IUSS
Scuola Universitaria Superiore Pavia

UME PhD Short Course on

Seismic Design of Self-Centering Systems

Pavia, Italy, May 27-31, 2019
Sala del Camino@ IUSS

• BACKGROUND

The advances in earthquake engineering over the last century have meant that a structure that is designed and constructed according to modern codes will generally be safe for users of that structure during an earthquake. However, recent earthquakes have also demonstrated that structural damage to a well-designed building can be extensive, with demolition and replacement often being more economical than repair. For this reason, there is increasing interest in structural systems that can be designed to provide at least the same level of safety as conventional systems, while also allowing much more rapid return to occupancy after a major earthquake.

This course will provide an overview of major developments in the conceptualization and design of self-centering structural systems. The main systems that have emerged will be discussed in terms of their behaviour, design, modelling, and implementation in practice. At a time when building owners and code writers are moving towards performance-based engineering for more resilient construction, those who take this course will be equipped with knowledge of the next generation of self-centering structural systems.

• OBJECTIVES OF THE COURSE

By the end of this short course, participants will have the tools to:

- discuss the expected seismic performance of conventional and self-centering structures, based on observations from recent earthquakes and test programs
- describe the development of self-centering systems, including their motivation and major research efforts
- explain the advantages and limitations of linear and static methods for the design of self-centering systems
- design self-centering systems in concrete, masonry, steel, and wood
- develop analytical and numerical models for self-centering systems

• ABOUT THE INSTRUCTOR

Lydell Wiebe is an Associate Professor in the Department of Civil Engineering at McMaster University in Hamilton, Canada. He received his BASc (2005) and PhD (2013) from the University of Toronto, and his MSc from the ROSE School (2008). Dr. Wiebe is the Vice Chair of Working Group 9 (Seismic Design) for CSA S16 (Design of Steel Structures), the Secretary of the Canadian Association for Earthquake Engineering, an Associate Editor of the Canadian Journal of Civil Engineering, and he led the writing of a New Zealand Design Guide for Controlled Rocking Steel Braced Frames. His research seeks to develop economical ways to improve structural performance, with a focus on self-centering systems under earthquake loading.

Palazzo del Broletto
Piazza della Vittoria n. 15
27100 Pavia - Italia
Tel. 39 0382 375811 Fax +39 0382 375899

info@iusspavia.it
www.iusspavia.it
C.F. 96049740184
P. IVA 02202080186

- ## COURSE SCHEDULE May 27-31, 2019

Day 1, May 27- INTRODUCTION: WHY SELF-CENTERING?

09:00-12:00 and 14:00-16:00

Morning Session: **What can we learn from recent earthquakes?**

- course objectives, scope, and format
- damage observed after recent earthquakes, particularly in Christchurch
- reconstruction after the Christchurch earthquake series
- societal expectations of seismic performance

Afternoon Session: **What are residuals, and why do they matter?**

- damage indices and residuals
- performance-based engineering framework including residual drifts
- overview of modelling approaches: SDOF, MDOF, linear/nonlinear, static/dynamic
- introduction to modelling tools for self-centering systems: SAP2000, Ruaumoko, OpenSees

Day 2, May 28 – FUNDAMENTALS, HISTORY, AND CONCRETE/MASONRY SELF-CENTERING STRUCTURES

09:00-12:00 and 14:00-16:00

Morning Session: **How were self-centering systems discovered and developed?**

- ancient rocking structures
- Housner's rocking analysis
- early studies of rocking systems
- the PRESSS program: Precast Seismic Structural Systems
- fundamental dynamics of self-centering systems
- comparison of rocking, controlled rocking, and spine systems

Afternoon Session: **How have self-centering systems been built with concrete and masonry?**

- controlled rocking precast concrete walls
- unbonded post-tensioned concrete moment frames
- post-tensioned masonry walls
- design guidance for concrete and masonry self-centering structures
- modelling techniques for concrete and masonry self-centering structures
- examples from practice

Day 3, May 29 – STEEL SELF-CENTERING STRUCTURES

09:00-12:00 and 14:00-16:00

Morning Session: **How can steel braced frames be designed to rock?**

- development of controlled rocking steel braced frames
- base rocking joint design
- higher mode effects and capacity design
- collapse performance
- collector beams and diaphragms
- design guidance for controlled rocking steel braced frames
- examples from practice

Afternoon Session: **Can steel moment frames be self-centering?**

- development of post-tensioned steel moment-resisting frames
- frame expansion and diaphragm detailing
- modelling techniques for self-centering steel braced frames and moment frames

Day 4, May 30 – SELF-CENTERING DEVICES AND WOOD STRUCTURES

09:00-12:00 and 14:00-16:00

Morning Session: **What other devices can be used for self-centering systems?**

- self-centering braces
- shape memory alloy materials
- shape memory alloy implementations
- ring springs
- other devices
- modelling techniques for self-centering axial elements

Afternoon Session: **How can wood be made self-centering?**

- controlled rocking mass timber
- PresLAM / post-tensioned timber structures
- design guidance for self-centering wood structures
- modelling techniques for self-centering wood structures
- examples from practice

Day 5, May 31 – BRIDGES, OBJECTS, AND DESIGN APPROACHES

09:00-12:00 and 14:00-16:00

Morning Session: **How can bridges be made self-centering?**

- post-tensioned bridge piers
- accelerated bridge construction
- combined sliding-rocking
- comparison with rocking implementations in buildings
- examples from practice

How does free rocking compare to controlled rocking?

- solution of equation(s) of motion for rocking objects
- rocking spectra
- applications: contents and monuments

Afternoon Session: **Are we limited to force-based design?**

- codified design requirements
- design guides
- emerging design codes and standards
- direct displacement-based design of self-centering structures