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**

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

**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 Magnuson 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 ACTIVITIES

Thomas M. Murray Structures Laboratory Tour

Mr. Hooper was given a tour by Dr. Chamney 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.
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
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

Operational  Immediate Occupancy  Life Safety  Collapse Prevention

Structural Performance Based on Nonlinear Response

Structural Displacement $\Delta$ (earthquake intensity)

Base Shear

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
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

As mentioned previously, not really covered by present procedures

Nonstructural Performance

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**

1. **Ground Motion**
2. **Structural Response**
3. **Damage**

**Predicting Performance**

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

**The Results of Next-Generation Performance Assessment**

- 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.

**Intensity- and Scenario-Based Assessments**

![Graph showing loss distribution](image)
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
Fragility Specification

<table>
<thead>
<tr>
<th>Peak Ground Acceleration</th>
<th>Drift Ratio</th>
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<tbody>
<tr>
<td>0.2g</td>
<td>1.0%</td>
</tr>
<tr>
<td>0.5g</td>
<td>2%</td>
</tr>
<tr>
<td>1.0g</td>
<td>5%</td>
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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

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

Performance Assessment Calculation Tool

Repair Cost
Casualties

Unsafe Placards

Repair Time

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

Questions?