# 2019 PEER Blind Prediction (BP) Contest

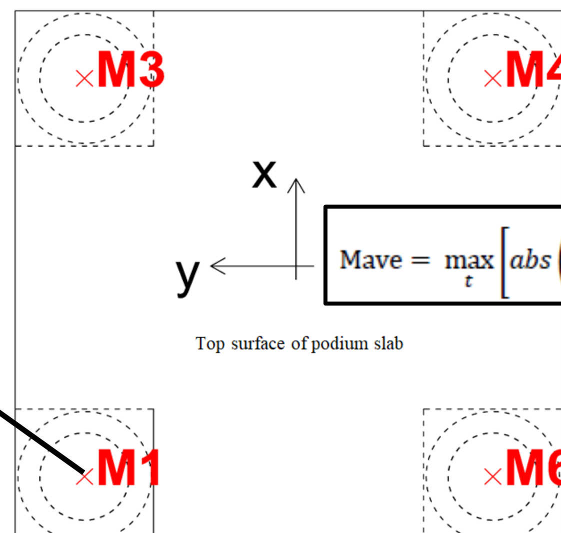
Michalis Vassiliou, ETH
Selim Günay, PEER
Bozidar Stojadinovic, ETH
Khalid M. Mosalam, PEER/UCB
PEER Staff Support: Erika Donald

January 16, 2020

# 2019 PEER BP Contest: Overview

- Four-column **rocking** podium structure excited by **200** artificial ground motions on a shaking table.
- Objective: Prediction of **maximum bi-directional** seismic response.
- The structure was designed by an ETH Zurich team led by Profs. Michalis Vassiliou & Bozidar Stojadinovic.

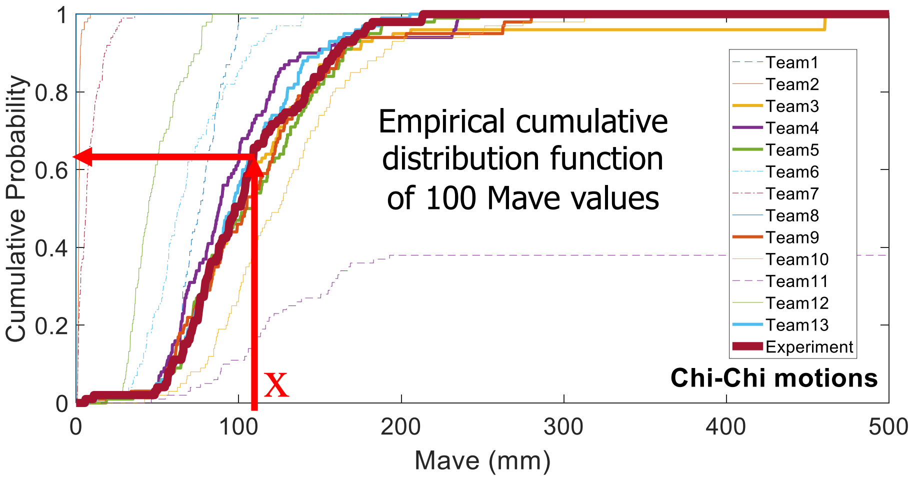
- The tests were conducted using the 6-dof shaking table located at the Earthquake and Large Structures (EQUALS) Laboratory of the University of Bristol.
- Tests were supervised by Profs. George Mylonakis & Anastasios Sextos under the SERA transnational access project "3DROCK: Statistical Verification and Validation of 3D Seismic Rocking Motion Models" http://www.sera-eu.org/en/home/.

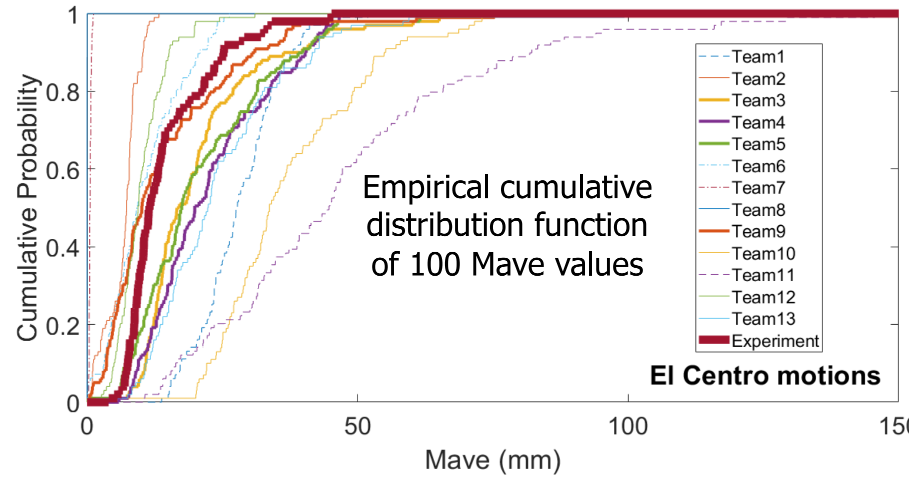



M1, M3, M4 & M6 are planar horizontal displacements of 4 points at podium slab surface.

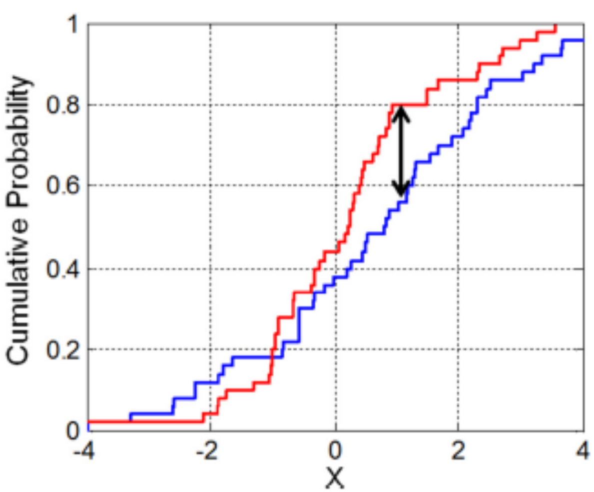
$$\mathrm{Mave} = \max_t \left[ abs\left( \frac{\mathrm{M1(t)} + \mathrm{M3(t)} + \mathrm{M4(t)} + \mathrm{M6(t)}}{4} \right) \right]$$

# 2019 PEER BP Contest: Evaluation




13 teams with contestants from 10 different countries




<u>Cumulative Probability</u>: CDF(x) = (# of Mave < x)/100

- ❑ <u>For each team</u>:
  *ErrEC, ERRCC = abs (max vertical distance between team prediction CDF & experimental data CDF)*
- ❑ *ERR* = *ERR**EC*** + *ERR**CC*** (**EC**: El Centro, **CC**: Chi Chi)
- ❑ Teams are ranked in order of increasing *ERR*



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# 2019 PEER BP Contest: Winners

# 2nd Place


PEER
Pacific Earthquake Engineering Research Center
2019 BLIND PREDICTION COMPETITION
SECOND PLACE
Awarded to
?
Awarded January 16, 2020

# 2nd Place


PEER
Pacific Earthquake Engineering Research Center
2019 BLIND PREDICTION
COMPETITION
SECOND PLACE
Awarded to
Daniele Malomo
Anjali Mehrotra
Matthew DeJong
UC Berkeley
Awarded January 16, 2020

# Discrete Element Modeling of a rocking podium structure subjected to biaxial shake-table test

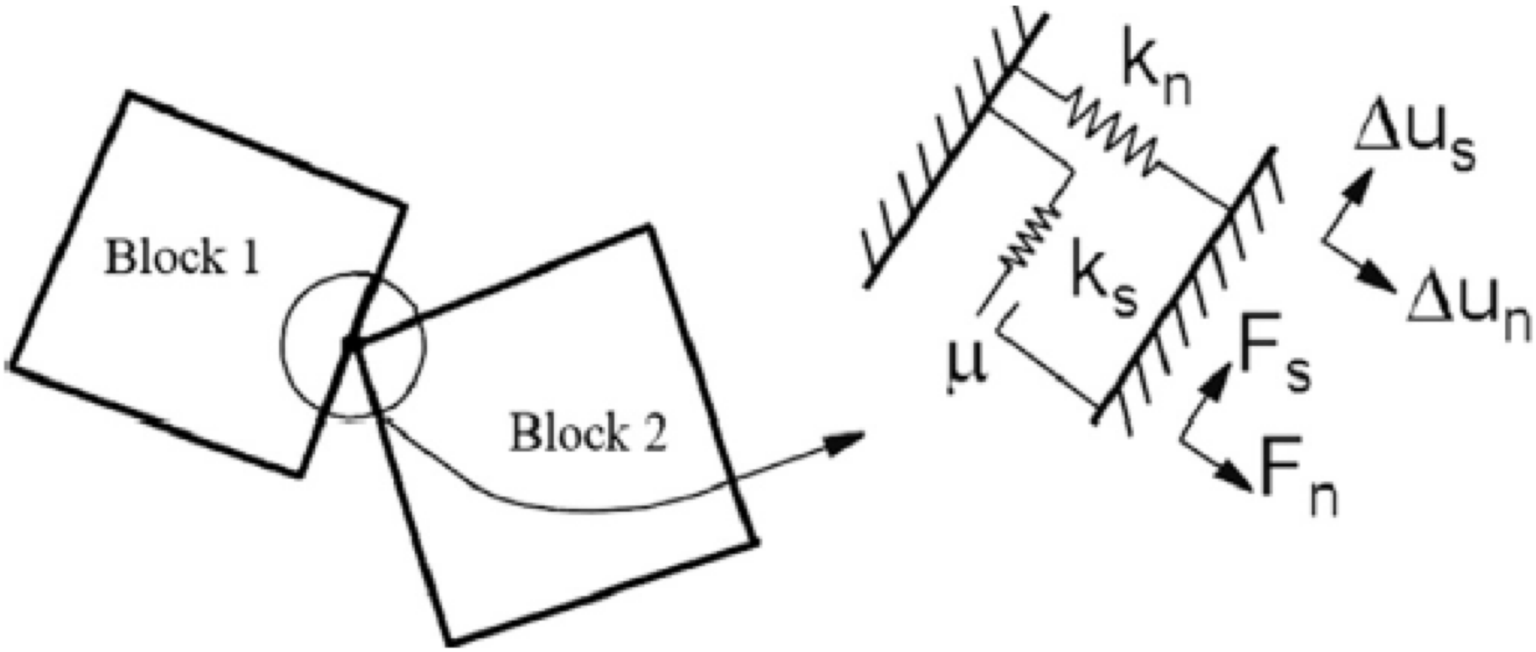
PEER Blind Prediction Contest 2020

Malomo D., Ph.D., Mehrotra A., Ph.D., DeJong, M.J., Ph.D.
Department of Civil and Environmental Engineering, UC Berkeley

Matthew DeJong Research Group - MDRG

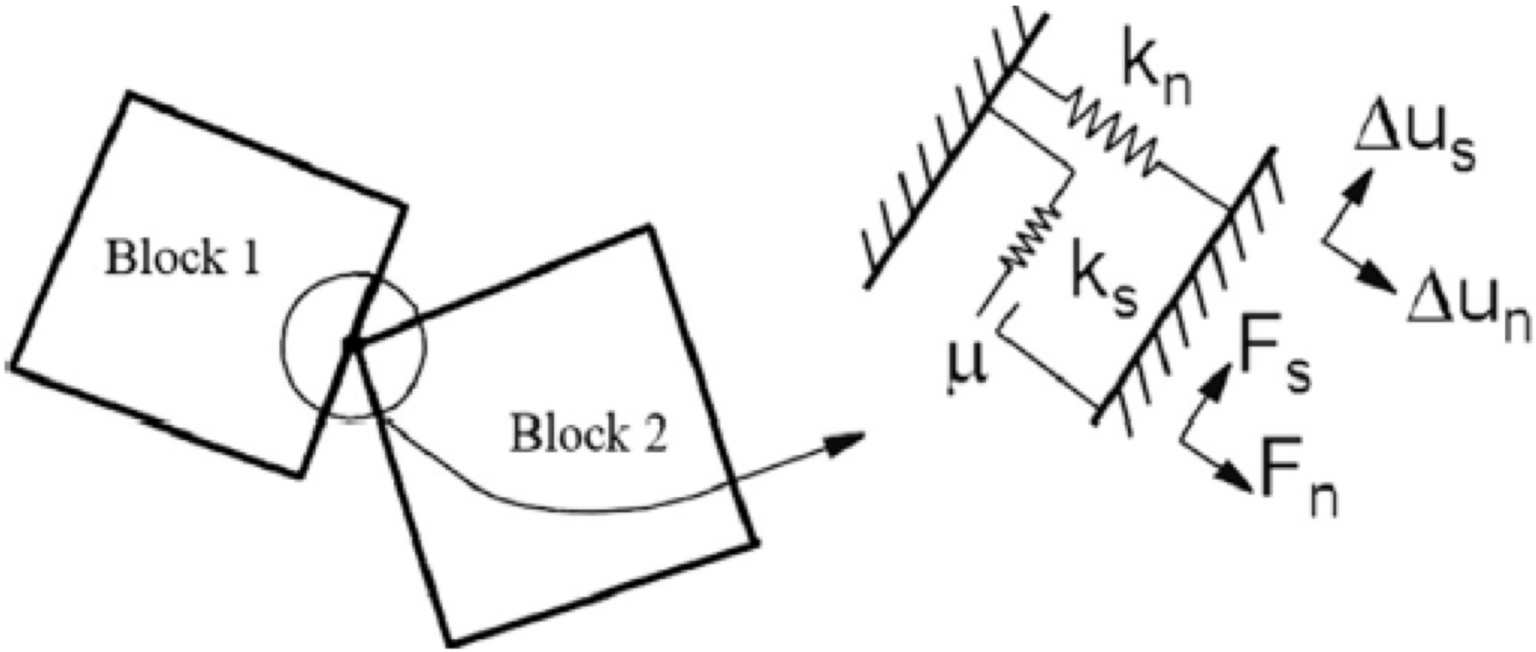
# Numerical method & main assumptions

- Distinct Element (DE) Method-based numerical model
- Rigid blocks connected by nonlinear springs with normal (*kn*) and shear stiffnesses (*ks*)
- Mohr-Coulomb criterion with no-tension (assumed μ=0.2)



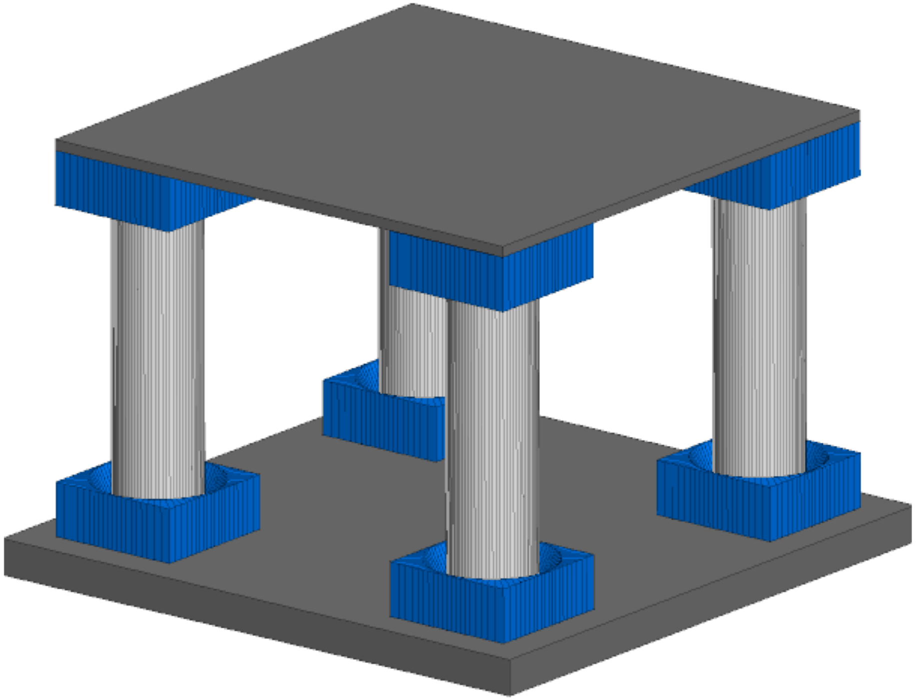
# Numerical method & main assumptions

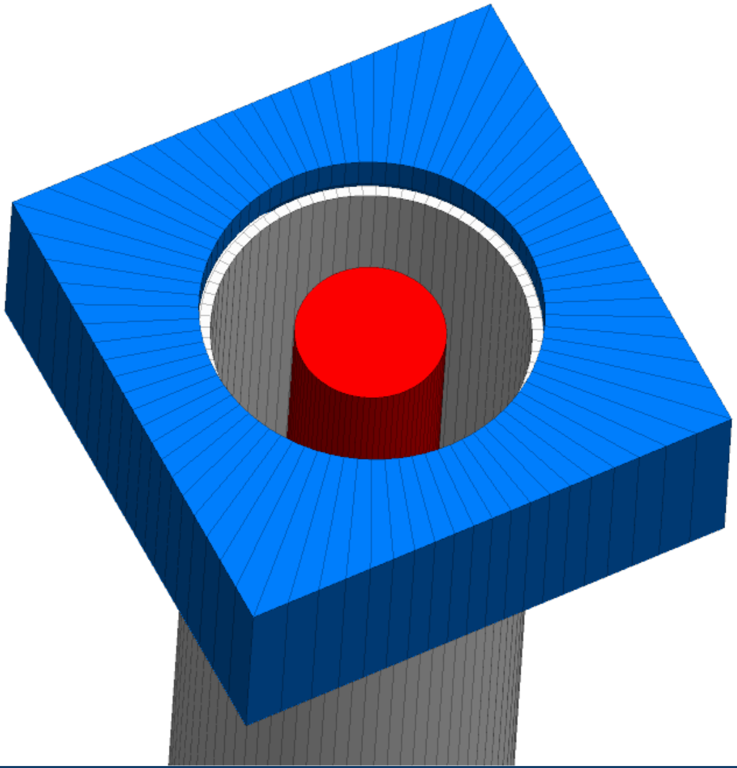
- No artificial (numerical) damping was introduced to the system
- Only frictional dissipation was considered
- This assumption also reduces the runtime of analysis, as damping generally decreases the time step



# Modeling strategy

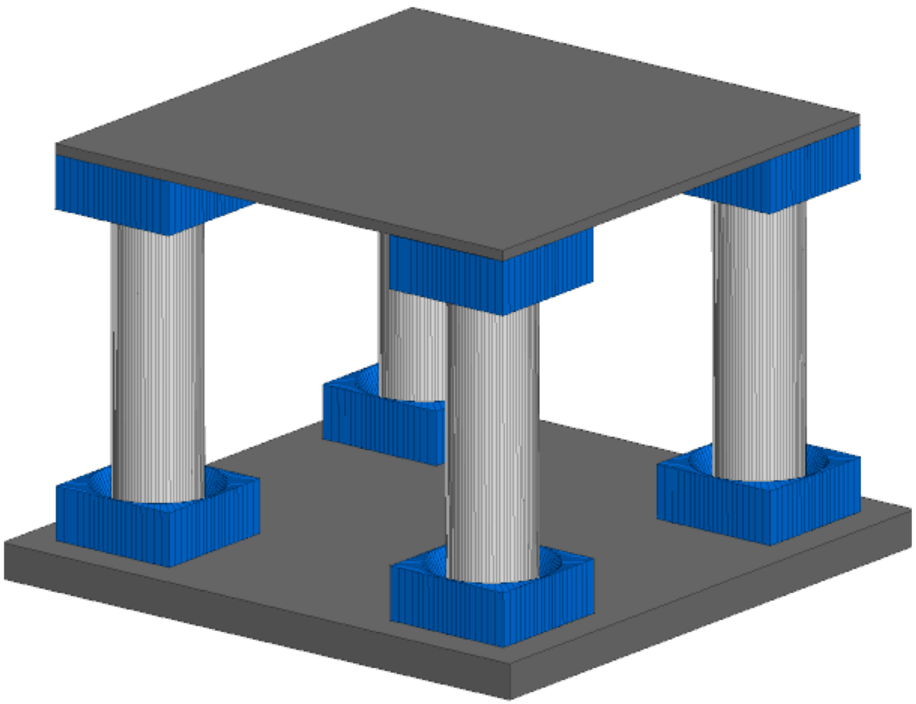
- Each structural component faithfully reproduced numerically
- Conical restraints and top/bottom slabs rigidly connected

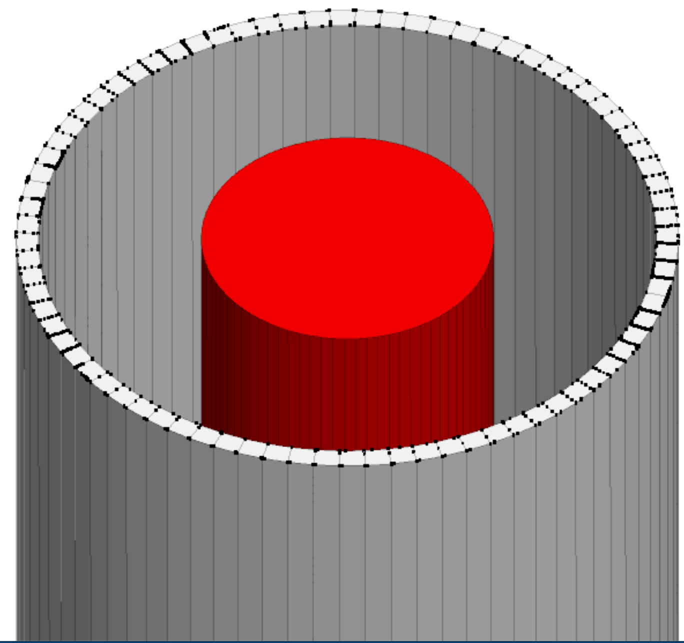




# Modeling strategy

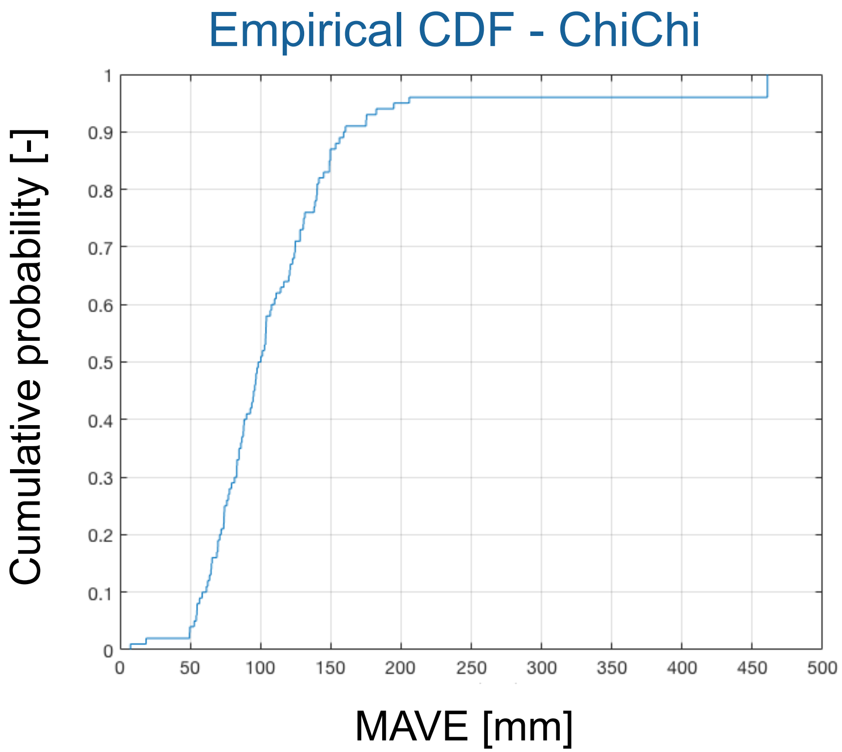
- Each structural component faithfully reproduced numerically
- Conical restraints and top/bottom slabs rigidly connected
- System nonlinearity lumped into columns-to-restraints interface springs

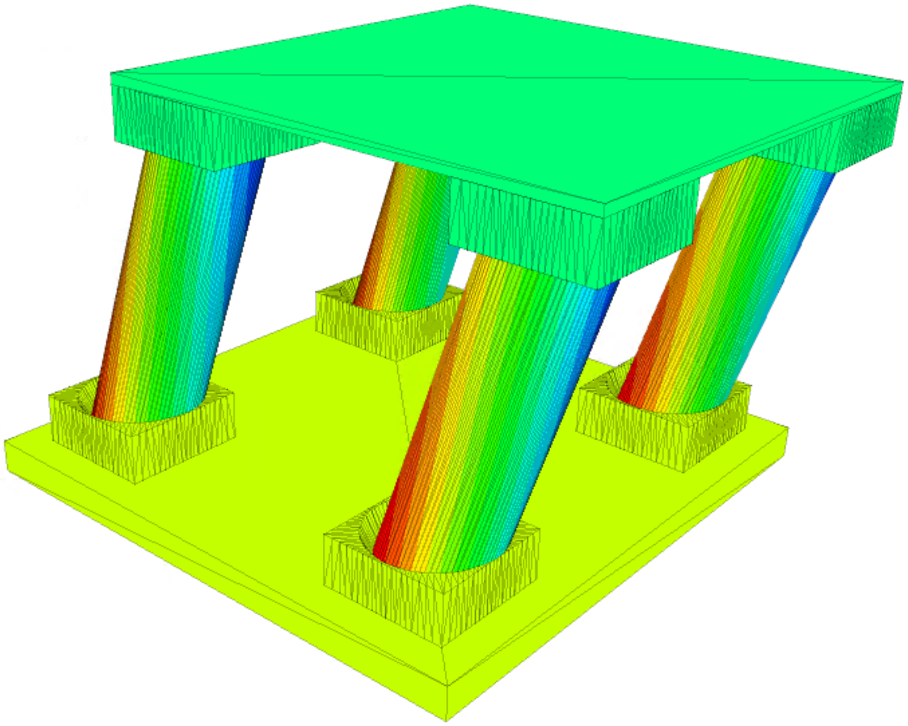




# Results and Conclusions

- Simplified modeling strategy enabled to obtain results in a reasonable timeframe
- Collapse mechanisms explicitly reproduced numerically



For details, see the related poster

# 1st Place


PEER
Pacific Earthquake Engineering Research Center
2019 BLIND PREDICTION COMPETITION
FIRST PLACE
?
University of Toronto
Awarded January 16, 2020

# 1st Place


PEER
Pacific Earthquake Engineering Research Center
2019 BLIND PREDICTION COMPETITION
FIRST PLACE
Awarded to
Chiyun Zhong
Constantin Christopoulos
University of Toronto
Awarded January 16, 2020

UNIVERSITY OF TORONTO

2019 PEER Blind Prediction Contest
Seismic Response of a Rocking Podium Structure

# Overview of Finite Element Modelling and Results

**Myron Chiyun Zhong**, PhD Candidate
**Constantin Christopoulos**, Professor
University of Toronto
Jan 16th, 2020

UNIVERSITY OF TORONTO | Civil + Mineral Engineering

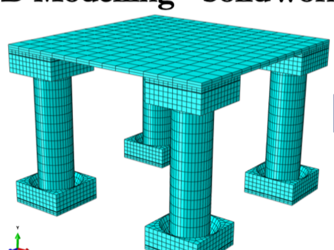
# Finite Element Modelling



## Model Overview

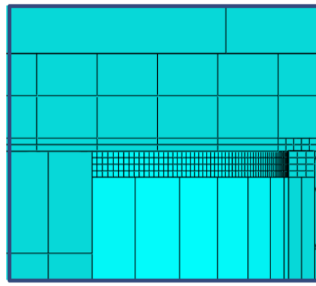
Test Specimen (PEER 2019)

3D Modelling - SolidWorks



FE Modelling - ABAQUS

## FE Model Detail

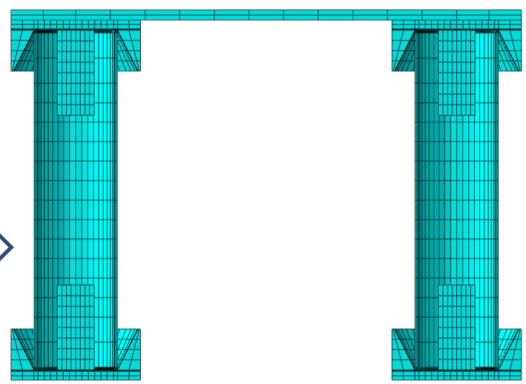


**refined mesh in the rocking contact area**

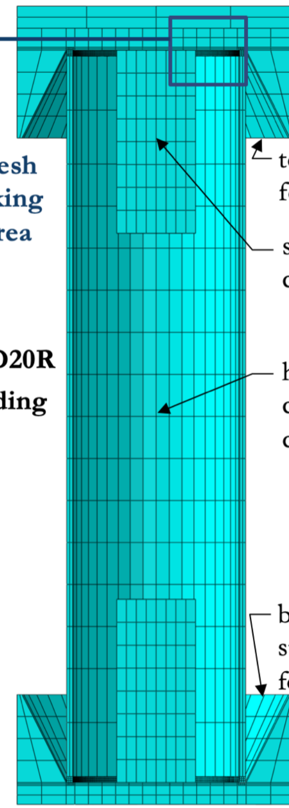
**Detailed Mesh Layout**

Friction Coefficient: **0.3** Element Type: **C3D20R**

Inherent Damping Ratio: **0** Contact: **Small-Sliding**

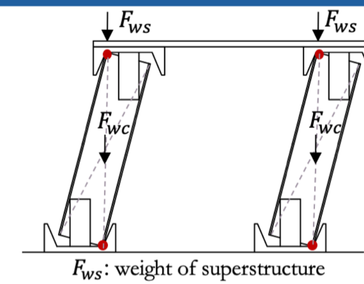


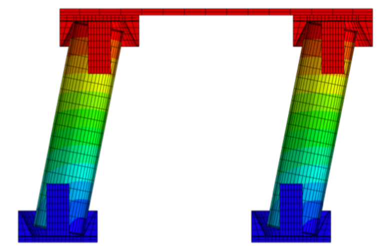
**Rocking Podium Model Overview**

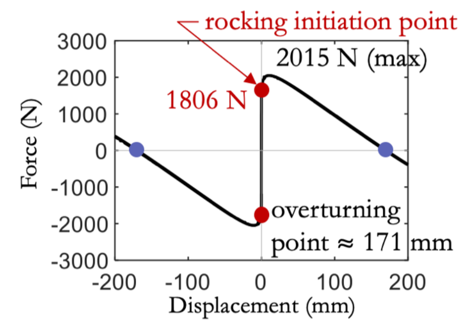



**Rocking Column**

## Push-Pull Analysis





# Overview of Analysis Results

## Sensitivity Analysis

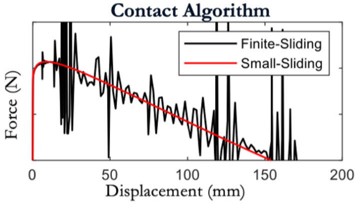
Perform **Sensitivity Analysis** to investigate:

- **Pushover responses**
- **Dynamic responses** under a few selected ground motions

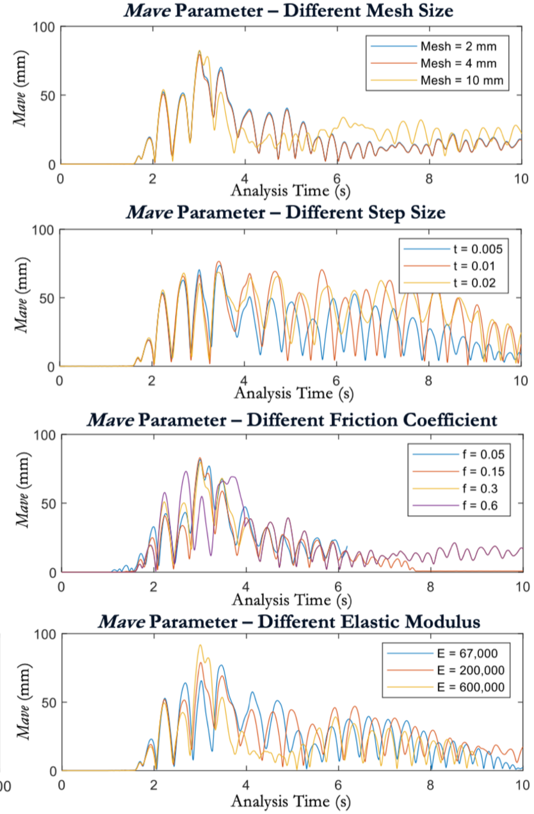
Varying **Parameters:**

- element type;
- analysis step size;
- mesh size;
- friction coefficient;
- contact algorithm;
- relative stiffness between contact regions

### Pushover Responses:

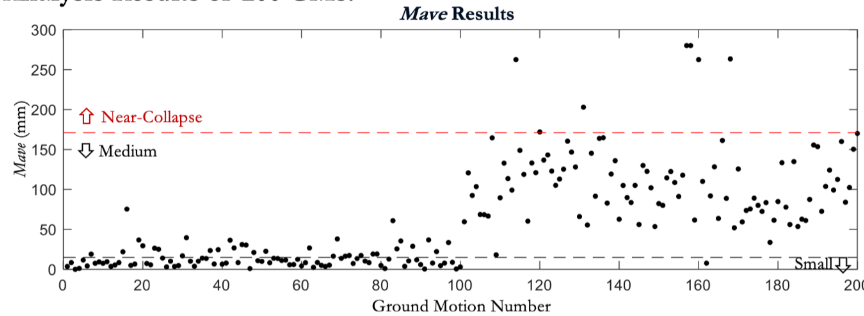



### Dynamic Responses:

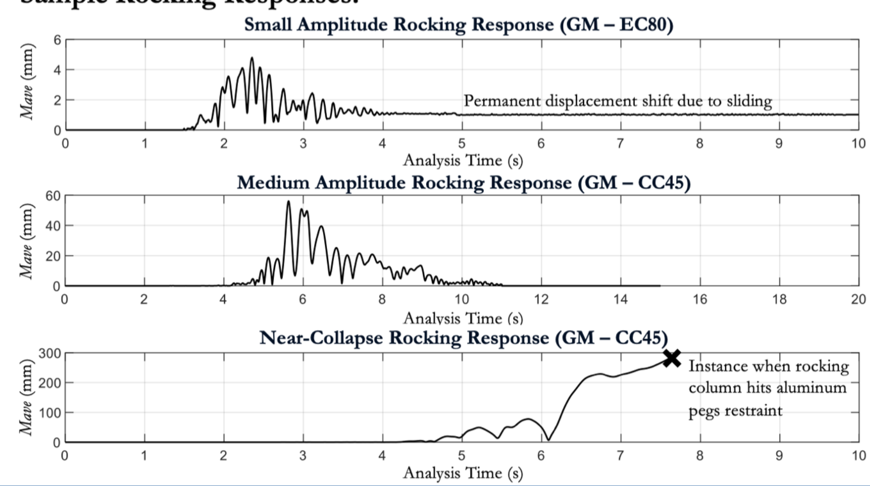



## Results Summary of 200 GMs

### Analysis Results of 200 GMs:




### Sample Rocking Responses:



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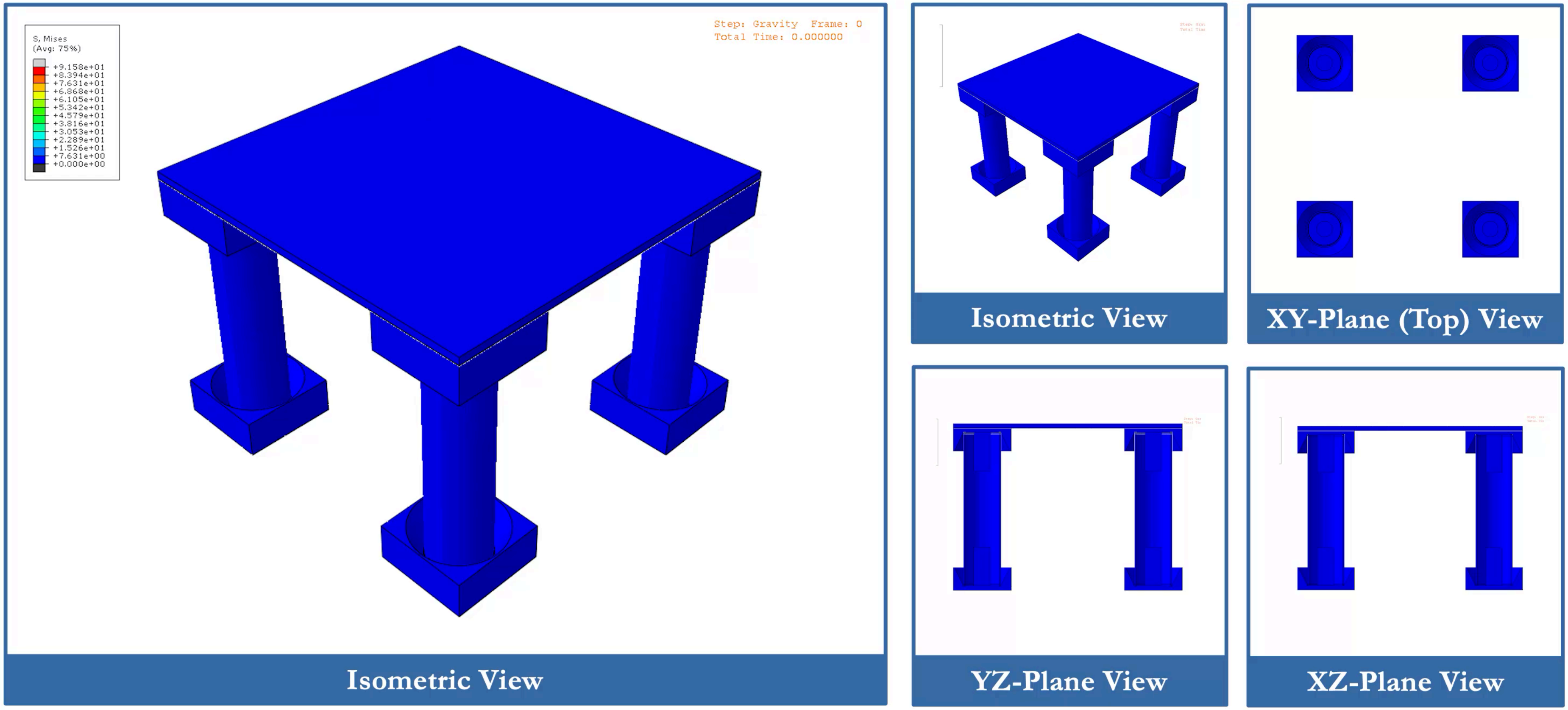
# Sample Analysis Results - Animation



## Ground Motion CC61 – Analysis Results Animation




For details, see the related poster



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# Next: Poster Session & Reception

University Club, California Memorial Stadium