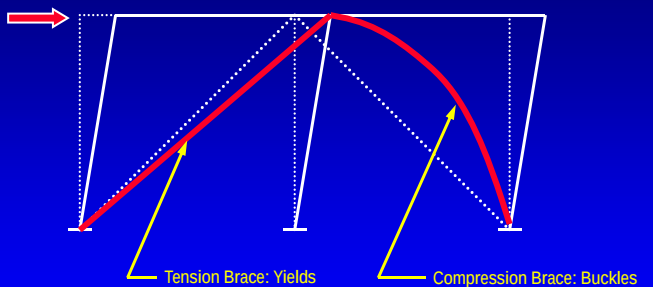

Columns and beams: remain essentially elastic

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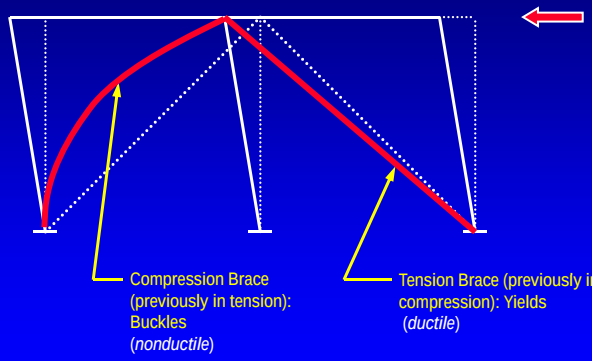
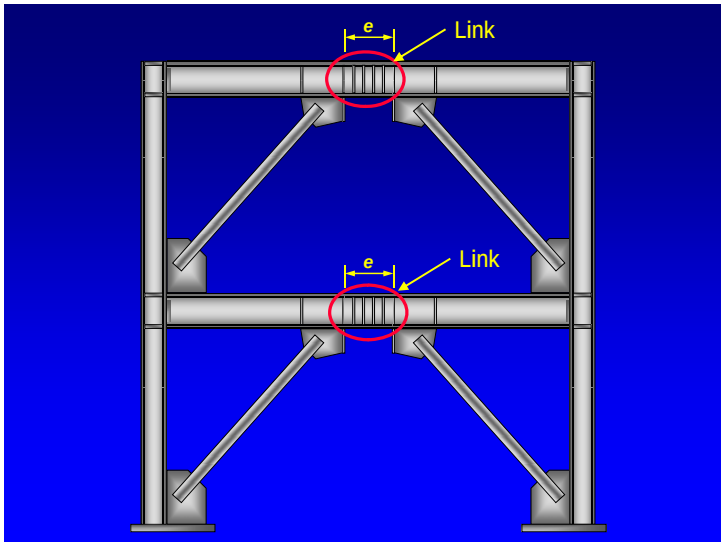
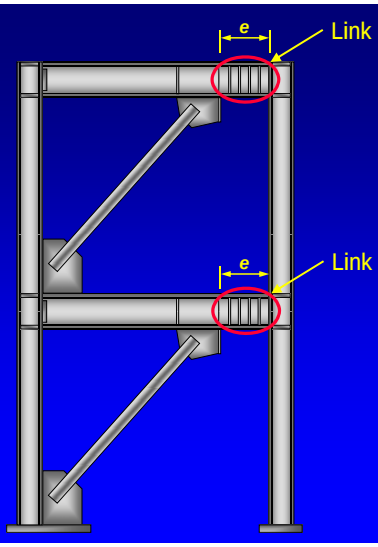


Columns and beams: remain essentially elastic

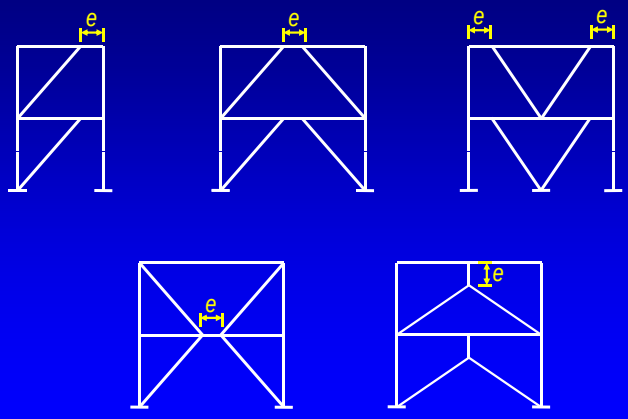
Eccentrically Braced Frames (EBFs)

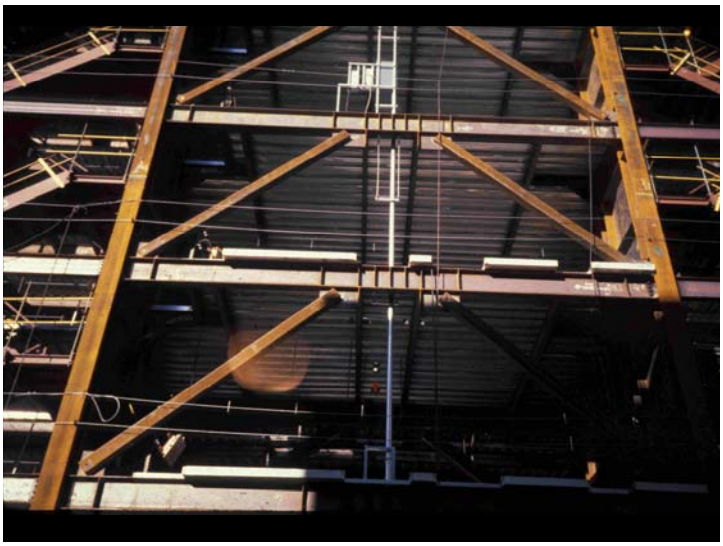
- Framing system with beam, columns and braces. At least one end of every brace is connected to isolate a segment of the beam called a *link*.
- Resist lateral load through a combination of frame action and truss action. EBFs can be viewed as a hybrid system between moment frames and concentrically braced frames.
- Develop ductility through inelastic action in the links.
- EBFs can supply high levels of ductility (similar to MRFs), but can also provide high levels of elastic stiffness (similar to CBFs)

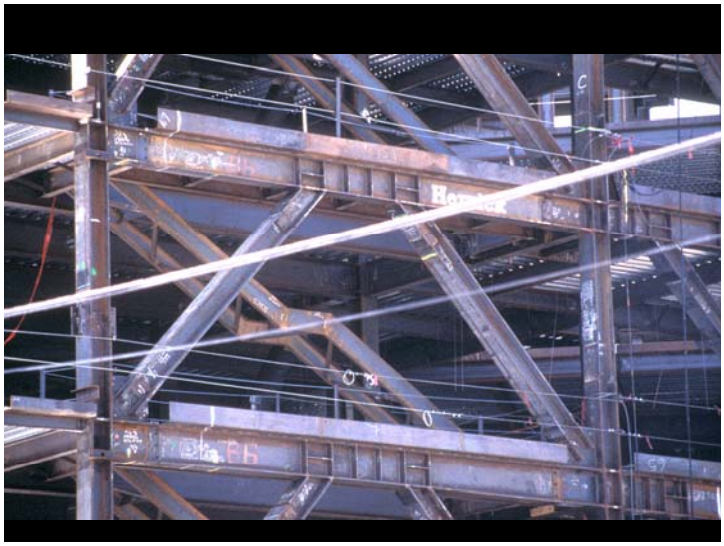




Some possible bracing arrangement for EBFS

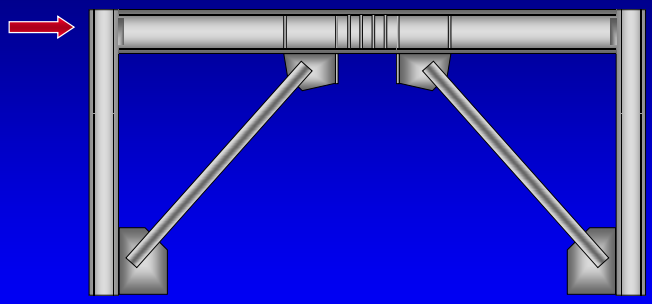


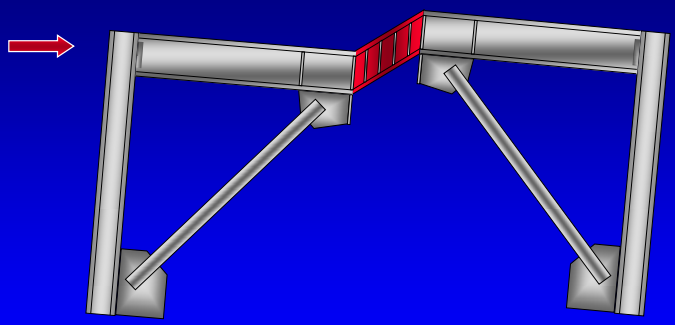


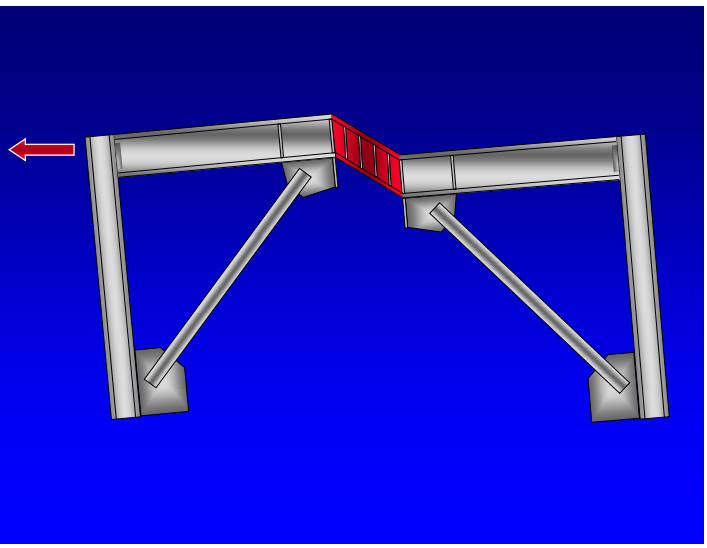



Herrick

Inelastic Response of EBFs



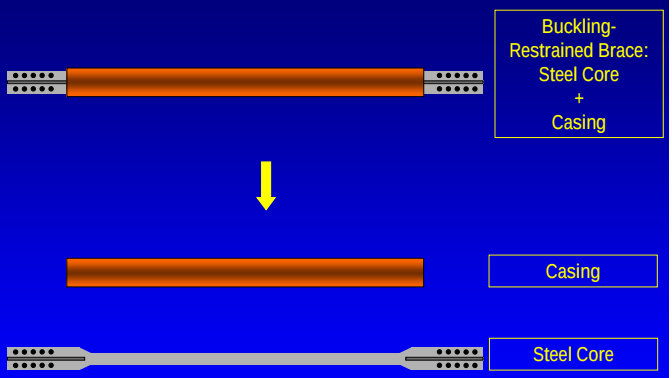




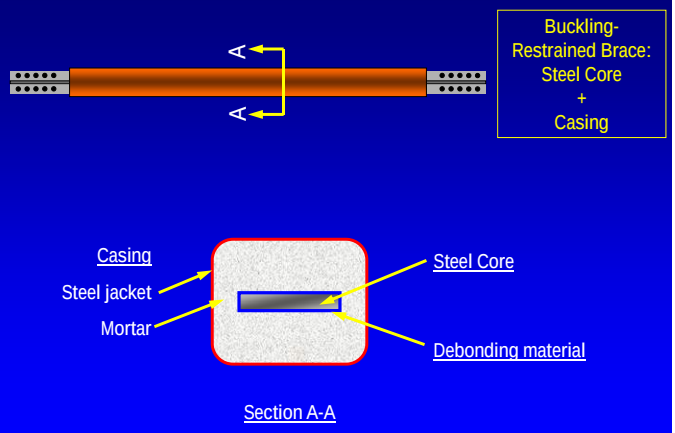
Buckling-Restrained Braced Frames (BRBFs)

- Type of concentrically braced frame.
- Beams, columns and braces arranged to form a vertical truss. Resist lateral earthquake forces by truss action.
- Special type of brace members used: *Buckling-Restrained Braces (BRBs)*. BRBS yield both in tension and compression *- no buckling !!*
- Develop ductility through inelastic action (cyclic tension and compression yielding) in BRBs.
- System combines high stiffness with high ductility.

Buckling-Restrained Brace



Buckling-Restrained Brace

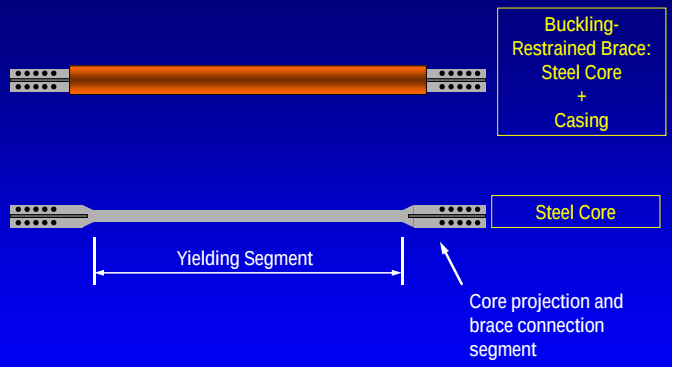


Buckling-Restrained Brace

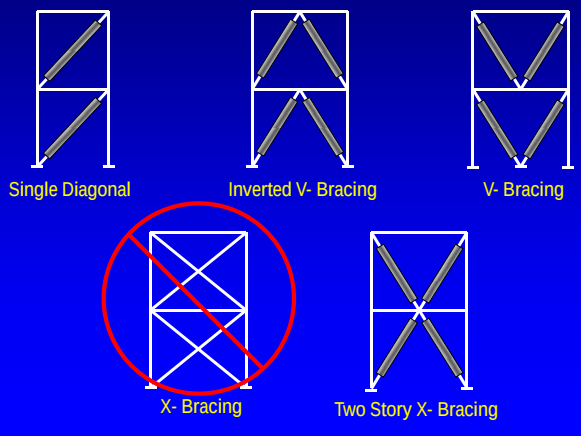
Steel core resists entire axial force P

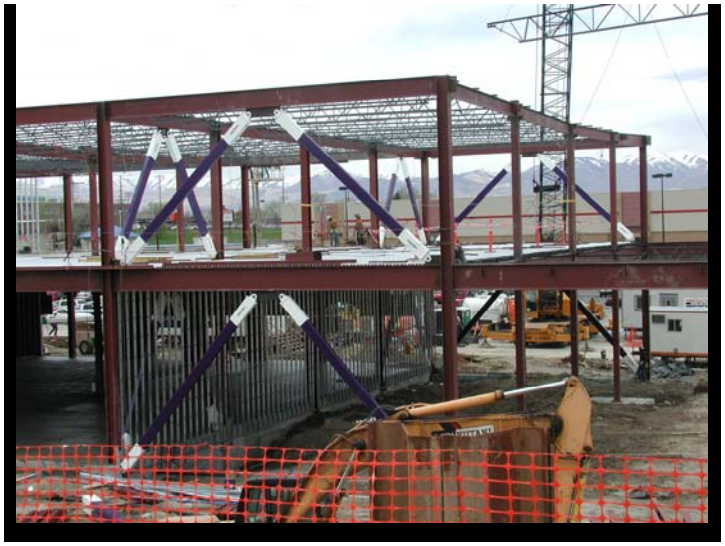
Casing is debonded from steel core
- casing does not resist axial force P
- flexural stiffness of casing restrains buckling of core

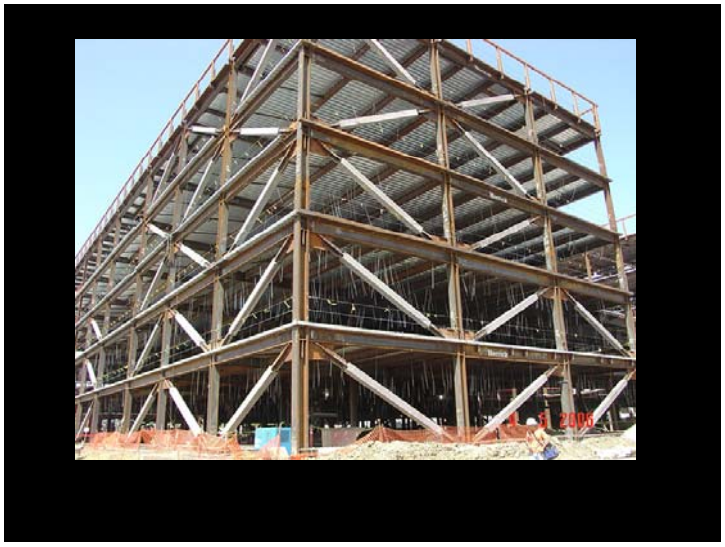
Buckling-Restrained Brace



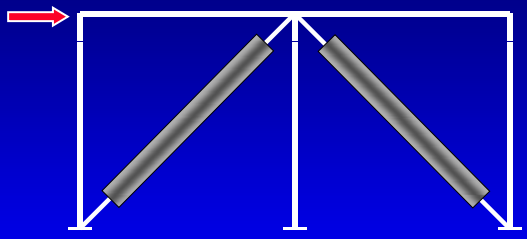
Bracing Configurations for BRBFs

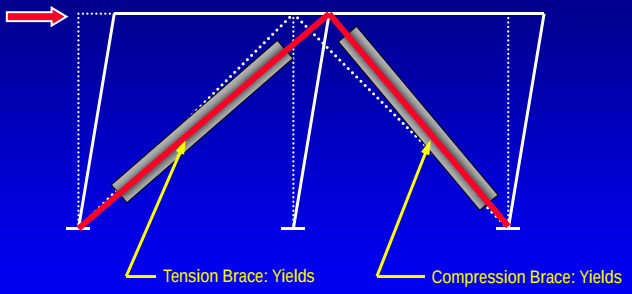




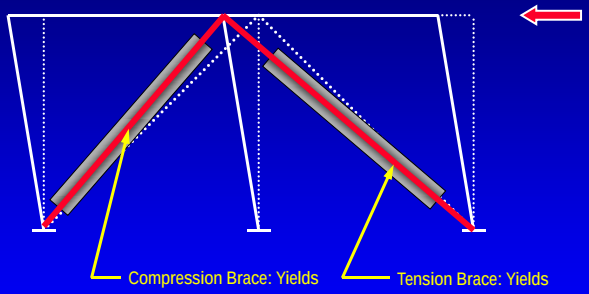


Inelastic Response of BRBFs under Earthquake Loading





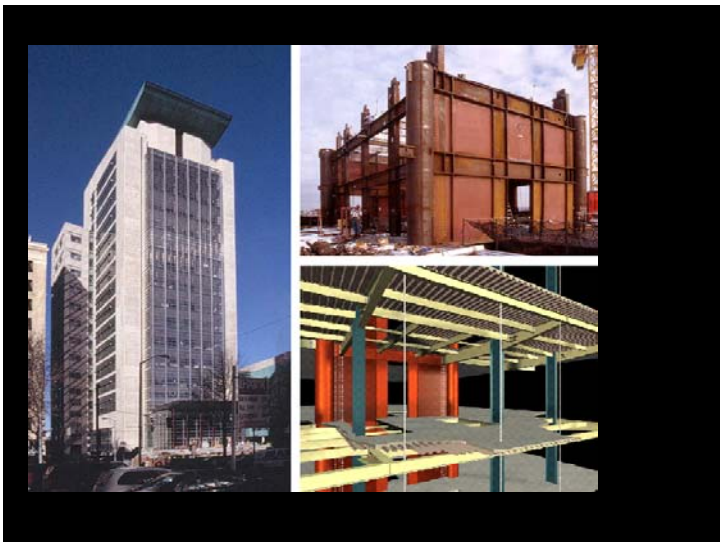
Columns and beams: remain essentially elastic



Columns and beams: remain essentially elastic

Special Plate Shear Walls (SPSW)

- Assemblage of consisting of rigid frame, infilled with thin steel plates.
- Under lateral load, system behaves similar to a plate girder. Wall plate buckles under diagonal compression and forms tension field.
- Develop ductility through tension yielding of wall plate along diagonal tension field.
- System combines high stiffness with high ductility.



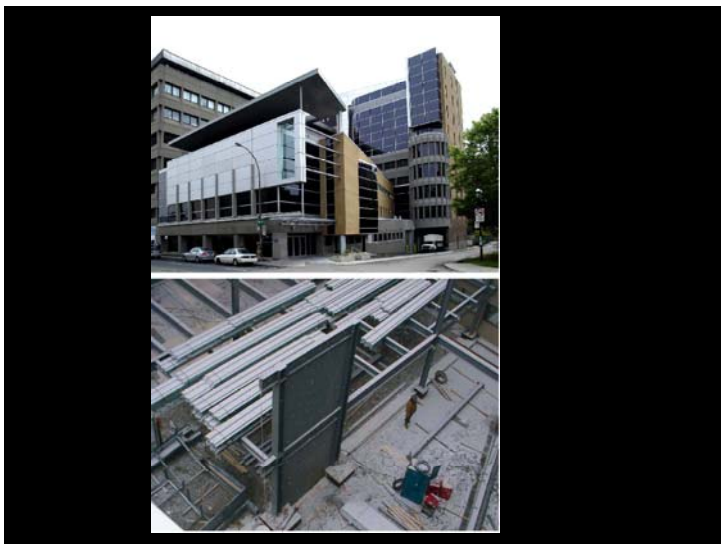
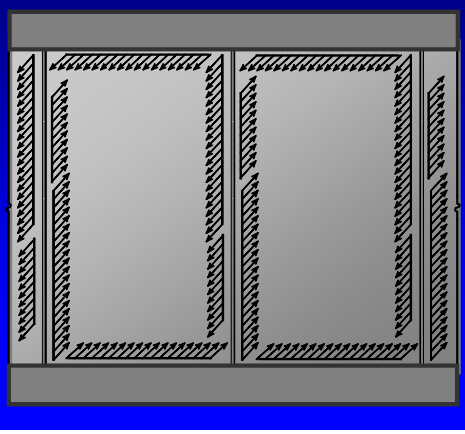
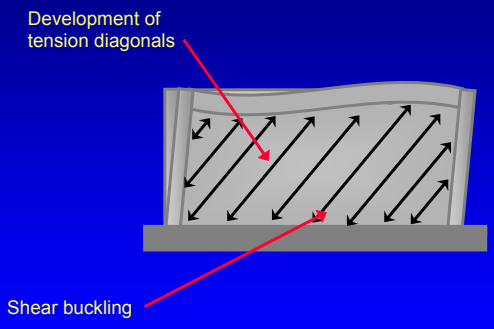


Plate-Girder Analogy



Inelastic Response of a SPSW



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2005 AISC Seismic Provisions


ANSI/AISC 341-05
An American National Standard

Seismic Provisions for Structural Steel Buildings

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