

Chapter 5

Nonlinear Analysis Steps

5.1 Free Field 1D

Elastic Material The Real-ESSI input files for elastic example are available [HERE](#). The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- Elastic Material Properties
 - Mass Density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1

Elastoplastic Material The Real-ESSI input files for elastoplastic material example are available [HERE](#). The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises nonlinear hardening material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - von Mises radius, k , 60 kPa
 - nonlinear kinematic hardening rate, H_a , 30 MPa
 - nonlinear kinematic hardening rate, C_r , 25
 - isotropic hardening rate, K_{iso} , 0 Pa



Figure 5.1: Simulation Model

The illustration results of the simulation is shown in Fig. 5.1. As shown in the results, outside the DRM layer, there is no outgoing waves.

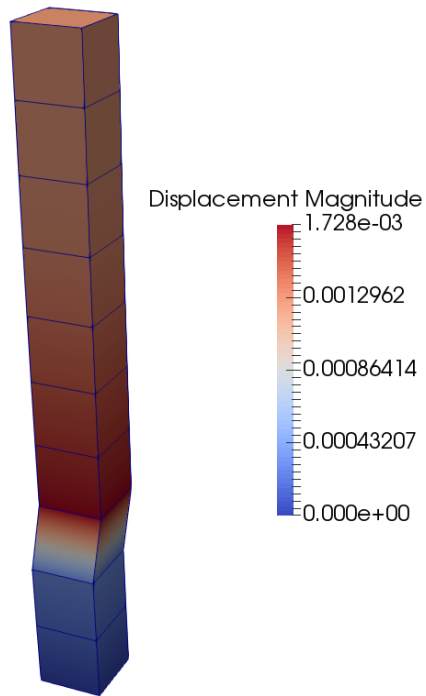


Figure 5.2: Simulation Model

The time series of simulation results is shown in Fig. 5.3.

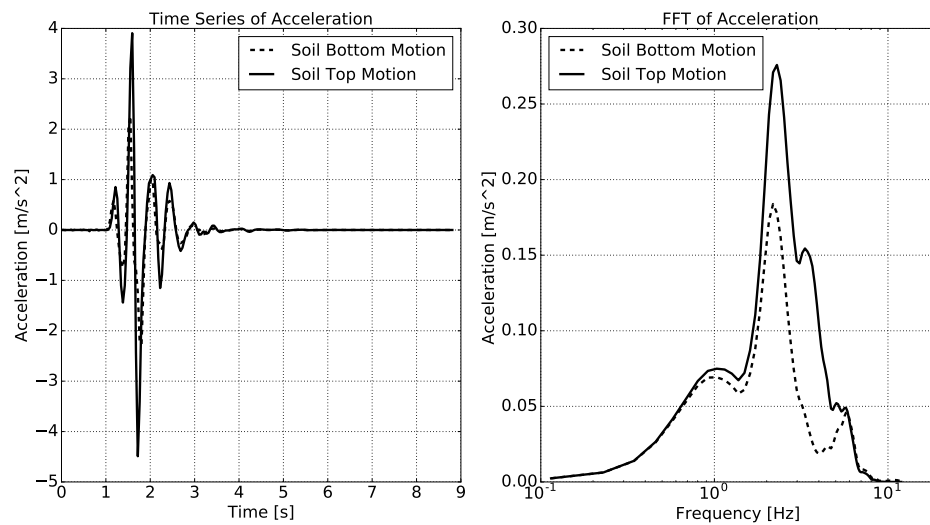


Figure 5.3: Simulation Results: Acceleration Time Series

The response spectrum of motion is shown in Fig. 5.4.

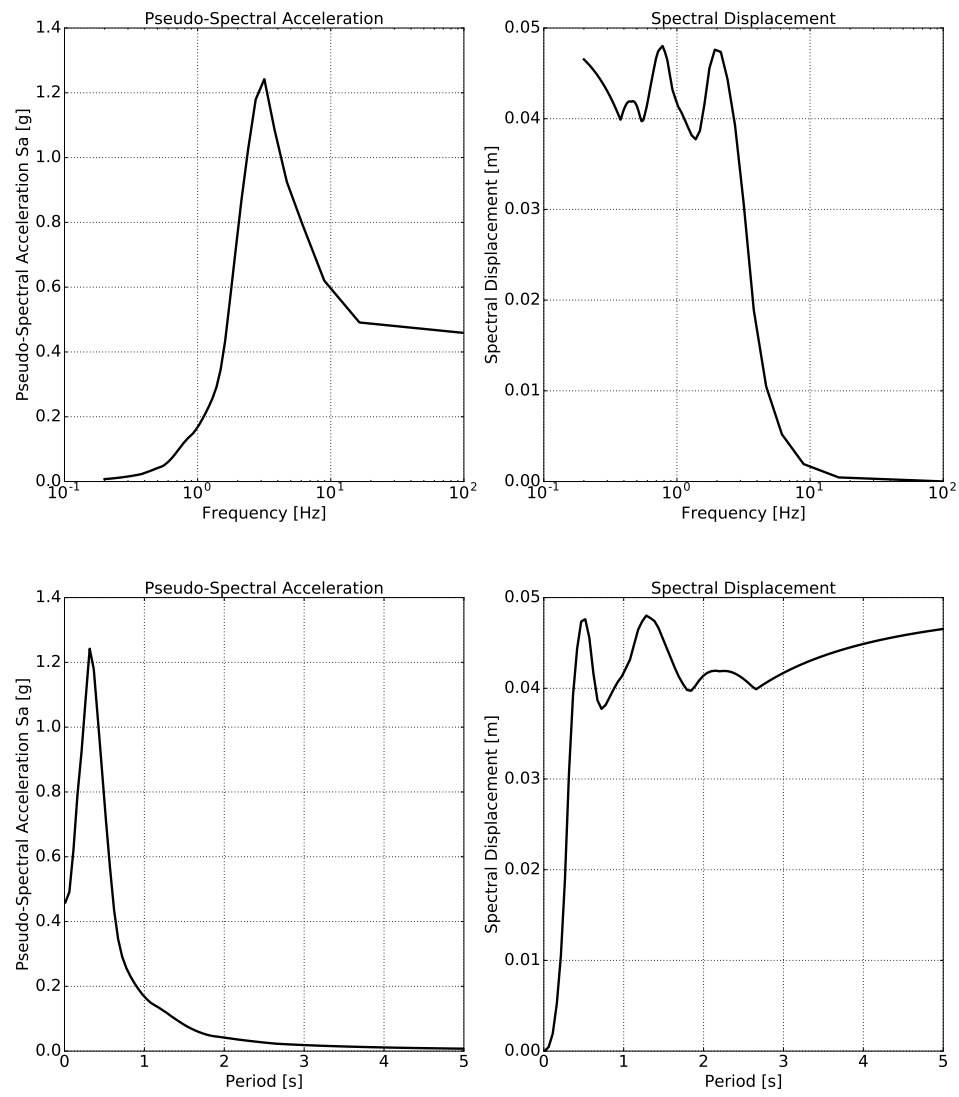


Figure 5.4: Simulation Results: Response Spectrum at Soil Top

5.2 Free Field 3D

Elastic Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- Elastic Material Properties
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 5 minutes.

von-Mises Armstrong-Frederick Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises nonlinear hardening material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - von Mises radius, k , 60 kPa
 - nonlinear kinematic hardening rate, H_a , 30 MPa
 - nonlinear kinematic hardening rate, C_r , 25
 - isotropic hardening rate, K_{iso} , 0 Pa

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 17 minutes.

von-Mises G/Gmax Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises G/Gmax material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - Total number of shear modulus 9
 - G over Gmax, 1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063
 - Shear strain gamma, 0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 565 minutes.

Drucker-Prager G/Gmax Material The compressed package of input files is [HERE](#).
The Modeling parameters are listed.

- Drucker-Prager G/Gmax material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - Initial confining stress, p_0 , 100 kPa
 - Reference pressure, p_{refer} , 100 kPa
 - Pressure exponential, n , 0.5
 - Cohesion, c , 1 kPa
 - Total number of Shear Modulus 9
 - G over Gmax, 1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063
 - Shear strain gamma, 0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 565 minutes.

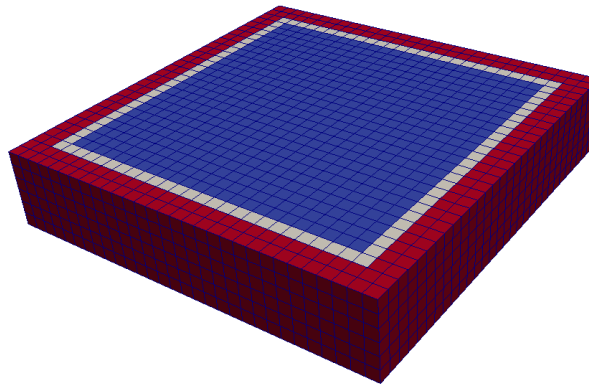


Figure 5.5: Simulation Model

The illustration results of the simulation is shown in Fig. 3.12. As shown in the results, outside the DRM layer, there is no outgoing waves.

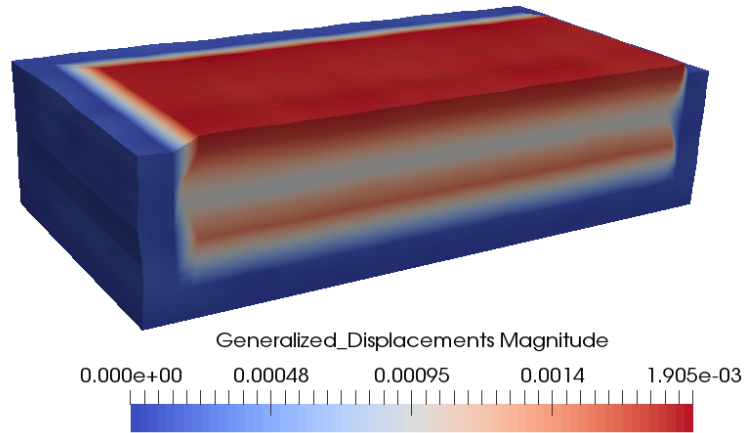


Figure 5.6: Simulation Model

The node tags of critical points for postprocessing are shown in Fig.5.12.

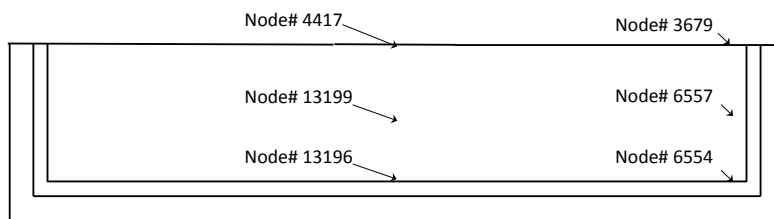


Figure 5.7: Critical Points of Simulation Model

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 871 minutes.

The time series of simulation results is shown in Fig. 5.8.

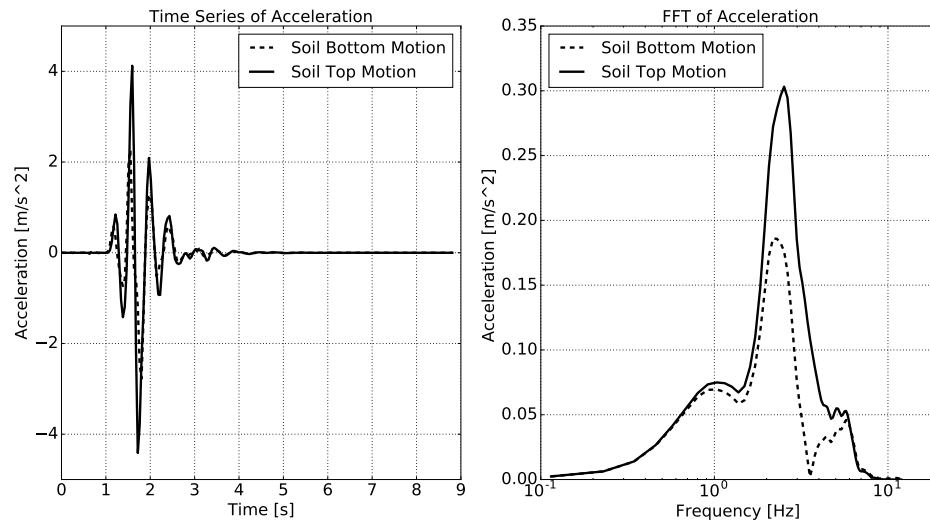


Figure 5.8: Simulation Results: Acceleration Time Series

The response spectrum of motion is shown in Fig. 5.9.

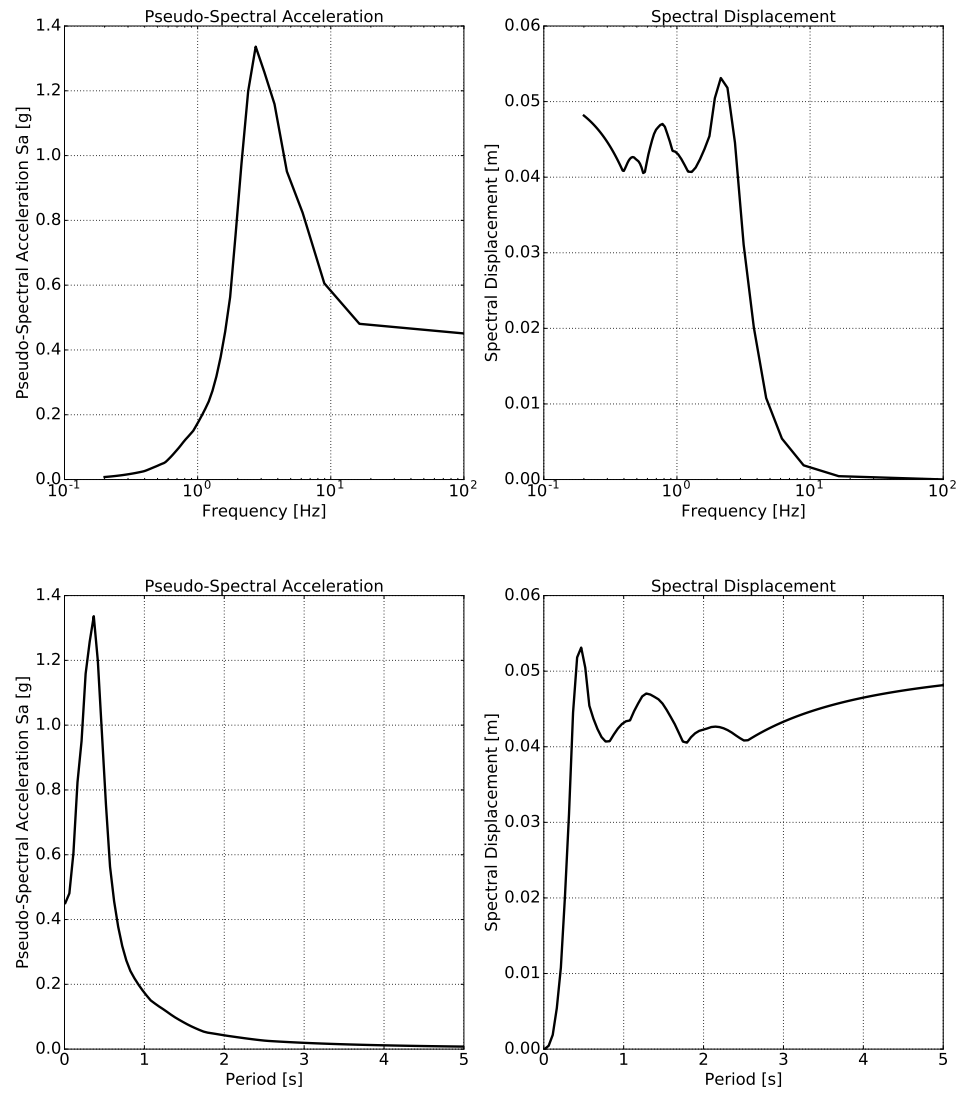


Figure 5.9: Simulation Results: Response Spectrum at Soil Top

5.3 Soil-Foundation Interaction 3D

Elastic Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- Elastic Material Properties
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 13 minutes.

von-Mises Armstrong-Frederick Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises nonlinear hardening material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - von Mises radius, k , 60 kPa
 - nonlinear kinematic hardening rate, H_a , 30 MPa
 - nonlinear kinematic hardening rate, C_r , 25
 - isotropic hardening rate, K_{iso} , 0 Pa

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 36 minutes.

von-Mises G/Gmax Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises G/Gmax material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - Total number of shear modulus 9
 - G over Gmax, 1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063
 - Shear strain gamma, 0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 726 minutes.

Drucker-Prager G/Gmax Material The compressed package of input files is [HERE](#).
The Modeling parameters are listed.

- Drucker-Prager G/Gmax material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - Initial confining stress, p_0 , 100 kPa
 - Reference pressure, p_{refer} , 100 kPa
 - Pressure exponential, n , 0.5
 - Cohesion, c , 1 kPa
 - Total number of Shear Modulus 9
 - G over Gmax, 1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063
 - Shear strain gamma, 0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 1252 minutes.

Contact Elements The compressed package of input files is [HERE](#).
The Modeling parameters are listed.

- Elastic Material Properties
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 24 minutes.

Both Elastoplastic Material and Contact Elements The compressed package of input files is [HERE](#).

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 41 minutes.

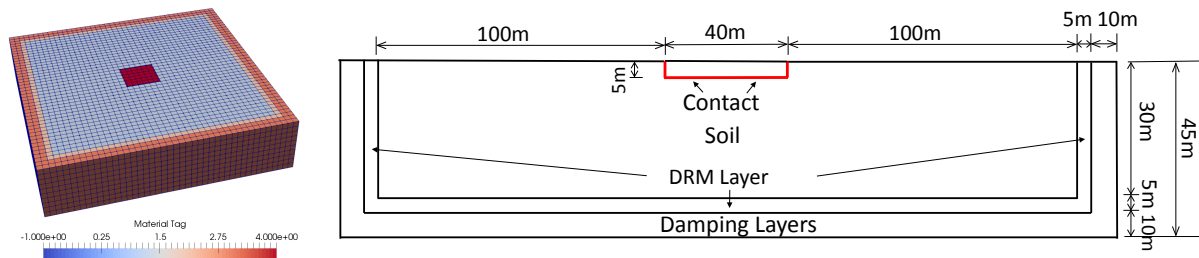


Figure 5.10: Simulation Model

The illustration results of the simulation is shown in Fig. 5.14. As shown in the results, outside the DRM layer, there is no outgoing waves.

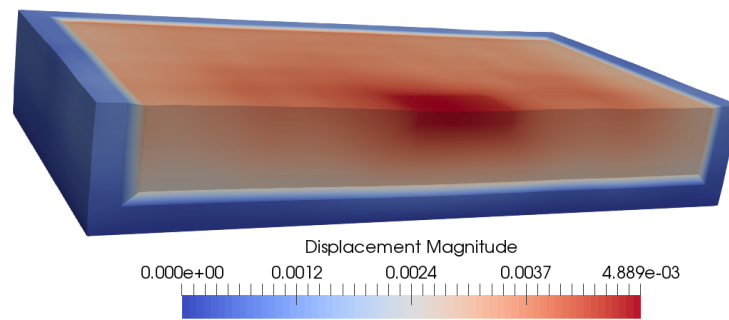


Figure 5.11: Soil Foundation Interaction Results

The node tags of critical points for postprocessing are shown in Fig.5.12.

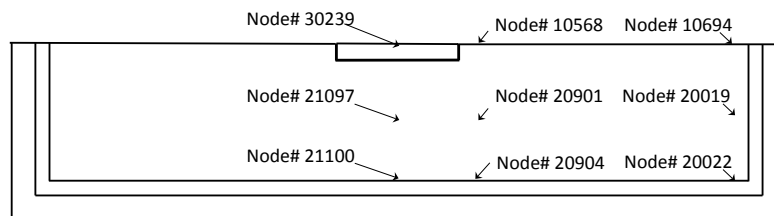


Figure 5.12: Critical Points of Simulation Model

5.4 Soil-Structure Interaction 3D

Elastic Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- Elastic Material Properties
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 10 minutes.

von-Mises Armstrong-Frederick Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises nonlinear hardening material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - von Mises radius, k , 60 kPa
 - nonlinear kinematic hardening rate, H_a , 30 MPa
 - nonlinear kinematic hardening rate, C_r , 25
 - isotropic hardening rate, K_{iso} , 0 Pa

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 46 minutes.

von-Mises G/Gmax Material The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- von-Mises G/Gmax material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - Total number of shear modulus 9
 - G over Gmax, 1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063
 - Shear strain gamma, 0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 755 minutes.

Drucker-Prager G/Gmax Material The compressed package of input files is [HERE](#).

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 1178 minutes.

The Modeling parameters are listed.

- Drucker-Prager G/Gmax material model
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1
 - Initial confining stress, p_0 , 100 kPa
 - Reference pressure, p_{refer} , 100 kPa
 - Pressure exponential, n , 0.5
 - Cohesion, c , 1 kPa
 - Total number of Shear Modulus 9
 - G over Gmax, 1,0.995,0.966,0.873,0.787,0.467,0.320,0.109,0.063
 - Shear strain gamma, 0,1E-6,1E-5,5E-5,1E-4, 0.0005, 0.001, 0.005, 0.01

Contact Elements The compressed package of input files is [HERE](#).

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 15 minutes.

Both Elastoplastic Material and Contact Elements The compressed package of input files is [HERE](#).

The thickness of the shell structure is 2 meters.

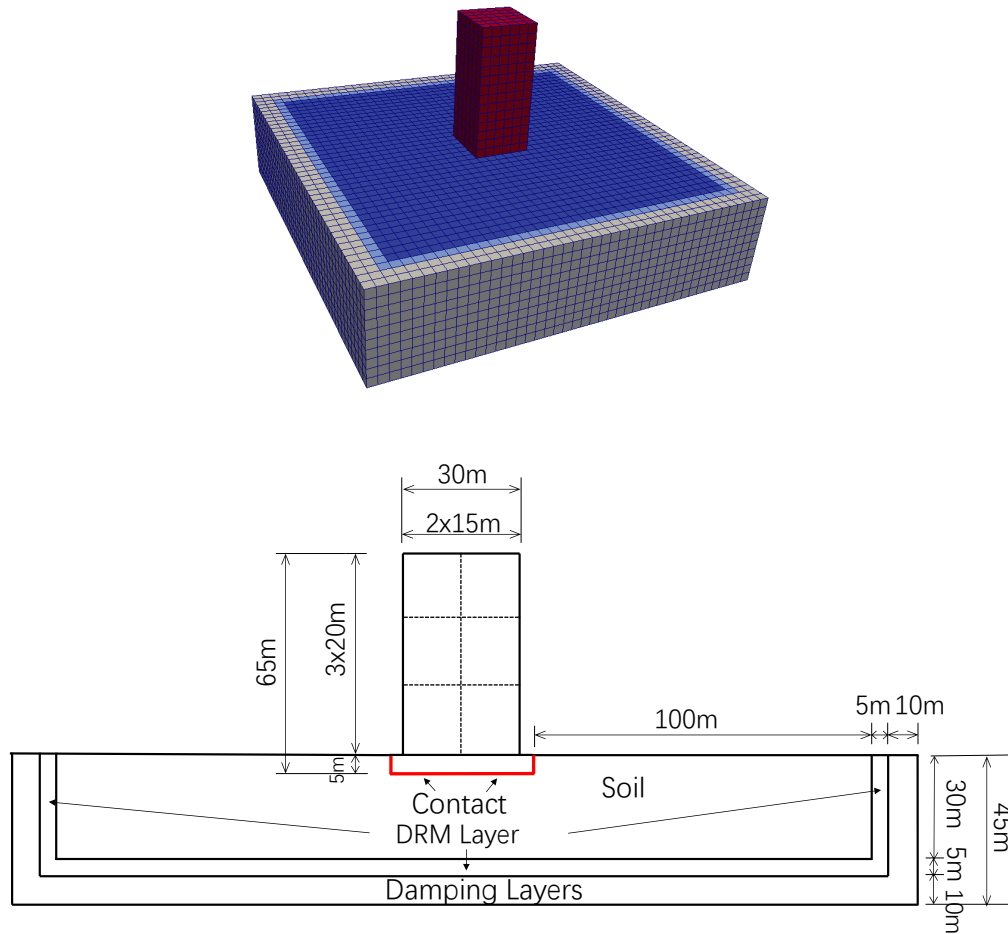


Figure 5.13: Simulation Model

The illustration results of the simulation is shown in Fig. 5.14. As shown in the results, outside the DRM layer, there is no outgoing waves.

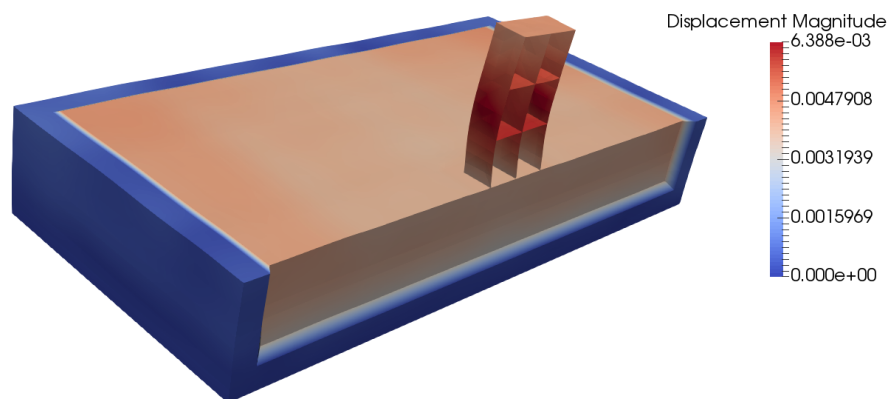


Figure 5.14: Simulation Model

The node tags of critical points for postprocessing are shown in Fig.5.15.

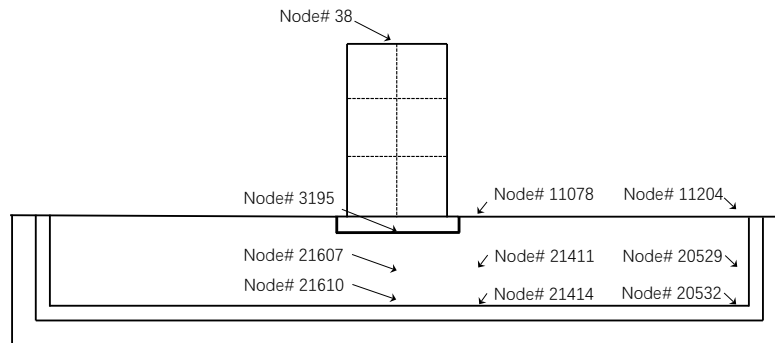


Figure 5.15: Critical Points of Simulation Model

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 47 minutes.

Simulation with 1D motion The time series of simulation results is shown in Fig. 5.16.

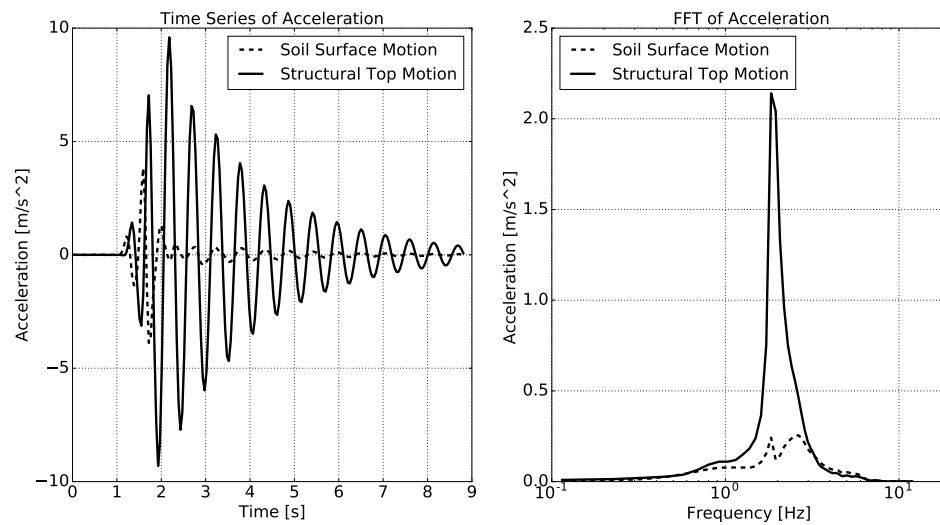


Figure 5.16: Simulation Results: Acceleration Time Series with 1D motion

The response spectrum of motion is shown in Fig. 5.17.

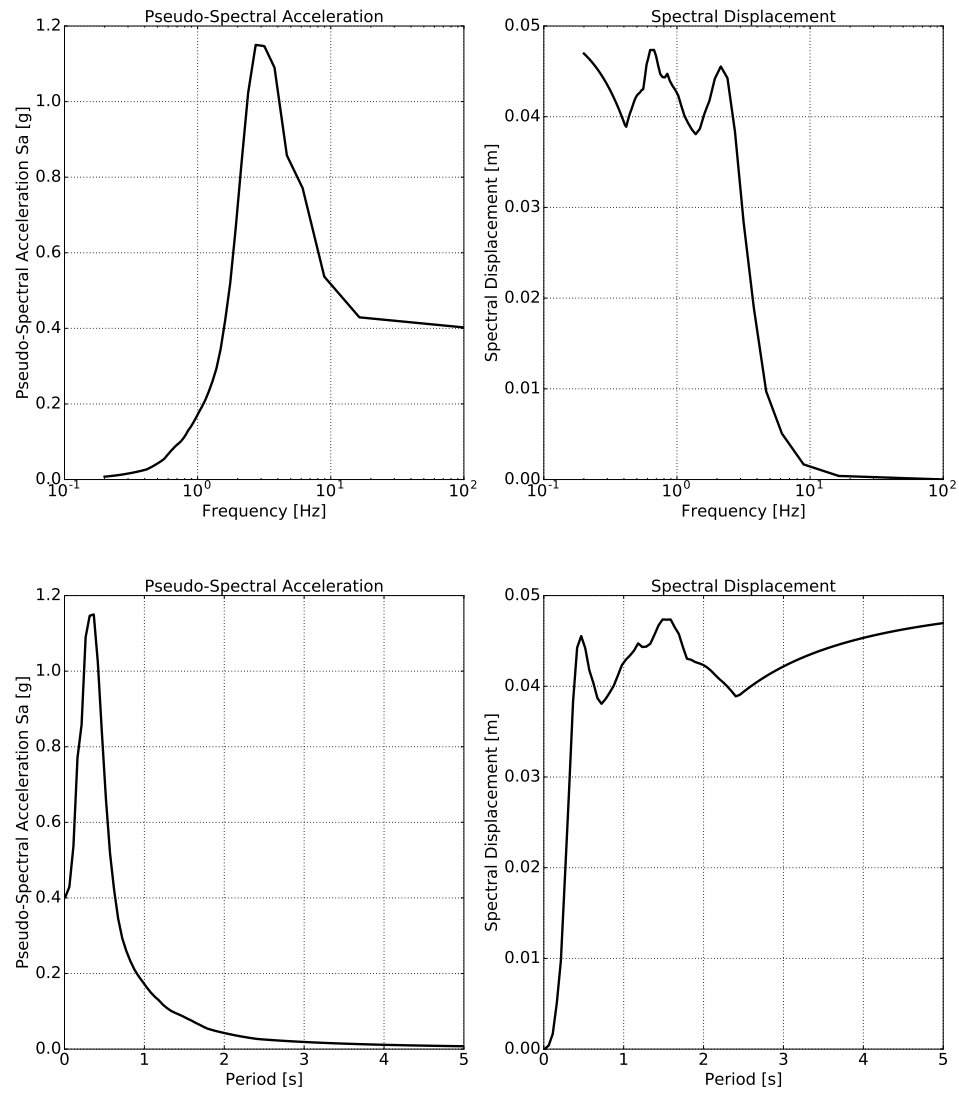


Figure 5.17: Simulation Results: Response Spectrum of Structure Top with 1D motion

Simulation with $3 \times 1D$ motion The time series of simulation results is shown in Fig. 5.18.

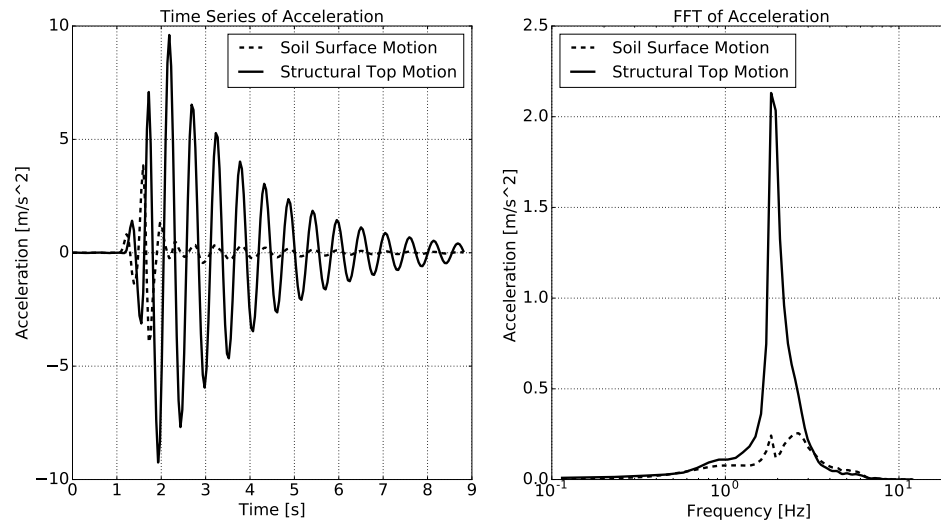


Figure 5.18: Simulation Results: Acceleration Time Series with 3D motion

The response spectrum of motion is shown in Fig. 5.19.

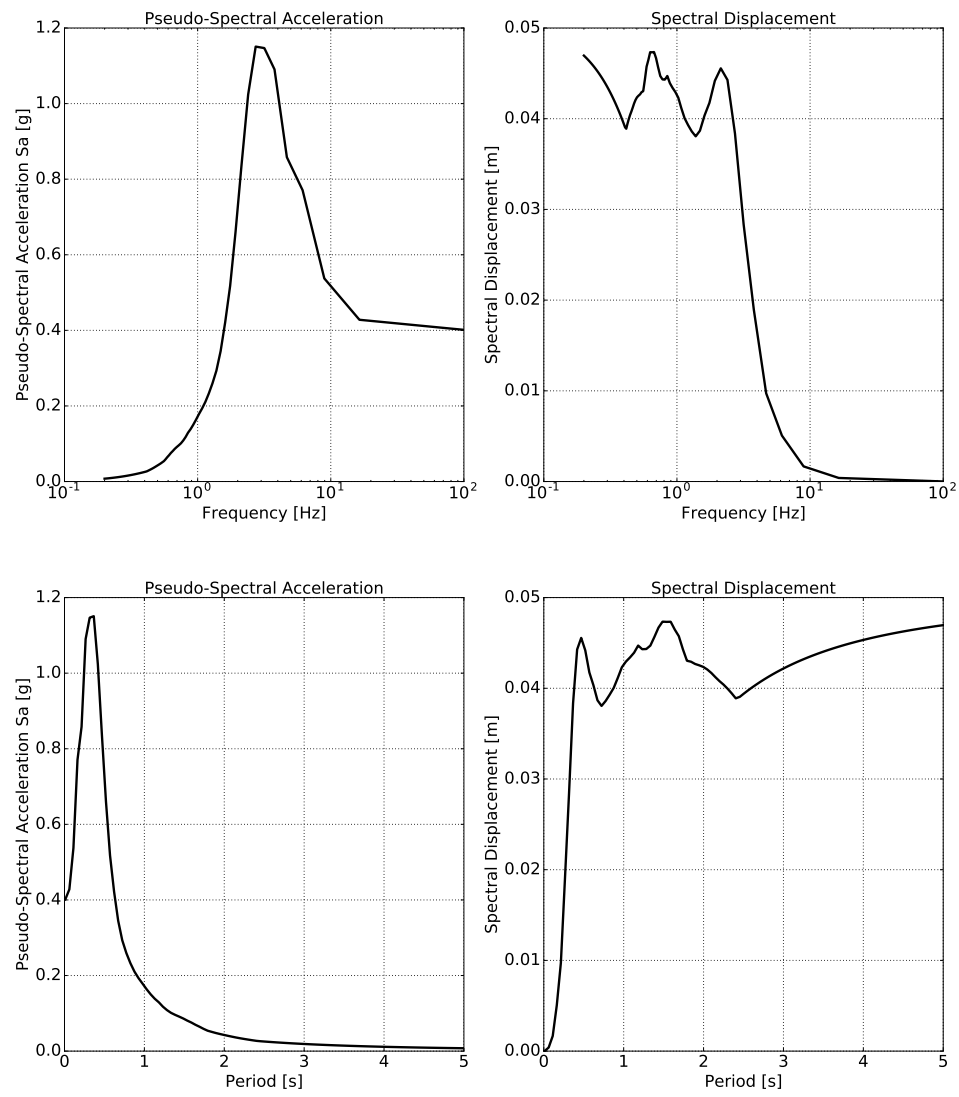


Figure 5.19: Simulation Results: Response Spectrum of Structure Top with 3D motion

5.5 Structure Analysis without Soil

5.5.1 Eigen Analysis

The Real-ESSI input files for this example are available [HERE](#). The compressed package of input files is [HERE](#).

The thickness of the shell structure is 2 meters. The simulation model is shown below.

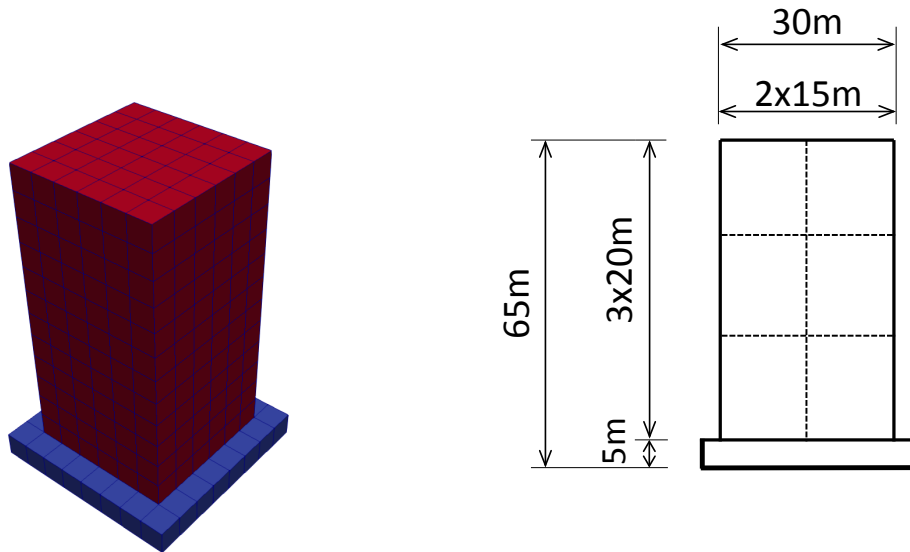


Figure 5.20: Simulation Model

The eigen results:

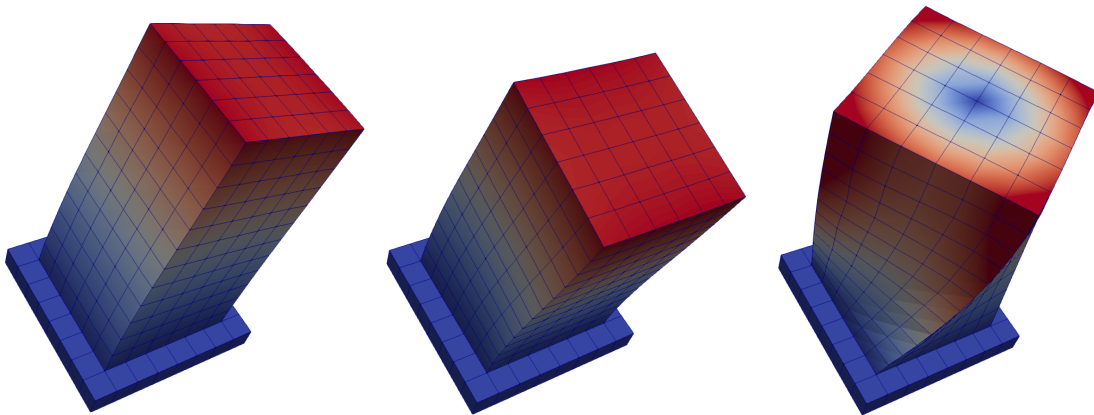


Figure 5.21: Eigen Results (Eigen Mode 1 to 3 from left to right)

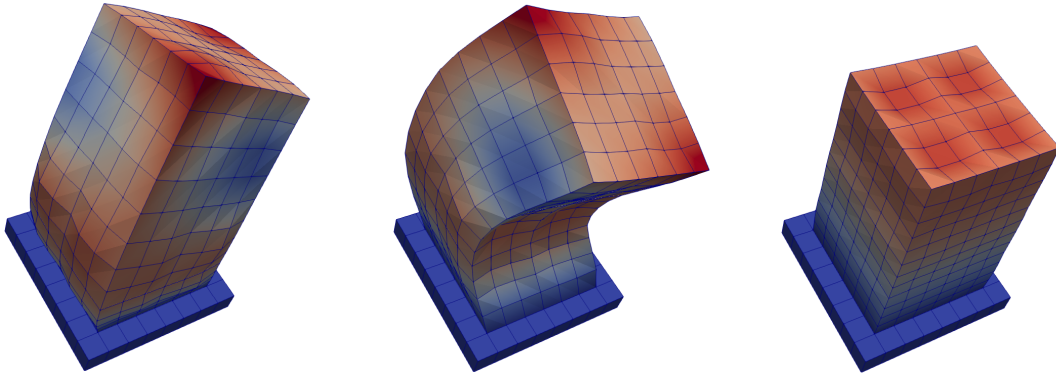


Figure 5.22: Eigen Results (Eigen Mode 4 to 6 from left to right)

5.5.2 Imposed Motion

The Real-ESSI input files for this example are available [HERE](#). The compressed package of input files is [HERE](#).

The Modeling parameters are listed.

- Elastic Material Properties
 - Mass density, ρ , 2000 kg/m^3
 - Young's modulus, E , 1.1 GPa
 - Poisson's ratio, ν , 0.1

The thickness of the shell structure is 2 meters. The simulation model is shown below.

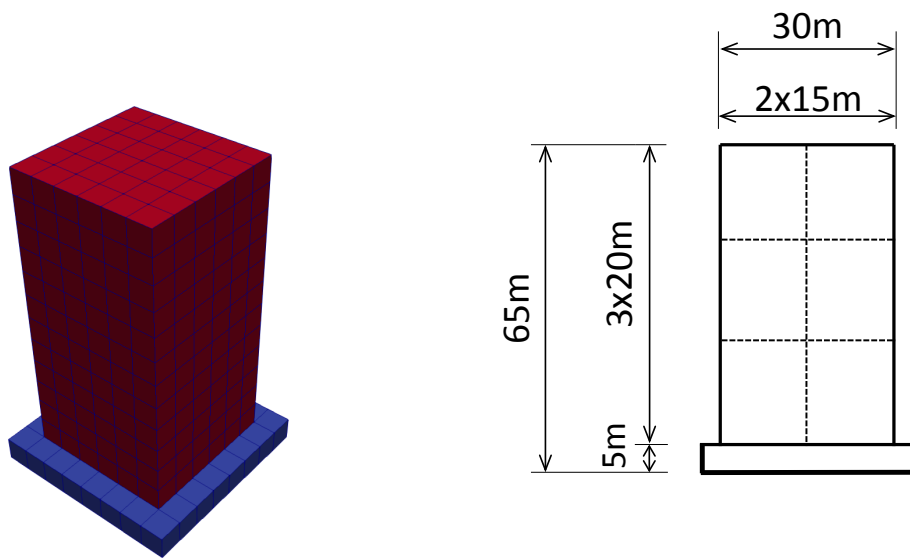


Figure 5.23: Simulation Model

The simulation results:

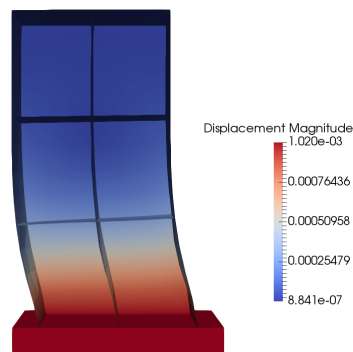


Figure 5.24: Simulation Results