FRIEDMAN FAMILY VISITING PROFESIONALS PROGRAM

Visit to Virginia Tech: November 06, 2015

This report summarizes the visit of **John Hooper** from Magnusson Klemencic Associates that took place at the Virginia Polytechnic Institute & State University on November 06, 2015.

ITINERARY OR AGENDA

TIME:	ACTIVITY:
8:30 AM – 9:15 AM	Breakfast at the Inn at VT with Professors Charney, Eatherton, and Hebdon
9:30 AM – 10:30 AM	Tour of the Thomas Murray Structures Lab, led by grad. students and Prof. Eatherton
10:30 AM – 11:40 AM	Student research presentations at the Structures Lab
11:50 AM – 1:15 PM	Lunch with VT EERI Student Chapter
1:15 PM – 1:45 PM	Meeting with Prof. Charney
1:45 PM – 3:30 PM	Open time / informal meetings with VT faculty
3:30 PM – 5:00 PM	Presentation on Performance-Based Seismic Design
5:00 PM – 5:45 PM	Reception following presentation to facilitate discussion with student and faculty bodies
6:30 PM – 8:00 PM	Dinner at 622 North with Professors Charney, Flint, Koutromanos, Rodriguez-Marek, and Mouras

STUDENT CHAPTER VISIT PLANNING COMMITTEE

LEAD ORGANIZERS:

- Gage Pepin, Chapter President, gage22p@vt.edu
- Pat O'Brien, Chapter Vice President, pato91@vt.edu
- Jeena Jayamon, Chapter Secretary, jeenarj@vt.edu
- Max O'Krepki, Chapter Treasurer, maxo1@vt.edu
- Adrian Tola, Chapter Diplomat, atola@vt.edu
- Professors Ioannis Koutromanos, Finley Charney, Matt Eatherton

VISITING PROFESSIONAL LECTURE OVERVIEW

Lecture Abstract

The lecture presented by John Hooper at Virginia Tech as part of the Friedman Family Visiting Professional Program addressed the current state of art of performance based seismic design (PBSD). Starting by describing the paradigm shift from a code perspective seismic design, the lecture continued by describing the objective of PBSD. Next, the sequence of basic steps involved in PBSD was outlined and a detailed explanation of the selection of performance objective was given with practical examples. With the information about the different performance levels of a building system (including *Operational, Immediate Occupancy, Life Safety and Collapse Prevention*), the lecture then focused on identifying these performance levels from structural analysis results.

To appreciate the importance of PBSD, two examples were presented – (1) Transbay Tower, which is a high-rise concrete structure that exceeds the code height limits and (2) San Francisco Museum of Modern Arts, which is a steel building that used nonlinear response history analysis to fine-tune the seismic design and reduce construction codes. These examples were used to explain how the building meets the intended performance objective of a low likelihood of collapse for a given MCE level of ground shaking and how to move beyond this sole collapse metric for acceptable design.

By clearly recognizing the future needs for PBSD, the presentation then focused on how to implement this in practice and the details of FEMA P-58 process, which allows the engineers to estimate the information about their building including – repair cost, repair time, unsafe placards and causalities. The discussion about FEMA P-58, emphasized on the different performance assessment methods (intensity/scenario based and time-based assessments) and how to develop the building performance model using the fragility specification about each of the building structural / nonstructural component. How to use the building performance model in structural analysis and how to interpret these analysis results in computing building performance was explained to conclude the steps in FEMA P-58 process. Understanding the extend of structural analysis and probabilistic simulations involved in FEMA P-58 process, the lecture introduced the Performance Assessment Calculation Tool (PACT), which was developed to automate the process. With examples, the lecture illustrated how does the tool helped to identify the repair cost, causalities, downtime and how to red tag the damaged components.

The lecture concluded with the discussion of benefits of the new PBSD approach in estimating the building performance at hazard levels other than collapse. As a final note, the speaker lists few of the ongoing developments in extending and refining the PBSD process.

The audience of the lecture included students and faculty from Virginia Tech and professionals working in different firms in Roanoke. There was an engaging attendee interaction following the lecture, about topics on the emerging trends in seismic engineering practice. John Hooper helped to answer students queries about the opportunities of PBSD in practice and academic research. Faculties who attended the seminar initiated discussions on how to prepare the student community to be part of the new directions in structural design and assessment.

Professional Bio

John Hooper is a Senior Principal and the Director of Earthquake Engineering at Magnusson Klemencic Associates, a consulting structural and civil engineering firm in Seattle, Washington. He received his Bachelor of Civil Engineering from Seattle University and Master of Science from the University of Berkeley. John has over 30 years of engineering experience in the fields of renovation, seismic engineering, earthquake engineering and structural analysis. He is Chair of the American Society of Civil Engineer (ASCE 7's) Seismic Subcommittee and is a member of the Main Committee, member of the NEHRP Advisory Committee on Earthquake Hazard Reduction (ACEHP) and a member of the Building Seismic Safety Council (BSSC) NEHRP Provisions Update Committee. John has been involved in the majority of MKA's Performance-Based Seismic high rise designs over the past 15 years and has been part of the Project Technical Committee responsible for developing the FEMA P-58 Seismic Performance Assessment of Buildings Methodology.

SUPPLEMENTAL ACTIVITES

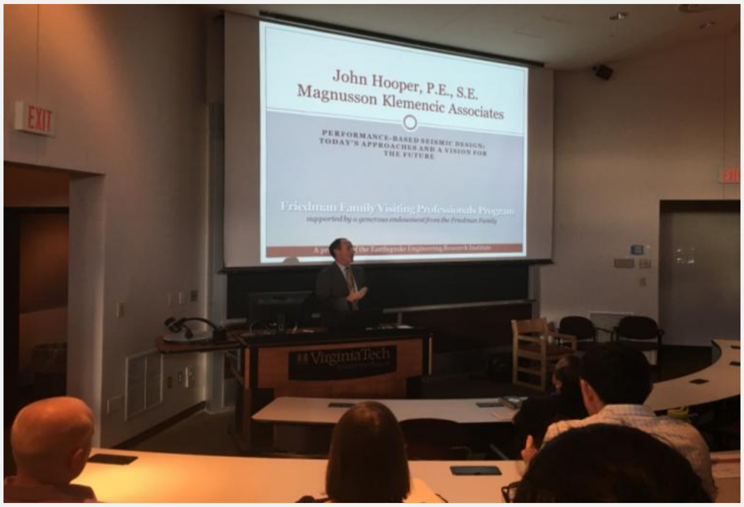
Thomas M. Murray Structures Laboratory Tour

Mr. Hooper was given a tour by Dr. Charney and Dr. Eatherton around the structures lab. Since several experimental tests were being conducted the day Mr. Hooper visited, he got to see students in action completing their research. Along with the students that were testing that day, everyone else that had a test in the lab was also available to give Mr. Hooper a brief presentation on their research (this included ring-shaped shear wall testing, push off tests on composite slab specimens, flexure tests on concrete bridge girders and more). After experimental testing presentations were done, Mr. Hooper got to meet more students conducting analytical research, who were accompanied by their faculty advisors. These students' presentations concluded Mr. Hooper's lab tour by presenting on their work as well.

Lunch with EERI Officers

After the lab tour, Mr. Hooper was taken to lunch at a local Blacksburg restaurant, The Cellar. Here, a casual lunch ensued where the EERI student officers got a chance to ask Mr. Hooper about his experiences as a leader in the field, and got to know him a little better on a non-professional level. Mr. Hooper reciprocated with his own questions about Virginia Tech, its student body and organizations, and Blacksburg life in general. Once lunch was over, the students walked Mr. Hooper back to campus while giving him a brief tour of downtown Blacksburg and Virginia Tech's campus.

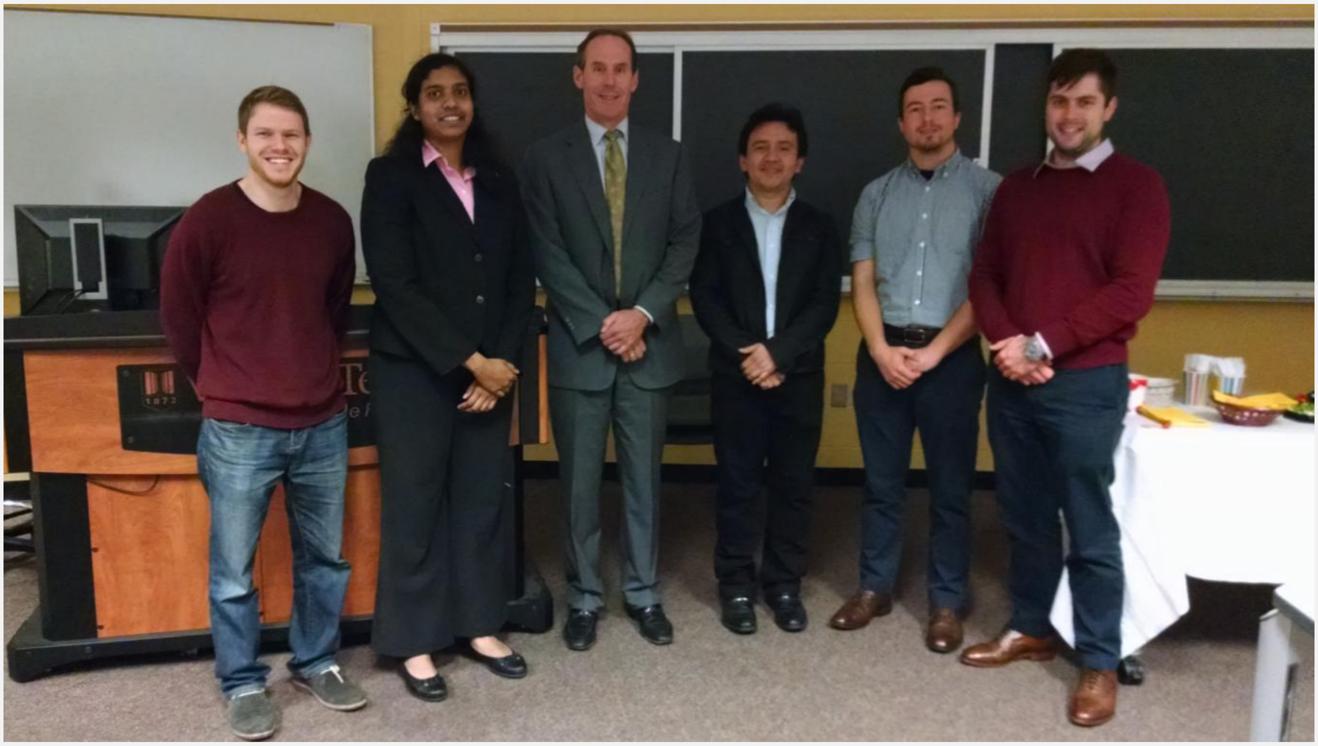
Lecture



As described previously, Mr. Hooper gave an engaging lecture on performance based seismic design, and delved into the complexities that arise when this design approach is taken, particularly in high hazard areas. Before his presentation, Mr. Hooper gave an introduction on EERI's national chapter, how he got involved, and encouraged everyone in the audience that has any interest in earthquakes (whether technical or not) to join EERI. He posed questions to the audience throughout his presentation and concluded by answering questions from those who attended.

Reception

After his lecture, everyone who attended was invited to join Mr. Hooper, the EERI Chapter, and faculty in a reception where refreshments were offered. All who wanted to, got a chance to introduce themselves to Mr. Hooper and ask any questions that they might not have gotten a chance to at the end of his presentation. Mr. Hooper was nice enough to stick around and answer any questions and share his experiences. After this long, busy day, Mr. Hooper and several faculty members left for dinner.



RESULTS, FEEDBACK AND LESSONS LEARNED

- The only major challenge we faced was the timeline, since we were attempting to bring Mr. Hooper in so soon after the applications for the Visiting Professional program were posted. Thankfully, this was resolved very smoothly and became a nonissue; EERI was very accommodating here.
- Mr. Hooper's visit was extremely well received. Following his presentation, several faculty members even commented that this had been the most successful Fall seminar yet (Mr. Hooper presented as part of an annual, extracurricular seminar hosted by the CEE department).
- Since VT's EERI chapter has now hosted seminars in both Geotechnical and Structural fields (and even a presentation on Risk Analysis, outside of the Visiting Professional program), the idea of hosting a seminar on Seismology seems like it would work well as a marriage between all of these topics. A seminar on Emergency Management would also be a great opportunity, allowing for a more direct inclusion of students interested in social sciences. Generally speaking, we would like to make these visits as inclusive and interactive as possible for students across all fields related to Earthquake Engineering.

ACKNOWLEDGEMENTS

The Virginia Tech EERI Student Chapter gratefully acknowledges the support of the Friedman Family for sponsoring the travel of John Hooper through their Friedman Family Visiting Professional Program endowment. The lecture presented by Mr. Hooper and the interaction with students and faculty had a very positive impact in the Civil Engineering Department, and it raised more awareness on current earthquake engineering issues. We look forward to hosting new guests from the Friedman Family in years to come.

LIST OF ATTACHMENTS

Included at the end of this report are various attachments to supplement the information included above. A list of the attachments is included below:

- Item 1, Event Flier
- Item 2, Mr. Hooper's Presentation Slides

The Ninth Annual CELES Lecture

Performance-Based Seismic Design: Today's Approaches and a Vision for the Future

John Hooper, P.E, S.E.
Senior Principal/Director of Earthquake Engineering
Magnusson Klemencic Associates

Friday, November 6, 2015
Presentation at 4:00 - Reception at 5:00 p.m.
3100 Torgersen Hall

Synopsis:

Performance-Based Seismic Design (PBSD) has been used for decades for the seismic retrofit of existing buildings and the design of new structures. Today's PBSD approaches focus on providing a design that typically targets one of the following performance levels for a one of several ground shaking hazard levels: Operational, Immediate Occupancy, Life Safety, or Collapse Prevention.

The building code performance objective for new, ordinary (Risk Category II) buildings is to provide Life Safety for Design Earthquake (DE) ground shaking and Collapse Prevention for Maximum Considered Earthquake (MCE) ground shaking. PBSD for new buildings is typically targets performance equivalent to a code-prescriptive design. Two examples will be presented: (1) A high-rise concrete structure that exceeds the code height limits and (2) a steel building that used nonlinear response history analysis to fine-tune the seismic design and reduce construction costs.

Both examples evaluated whether the building meets in the intended performance objective of a low likelihood of collapse given MCE ground shaking. Moving beyond solely using collapse as the metric for whether a design is acceptable is the vision for the future. A FEMA-sponsored, Applied Technology Council-managed research effort has been underway for nearly 15 years developing the methodology. The results of this effort have been published in FEMA P-58 Seismic Performance Assessment of Buildings. The final portion of the presentation will focus on this new approach, which will allow engineers to estimate the following information for their buildings: Repair costs, Repair time, Unsafe placards, and Casualties.

About the speaker:

John Hooper is a Senior Principal and the Director of Earthquake Engineering at Magnusson Klemencic Associates, a consulting structural and civil engineering firm in Seattle, Washington. He received his Bachelor of Civil Engineering from Seattle University and a Master of Science from the University of California at Berkeley. John has over 30 years of engineering experience in the fields of renovation, seismic engineering, earthquake engineering, and structural analysis. He is Chair of the American Society of Civil Engineer (ASCE 7's) Seismic Subcommittee and is a member of the Main Committee, member of the NEHRP Advisory Committee on Earthquake Hazards Reduction (ACEHR), and a member of the Building Seismic Safety Council (BSSC) NEHRP Provisions Update Committee. John has been involved in the majority of MKA's Performance-Based Seismic high-rise designs over the past 15 years and has been part of the Project Technical Committee responsible for developing the FEMA P-58 Seismic Performance Assessment of Buildings Methodology.

John Hooper, P.E., S.E.
Magnusson Klemencic Associates

PERFORMANCE-BASED SEISMIC DESIGN: TODAY'S APPROACHES AND A VISION FOR THE FUTURE

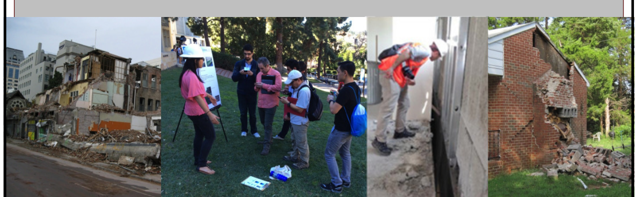
Friedman Family Visiting Professionals Program

supported by a generous endowment from the Friedman Family

A program of the Earthquake Engineering Research Institute

About EERI

- Global earthquake engineering institute
- Nonprofit, technical membership society
- Dedicated to reducing earthquake risk



EERI's Mission

EERI's mission is to reduce earthquake risk by:

1. Advancing the science and practice of earthquake engineering
2. Improving understanding of the impact of earthquakes
3. Advocating comprehensive and realistic measures for reducing earthquake effects

Who Are EERI Members?

EERI Members include:

- Geoscientists:
  - Geologists
  - Seismologists
- Engineers:
  - Structural
  - Geotechnical
  - Civil
  - Transportation
  - Lifelines
- Architects/Planners
- Social Scientists
- Public Officials
- Emergency Managers
- Tsunami Scientists
- Economists & Business Analysts

Who work as:

- Researchers
- Scientists
- Practicing professionals
- Professors
- Educators
- Government officials
- Building code regulators

Members are organized into committees, projects, and chapters to implement EERI's mission

Benefits for Students

- Friedman Family Visiting Professionals Program
- EERI Competitions: Seismic Design, Student Paper, Fellowships
- Travel Grants to EERI meetings
- EERI Internship Program
- Online access to *Earthquake Spectra* and more!

Continuing your EERI Membership

- EERI membership demonstrates your commitment to reducing earthquake risk
- Student members get the 1st year of Young Professional membership FREE and reduced rates for the next 4 years

Learn More at www.eeri.org

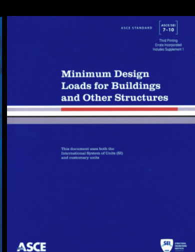
Together, we can reduce earthquake risk.

How I got involved in EERI

- Member since 1987—natural extension of my focus on earthquake engineering!
- Attended many of the annual meetings
- Served on numerous committees
- Opportunity to be a Friedman Family Visiting Professional for over a decade

PBSD: Today's Approaches

Code Prescriptive Seismic Design



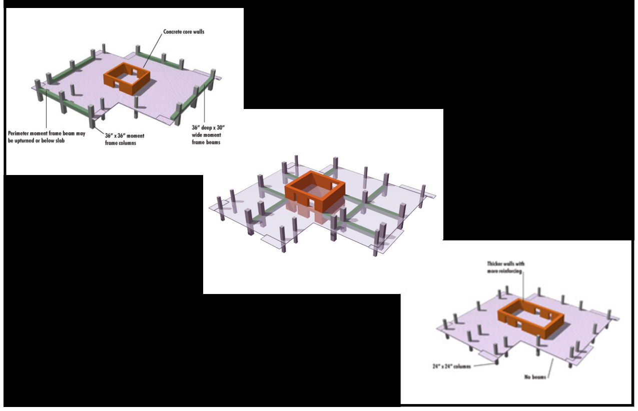
- Minimum acceptable lateral strength and stiffness
- Minimum acceptable detailing practices
- Required attachment strength and displacement capacity of nonstructural components

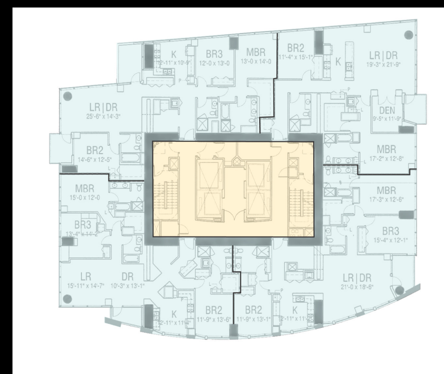
Presumed to provide acceptable performance
Actual performance capability never actually evaluated

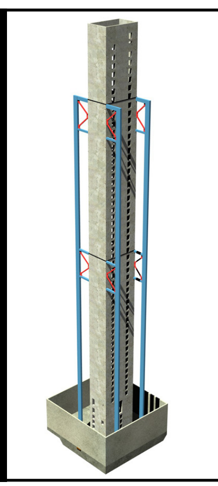
PBSD – What is it?

- An approach to obtain:
  - Buildings that perform better than typical code confirming buildings
  - Buildings that don't meet the code, but can perform as well as a code, prescriptively-designed building

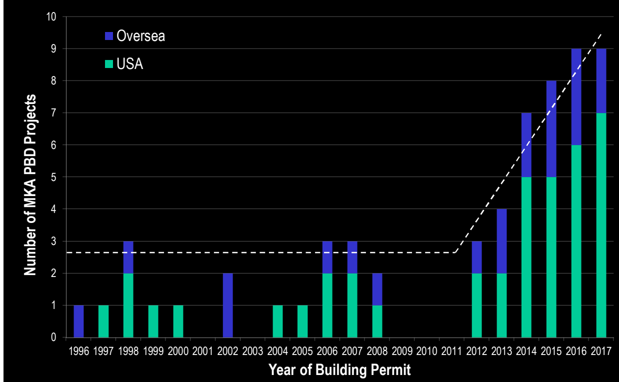
PBSD – Why is it?



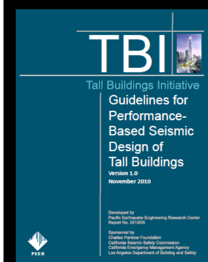


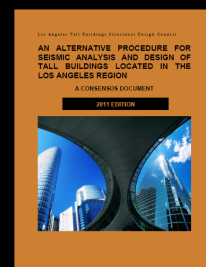


History of High-Rise PBSD at MKA

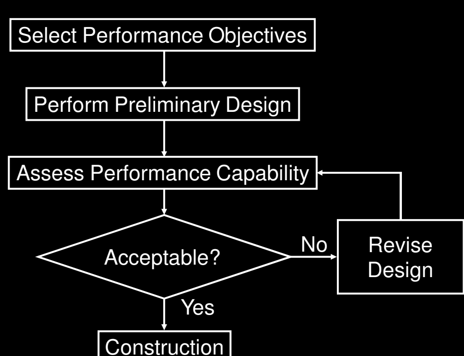


PBSD Today

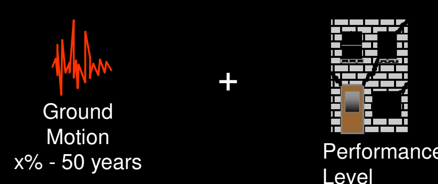




The PBSD Process



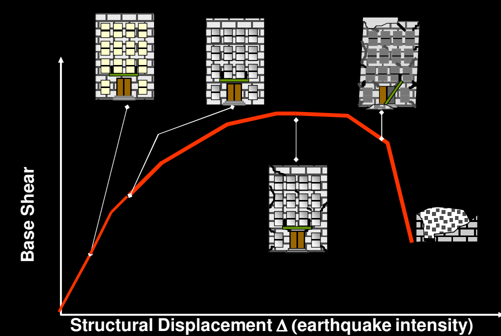
Performance Objectives



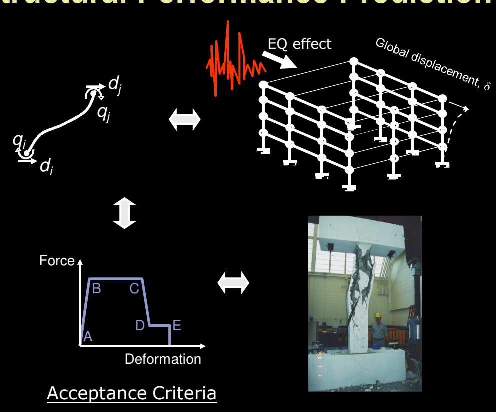
- **Design Hazard (earthquake ground shaking)**
- **Acceptable Performance Level (maximum acceptable damage, given that shaking occurs**

Standard Performance Levels

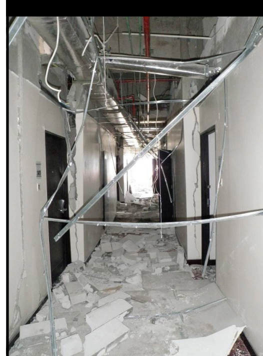
Structural Performance Based on Nonlinear Response



Structural Performance Prediction



Nonstructural Performance

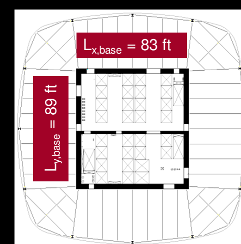


- **Accounts for more than 70% of earthquake economic losses**
- **Not really covered by present procedures**
  - **Simple review of anchorage and bracing requirements similar to prescriptive code**
  - **Shake table qualification of “essential” systems**

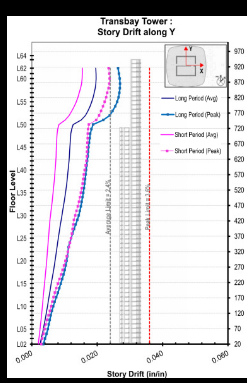
Transbay Tower

Structural Systems

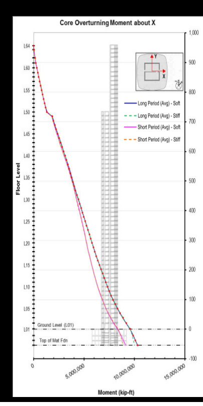
- Gravity: Structural steel columns and floor framing supporting composite deck
- Lateral: Special reinforced concrete shear walls
  - North cell stops at Level 50
  - Walls 48” to 24” thick
  - $h/L_x = 12.9$
  - $h/L_y = 12.0$

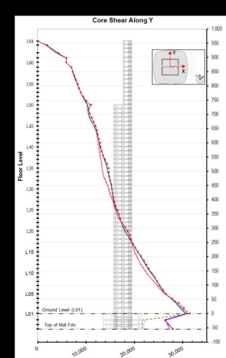


Results – Story Drift



Results – Core Shear & Moment





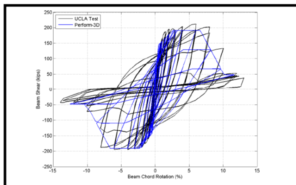


Figure 13. Diagonally Reinforced Coupling Beam Test vs. Modeled Behavior – Ref: UCLA Testing by Dr. John Wallace

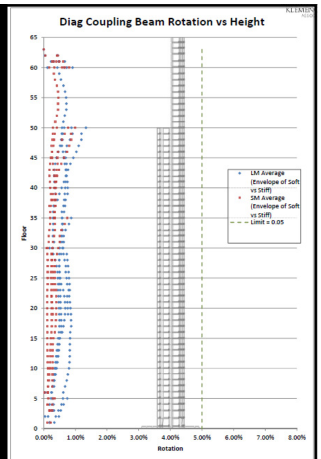


Figure 42. Diagonally Reinforced Coupling Beam Rotation

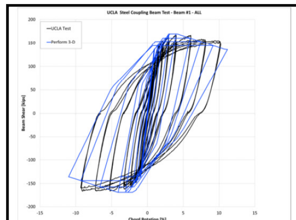


Figure 14. Steel Coupling Beam Test vs. Modeled Behavior – Ref: UCLA Testing by Dr. John Wallace

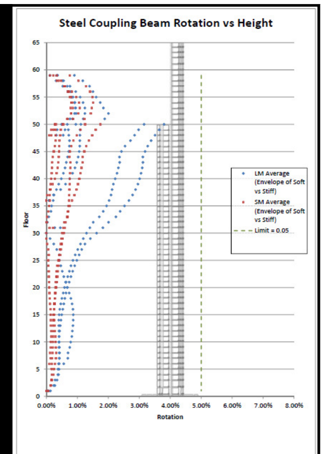
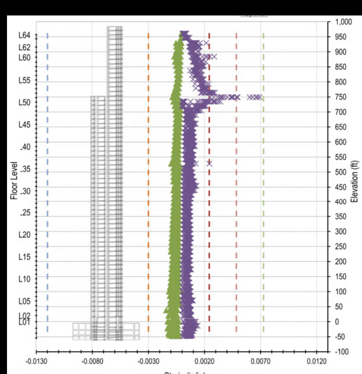


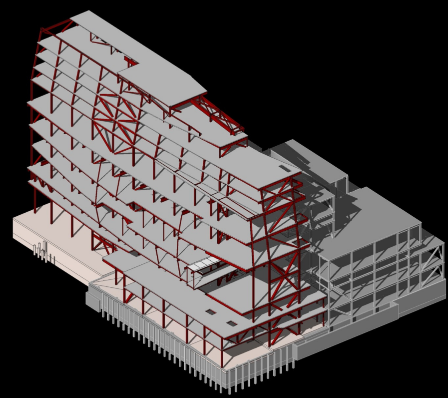
Figure 43. Steel Coupling Beam Rotation

Results – Shear Wall Strain

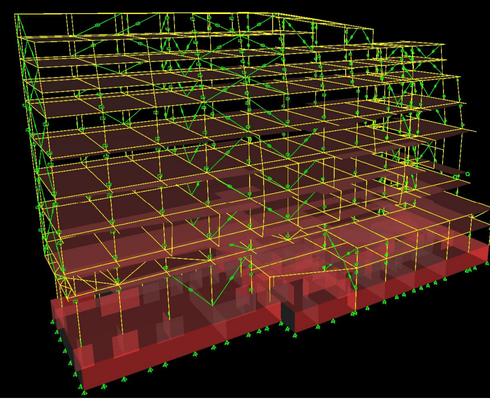


San Francisco MOMA

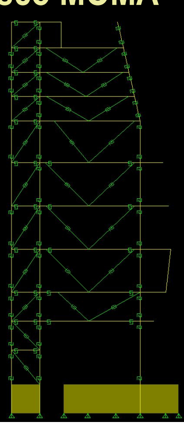
San Francisco MOMA



San Francisco MOMA

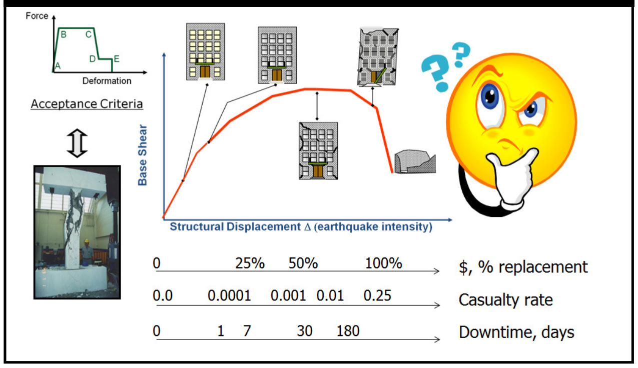


San Francisco MOMA



PBSD: A Vision for the Future

Present Generation – Doesn't Answer These Questions



Nonstructural Performance

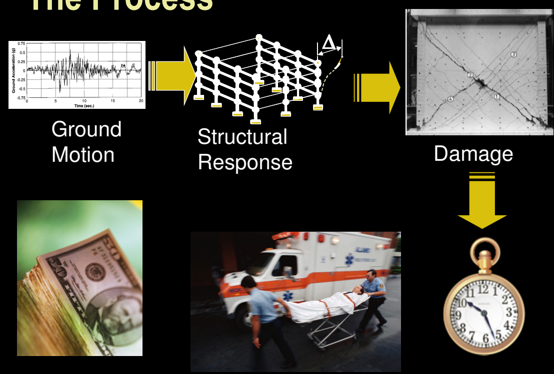
- As mentioned previously, not really covered by present procedures

Reliability

- FEMA 273/FEMA P-695/ASCE 7-10
  - Perhaps 1 out of 10 structures may experience poorer performance than intended by the design
  - One out of 10 is not particularly good, unless the building owner buys into this and is willing to accept it
  - No one even knows if we are really getting 90% reliability

Performance Prediction

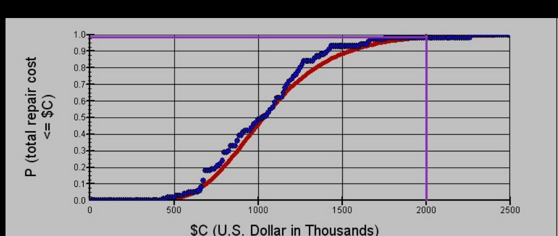
The Process



Predicting Performance

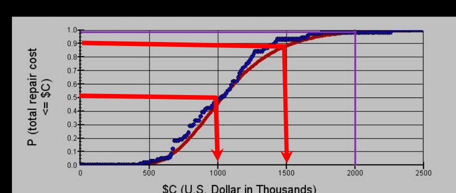
- It is impossible to predict performance precisely
- Each step of the process entails uncertainties

The Results of Next-Generation Performance Assessment



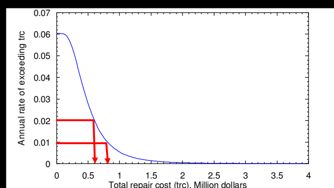
Loss Distribution

Intensity- and Scenario-Based Assessments



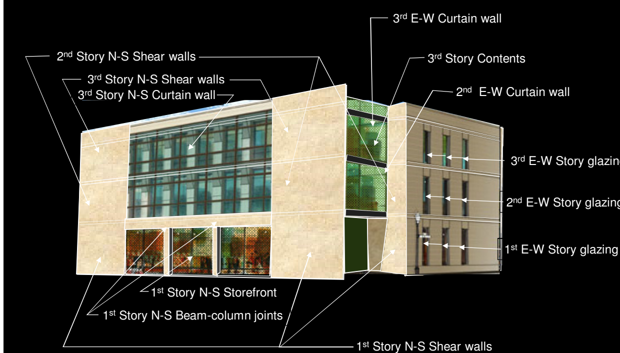
- 50% probability that repair cost (for the scenario or intensity) will not exceed $1M, 1 month repair, 1 injury
- 90% confidence that repair cost (for the scenario or intensity) will not exceed $1.5M, 1.5 month repair, 3 injuries, 1 death
- Expected loss (for scenario or intensity) of $1.2M

Time-based Assessments



- 50-year loss = $600,000
- 100-year loss = $800,000
- Average annual loss = $66,000

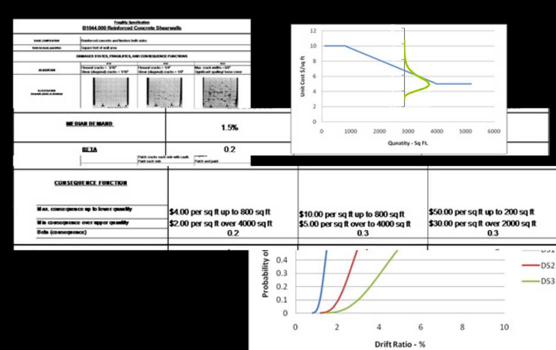
Building Performance Model



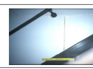
Fragility Specification

Fragility Specification B1044.000 Reinforced Concrete Shearwalls			
[illegible]	Reinforced concrete and finishes both sides		
[illegible]	Square feet of wall area		
DAMAGES STATES, FRAGILITES, AND CONSEQUENCE FUNCTIONS			
	DS1	DS2	DS3
[illegible]	Flexural cracks < 3/16" Shear (diagonal) cracks < 1/16"	Flexural cracks > 1/4" Shear (diagonal) cracks > 1/8"	Max. crack widths >3/8" Significant spalling/ loose cover
[illegible]			
[illegible]	1.5%	3.0%	5.0%
BETA	0.2	0.3	0.4
[illegible]	70%		
[illegible]	Patch cracks each side with caulk Paint each side	Remove loose concrete Patch walls with NS grout Patch cracks each side with caulk Paint each side	Shore Demo existing wall Replace Patch and paint
[illegible]			
[illegible]	$4.00 per sq ft up to 800 sq ft	$10.00 per sq ft up to 800 sq ft	$50.00 per sq ft up to 200 sq ft
[illegible]	$2.00 per sq ft over 4000 sq ft	$5.00 per sq ft over to 4000 sq ft	$30.00 per sq ft over 2000 sq ft
[illegible]	0.2	0.3	0.3
[illegible]	days	weeks	months

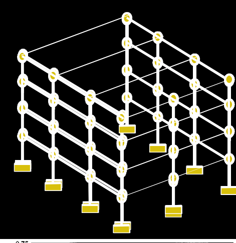
Fragility Specification

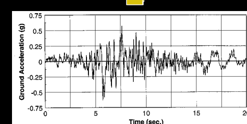


Fragility Specification

Fragility, damage measures, and consequence functions for **Interior Partitions Type 9a C1011.009a**			
BASIC COMPOSITION	Full height 5/8 inch gypsumboard screwed on metal studs. No slip track or window panels.		
NORMATIVE QUANTITIES	Linear feet of partition wall oriented in a specified *direction* per square foot of floor area at a specified level. This quantity will be multiplied by story height to obtain square feet of partition wall.		
DAMAGES STATES, FRAGILIITES, AND CONSEQUENCE FUNCTIONS			
	DS1	DS2	DS3
DESCRIPTION	Visible damage and small cracks in gypsum boards that can be repaired with taping, pasting and painting. No window and door damage	Extensive cracking or crushing in gypsum boards and minimal or no damage to metal studs. Re-hang door.	Severe damage to gypsum boards and enough damage to metal studs and runners
ILLUSTRATION (example photo or drawing)			
MEDIAN EDP (interstory drift in specified direction)	0.20%	0.80%	1.40%
BETA	0.40	0.40	0.40
CORRELATION (%)	low	low	low
REPAIR MEASURES	Taping ,patching and painting	Replacing the gypsum boards, and then taping, and painting Re-hang doors	Remove damaged materials Reframe walls Repair damaged electrical Install new Gyp Tape, Sand and Paint Includes some door repairs Includes some minor mechanical repairs
CONSEQUENCE FUNCTION Cost per sq ft of interior partition			
Max. cost up to lower quantity	$ 3.33 100	$ 5.56 100	12.92 100
Min cost over upper quantity	$ 2.94 10,000	$ 4.76 10,000	$ 10.92 10,000
Beta (cost)	0.20	0.30	0.30
TIMEFRAME FOR REPAIRS	Minor repairs can be done in a couple of days, including repainting patches	Larger repairs take min. 5 days to remove damage, patch and paint	Major reframing of walls and mechanical damge repairs will take a minimum of 10 days, and possible longer depending on crew size, amount ot damage, and availability of mechanical parts for repairs

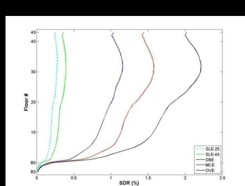
Analysis

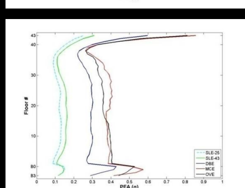




Peak Ground Acceleration	Drift Ratio
0.2g	1.0%
0.5g	2%
1.0g	5%

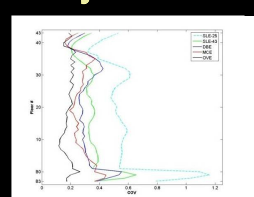
Analysis Results

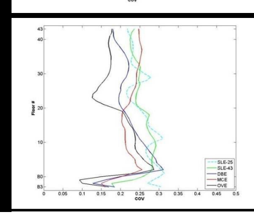




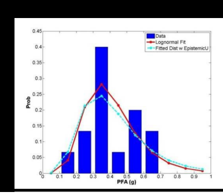
- Median values of peak transient:
  - Story drift
  - Floor acceleration
  - Floor velocity

Analysis Results





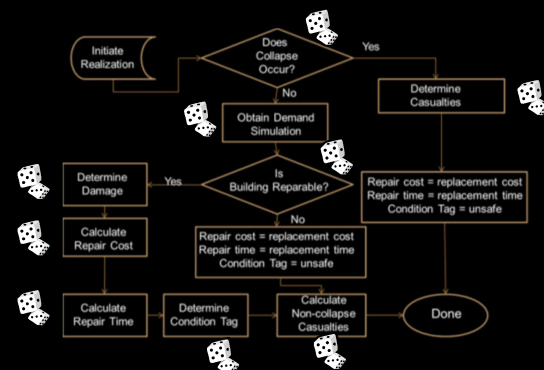
- Logarithmic standard deviate of:
  - Peak story drift
  - Peak floor acceleration



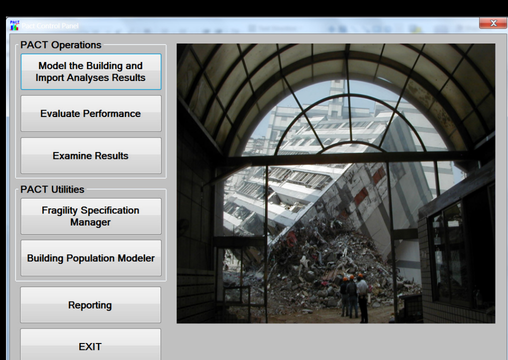
Calculate Performance

- Monte Carlo Process
- Hundreds to thousands of "spins"
- For each "spin" termed a "realization"
- Unique
  - Demands
  - Damage
  - Consequences

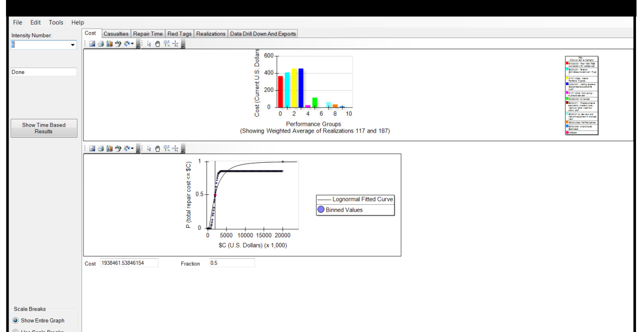
Computing Building Performance



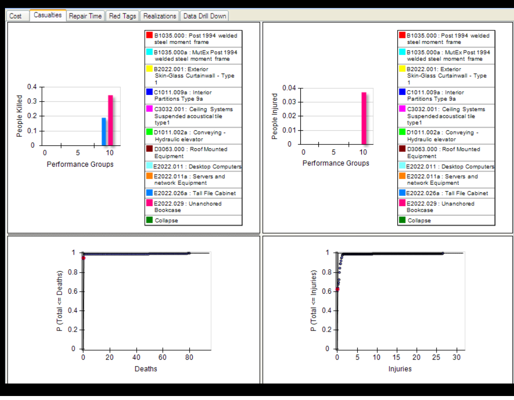
Performance Assessment Calculation Tool



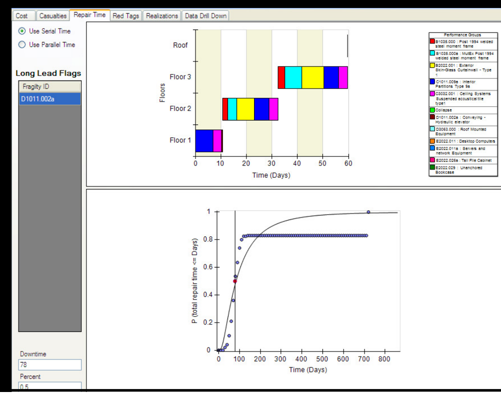
Repair Cost



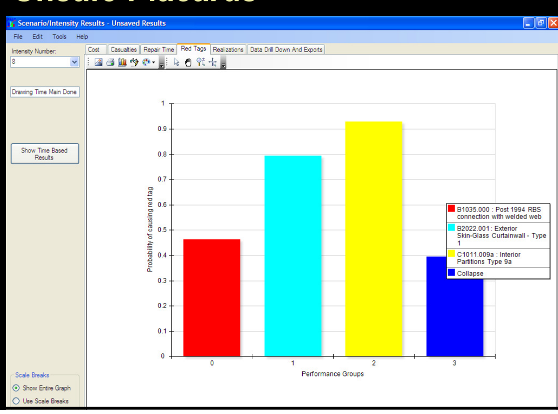
Casualties



Repair Time



Unsafe Placards



Benefits of This New Approach

- Provides data directly useful for cost-benefit analyses and decision making
- Inherently acknowledges and quantifies the possible range of performance outcomes
- Recognizes the effect of nonstructural components
- Permits engineers to conveniently explore the effects of design modification on performance

On-going Development of the Process

- Continued refinement in the process
- Assessment of Code-designed buildings
  - What are we achieving?
- Guidance for providing better performance
- Primer for Structural Engineers
- Information to provide to Owners, Developers and Architects

Virginia Tech at MKA

Questions?