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## R-Factors for Coupled Composite Plate Shear Walls—Concrete Filled (Coupled-C-PSW/CF)

Presented to BSSC PUC  
San Francisco, December 4, 2018

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## Project Scope

- This project seeks R-Factors developed from FEMA P-695 studies for Coupled Composite Plate Shear Walls—Concrete Filled (Coupled-C-PSW/CF), for inclusion in ASCE-7, higher than R-factors for corresponding non-coupled walls.

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## Agenda

- Brief summary of previously presented completed work
- Recent experimental results on C-shaped walls
- Calibration of non-linear models
- IDA analysis results for 8 and 12 story walls
- FE verifications (“spot-checking”)
- Overview of proposed design procedure
- Steps forward

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## Previous Meetings with BSSC PUC


- April 4<sup>th</sup> 2018
  - Project objectives, research team and PRP, description of structural system and applications, past experimental and analytical research, AISC H7, archetype developments, non-linear models used for P-695 study, and example IDA result
- August 16<sup>th</sup> 2018
  - Design Philosophy for Archetype Structures, calibration of non-linear models to planar walls and coupling beams, example results and cross-checks

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## C-PSW/CF

- Concrete-filled steel sandwich
- Steel serves as formwork and able to resist gravity loads during erection
- Shipped assembled in segments




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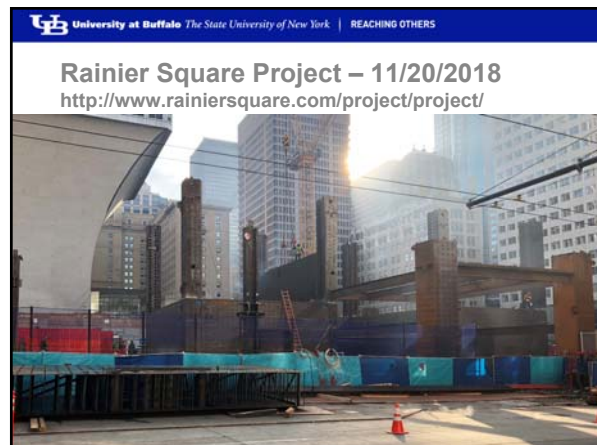
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## Implementation

- Rainier Square Project
  - 58 Stories
  - Seattle
  - Under construction
  - MKA Project
  - Webcam on project website



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**ASCE-7 2010**

Table 12.2-1 of ASCE-7 2010 refers to "composite plate shear walls" and ASCE Section 14.3 for detailing requirements, which itself, refers to AISC 341-10.

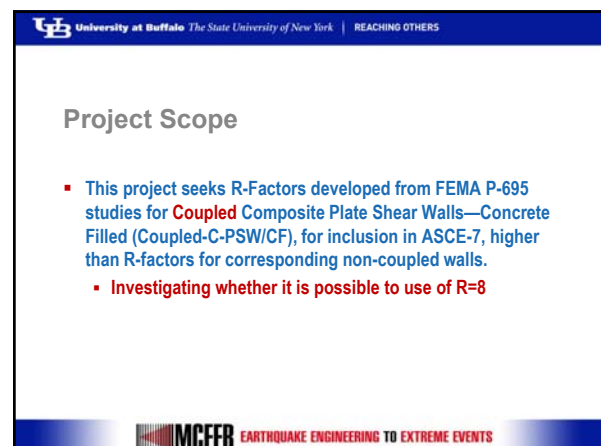
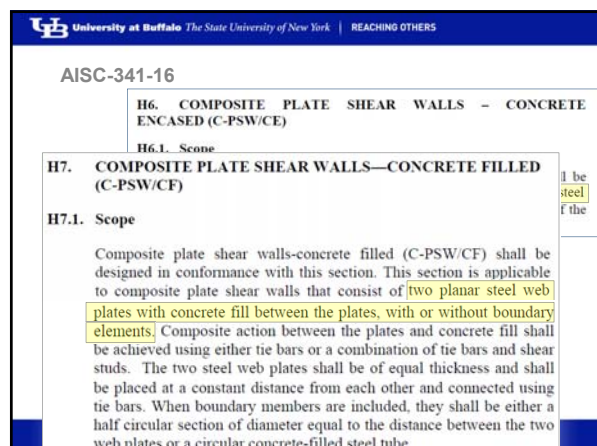
Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, $R$	Overstrength Factor, $\Omega$	Deflection Amplification Factor, $\Delta$	Structural System Limitations (Height, $h$ , in Feet)			
					B	C	1F	1F
4. Special reinforced concrete shear walls <sup>a</sup>	14.2	6	2%	5	NS	NS	100	100
5. Ordinary reinforced concrete shear walls <sup>a</sup>	14.2	5	2%	4%	NS	NS	NP	NP
6. Encased plain concrete shear walls <sup>a</sup>	14.2 and 14.2.5.8	2	2%	2	NS	NP	NP	NP
7. Ordinary plain concrete shear walls <sup>a</sup>	14.2	3%	2%	1%	NS	NP	NP	NP
8. Nonmoment-resisting shear walls <sup>a</sup>	14.2	5	2%	4%	NS	NS	NP	NP
9. Ordinary moment-resisting shear walls <sup>a</sup>	14.2	4	2%	4	NS	NP	NP	NP
10. Steel and concrete composite moment-resisting braced frames	14.3	8	2%	4	NS	NS	100	100
11. Steel and concrete composite special moment-resisting braced frames	14.3	5	2	4%	NS	NS	100	100
12. Steel and concrete composite ordinary moment-resisting frames	14.3	3	2	3	NS	NS	NP	NP
13. Steel and concrete composite plate shear walls	14.3	6½	2%	7%	NS	NS	100	100

**14.3.3 Seismic Requirements for Composite Steel and Concrete Structures**  
 Where a response modification coefficient,  $R$ , in accordance with Table 12.2-1 is used for the design of systems of structural steel acting compositely with reinforced concrete, the structures shall be designed and detailed in accordance with the requirements of AISC 341.

**13. Steel and concrete composite plate shear walls**

14.3      6½      2½      5½

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**FEMA P-695 REQUIREMENTS**

- Peer Review Panel (PRP) responsible for reviewing and commenting on all steps of the approach taken by the system development team (see figure)
- PRP members to evaluate the development and provide an unbiased assessment (FEMA 2009)
- PRP meetings to review:
  - Archetype selection
  - Inelastic models**
    - IDA results and interpretation
    - Selection of  $\beta$  factors
    - Others?

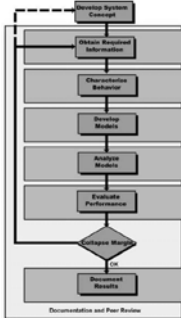
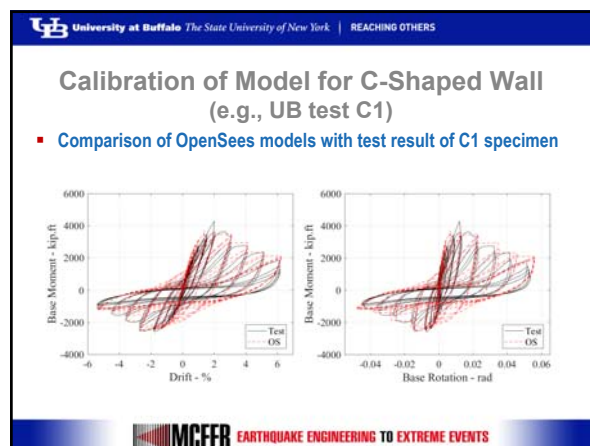
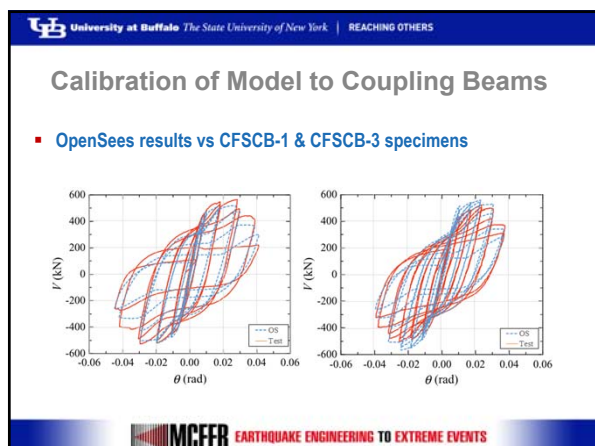
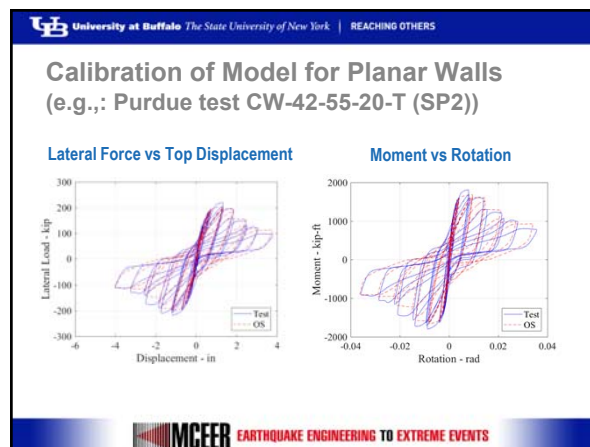
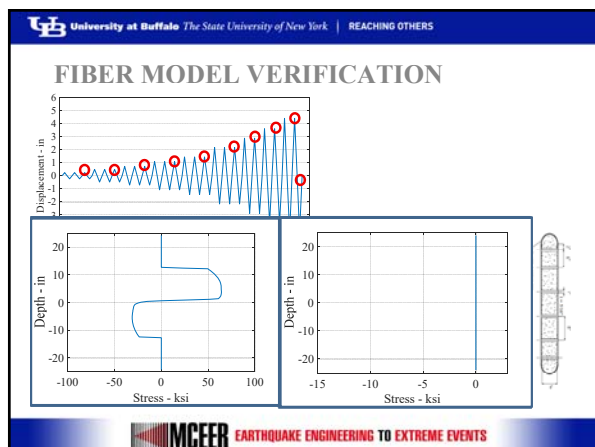
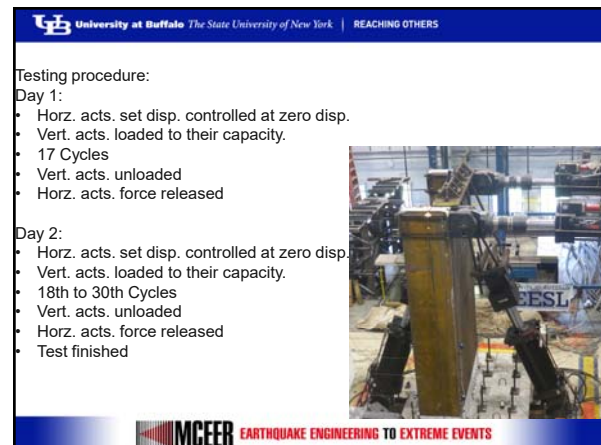
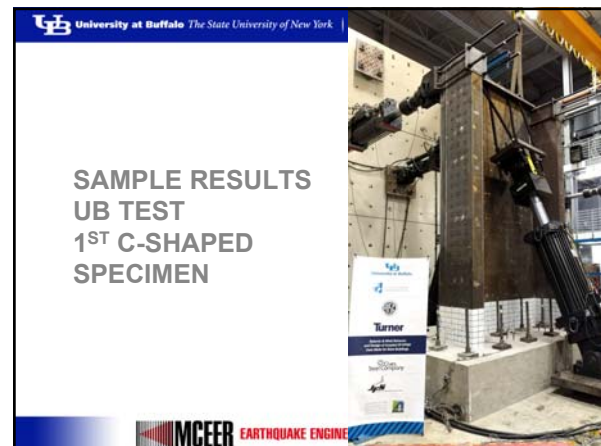
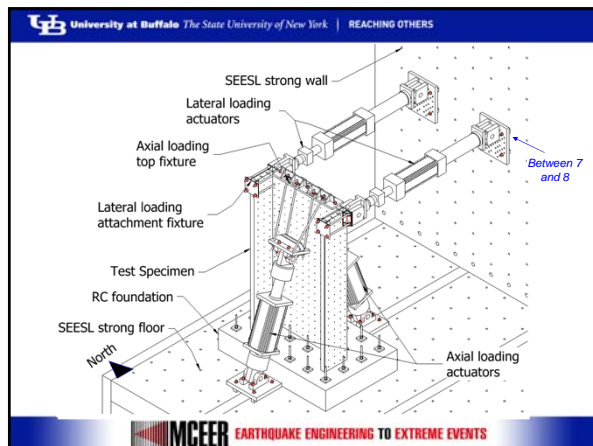


Figure 2: Steps of the FEMA P-695 Methodology

**Status Report on Inelastic Modeling**

- Deliberate decision to model the walls with different approaches to enhance confidence in results
  - UB: OpenSees, fiber hinges in walls and coupling material models using *Reinforcing Steel Material* (Kunnath) and Concrete 02 (properties by Susantha et al.)
  - Purdue: OpenSees, fiber hinges in walls using *Reinforcing Steel Material* (Kunnath) and Tao Concrete Model, discrete plastic hinges in coupling beams
  - Purdue: "Spot-checking" select IDA results with Abacus





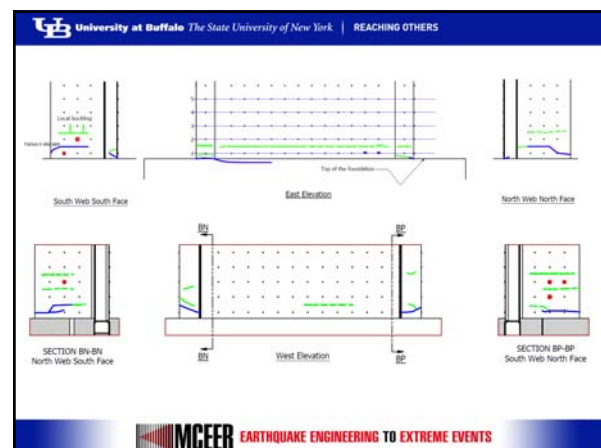
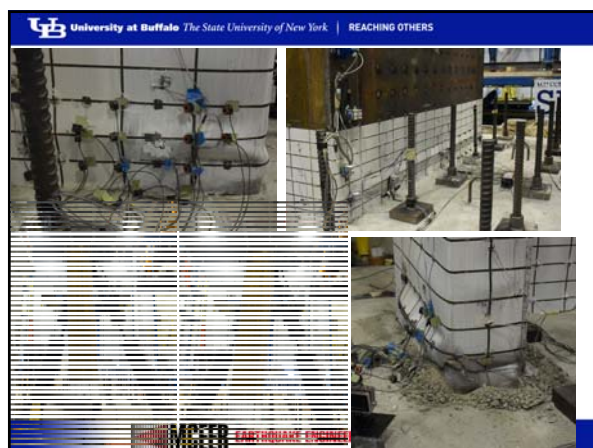
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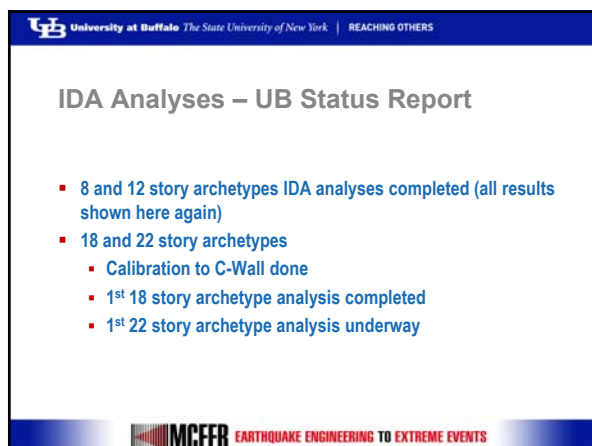
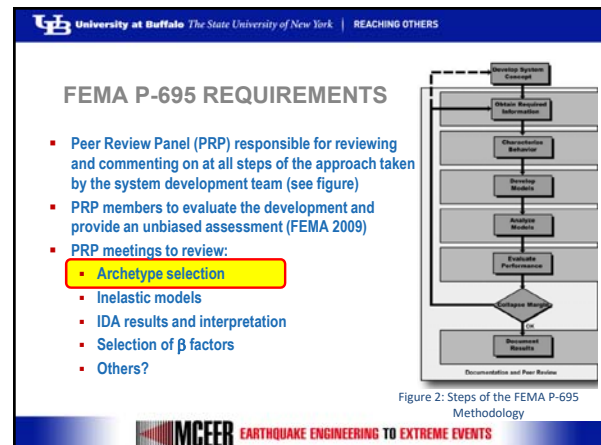
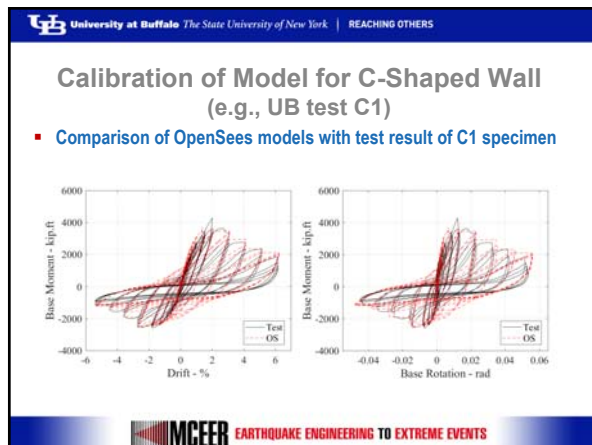
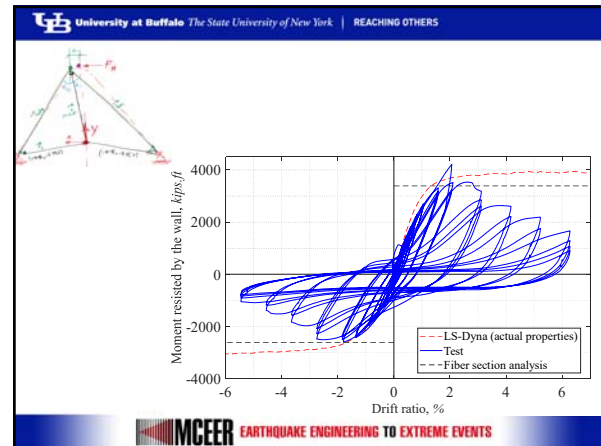
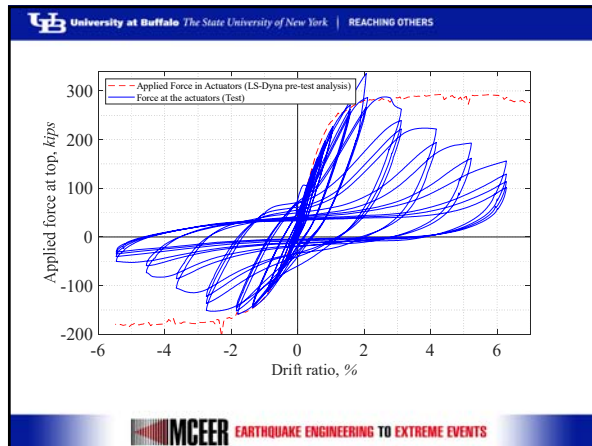
##### Day 1:

- Horz. acts. set disp. controlled at zero disp.
- Vert. acts. loaded to their capacity.
- 17 Cycles
- Vert. acts. unloaded
- Horz. acts. force released

##### Day 2:

- Horz. acts. set disp. controlled at zero disp.
- Vert. acts. loaded to their capacity.
- 18th to 30th Cycles
- Vert. acts. unloaded
- Horz. acts. force released
- Test finished





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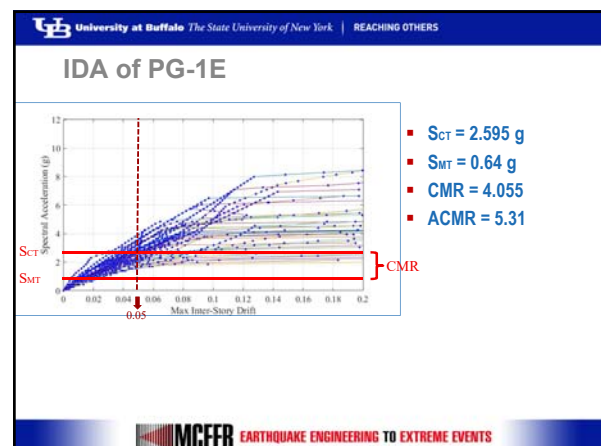
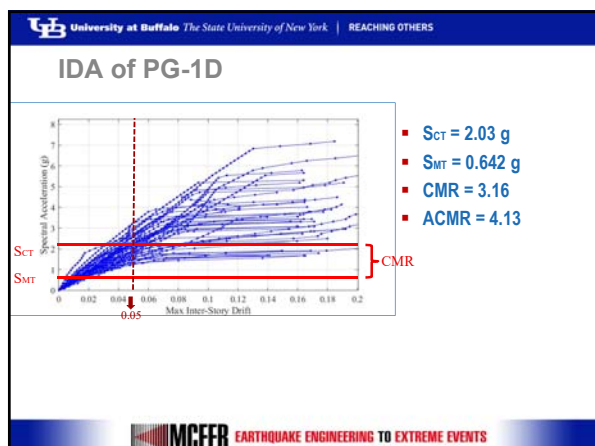
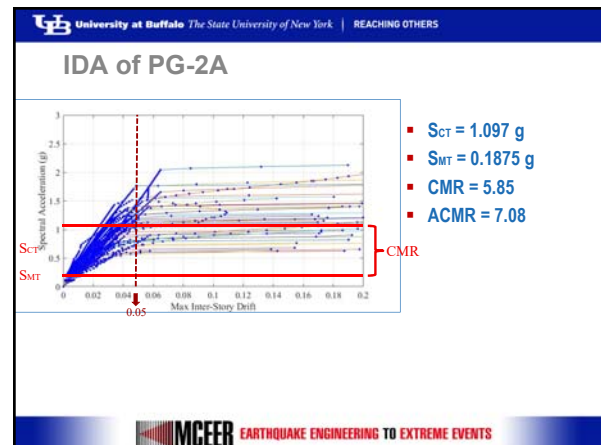
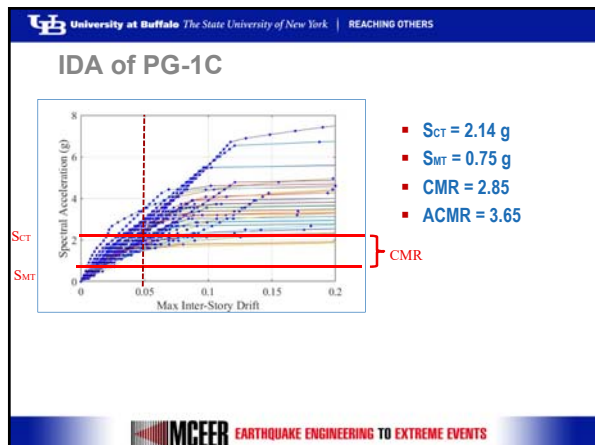
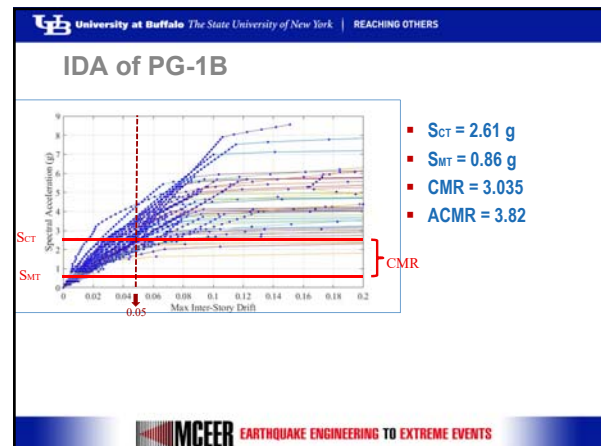
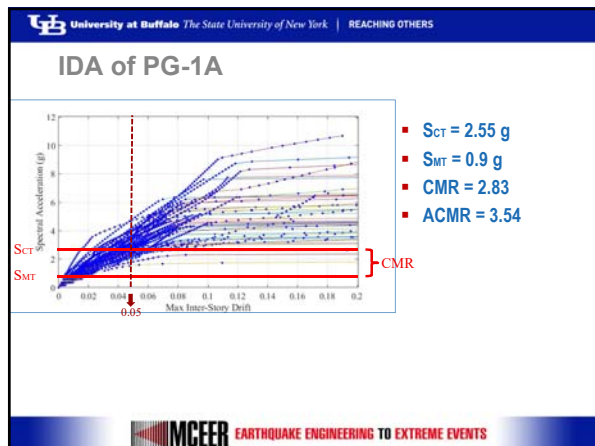
### ARCHETYPES

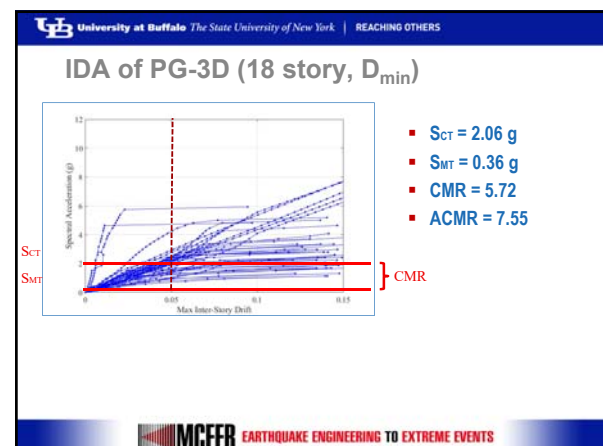
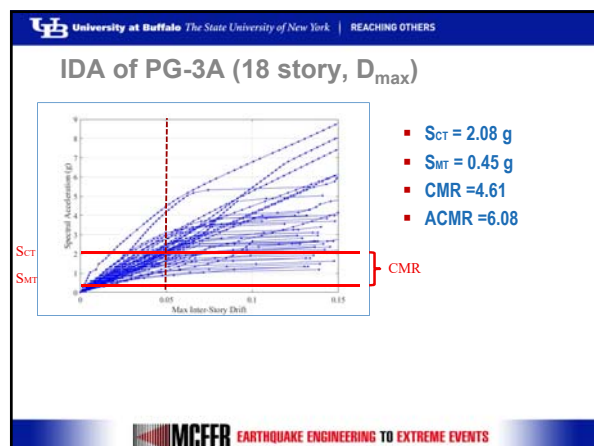
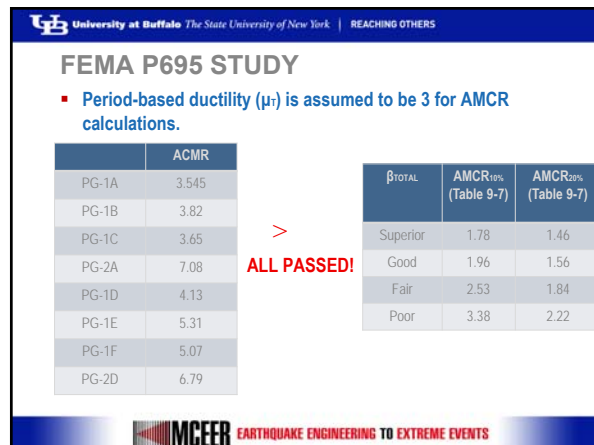
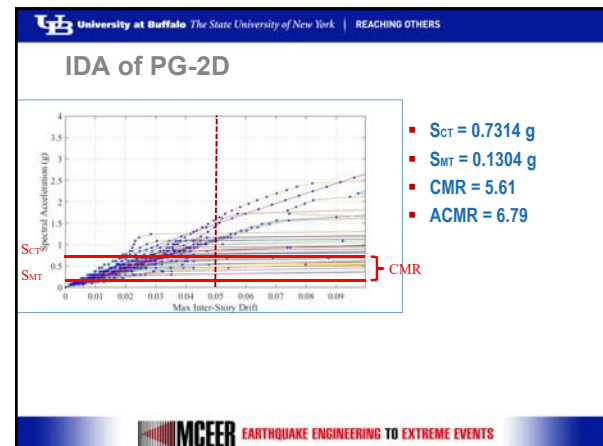
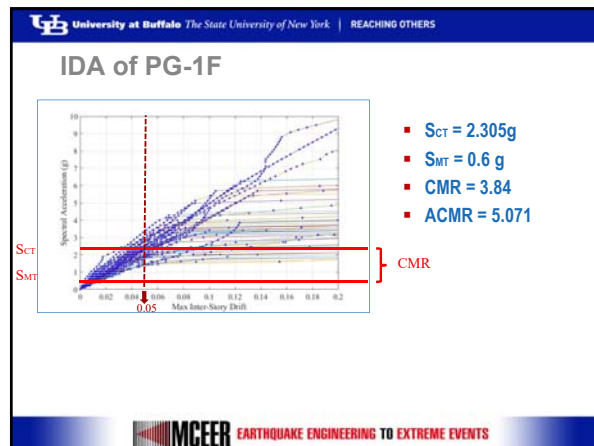
Case	No. Stories	$L/d$	$Cu/Tu, x$	$Tmbs, x$	$Cs$	$Lx, in$	$h, in$	$tp, in$	$Lp, in$	CB Section, in	$Lz, in$	$\phi MuOTM$	$\phi Vu/Vms$	IDR <sub>max</sub>
PG-1A	8	3	0.98	1.03	0.076	144	20	9/16	72	$20 \times 24$ $1/4(d), 1/4(w)$	252	1.17	6.3	2.2%
PG-1B	4	0.98	1.06		132	24	9/16	96		$24 \times 24$ $1/4(d), 1/4(w)$	240	1.26	6.00	2.2%
PG-1C	5	0.98	1.16		120	24	5/8	120		$24 \times 24$ $1/4(d), 1/4(w)$	240	1.78	5.93	2.3%
PG-2A	8	3	1.05	1.71	0.024	153	8	3/16	54	$8 \times 18$ $1/4(d), 1/4(w)$	252	1.22	7.45	2.1%

Case	No. Stories	$L/d$	$Cu/Tu, x$	$Tmbs, x$	$Cs$	$Lx, in$	$h, in$	$tp, in$	$Lp, in$	CB Section, in	$Lz, in$	$\phi MuOTM$	$\phi Vu/Vms$	IDR <sub>max</sub>
PG-1D	12	3	1.32	1.44	0.057	204	18	9/16	72	$18 \times 24$ $1/4(d), 1/4(w)$	348	1.12	7.81	2.2%
PG-1E	4	1.32	1.39		192	22	9/16	96		$22 \times 24$ $1/4(d), 1/4(w)$	336	1.16	7.70	2.2%
PG-1F	5	1.32	1.43		180	24	9/16	120		$24 \times 24$ $1/4(d), 1/4(w)$	324	1.30	7.34	2.3%
PG-2D	12	3	1.42	2.21	0.017	213	6	3/16	54	$6 \times 18$ $1/4(d), 1/4(w)$	348	1.02	8.73	2.1%

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**FEMA P695 STUDY**

- Period-based ductility ( $\mu_T$ ) is assumed to be 3 for AMCR calculations.

	ACMR
PG-3A	6.08
PG-3D	7.55

**ALL PASSED!**

$\beta_{TOTAL}$	AMCR <sub>10%</sub> (Table 9-7)	AMCR <sub>20%</sub> (Table 9-7)
Superior	1.78	1.46
Good	1.96	1.56
Fair	2.53	1.84
Poor	3.38	2.22

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**Amit Varma to Present**

- IDA Analyses – Purdue Results
  - 8 & 12 story archetypes
  - F.E. “spot-checks”
- Review of Design Procedure

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**PUC Submission Schedule**

- “Straw-man” draft submitted to PUC to collect red-flags
- Early January submission of draft proposal to IT-4
- IT-4 February 6<sup>th</sup> meeting to review draft proposals
- S.K. Ghosh submits proposals to PUC in February
- April PUC ballot

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**BSSC – PUC Timetable**

2020 NEHRP PROVISIONS SCHEDULE

	2016	2017	2018	2019	2020
PUC MEETINGS	J, F, M, A, M, J, J, A, S, O, N, D	J, F, M, A, M, J, J, A, S, O, N, D	J, F, M, A, M, J, J, A, S, O, N, D	J, F, M, A, M, J, J, A, S, O, N, D	J, F, M, A, M, J, J, A, S, O, N, D
PUC Scope Development					
PUC Proposal Development					
PUC Meeting					
PUC Ballots					
MO Ballots					
Proposals to ASCE/SEI 7 SSC					
Publish 2020 Provisions					

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