National Earthquake Hazards Reduction Program

NIST/EEG Earthquake Engineering Research Update

Advisory Committee on Earthquake Hazards Reduction

March 3 & 4, 2016

FEMA

NIST
National Institute of Standards and Technology

NSF

USGS
science for a changing world

nehrp

national earthquake hazards reduction program

National Earthquake Hazards Reduction Program

Steven L. McCabe, Leader

Earthquake Engineering Group

Materials and Structural Systems Division

Engineering Laboratory

Presentation Outline

- NIST/EEG Program Overview
  - Current and Planned Projects
    - Internal and External
    - Accomplishments
- Response to ACEHR Comments
- Questions

NIST/EEG Internal Projects

Validation of ASCE 41 Procedures in Performance Based Seismic Engineering - completion in FY2016

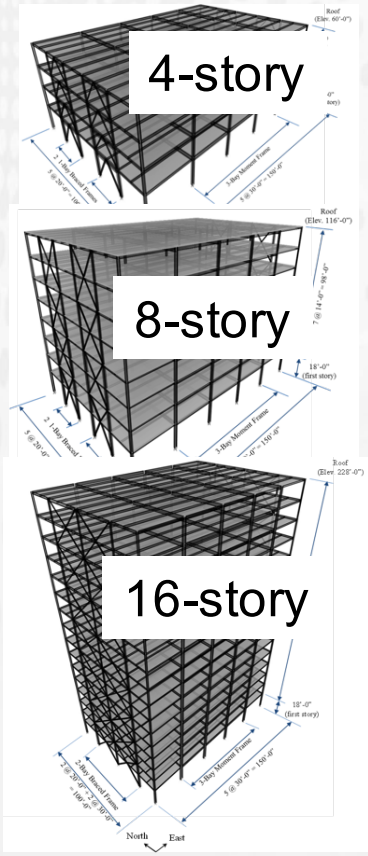
Jay Harris, Matthew Speicher & Siamak Sattar

- To advance first-generation performance-based seismic engineering (PBSE) methods by assessing the performance of a set of code-compliant buildings using ASCE/SEI 41 methodologies.
  - Project 1: 3 Structural Steel Systems
  - Project 2: 1 Structural Steel System
  - Project 3: 1 Reinforced Concrete System

Significant Interest by the Community

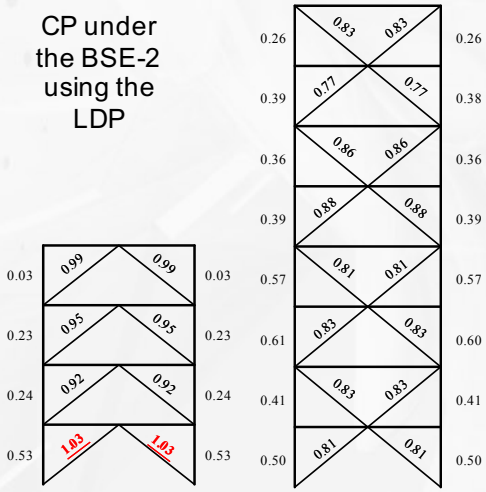
- ASCE 41 and LA Tall Buildings Council have engaged NIST on the results of this work
  - ASCE 41 committee has the questions raised by this study on their agenda for the next update cycle
- Presentations on work given at ATC/SEI workshop in SF December 2015
- Invited presentation to LA Tall Buildings meeting in May 2016
- One journal paper accepted and another under review. Three others in preparation

Project 2: Buckling-Restrained Braced Frame - Ongoing



Linear

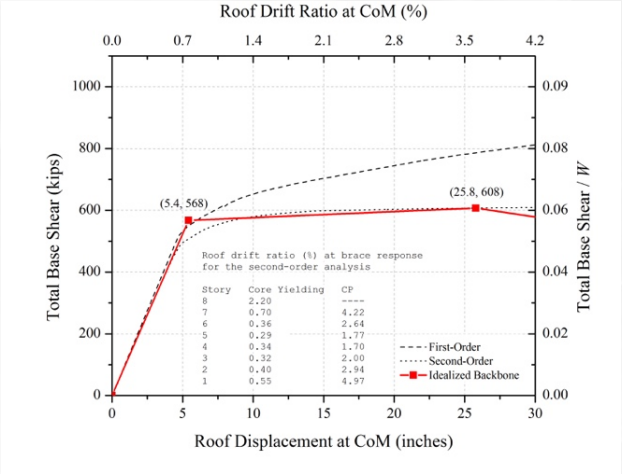
CP under the BSE-2 using the LDP



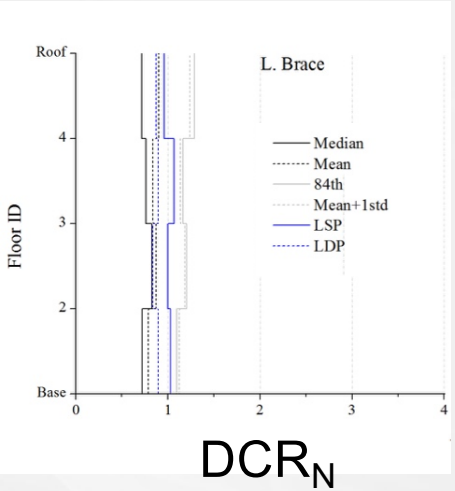
DCR_N

Nonlinear

Example pushover curve



Example nonlinear dynamic result



DCR_N

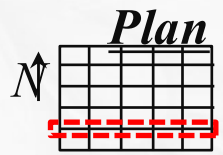
Increasing level of effort

(DCR_N = Normalized demand-to-capacity ratio)

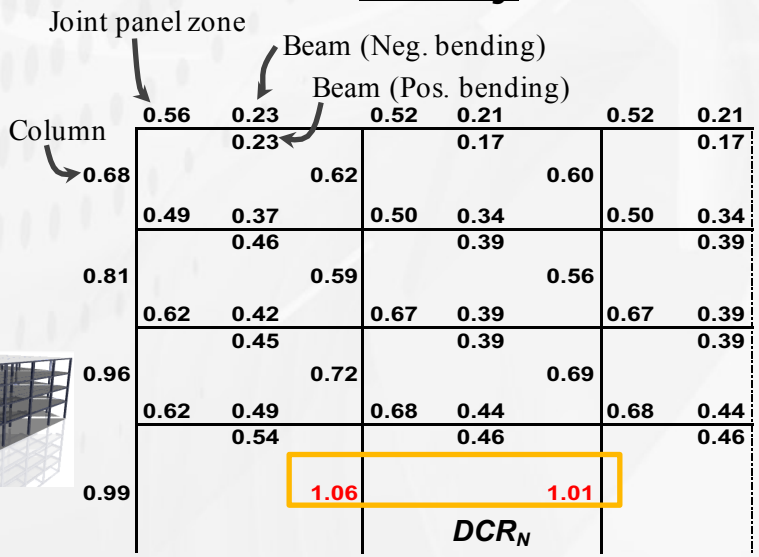
Preliminary results

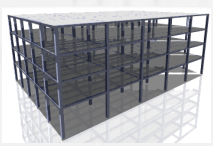
Project 3: Reinforced Concrete Special Moment Frames -- Ongoing

– Linear Static Procedure Snapshot

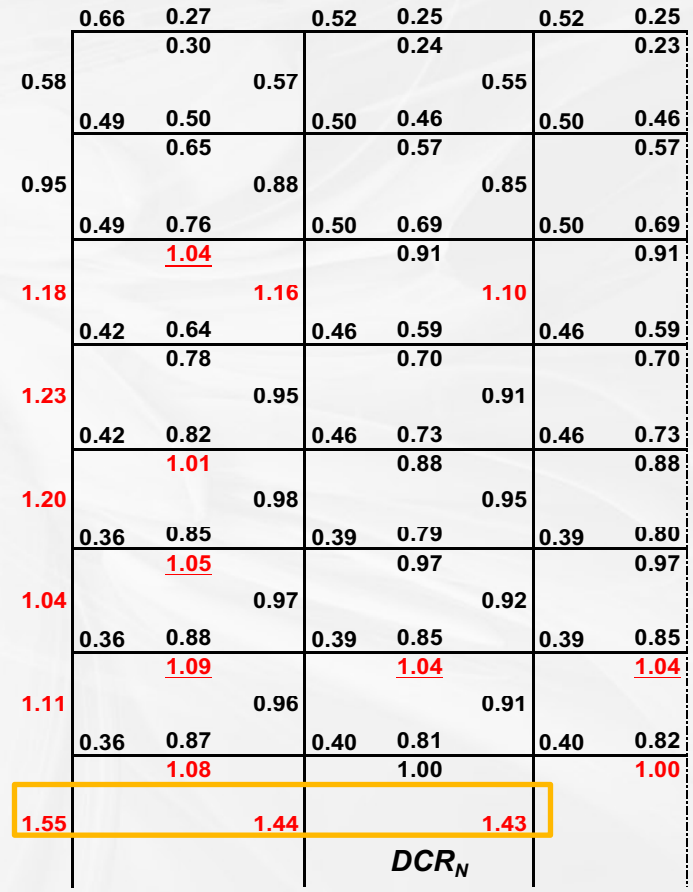


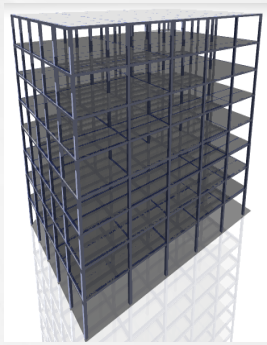
4-story





8-story





Preliminary results

Correlation between ASCE 41 and ASCE 7: Observations for Reinforced Concrete Frames

- Results indicate that ASCE 7 code-compliant reinforced concrete moment frame buildings can have difficulty achieving the acceptance criteria targeted by ASCE 41
- ASCE 7 and ASCE 41 appear to be not consistent with regard to the expected performance of reinforced concrete SMFs
- Four evaluation procedures of ASCE 41 are not calibrated with respect to each other
- Need for changes to the current design and assessment standards to achieve consistent structural seismic performance
- These are preliminary pending completion of the study

Performance of Ordinary Reinforced Concrete Columns under Axial and Seismic Loading

Launch in Fall 2016

Siamak Sattar & Steve McCabe

- Objective:
  - Develop a new analytical model to determine ordinary reinforced concrete column performance under significant levels of axial and cyclic lateral loading.
  - The goal is to provide a means to identify performance up to collapse for use in structural evaluation.
  - The models will assist designers in characterizing earthquake behavior of ordinary reinforced concrete columns, as required for advanced PBSE methodologies such as ASCE/SEI 41.

Background Information/Motivation

- Ordinary columns are susceptible to shear/axial failure
  - Widely used especially in low to moderate seismic zones.
  - Approximation to columns used in older nonductile buildings on the west coast
- Important for PBSE evaluation/design of ordinary RC columns and assessment of existing columns.
  - Supports nonductile concrete structures policy efforts by USGS and triage efforts by FEMA in the LA region
- Three year study conducted to assess/improve shear/axial load failure prediction capabilities
    - Working closely with FEMA
- Hybrid Extramural-Internal Project

NIST/EEG Extramural Projects

NIST/EEG Extramural Projects

- Completed by IDIQ Contractor – Applied Technology Council (ATC) – through Task Orders
  - TechBriefs
  - Roadmap Reports (idle)
  - Applied Research Projects
- Extramural Work Managed by EEG Engineers who are engaged with these projects

NIST/EEG Recent /Current Extramural Projects

- TechBriefs –
  - Summary of recent research and best practices on important topics
  - 12 month duration, 40 pages in length
  - TO 35/TechBrief 9 *Special Reinforced Masonry Shear Walls*
    - *GCR 14-917-31, August 2014*
  - TO 36/TechBrief 10 *Wood Light-Frame Structural Diaphragms*
    - *GCR 14-917-32, September 2014*
  - TO 40/TechBrief 11 *Buckling Restrained Braced Frames*
    - *GCR 15-917-34, September 2015*
  - FY2015 Updates to TechBriefs 1-3 and ICSSC RP 8 are underway
    - ICSSC RP8 update is a priority
  - FY2016 TechBrief on seismic design of precast concrete diaphragms (by request) – task order in preparation

NIST/EEG Planned Extramural Projects

- New Project –
  - FY2016 – study of available information concerning liquefaction
    - Issue in Christchurch and apparently in Taiwan.

Stability of Steel Wide-flange Beam-Columns in Seismic Loading

Jay Harris & Steve McCabe, independent consultant

Objective:

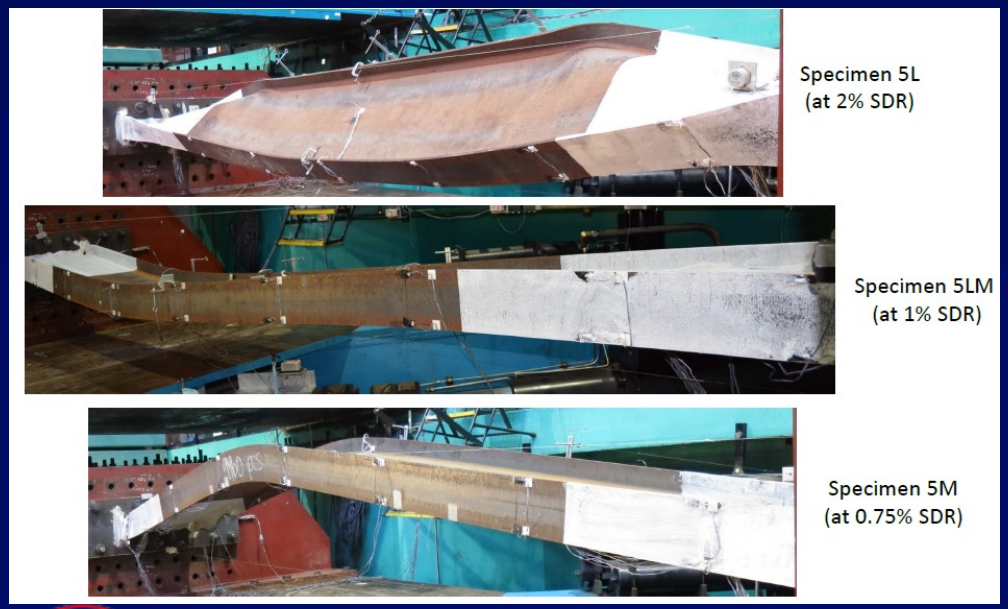
Provide important new experimental data and validated structural behavior models for refining key seismic design provisions in U.S. model building codes and standards used for designing steel wide-flange beam-columns

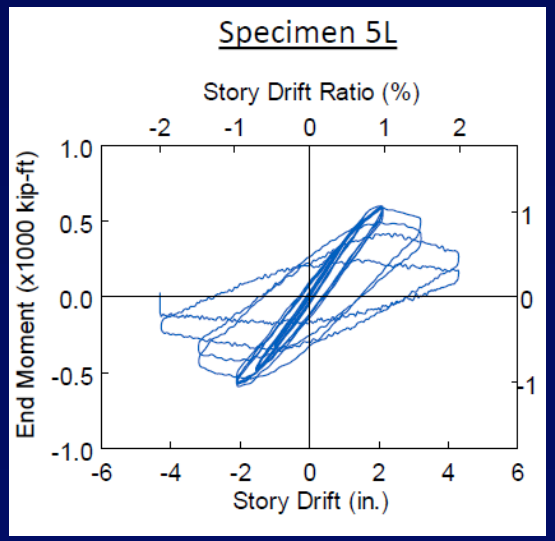
Research plan:

- Investigated twenty-five (25) deep, steel beam-column members that are stability-sensitive at large deformations
- Supplement full-scale experiments with finite element studies – now underway
- Develop improved AISC design provisions
- All data archived in the NEES Data Repository >> NEHRI Data

Stability of Steel Wide-flange Beam-Columns in Seismic Loading

- Test results illustrated a gap in fundamental knowledge about behavior of deep wide-flange steel beam-columns under cyclic inelastic demands.
- Interaction between web and flange local buckling was noticeable; however, current code provisions treat the two separately.
- Global buckling (flexural and torsional) was observed in a class of columns - it is not well understood what triggered this global buckling.



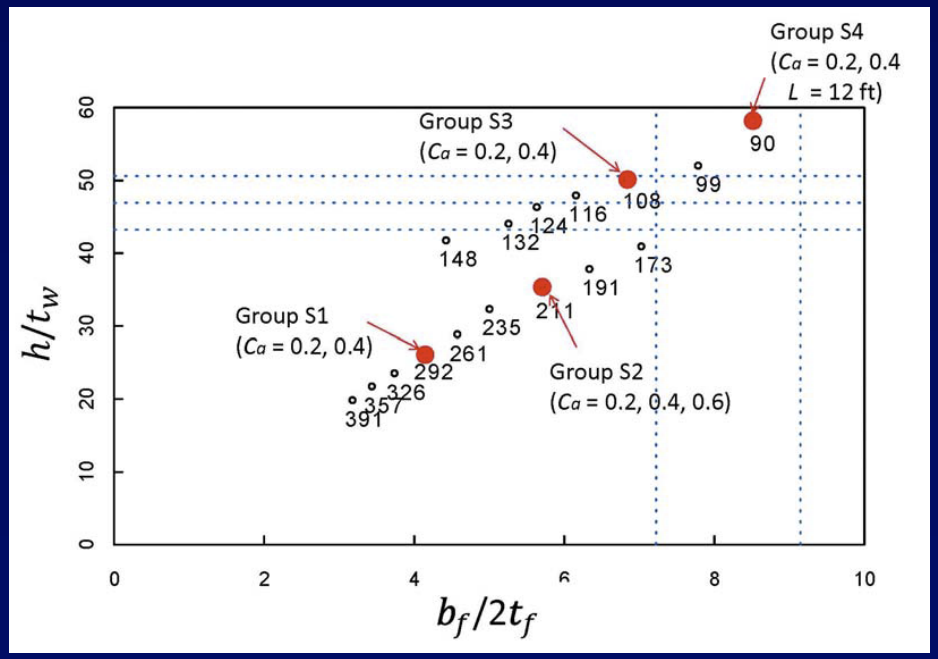


Stability of Steel Wide-flange Beam-Columns in Seismic Loading – Phase 2

- Additional testing work at UCSD – to be awarded in March
- 23 new specimens that have similar geometric attributes to the first set of specimens
  - ~4 specimens will repeat tests done in either series. These specimens will evaluate repeatability of observed phenomenon and provide insight into uncertainty and error in test results.

Table 1 Supplemental Test Matrix

Group No.	Specimen Designation	Shape	L (ft)	C_a
S1	S1L S1M	W30×292	18	0.2 0.4
S2	S2L S2L-P S2M S2H	W30×211	18	0.2 0.2 0.4 0.6
S3	S3L S3L′ S3M S3M′	W30×108	18 12 18 12	0.2 0.2 0.4 0.4
S4	S4L S4M	W30×90	12	0.2 0.4
S5	S5L S5M	W24×55	12	0.2 0.4
S6	S6L S6M	W18×71	18	0.2 0.4



Task Order 38 (ATC-114) – Analysis, Modeling and Simulation for Performance-Based Seismic Engineering – BigFoot

Goal: To critically evaluate the current evaluation and analysis approaches for Performance Based Seismic Engineering.

- Identify improved methods and acceptance criteria including backbone curves and other specific features
- Develop guidelines and best practices
- ASCE 7 and 41 standards used as a starting point for discussion.
- *Critical project* as Performance Based Design is being increasingly employed for new buildings and in evaluating existing buildings.
- Major effort that is ongoing and on schedule

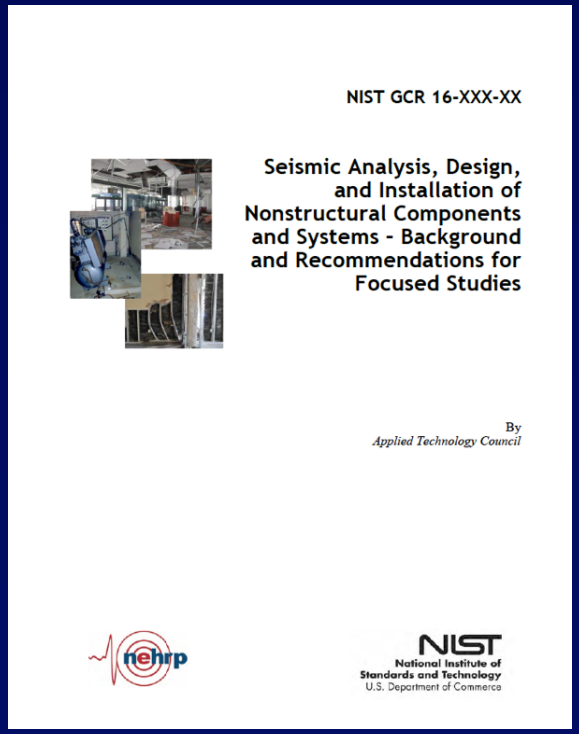
Task Order 39 (ATC-120)

SEISMIC ANALYSIS AND DESIGN OF NONSTRUCTURAL COMPONENTS AND SYSTEMS

Goal: To improve technical aspects of nonstructural system design in the areas that will have the largest impact for public safety and economic welfare.

Major achievements since 4/2015:

- 95% draft report for Phase 1 completed
- Phase 2 plan being developed


NIST GCR 16-XXX-XX

Seismic Analysis, Design, and Installation of Nonstructural Components and Systems - Background and Recommendations for Focused Studies

By
Applied Technology Council

nehrp

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Responses to ACEHR Comments Regarding NIST Research

Response to ACEHR Comments Regarding NIST Research

RECOMMENDATIONS FOR NIST RESEARCH

NIST Recommendation 1

ACEHR recommends NIST improve the dissemination of NEHRP- related information and products to the architectural and engineering professions.

Response to ACEHR Comments Regarding NIST Research

NIST response:

- NIST posted information regarding techbrief publications with Earthquake Engineering Research Institute (EERI) and the American Society of Civil Engineers (ASCE).
- NIST will continue to contact publications and organizations with notices about available downloads on the NEHRP web site.
- NIST will expand the distribution of reports in hardcopy and electronic (jump drive) format at future technical conferences (in concert with FEMA's continuing efforts in this area)
- A new jump drive containing all NIST NEHRP-related publications of the past 10 years is in preparation and should be available soon.

Response to ACEHR Comments Regarding NIST Research

NIST response:

- The Applied Technology Council (ATC) has presented webinars based on recent NIST NEHRP reports that it has prepared, and NIST will work with ATC on possible future webinars featuring NIST-supported research results.
  - Webinar concerning results of the wall research efforts is now being developed
- At the invitation of the National Council of Structural Engineers Associations, NIST plans to present a webinar in the near future on the results of recent ASCE 41-related research at NIST.

Response to ACEHR Comments Regarding NIST Research

RECOMMENDATIONS FOR NIST RESEARCH

NIST Recommendation 2

ACEHR recommends NIST continue and emphasize NEHRP-related research and development programs on critical infrastructure and lifeline systems, geotechnical engineering, non-structural elements, and residential and industrial structures that have seismic vulnerabilities.

Response to ACEHR Comments Regarding NIST Research

<u>NIST response:</u> NIST is considering this recommendation as NIST plans future research.

- NIST has attempted to be faithful to the goals outlined in NIST GCR 13-917-23, *Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings*
  - As augmented by the recommendations of several other roadmaps (e.g., performance-based seismic design and existing buildings) commissioned by NEHRP agencies since 2006.
  - These roadmaps were developed by substantial groups of leading researchers and practitioners.

Response to ACEHR Comments Regarding NIST Research

- NIST has supported some extramural geotechnical engineering work already
  - NIST GCR 11-917-15, *Selecting and Scaling Ground Motions for Performing Response History Analyses*
  - NIST GCR 12-917-21, *Soil-Structure Interaction for Building Structures*
  - NIST GCR 12-917-22, *Seismic Design of Reinforced Concrete Mat Foundations*)
  - Additional geotechnical work is planned

Response to ACEHR Comments Regarding NIST Research

- There is a large ongoing extramural contract effort that takes first steps in addressing non-structural elements – see above

- Recent techbriefs address issues that are found in residential and industrial structures:
  - NIST GCR 14-917-31, *Seismic Design of Special Reinforced Masonry Shear Walls*
  - NIST GCR 14-917-32, *Seismic Design of Wood Light-Frame Structural Diaphragm Systems*.

Response to ACEHR Comments Regarding NIST Research

NIST welcomes the ACEHR's highlighting specific research activities in residential and industrial structures that it wishes to move forward at NIST.

NIST believes that many of the topics in roadmap address issues for the kinds of structures mentioned in the ACEHR's recommendations

- low-rise
- residential, at least multi-family
- industrial
- *None* of NIST's recent NEHRP research has focused on high-rise construction; such construction has not specifically been a major area of NIST NEHRP research.

NIST/EEG Support for Resilience

- Actively working with NIST Resilience Group on Lifelines Report in final stages of completion
- Working to identify areas of collaboration with the NIST-funded Center of Excellence led by Colorado State
  - CoE has requested support from NIST concerning the Eastern US and areas such as Memphis
  - Ongoing discussion
- Developing potential projects that can benefit the resilience effort as well as traditional seismic evaluation and mitigation.
    - Evaluation of low-rise and mid-rise buildings in the Eastern US to moderate seismicity and high wind loads to determine performance

NIST/EEG Extramural Research: Support for Resilience

- ATC 102/TO 28 *Research Plan for EQ Resilient Lifelines: NEHRP Research, Development and Implementation Roadmap*
  - *GCR 14-917-33; October 2014*
- ATC 126/TO 41 – *Critical Assessment of Lifeline System Performance: Understanding Societal Needs in Disaster Recovery*
  - *Direct extension of earthquake report (above)*
  - *GCR 16-917-39 - Completion end of March 2016*

NIST/EEG – How are we doing with outreach?

National Institute of Standards and Technology: *NEHRP.gov Google Analytics from January 1 – February 29, 2016*

NEHRP.gov Web Statistics

Using Google Analytics, OPP collected web statistics for NEHRP.gov from January 1 – February 29, 2016. Google Analytics is a service offered by Google that generates detailed statistics about a website's traffic and traffic sources. Web analytics is not just a tool for measuring web traffic, but can be used as a tool for stakeholder research, and to assess and improve the effectiveness of a website.

Specifically, the following url's were reviewed:

- http://nehrp.gov/library/techbriefs.htm
- http://nehrp.gov/library/guidance_new.htm
- http://nehrp.gov/library/guidance_pbsd.htm

	Page:	Page Title:	Pageviews:	% of Total Pageviews:	Avg Time Spent on Page:
1.	/library/techbriefs.htm	NEHRP - Technical Briefs	1,672	13.39%	00:02:07
2.	/library/guidance_new.htm	NEHRP – New Buildings	1,146	9.17%	00:02:18
3.	/library/guidance_pbsd.htm	NEHRP – Performance-Based Design	656	5.25%	00:02:32

Current web analytics do not allow for the tracking of events (such as downloads) on the NEHRP website. Moving forward, OPP will work with both the NEHRP.gov and the NIST site administrators to ensure Google Analytics is tracking all pertinent data.

National Institute of Standards and Technology: *NEHRP.gov Google Analytics from January 1 – February 29, 2016*

Overall Top Ten NEHRP Pages (01/01/2016-02/29/2016):

	Page:	Page Title:	Pageviews:	% of Total Pageviews:	Avg Time Spent on Page:
1.	/library/techbriefs.htm	NEHRP - Technical Briefs	1,672	13.39%	00:02:07
2.	/library/guidance.htm	NEHRP – Design & Construction	1,574	12.60%	00:00:25
3.	/library/guidance_new.htm	NEHRP – New Buildings	1,146	9.17%	00:02:18
4.	/library/index.htm	NEHRP – Library	1,050	8.41%	00:01:26
5.	/library/guidance_pbsd.htm	NEHRP – Performance-Based Design	656	5.25%	00:02:32
6.	/library/guidance_existing.htm	NEHRP – Existing Buildings	504	4.03%	00:01:59
7.	/index.htm	NEHRP – National Earthquake Hazards Reduction Program- A research and implementation partnership	460	3.68%	00:01:48
8.	/news/index.htm	NEHRP – News	449	3.59%	00:01:32
9.	/library/guidance_steel.htm	NEHRP – Moment Resisting Frame Buildings	343	2.75%	00:1:43
10.	/resources/guidance.htm	NEHRP – Annual Reports, Budgets & Plans	247	1.98%	00:01:07

In Summary

- Significant **results**
- Important new knowledge
- Outreach through technical committees and publications
- Important accomplishments and impact
- Plans for future work

Questions?