

# Assessing and Increasing Resilience of Soil-Structure Systems for Seismic Loads

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Italy

# Outline

Introduction

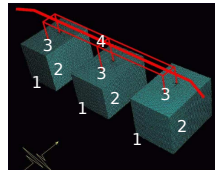
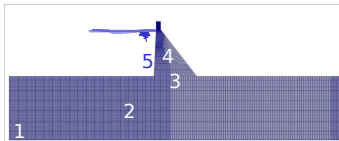
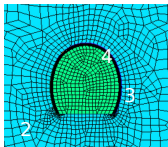
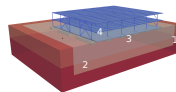
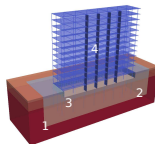
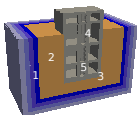
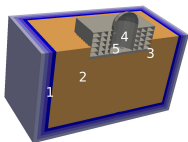
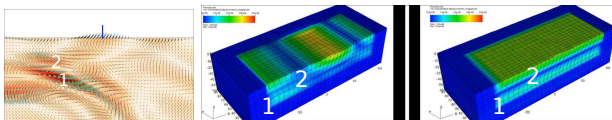
Assess and Increase Resilience of Infrastructure  
Stress Test Motions  
Seismic Energy Dissipation

Summary

# Motivation

- Safety and economy of infrastructure
- Design, build and maintain sustainable infrastructure
- Responsible Engineer, with Executive Powers
- Engineer with versatile, quality assured analysis tool to
  - Explore design concepts
  - Assess infrastructure performance
- Engineering analysis to predict and inform
  - Stress test ESSI systems
  - Control/Direct seismic energy propagation in ESSI systems

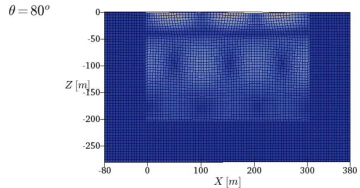
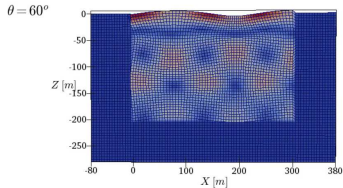
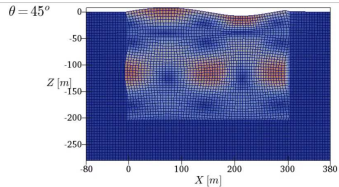
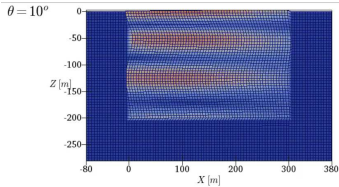
# Civil Engineering Analysis Challenges



# Stress Test Motions

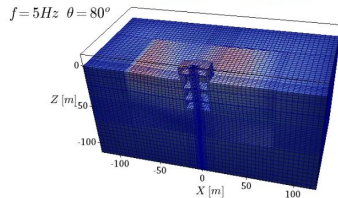
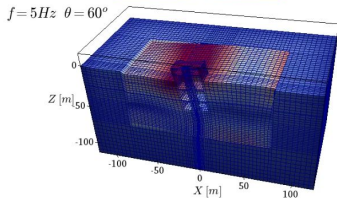
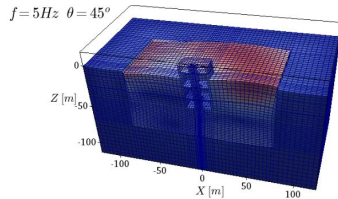
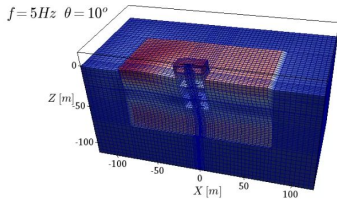
- Excite SSI system with a suite of motions
- Motions: variation in strike and dip, body waves P, S; (near) surface waves (Rayleigh, Love, Stoneley, etc.), real/seismic and wavelet signals
- Plane wave stress test motions: 3D-6C (Thompson/Haskell solution for plane harmonic waves) and/or 3D-3×1C and/or 3D-1C and or 1D-1C motions
- Regional scale seismic models
- Deep, shallow geology and soil is important !

## Stress Test Motions

Free Field, Variation in Input Wave Angle,  $f = 5\text{Hz}$ 

(MP4)

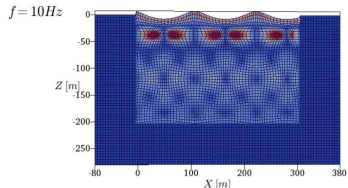
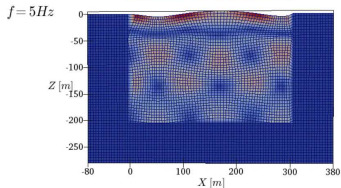
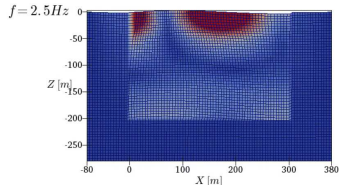
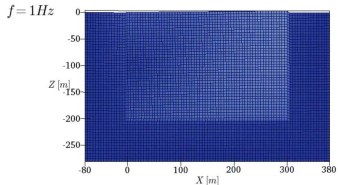
## Stress Test Motions

SMR ESSI, Variation in Input Wave Angle,  $f = 5\text{Hz}$ 

(MP4)



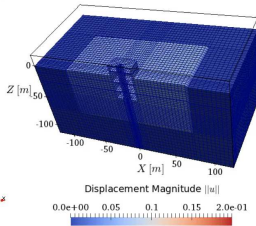
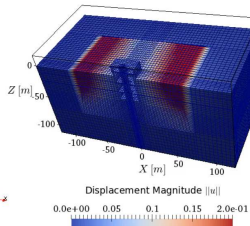
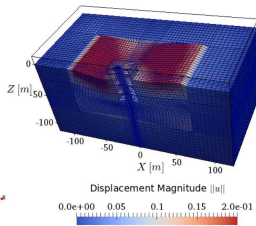
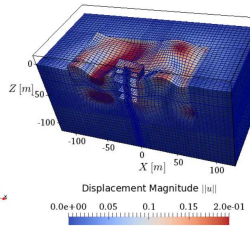
## Stress Test Motions

Free Field, Variation in Input Frequency,  $\theta = 60^\circ$ 

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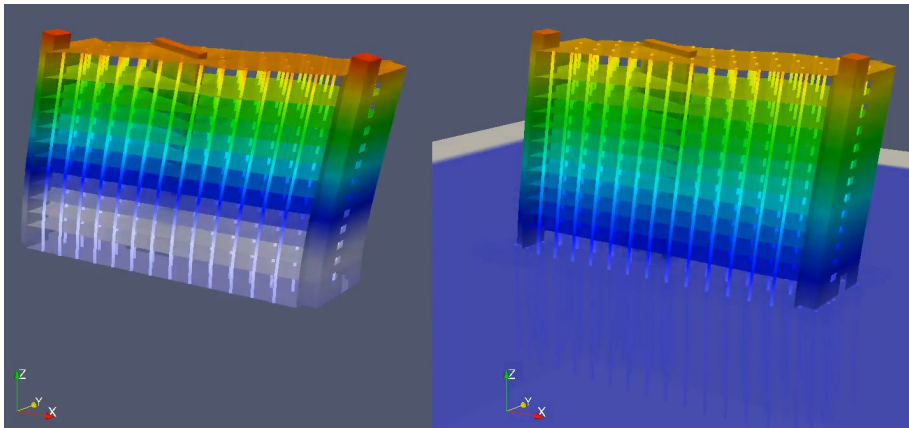


## Stress Test Motions

SMR ESSI, Variation in Input Frequency,  $\theta = 60^\circ$  $f = 1Hz$  $f = 2.5Hz$  $f = 5Hz$  $f = 10Hz$ 

(MP4)

# nonSSI vs SSI, Ventura Hotel, Northridge Eq.



(MP4)

# Seismic Energy Propagation in ESSI System

Energy input, forces/loads, static/dynamic

Energy dissipation outside SSI domain:

SSI system oscillation radiation

Reflected waves radiation

Energy dissipation/conversion inside SSI domain:

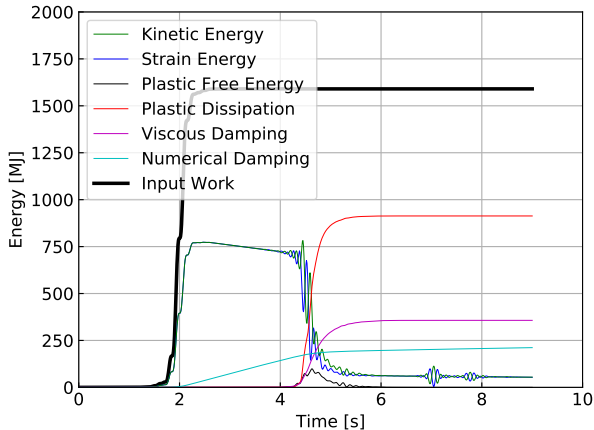
Inelasticity/damage: rock, soil, interfaces, structure, dissipators

Viscous coupling: internal, pore and external fluids

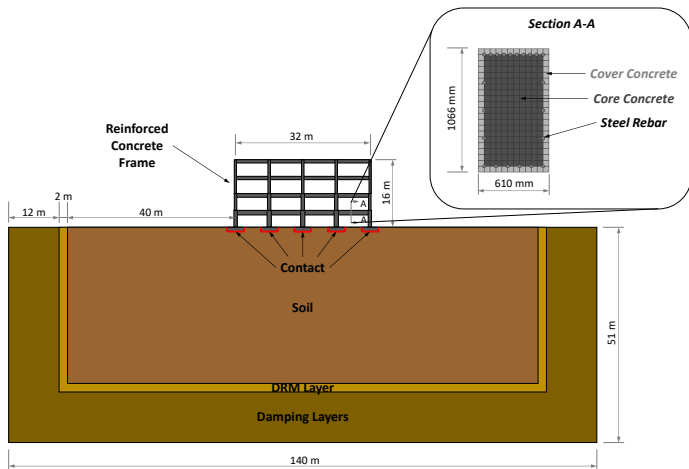
Energy deflectors, meta-materials

Numerical energy dissipation/production

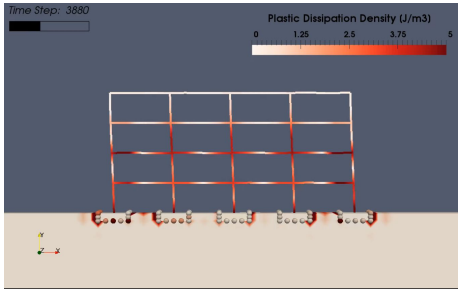
# Energy Dissipation Control, Analysis



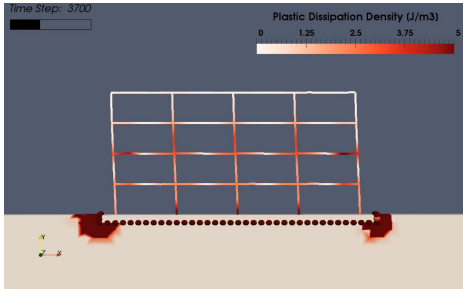
# Energy Dissipation for Design



# Design Alternatives



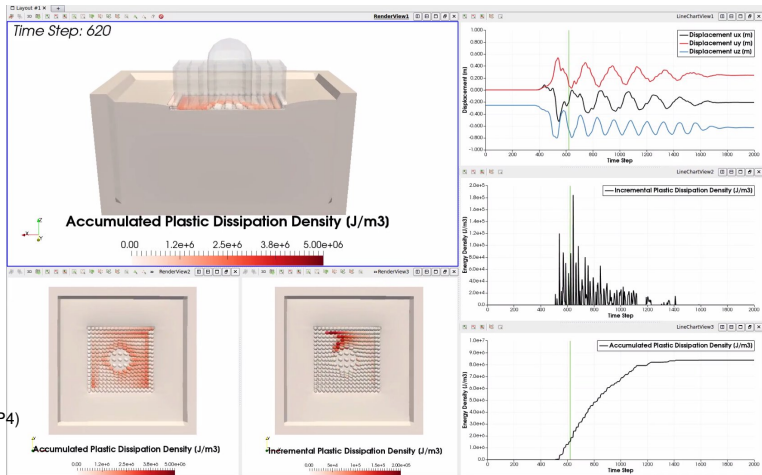
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(MP4)

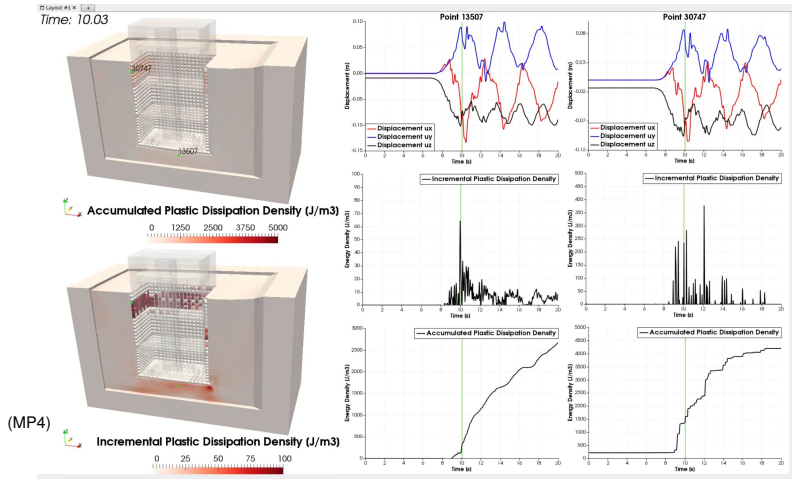
## Seismic Energy Dissipation

## Important Infrastructure, Energy Dissipation



## Seismic Energy Dissipation

## SMR Seismic Response, Energy Dissipation





# Summary

- Engineering analysis to predict and inform
- Education and Training is the Key !
- Analysis tool: <http://real-essi.us>
- Collab. Yang, Cheng, Tafazzoli, Feng, Yang, Sinha, Wang, Pisanó, Abell, Tafazzoli, Sett, Vilhar, Jeong, Jie, Preisig, Liu, Jain, Liao, Wu, Li, Tasiopoulou, Watanabe, Luo, Cheng, Yang, Kanellopoulos, Staszewska ...
- Collab./Fund. US-DOE, US-NRC, US-NSF, US-DOD, Caltrans, US-FEMA/ATC, CNSC-CCSN, UN-IAEA, CERN, ETH , CH-ENSI/Basler&Hofmann and Shimizu Corp.

