Observed Seismic Demand on Columns in SCBFs

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April 2017

Presentation Outline

- Introduction
- Seismic Response of a SCBF
- Effect of Loading Pattern
- Conclusions
- Further Study

Introduction

Fracture progress into column web (FEMA 355E)

cally Braced Fr

become popul

Column flange fracture

(Courtesy of Michael Engelhart, University of Texas, Austin)

Due to the severe damages in the SMFs in the 1994 Northridge earthquake, engineers became more interested in using SCBFs.

Reasons for damages in SMFs:

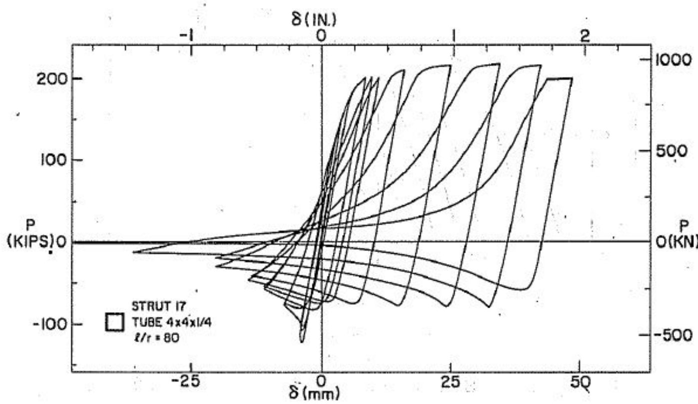
- Underestimating the material over strength
- Connection details
- On-site welding

Introduction

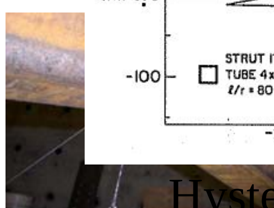
What is a CBF?

Two common shapes for braces

Dissipate EQ Energy



Hysteretic behavior of tubular bracing (Popov and Black, 1981)

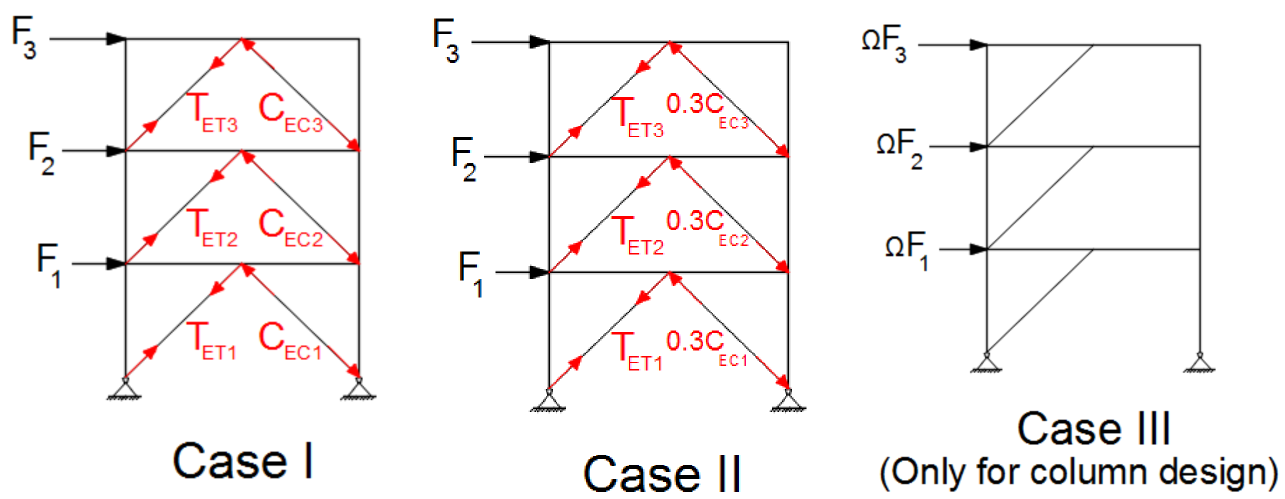


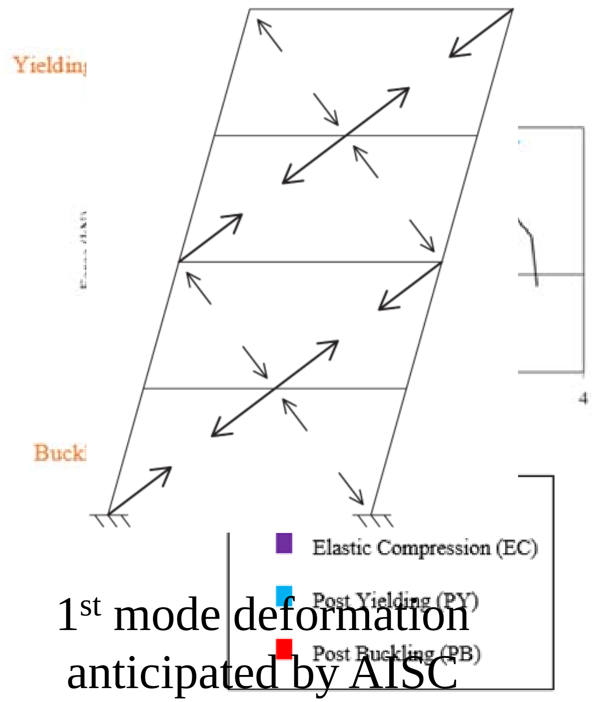
NEES Experimental Test, 2006

Lai & Mahin, 2013

Introduction

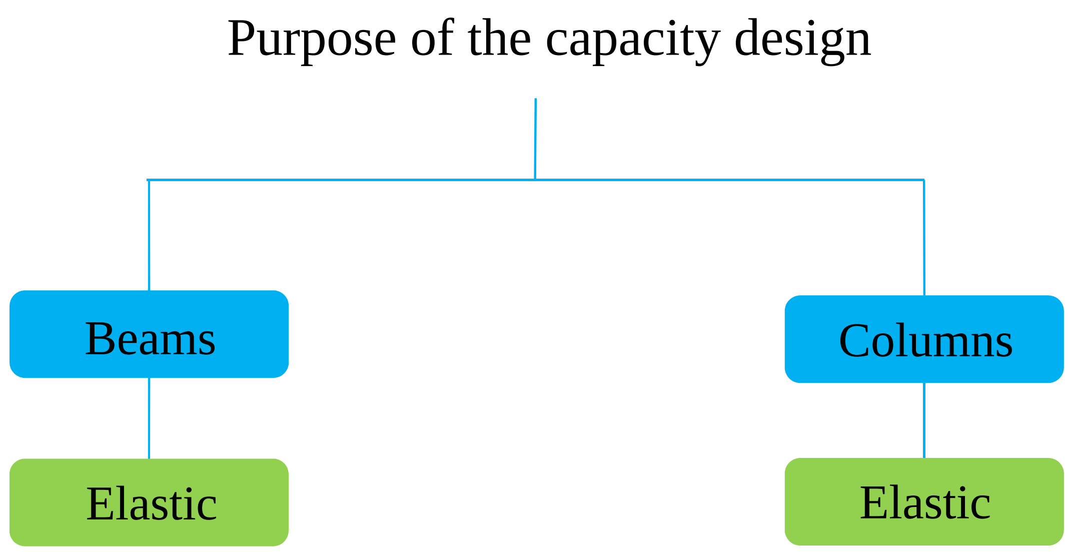
Current design procedure based on AISC 341-10





1st mode deformation anticipated by AISC

Introduction



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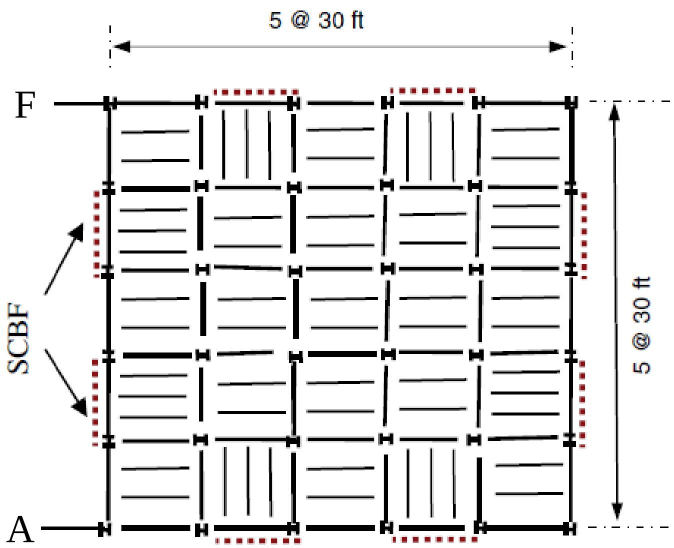
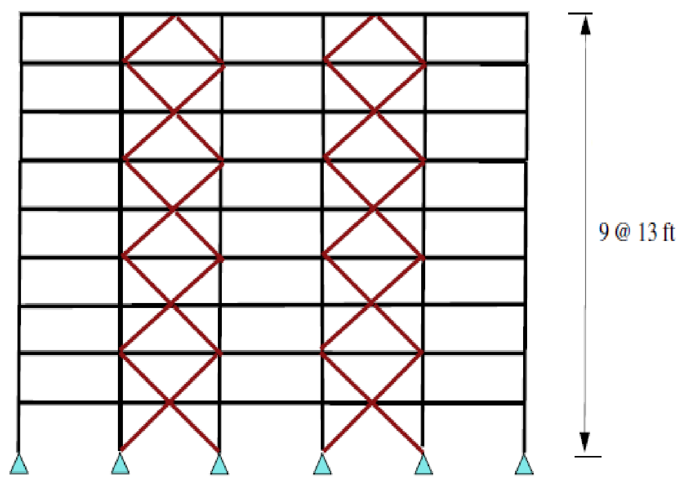
Seismic response of SCBF

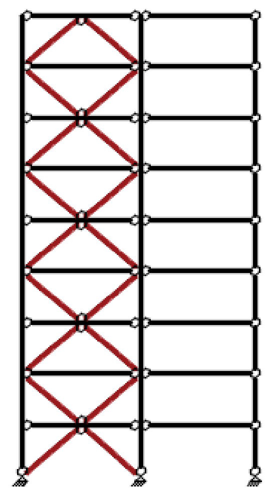
9-Story frame designed based on AISC 341-10



Typical floor plan



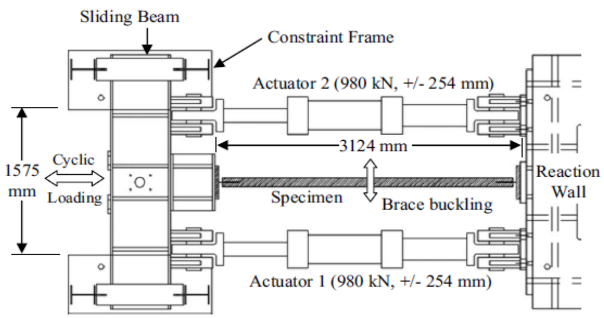
Elevation of Frame A or F



Numerical model

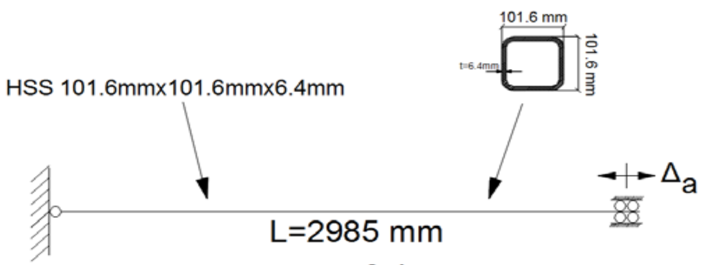
Seismic response of SCBF

Verification:



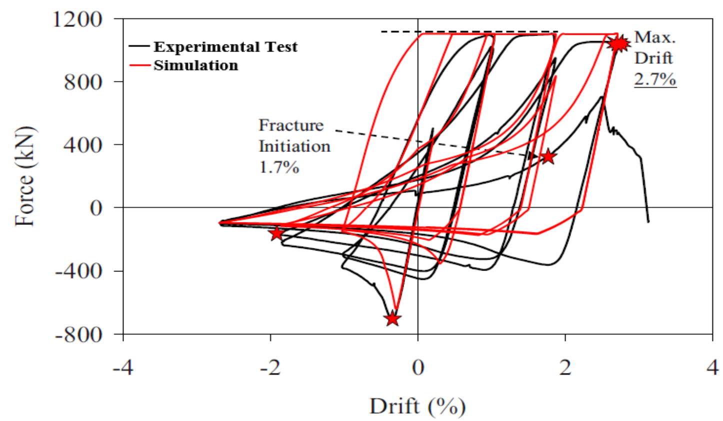
Standard Cyclic		
#cycles	Δ_a (mm)	Drift (%)
6	1.0	0.08
6	1.5	0.10
6	2.3	0.15
4	3.0	0.20 – B
2	15.5	1.03
2	27.9	1.85
2	40.4	2.68
2	59.9	4.00 - MCE
2+n	75.9	5.00

Test setup [Fell et al. (2009)]



$$\text{Drift}=\frac{2\times\Delta_a}{L}$$

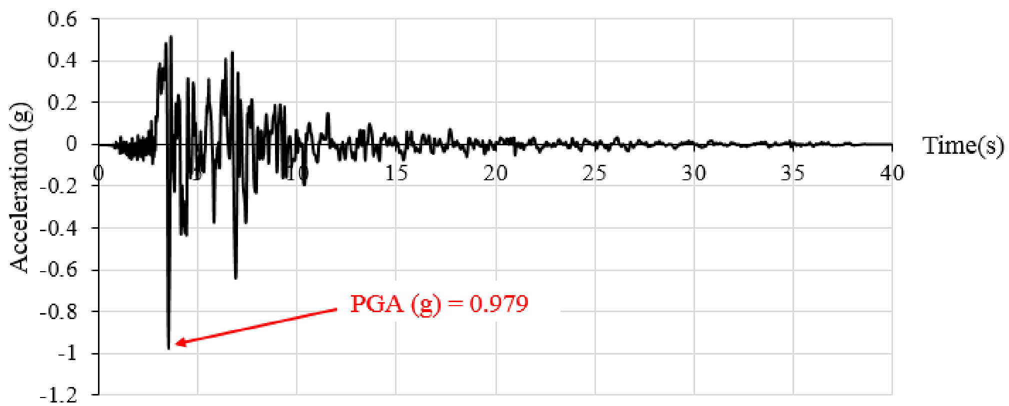
Simulated member

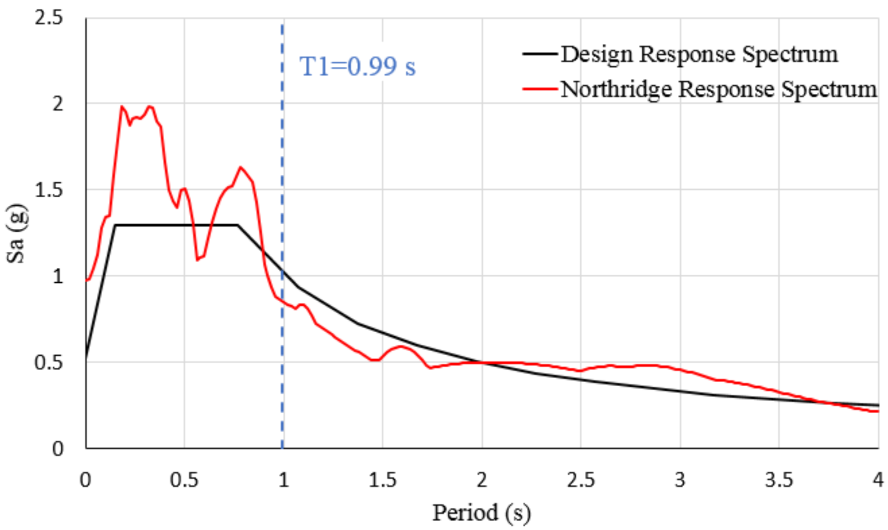


Test and simulation results

Seismic response of SCBF

Ground Motions



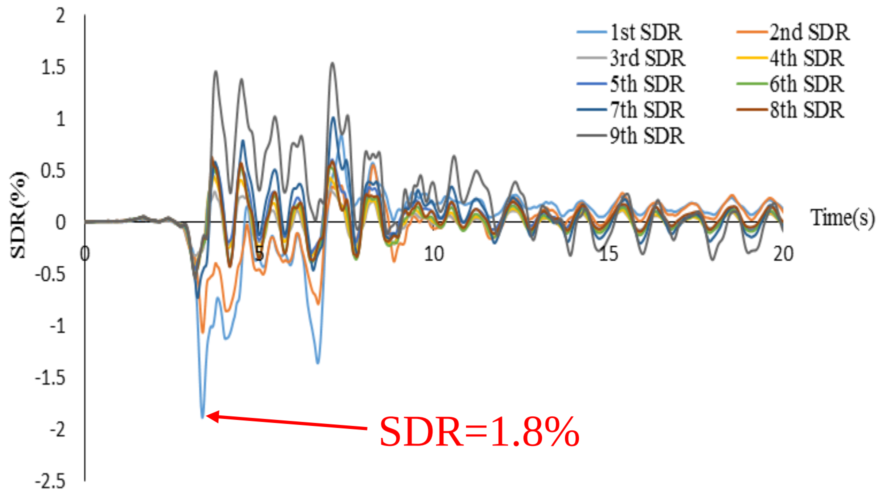


Northridge Ground Motion Specifications

ID no.	NGA#	Sc. factor	Event	Year	Mag	Duration(s)	PGA(g)	PGV(in./s)
GM01	1085	1.1675	Northridge	1994	6.69	40	0.979	53.5

Seismic response of SCBF

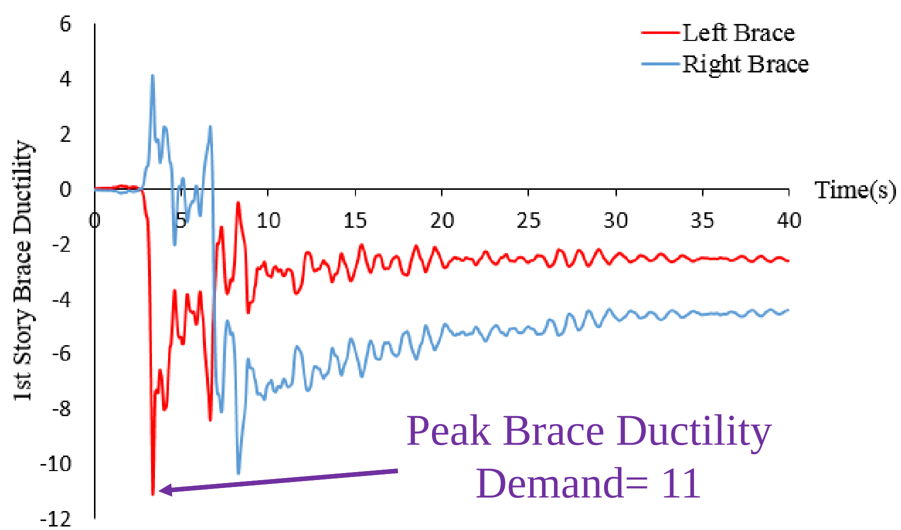
Time history analyses results-Overall response in terms of SDR



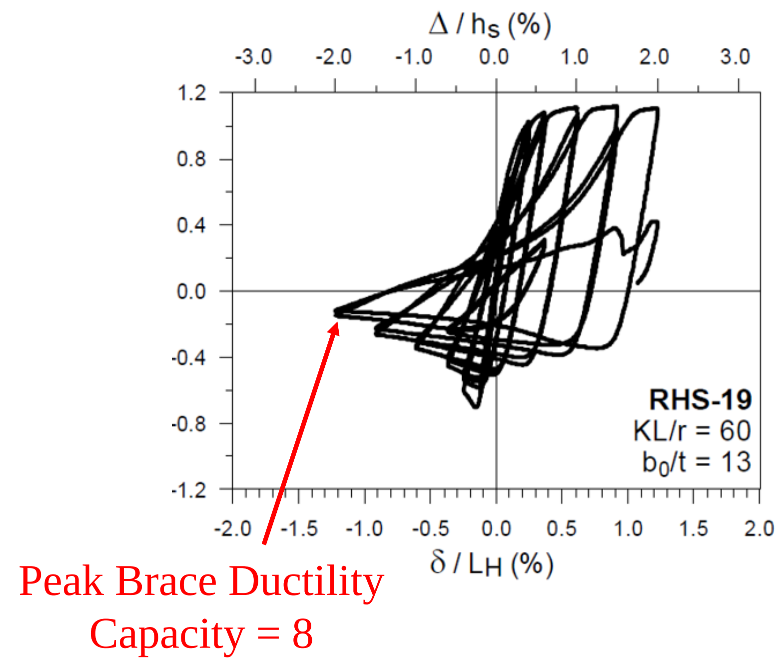
SDR time history under Northridge ground motion

Seismic response of SCBF

Time history analyses results-Brace response



Brace ductility history under Northridge ground motion

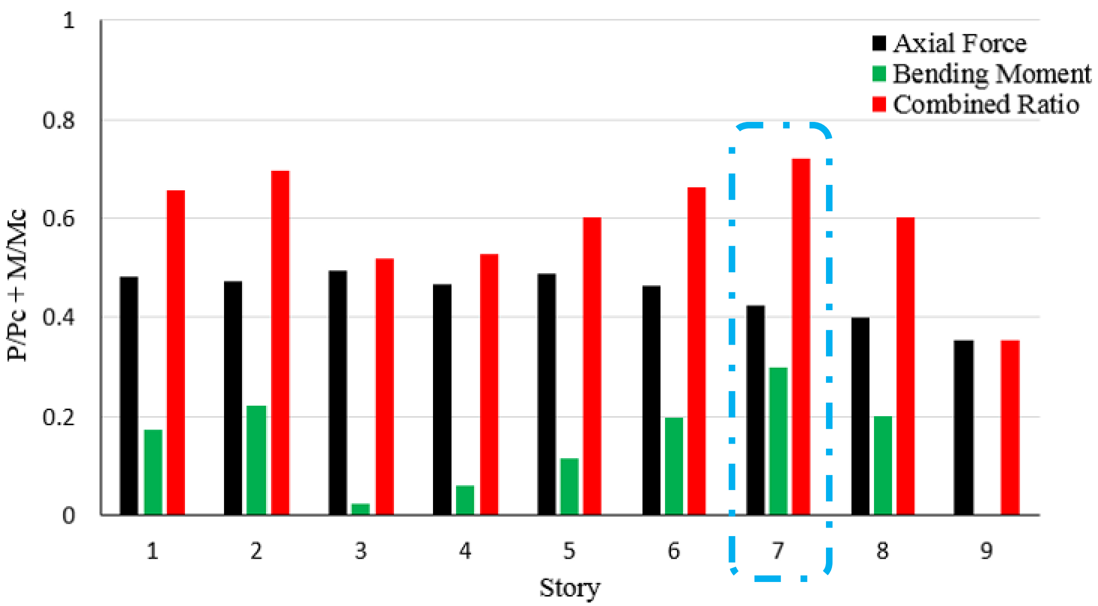


Experimental Test by Tremblay et al. (2008)

Seismic response of SCBF

Time history analyses results-Column response

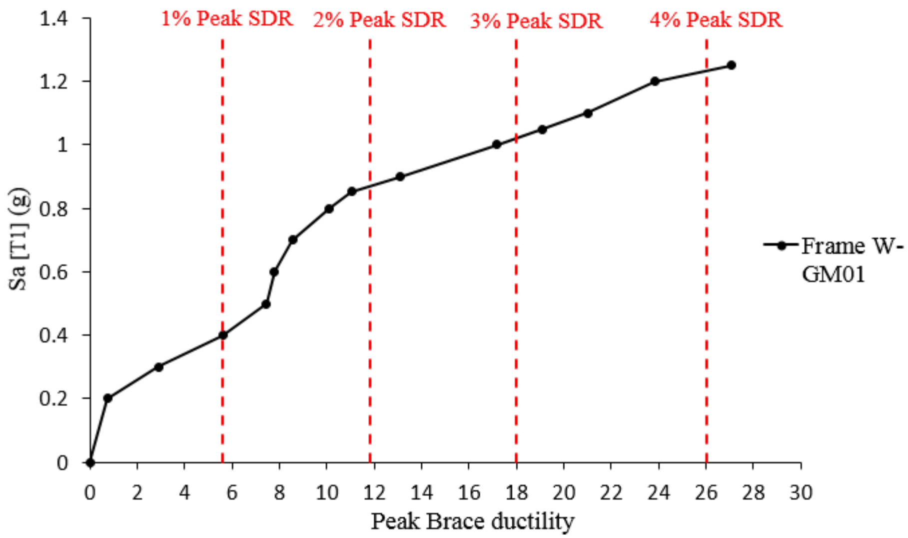
- Flexural demand grows with increasing the SDR of the frame.



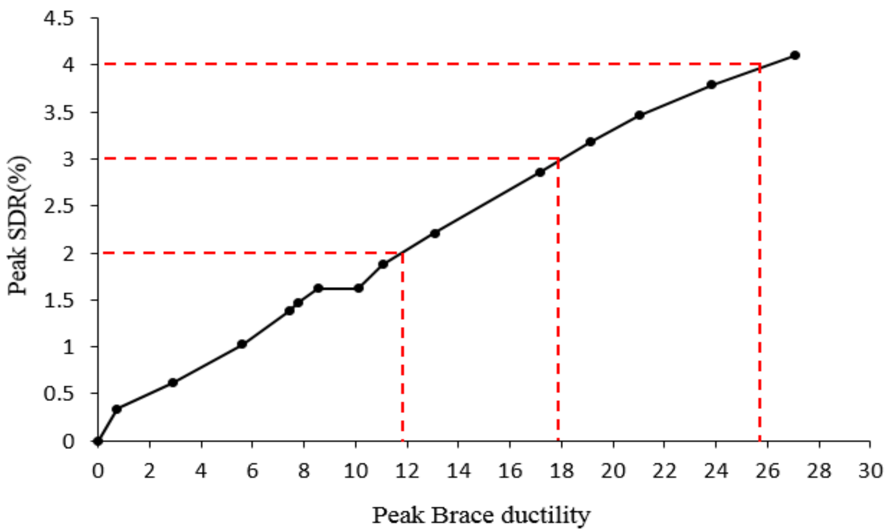
Peak demand on the columns under GM01

Seismic response of SCBF

Incremental Dynamic Analysis (IDA) results



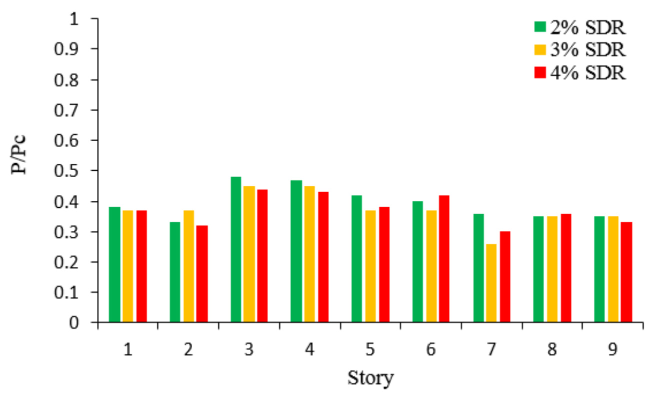
IDA response



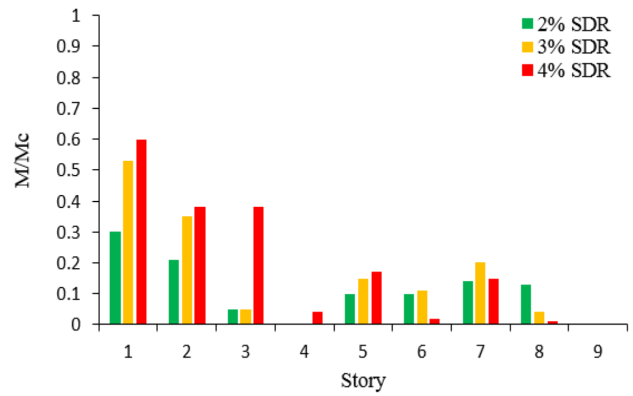
IDA response

Seismic response of SCBF

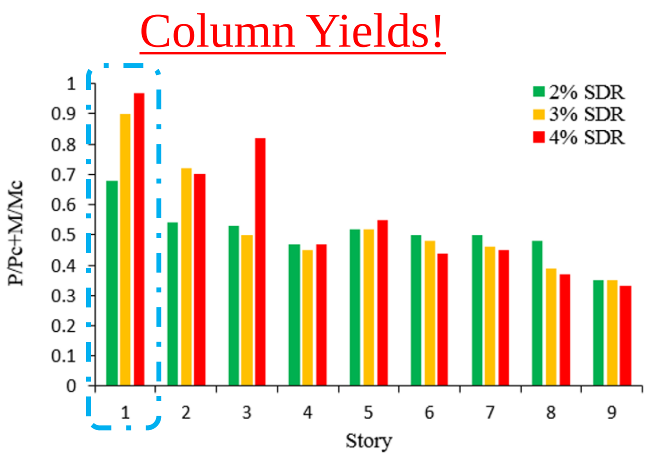
Incremental Dynamic Analysis (IDA) – Column results



Axial force demand/capacity



Flexural demand/capacity



Total demand/capacity

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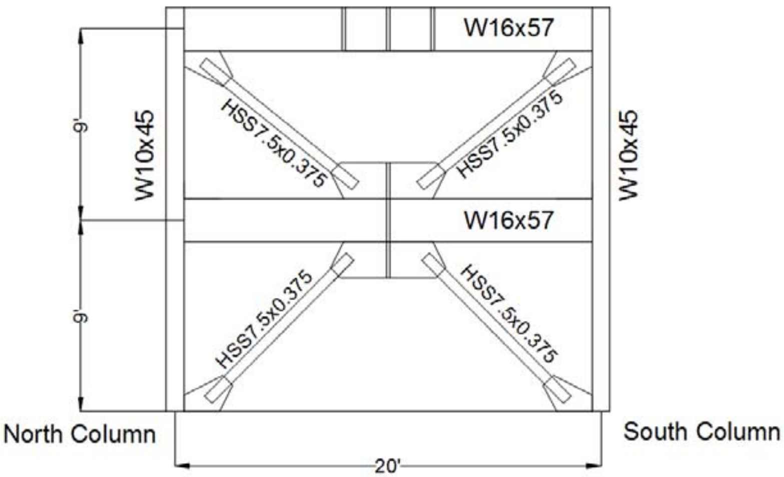
Effect of Loading Pattern

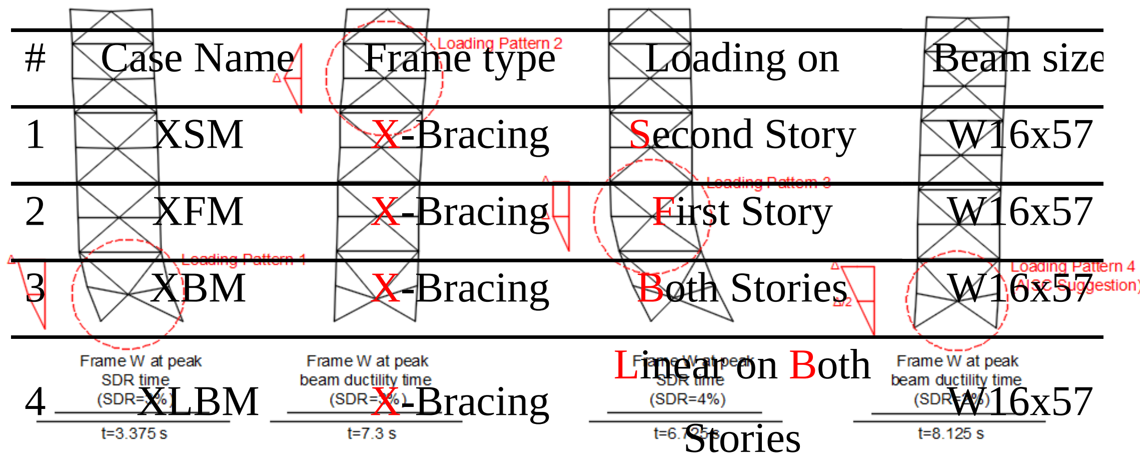
FEM of TSXBF



Simulated frame in ABAQUS

Simulated TSXB Cases

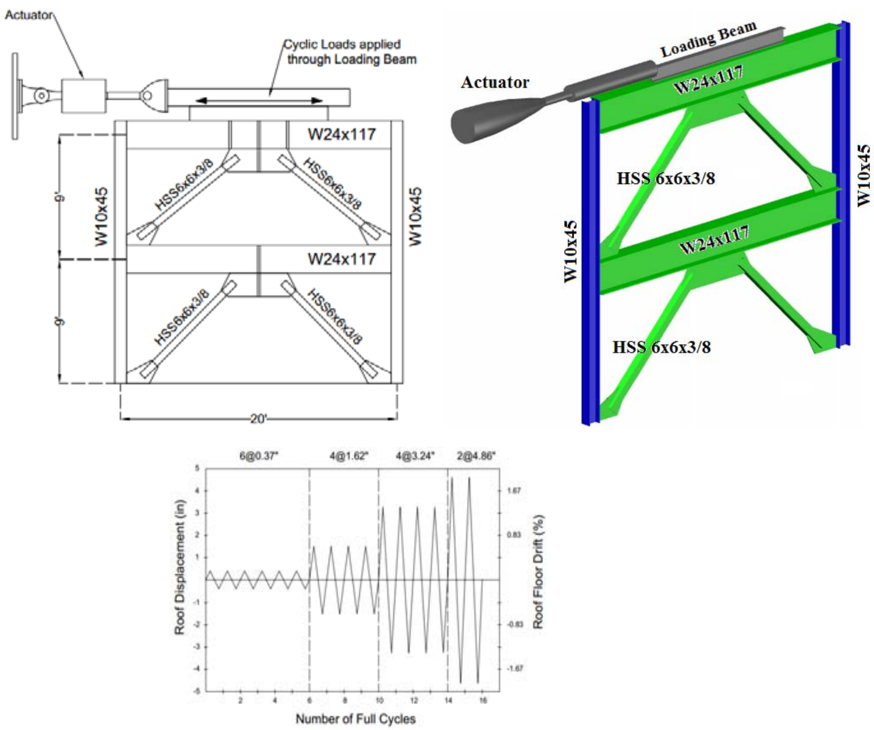
#	Case Name	Frame type	Loading on	Beam size
1	XSM	X-Bracing	Second Story	W16x57
2	XFM	X-Bracing	First Story	W16x57
3	XBM	X-Bracing	Both Stories	W16x57
4	XLBM	X-Bracing	Linear on Both Stories	W16x57



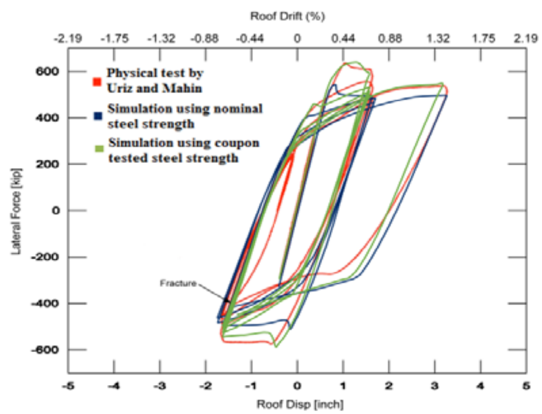
Four loading patterns achieved from dynamic time history analyses results

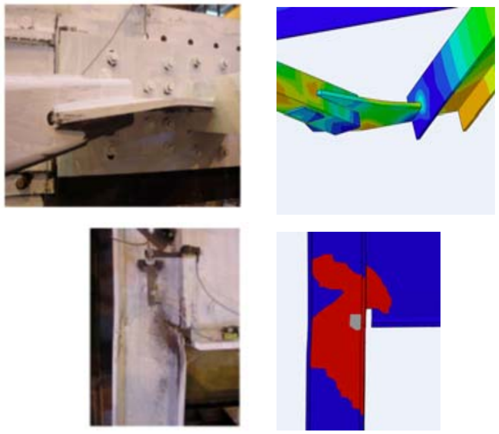
Effect of Loading Pattern

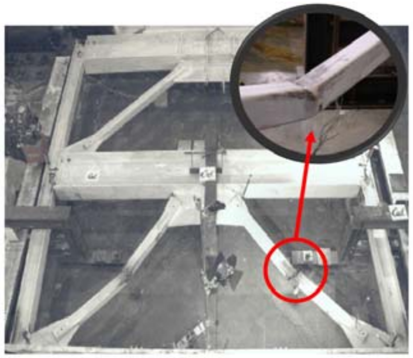
FE model verification

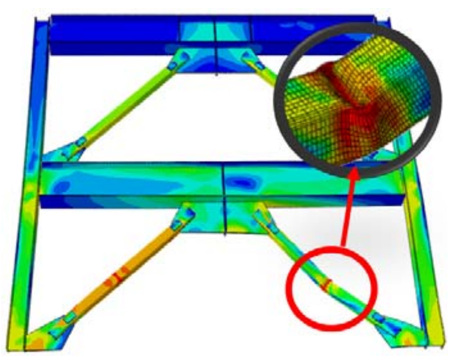


Test setup and loading protocol [Uriz and Mahin, 2001]



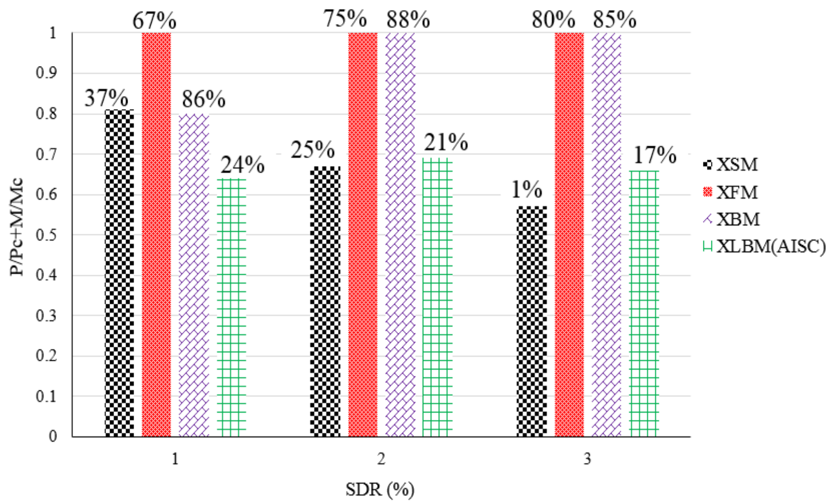


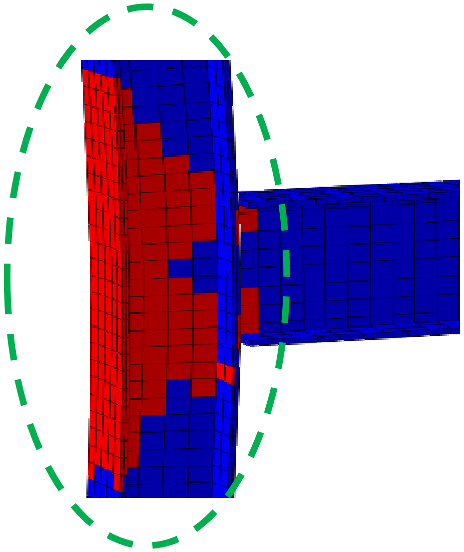




Effect of Loading Pattern

FEM results





Column yielded elements in XFM model

Observations:

- Loading pattern suggested by AISC is not necessarily the worst case.
- Higher mode deformation has a significant effect on the demand.

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Conclusions

- ***Brace ductility demand*** at design drift limit can be ***larger than*** brace ductility ***capacity***.
- ***Brace ductility demand*** might be ***as large as 25*** at 4% story drift ratio.
- ***Columns*** in special concentrically braced frames ***experience yielding*** which is unexpected.
- ***First mode loading pattern is not*** necessarily the most ***critical pattern*** for designing of the two-story X-braced frames.
- Further study needed to evaluate the seismic demand on the columns in SCBFs by using more ground motions and make recommendations to improve the current design procedure if necessary.

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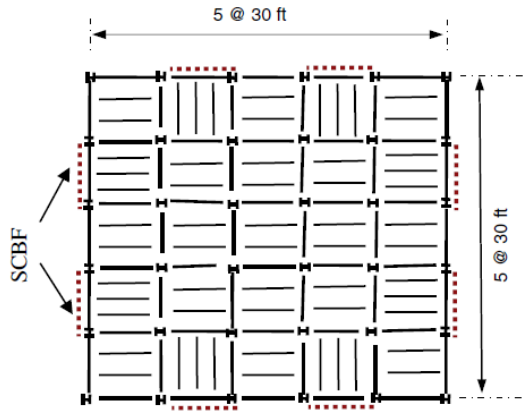
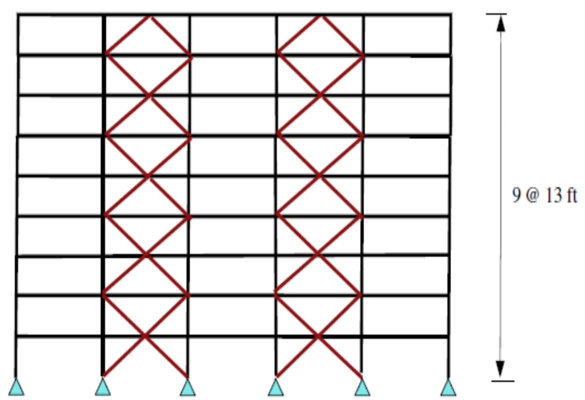
Further Study

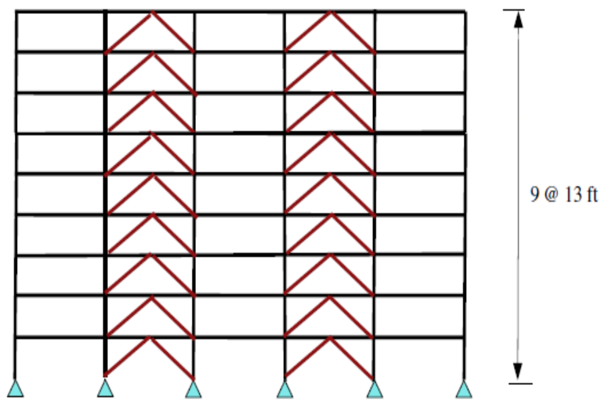
- Seismic performance of concentrically braced frames with and without brace buckling
  Engineering Structures
- Seismic demand on brace-intersected beams in two-story X-braced frames
  Engineering Structures
- Mechanisms in Two-Story X-Braced Frames
  Journal of Constructional Steel Research
- Seismic Performance of All-Steel Buckling-Controlled Braces with Various Cross-Sections
  Journal of Constructional Steel Research (under review)

Thank you!

Frame Design





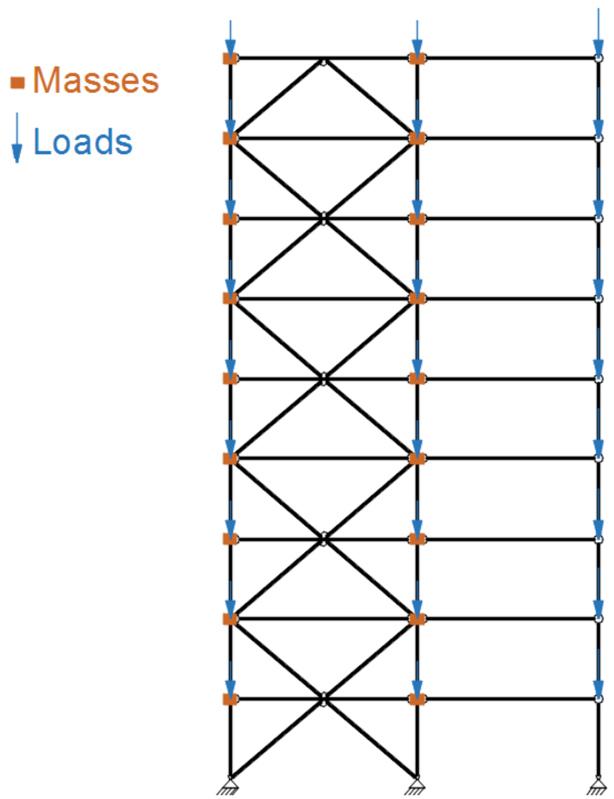


Dead Load= 80 psf
Live Load= 50 psf
S_s =2.0
S_1 =1.0
C_s =0.22

Frame Design

Level	Braces	Columns in braced bays	Beams			Gravity Columns	Gravity Beams
			Frame W	Frame S	Frame C		
9	HSS 8.625×0.375 (KL/r = 81, D/t = 24.7)	W14×48	W30×211	W30×211	W30×211	W10×33	W18×65
8	HSS 10×0.625 (KL/r = 71.1, D/t =17.2)	W14×132	W18×86	W18×86	W33×318	W10×33	
7			W18×65	W30×326			
6	HSS 10×10×5/8 (KL/r = 62.5, D/t = 14.2)	W14×233	W21×93	W21×93	W36×395	W10×33	
5			W18×65	W33×387			
4	HSS 14×0.625 (KL/r = 50, D/t = 24.1)	W14×370	W21×111	W21×111	W36×395	W10×33	
3			W18×65	W36×395			
2	HSS 14×0.625 (KL/r = 50, D/t = 24.1)	W14×550	W21×111	W21×111	W36×395	W10×33	
1			W18×65	W36×395			

Seismic Behavior of SCBFs



Loads and masses applied to the simulated frames.

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