Seismic Energy Flow Calculations for Earthquake Soil Structure Interaction Systems

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Outline

Introduction

Energy Flow Simulations

Conclusion

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Motivation

Improve modeling and simulation for infrastructure objects

Expert numerical modeling and simulation tool

Reduction of modeling uncertainty

Choice of analysis level of sophistication

Goal: Predict and Inform rather than fit

Engineer needs to know!

System for **Real**istic modeling and simulation of **E**arthquakes, **S**oils, **S**tructures and their **I**nteraction:

Real-ESSI Simulator `http://real-essi.info/`

ESSI: Energy Input and Dissipation

Energy input, dynamic forcing

Energy dissipation outside SSI domain:

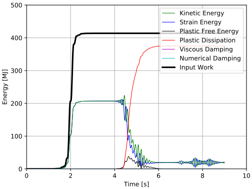
- SSI system oscillation radiation
- Reflected wave radiation

Energy dissipation/conversion inside SSI domain:

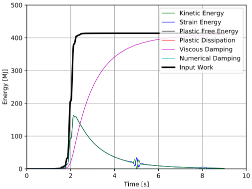
- Inelasticity of soil, contact/interface zone, structure, foundation, dissipators
- Viscous coupling with pore fluids, and external fluids

Numerical, algorithmic energy dissipation/production

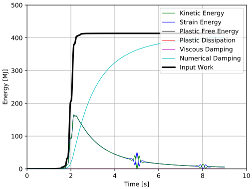
Energy Dissipation Control Mechanisms



Plasticity



Viscous



Numerical

Real-ESSI Simulator System

The Real-ESSI, **Real**istic Modeling and Simulation of **E**arthquakes, **S**oils, **S**tructures and their **I**nteraction. Simulator is a software, hardware and documentation system for time domain, linear and nonlinear, inelastic, deterministic or probabilistic, 3D, finite element modeling and simulation of:

- statics and dynamics of soil,
- statics and dynamics of rock,
- statics and dynamics of structures,
- statics of soil-structure systems, and
- dynamics of earthquake-soil-structure system interaction

Used for:

- Design, linear elastic, load combinations, dimensioning
- Assessment, nonlinear/inelastic, safety margins

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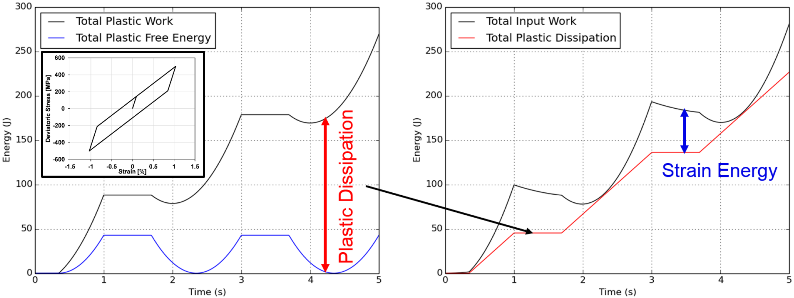
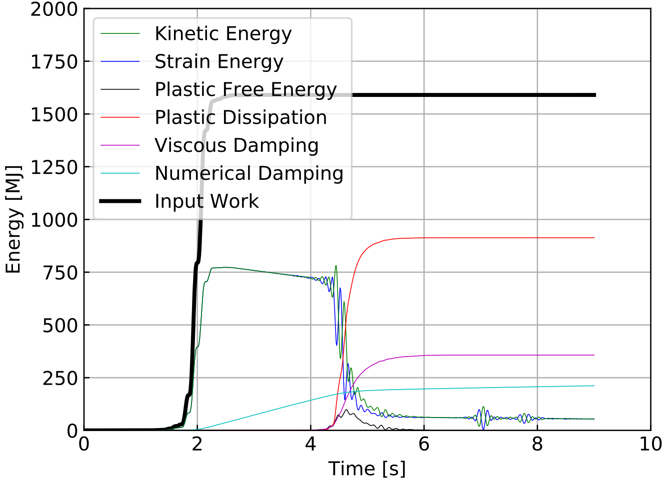
Plastic Energy Dissipation

Single elastic-plastic element under cyclic shear loading

- Difference between plastic work and plastic dissipation
- Plastic work can decrease
- Plastic dissipation always increases



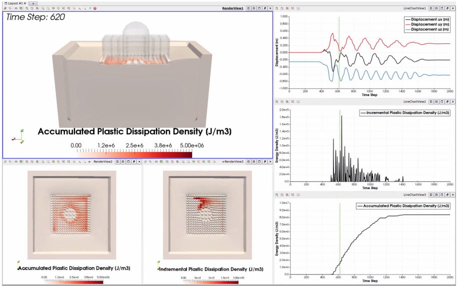
Energy Dissipation Control

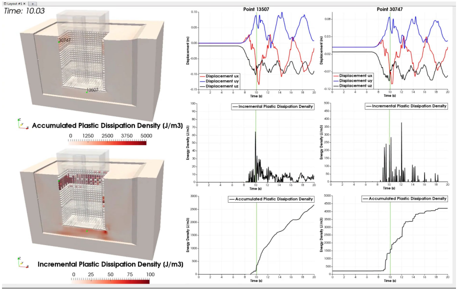


Inelastic Modeling of Soil Structure Systems

- Soil, inelastic, elastic-plastic
  - Dry, single phase
  - Unsaturated, partially saturated
  - Fully saturated
- Contact, inelastic, soil/rock – foundation
  - Dry, single phase,
    - Normal, hard and soft, gap open/close
    - Friction, nonlinear
  - Fully saturated, suction, excess pressure, buoyant force
- Structure, inelastic, damage, cracks
  - Nonlinear/inelastic 1D reinforced concrete fiber beam
  - Nonlinear/inelastic 3D reinforced concrete solid element
  - Alcali Silica Reaction concrete modeling

Energy Dissipation in a NPP and SMR Models

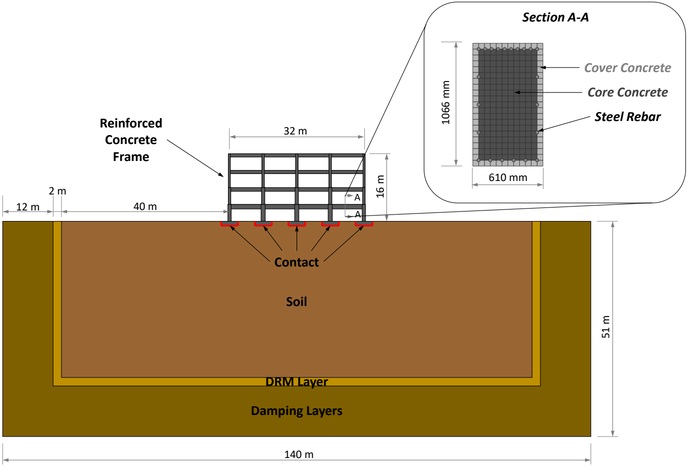




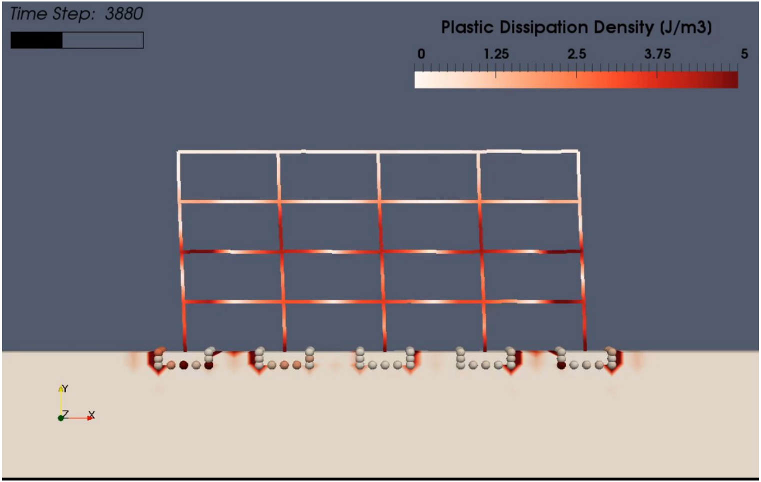
(MP4)

(MP4)

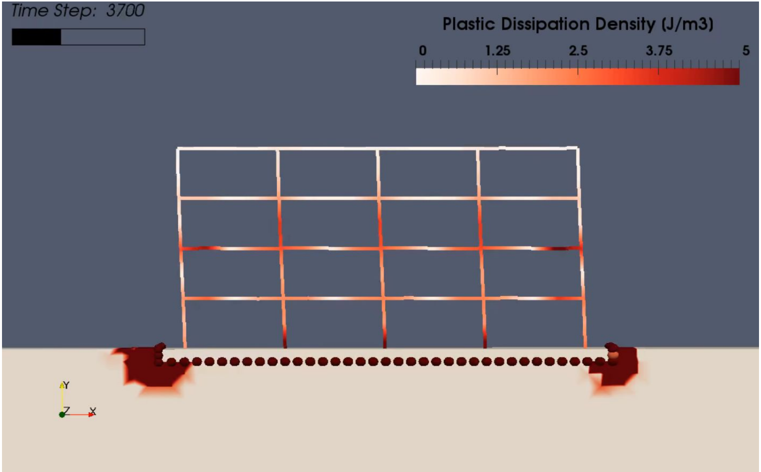
Energy Dissipation for Design



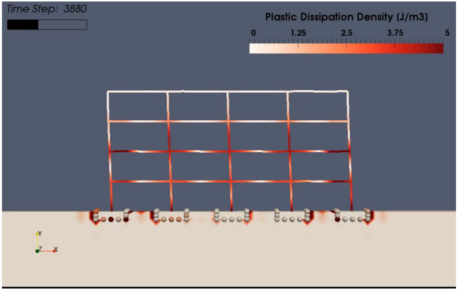
Design Alternatives, Individual Footing

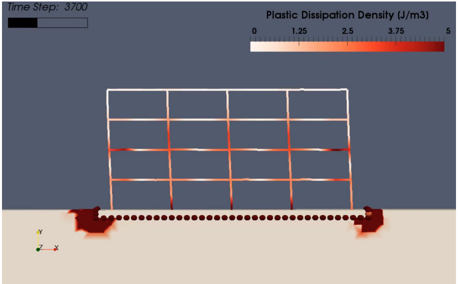


Design Alternatives, Slab Foundation

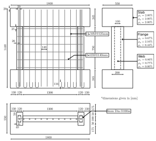


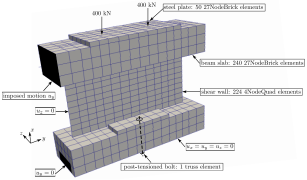
Design Alternatives

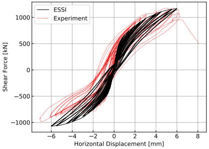


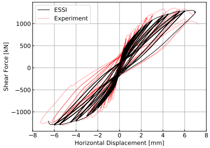


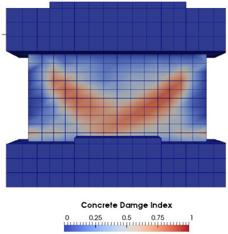
Wall, Regular and ASR Concrete



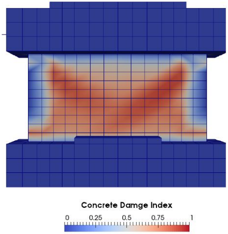




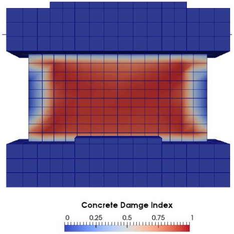




u_y = 1.4 mm



u_y = 1.8 mm



u_y = 3.0 mm

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Summary

- Numerical modeling to predict and inform, rather than fit
- Accurate energy dissipation calculations
- Education and Training is the key!
- Real-ESSI short course this Fall!
- **`http://real-essi.info/`**