

Online Lectures:
Realistic Modeling and Simulation of
Earthquakes, and Soils, and
Structures, and their Interaction (ESSI),
Theory Background and Real-ESSI Examples

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<http://real-essi.us/>

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Chapter 1

Online Education and Training

(2019-2020-2023-)

(In collaboration with Dr. Han Yang and Mr. Hexiang Wang)

1.1 Real-ESSI Simulator Online Education and Training

This chapter was created to present online material for the theory for modeling and simulation of earthquakes, soils, structures and their interaction, as well practical examples using the Real-ESSI Simulator, <http://real-essi.us/>.

It is worth noting that some early recorded material for use of the Real-ESSI Simulator on Amazon Web Services was created in 2019, however, majority of presented, recorded material was created during Corona-Virus (COVID-19) pandemic and quarantine from March through June of 2020, in Zürich Switzerland, where Boris Jeremić was locked-up, and in Davis, California, where Han Yang and Hexiang Wang were locked-up... Internet worked very good across the Atlantic ocean, zoom.us worked really well as well. Development of online educational material continued with all three contributors now in Davis, California during Summer and Fall 2020, Winter and Spring 2021, still during partial/full lock-down, shelter in place, still using zoom.us, and still keeping physical distance, wearing face masks, etc.

In addition to organizing slides and vide lectures through this document, a youtube video channel for the Real-ESSI is available here: [Real-ESSI youtube channel](#).

It is hoped that this material will be helpful to students and engineers that work in the area of modeling and simulation of earthquakes, soils, structures and their interaction.

1.1.1 Modeling and Simulations for ESSI

The following recorded lectures modeling and simulation approaches for Earthquakes, Soils, Structures and their Interaction are available:

1.1.1.1 Introduction to Modeling and Simulation

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.1.2 Introduction to Modeling Simplifications, Epistemic Uncertainty

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.1.3 Introduction to Parametric, Aleatory Uncertainty

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.2 Real-ESSI Simulator Modeling and Simulation System

The following recorded lectures about the Real-ESSI Simulator modeling and simulation system are available:

1. The Real-ESSI Simulator, Introduction:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. The Real-ESSI Simulator, Modeling Features:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. The Real-ESSI Simulator, Domain Specific Language:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

4. The Real-ESSI Simulator, Model Development:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

5. The Real-ESSI Simulator, Results Post Processing:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

6. The Real-ESSI Simulator, Quick Analysis Startup Guide, how to run simple example models:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.3 Finite Element Method

The following recorded lectures on the finite element method are available:

1.1.3.1 Background

1. Introduction to the Finite Element Method (FEM):

[PDF slides](#), [MP4 recording](#)

2. Derivation of FEM equations of motions for single phase, dry material:

[PDF slides](#), [MP4 recording](#)

3. Derivation of FEM equations of motions for coupled, two phase, fully and partially saturated material, u-p-U formulation:

[PDF slides](#), [MP4 recording](#)

1.1.3.2 Nonlinear, Inelastic FEM

4. Nonlinear, Inelastic FEM, residual equations:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

5. Solution of nonlinear, inelastic FEM equations:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.3.3 Dynamic FEM

6. Dynamic FEM equations:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

7. Time marching algorithms for dynamic FEM equations:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.4 Deterministic Elasto-Plasticity

1.1.4.1 Introduction to Modeling and Simulation

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

The following recorded lectures on deterministic elasto-plasticity are available:

1.1.4.2 Theory Background

1. Micromechanical origins of elasto-plasticity:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. Introduction to the incremental theory of elasto-plasticity:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. Explicit solution to the constitutive elastic-plastic problem:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

4. Implicit solution to the constitutive elastic-plastic problem:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.4.3 Elastic-Plastic Material Model Choices

5. Choice of elastic-plastic material models for soils and interfaces/contacts/joints:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

6. Choice of elastic-plastic material models for structural elements, beams and walls/plates/shells:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.4.4 Calibrating Elastic-Plastic Material Models

7. Calibration of elastic-plastic material models for sand:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

8. Calibration of elastic-plastic material models for clay:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

9. Calibration of elastic-plastic material models for interfaces/contacts/joints:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

10. Calibration of elastic-plastic material models for concrete, in reinforced beams and walls/plates/shells:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

11. Calibration of elastic-plastic material models for steel, in reinforced beams and walls/beams/shells:

[PDF slides](#),

and a direct

[MP4 recording](#)

and/or alternatively

[YouTube video](#)

1.1.5 Seismic Energy Dissipation

The following recorded lectures on energy dissipation are available:

1.1.5.1 Theory Background

1. Energy dissipation introduction:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. Energy dissipation in solids:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. Energy dissipation in fiber beams:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

4. Energy dissipation in interfaces/joints/contacts:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

5. Energy dissipation due to viscous effects:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

6. Energy dissipation due to time integration, algorithmic, numerical effects:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.5.2 Illustrative Examples

7. Energy dissipation examples:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.6 Probabilistic Elasto-Plasticity and Stochastic Elastic-Plastic Finite Element Method

1.1.6.1 Theory Background

1. Introduction to the Polynomial Chaos (PC) expansion:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. Introduction to the Karhunen-Loève (KL) expansion:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. Introduction to the Stochastic Elastic-Plastic Finite Element Method (SEPFEM)

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

4. Introduction to Sensitivity Analysis

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.6.2 Choice and Calibration of Probabilistic Material Models and Probabilistic Seismic Loads

5. Choice, analysis and calibration of probabilistic elastic material parameters:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively; [YouTube video](#)

6. Choice, analysis and calibration of probabilistic elastic-plastic, nonlinear, inelastic material parameters:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

7. Choice, analysis and calibration of probabilistic seismic motions:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.6.3 Simple Probabilistic Examples

8. SEPFEM, Two Examples:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

9. SEPFEM, Seismic Risk Analysis Example:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.6.4 Probabilistic Wave Propagation Examples

10. Analysis of one component (1C) seismic wave propagation with uncertain motions and uncertain elastic material parameters:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

11. Analysis of one component (1C) seismic wave propagation with uncertain motions and uncertain elastic-plastic, nonlinear, inelastic material parameters:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

12. Sensitivity analysis for uncertain motions and uncertain elastic material parameters:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

13. Sensitivity analysis for uncertain motions and uncertain elastic-plastic, nonlinear, inelastic material parameters:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.7 Seismic Motions

The following recorded lectures on seismic motions are available:

1. On earthquakes:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. On six component (6C) seismic motions:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. On the Domain Reduction Method (DRM):

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

4. Development of DRM motions from surface records, 1C, 2×1C, and 3×1C:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

5. Development of DRM motions from inclined, 3C seismic waves:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.8 Earthquake Soil Structure Interaction

The following recorded lectures on Earthquake Soil Structure Interaction (ESSI) are available:

1. On ESSI:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.9 Verification and Validation

Basic theory of Verification and Validation (V&V), as well as V&V examples for the Real ESSI Simulator are shown in recorded lectures below:

1. Verification and Validation introduction:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. Real ESSI Simulator Verification and Validation system:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. Real ESSI Simulator Verification examples:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

4. Real ESSI Simulator Validation examples:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.10 High Performance Computing

High Performance Computing (HPC) is helping with analysis of sophisticated models efficiently on sequential and parallel computers.

1.1.10.1 HPC Introduction

1. HPC, an Introduction:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

2. Fine grained HPC:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

3. Coarse grained HPC, a Distributed Memory Parallel (DMP) Introduction:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.10.2 HPC and Real-ESSI

1. Real-ESSI Simulator HPC Approach:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.10.3 Real-ESSI Parallel Computing Examples

1. Real-ESSI Simulator Parallel Examples:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

1.1.11 Real-ESSI Simulator Examples, Analysis and Post-Processing

Select Real-ESSI examples are shown in recorded lectures below:

1. How to run already installed Real-ESSI program on a simple example:

[MP4 recording](#) and/or alternatively [YouTube video](#)

2. Running Real-ESSI program for a frame model:

[MP4 recording](#) and/or alternatively [YouTube video](#)

3. Running Real-ESSI program for a elastic-plastic solids model:

[MP4 recording](#) and/or alternatively [YouTube video](#)

4. Running Real-ESSI program for a solids, beams and shells model:

[MP4 recording](#) and/or alternatively [YouTube video](#)

5. Post-processing Real-ESSI results using Paraview for frame model:

[MP4 recording](#) and/or alternatively [YouTube video](#)

6. Post-processing Real-ESSI results using Paraview for a solids, beams and shells model:

[MP4 recording](#) and/or alternatively [YouTube video](#)

7. Developing a DRM SSI model, solids and beams:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)

8. Running a DRM SSI model, solids and beams:

[PDF slides](#), and a direct [MP4 recording](#) and/or alternatively [YouTube video](#)