

Hybrid Simulation Demonstration with Instructional Equipment

Georgios Giotis

**MASc Candidate
Department of Civil Engineering
University of Toronto**



Introduction

□ Overview

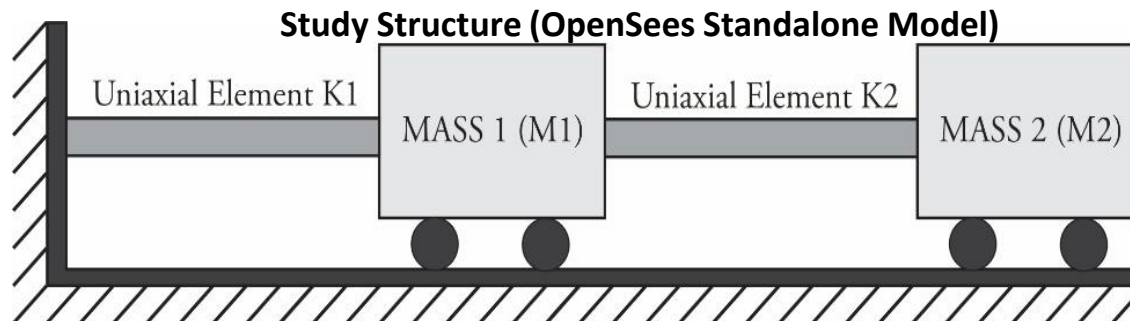
- ◇ Study structure description
- ◇ Substructures for the hybrid testing demonstration
- ◇ Testing setup overview
- ◇ Hybrid simulation demonstration
- ◇ Results



Study Structure Description

□ One-dimensional two DOF system

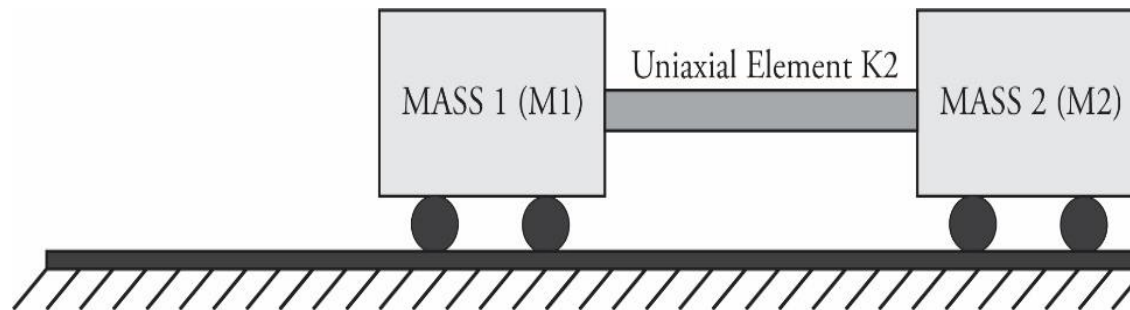
- ◇ Lumped masses: $M1=M2=20$ kg
- ◇ Uniaxial elements stiffness: $K1=K2=5$ N/mm (spring)
- ◇ Rayleigh damping equal to 2% for the 1st and 2nd response mode
- ◇ Eigen value analysis: 0.643 and 0.246 sec
- ◇ Excitation case: Artificial ground motion properly scaled with duration equal to 2.4 sec plus 0.6 sec free vibration



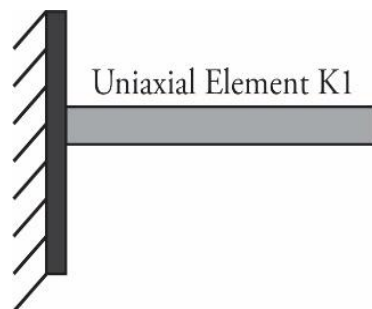
Substructures for the Hybrid Testing

□ Substructures Description

- ◇ Numerical Substructure & Integration Modules: OpenSees



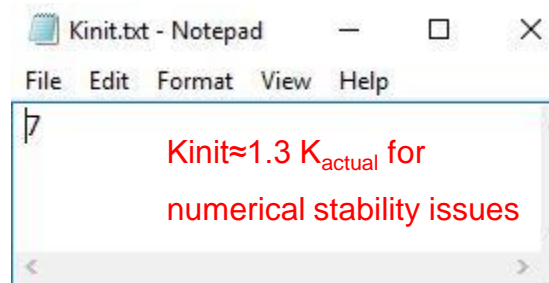
- ◇ Experimental Substructure: Physically tested specimen



Substructures for the Hybrid Testing

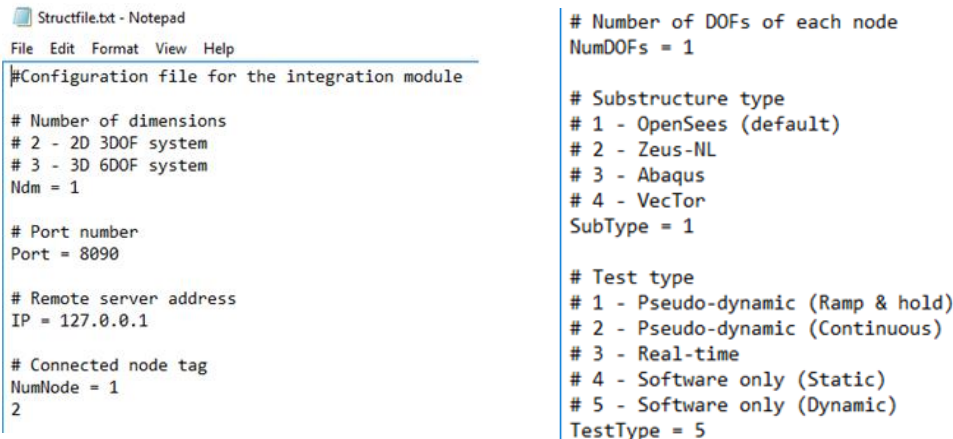
□ Integration module input files

- ◇ Numerical substructure/integration module script: 'HM.tcl'
- ◇ Dynamic link library (.dll) files
- ◇ Experimental substructure initial stiffness: 'Kinit.txt'



```
Kinit.txt - Notepad
File Edit Format View Help
Kinit ≈ 1.3 Kactual for
numerical stability issues
```

- ◇ Substructure configuration file: 'Stuctfile.txt'



```
Stuctfile.txt - Notepad
File Edit Format View Help
#Configuration file for the integration module

# Number of dimensions
# 2 - 2D 3DOF system
# 3 - 3D 6DOF system
Ndm = 1

# Port number
Port = 8090

# Remote server address
IP = 127.0.0.1

# Connected node tag
NumNode = 1
2

# Number of DOFs of each node
NumDOFs = 1

# Substructure type
# 1 - OpenSees (default)
# 2 - Zeus-NL
# 3 - Abaqus
# 4 - VecTor
SubType = 1

# Test type
# 1 - Pseudo-dynamic (Ramp & hold)
# 2 - Pseudo-dynamic (Continuous)
# 3 - Real-time
# 4 - Software only (Static)
# 5 - Software only (Dynamic)
TestType = 5
```



Substructures for the Hybrid Testing

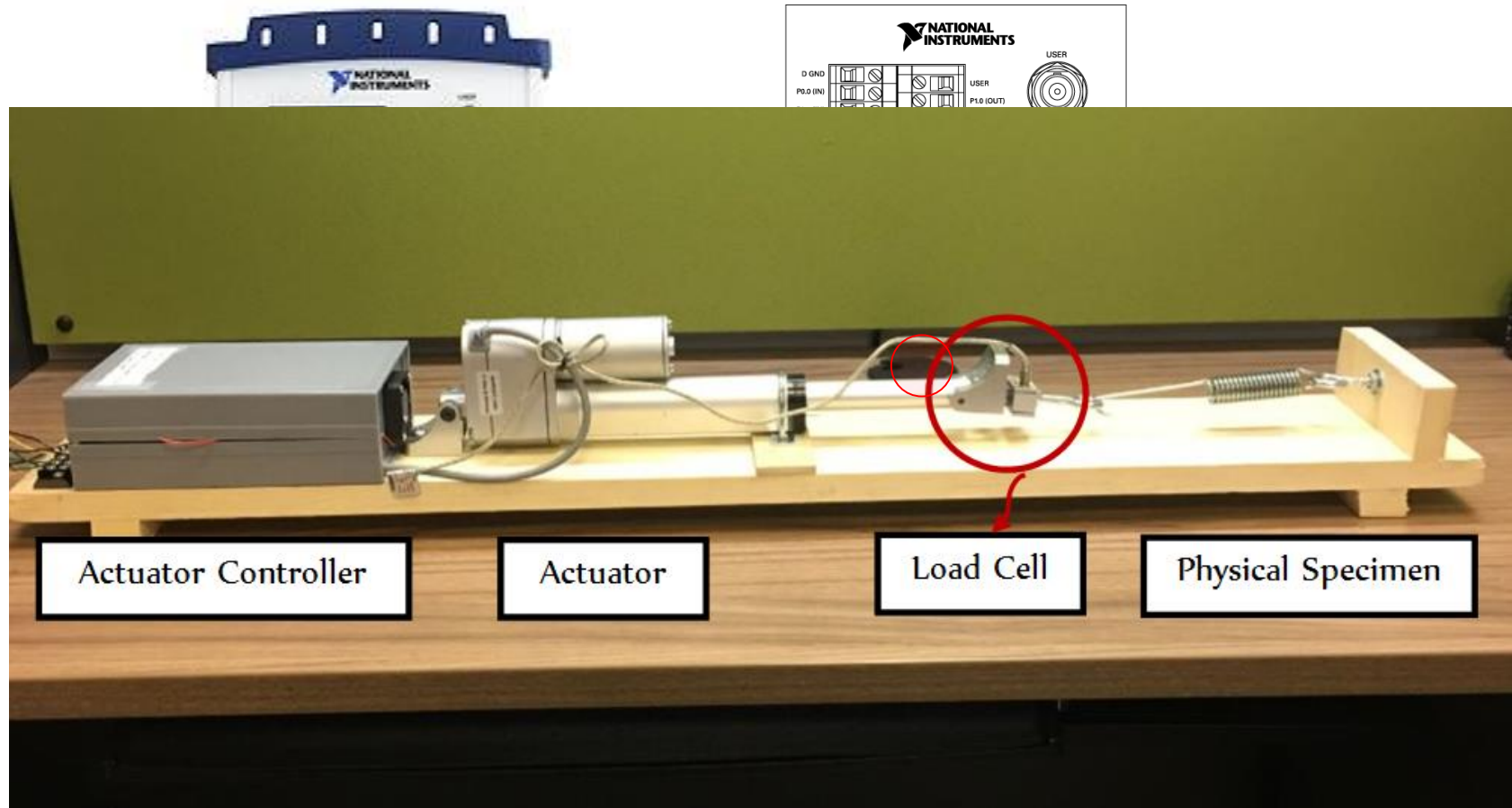
- ❑ Network Interface for Controllers (NICON) input file
 - ◇ NICON Configuration file: NICON_Config.xml

```
<?xml version="1.0" standalone="true"?>
- <LVData xmlns="http://www.ni.com/LVData">
  <Version>9.0.1</Version>
  - <Cluster>
    <Name>Configuration Cluster In</Name>
    <NumElts>29</NumElts>
    + <U32>
    + <DBL>
    + <DBL>
    - <Path>
      <Name>PathTimeHistory</Name>
      <Val>C:\Users\George\Desktop\Workshop NICON example\opensees-controller\NICON\mytimehistory.txt</Val>
    </Path>
    - <U32>
      <Name>PolynomialOrder</Name>
      <Val>5</Val>
    </U32>
    - <Boolean>
      <Name>RampMode</Name>
      <Val>1</Val>
    </Boolean>
    - <DAQChannel>
      <Name>OutputCh</Name>
      <Val>Dev1/ao1</Val>
    </DAQChannel>
    - <DAQChannel>
      <Name>InputCh1</Name>
      <Val>Dev1/ai0</Val>
    </DAQChannel>
    - <DAQChannel>
      <Name>InputCh2</Name>
      <Val>Dev1/ai1</Val>
    </DAQChannel>
```



Testing Setup Overview

- Data Acquisition System (DAQ): NI USB-6128 BNC



Hybrid Simulation Demonstration

□ Moving to NICON Environment

NICON - Network Interface for Controllers University of Toronto

Command Source
Network (PSD Test) | User Input | Time History
Note: PSD Test is compatible with SIMCOR Binary Protocol.
Port Number: 8090
CMD rcvd: 10
Current Step Number: 210
rcvied target Displacement: -6.92956
SocketNum: 48900
Start Server:
Start Communication:
NC Status: Ready to Read the values:
Create data exchange format:
Connected: Waiting CMD: Testing: Reporting: Completed:

Control Panel
Control | Limits | Scale Factors
Manual Auto
Previous Target Disp: -4.25025
Current Command Disp: -4.25881
Current Target Disp: -6.92956
Current Measured Disp: -4.31039
Execute Target CMD | Cancel
Displacement Limit Status:
Force Limit status:
Ramp Generation
RampMode: Sine Wave
Ramp (ms): 2500 | Hold (ms): 500
Control On/Off
Analog I/O update rate (ms): 10
Analog I/O logging rate (ms): 500
Control:

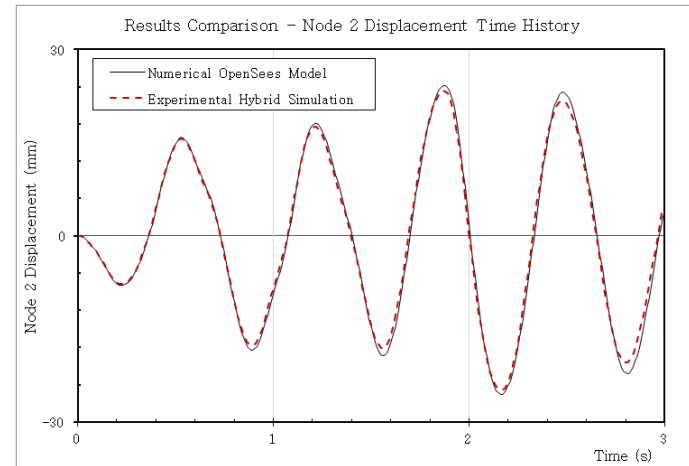
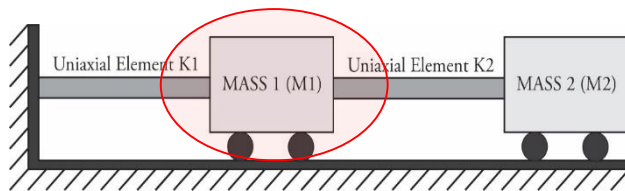
Monitoring Panel
Time History | Force - Displacement | Raw Voltages
Actual Tared
Measured Displacement (mm): -4.310
Command Displacement (mm): -4.257
Measured Force (KN): -7.530
Displacement, mm vs Time (7:55:44.376 PM to 7:55:49.376 PM)
Force, N vs Time (7:55:44.383 PM to 7:55:49.383 PM)



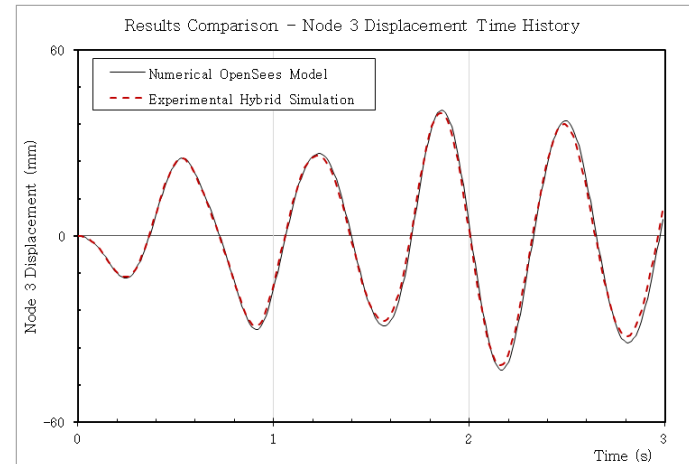
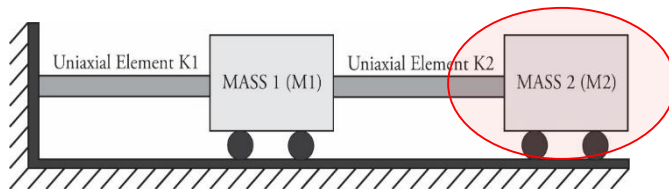
Results

□ Displacement time history comparison

◇ Node 2: Mass 1



◇ Node 3: Mass 2



**Thank you for you attention.
Questions?**

Georgios Giotis

**MASc Candidate
Department of Civil Engineering
University of Toronto**

