In [8]:
```
#          ############################################################################################
#          #                                        IN THE NAME OF ALLAH                              #
#          #                                 DYNAMIC RESPONSE SPECTRUM ANALYSIS                       #
#          #  EXTERNAL OBJECT CONTACT EFFECTS WITH SOIL-STRUCTURE INTERACTIONS VIA THE SPRING METHOD  #
#          #------------------------------------------------------------------------------------------#
#          #                  THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)              #
#          #                            EMAIL: salar.d.ghashghaei@gmail.com                           #
#          ############################################################################################
```

Utilizing OpenSees for External Object Contact Effects with Soil-Structure Interaction via the Spring Method:

Modeling soil-structure interaction (SSI) with lateral and rotational springs in OpenSees involves defining the properties and behavior of the springs to simulate the interaction between the soil and structure. Considering the large variation of stiffness across various deposits or within the same soil, its required to conduct site or lab-tests to estimate a reliable value of stiffness (direct or coupled stiffness) under proper drainage condition. An SSI study with an incorrect stiffness would spoil the purpose of the study. Further, the designer need to have a good estimate of strain levels to assume a suitable value of damping. For soils exhibiting elastic or elastoplastic behavior, the stiffness and damping ratio can vary significantly. Here are some general estimates:

Stiffness (k in N/m)

- Clay soils: Stiffness can range from 5 MPa to 20 MPa (MegaPascals, equivalent to N/m²).
- Sandy soils: Stiffness can range from 10 MPa to 50 MPa.
- Gravelly soils: Stiffness can range from 20 MPa to 100 MPa.
- Stony soils: Stiffness can range from 200 MPa to 1500 MPa.

Damping Ratio (ζ)

- Clay soils: Damping ratio typically ranges from 5% to 15%.
- Sandy soils: Damping ratio typically ranges from 2% to 10%.
- Gravelly soils: Damping ratio typically ranges from 1% to 5%.
- Stony soils: Damping ratio typically ranges from 0.5% to 3%.

These values are approximate and can vary based on factors such as moisture content, compaction, and the presence of organic material. For accurate assessments, it's best to conduct site-specific geotechnical investigations.

Contact problems in finite element analysis (FEA) are quite fascinating and complex! They involve the interaction between two or more bodies that come into contact with each other. Here's a brief overview:

What are Contact Problems?

Contact problems occur when two or more bodies come into contact and interact with each other. This interaction can involve forces, displacements, and stresses at the contact interface. Examples include metal forming, vehicle crashes, and gear systems.

Lateral Springs in Contact Problems

Lateral springs are used in FEA to model the contact behavior between bodies. They provide a way to simulate the stiffness and damping properties of the contact interface. Here's how they work:

1. Representation: Lateral springs are represented as elements that connect the nodes of the contacting bodies.
2. Stiffness: The stiffness of the lateral springs determines how much resistance they provide against lateral movements.
3. Damping: Damping properties help in absorbing energy and reducing oscillations at the contact interface.

Challenges in Modeling Contact Problems

Contact problems are inherently nonlinear and can be challenging to solve. Some of the key challenges include:

- Nonlinearity: The contact force-displacement relationship is highly nonlinear.
- Convergence: Ensuring the numerical model converges can be difficult due to the complex nature of contact interactions.
- Computational Cost: Tracking contact and separation can be computationally expensive.

Applications

Contact problems are crucial in various engineering fields, such as:

- Automotive Engineering: For crash simulations and component interactions.
- Mechanical Engineering: For gear and bearing analysis.
- Manufacturing: For metal forming and stamping processes.

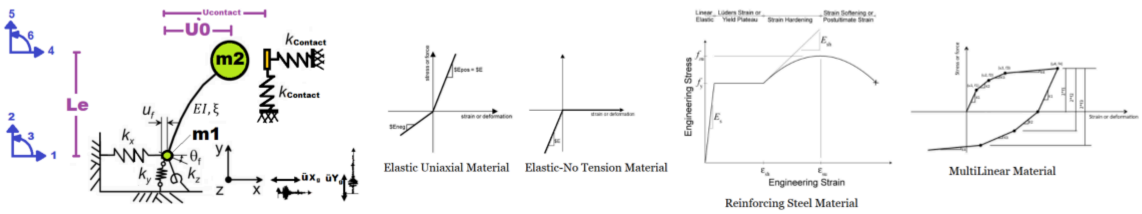
In [9]:
```python
# REPORT: Soil-Structure Interaction for Building Structures
'https://www.nehrp.gov/pdf/nistgcr12-917-21.pdf'
# WEBSITE: Learnig Different Concepts of Dynamic Analysis
'https://www.structuralengineeringsimplified.com/dynamics/toc'
```

Out[9]: 'https://www.structuralengineeringsimplified.com/dynamics/toc'

In [10]:
```python
# Load the image
def PLOT_IMAGE(image):
    import matplotlib.pyplot as plt
    import matplotlib.image as mpimg
    image = mpimg.imread(image_path)

    # Display the image
    plt.figure(figsize=(15, 8))
    plt.imshow(image)
    plt.axis('off')  # Hide axes
    plt.show()

image_path = 'OPENSEES_SOIL_STRUCTURE_INTERACTION_COLUMN_SEISMIC_CONTACT.png'
PLOT_IMAGE(image_path)
```



In [13]:
```python
#import the os module
import os
import time
import numpy as np
import openseespy.opensees as op
import opsvis as opsv
import matplotlib.pyplot as plt
```

In [14]:
```python
#to create a directory at specified path with name "Data"
os.mkdir('C:\\OPENSEESPY_SALAR')
```

```
---------------------------------------------------------------------------
FileExistsError                           Traceback (most recent call last)
Cell In[14], line 2
      1 #to create a directory at specified path with name "Data"
----> 2 os.mkdir('C:\\OPENSEESPY_SALAR')

FileExistsError: [WinError 183] Cannot create a file when that file already exists: 'C:\\OPENSEESPY_SALAR'
```

In [15]:
```python
FOLDER_NAME = 'SOIL_STRUCTURE_INTERACTION_COLUMN_CONTACT_ERESPONSE'
dir = f"C:\\OPENSEESPY_SALAR\\{FOLDER_NAME}\\"
if not os.path.exists(dir):
    os.makedirs(dir)
```

In [16]:
```python
# OUTPUT DATA ADDRESS:
SALAR_DIR = f'C://OPENSEESPY_SALAR//{FOLDER_NAME}//';
```

In [17]:
```python
## DELETE ALL FILES IN DIRECTORY
def DELETE_FOLDER_CONTANTS(folder_path):
    import os
    for filename in os.listdir(folder_path):
        file_path = os.path.join(folder_path, filename)
        try:
            if os.path.isfile(file_path) or os.path.islink(file_path):
                os.unlink(file_path)
        except Exception as e:
            print(f"Failed to delete {file_path}. Reason: {e}")
    print("Deletion done")

FOLDER_PATH = f'C:\\OPENSEESPY_SALAR\\{FOLDER_NAME}'  # Specify the folder path
#DELETE_FOLDER_CONTANTS(FOLDER_PATH)
```

In [18]:
```python
def PLOT_2D(X1, Y1, X2, Y2, XLABEL, YLABEL, TITLE):
    plt.figure(figsize=(10, 6))
    plt.plot(X1, Y1, label='Undamped', color='black')
    plt.plot(X2, Y2, label='Damped', color='red')
    plt.xlabel(XLABEL)
    plt.ylabel(YLABEL)
    plt.title(TITLE)
    plt.grid(True)
    #plt.semilogy()
    plt.legend()
    plt.show()

# --------------------------------

def PLOT_SPRING():
    import matplotlib.pyplot as plt
    # Extract displacements and forces
    displacement_kh, force_kh = zip(*kh)
    displacement_kv, force_kv = zip(*kv)
    displacement_kr, force_kr = zip(*kr)

    # Plotting the force-displacement relation
    plt.figure(figsize=(15, 5))

    plt.subplot(1, 3, 1)
    plt.plot(displacement_kh, force_kh, label='Horizontal Spring', color='blue')
    plt.xlabel('Displacement (m)')
    plt.ylabel('Force (N)')
    plt.title('Horizontal Spring Force-Displacement Relation')
    plt.legend()

    plt.subplot(1, 3, 2)
    plt.plot(displacement_kv, force_kv, label='Vertical Spring', color='green')
    plt.xlabel('Displacement (m)')
    plt.ylabel('Force (N)')
    plt.title('Vertical Spring Force-Displacement Relation')
    plt.legend()

    plt.subplot(1, 3, 3)
    plt.plot(displacement_kr, force_kr, label='Rotational Spring', color='red')
    plt.xlabel('Rotation (rad)')
    plt.ylabel('Moment (N.mm)')
    plt.title('Rotational Spring Moment-Rotation Relation')
    plt.legend()

    plt.tight_layout()
    plt.show()

# --------------------------------

def PLOT_4_CHART(time_undamped, time_damped,
                 displacement_n1x_undamped, displacement_n1x_damped,
                 displacement_n1y_undamped, displacement_n1y_damped,
                 displacement_n2x_undamped, displacement_n2x_damped,
```

```python
              displacement_n2y_undamped, displacement_n2y_damped,
              velocity_n1_undamped, velocity_n1_damped,
              velocity_n2_undamped, velocity_n2_damped,
              acceleration_n1_undamped, acceleration_n1_damped,
              acceleration_n2_undamped, acceleration_n2_damped,
              spring_force_H_undamped, spring_force_H_damped,
              spring_force_V_undamped, spring_force_V_damped,
              spring_force_M_undamped, spring_force_M_damped,
              ele_force_undamped, ele_force_damped, KIND):
    import matplotlib.pyplot as plt
    import numpy as np
    # Plot the results
    plt.figure(figsize=(18, 28))

    # Displacement - NODE 01
    plt.subplot(8, 1, 1)
    P1 = displacement_n1x_undamped
    P2 = displacement_n1x_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Displacement X')
    if KIND == 1:
        plt.title(f'Displacement Time History - NODE 01 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Displacement Response Spectrum - NODE 01 - Amplification Factor: {P3: .3f}')
    plt.legend()

    plt.subplot(8, 1, 2)
    P1 = displacement_n1y_undamped
    P2 = displacement_n1y_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Displacement Y')
    if KIND == 1:
        plt.title(f'Displacement Time History - NODE 01 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Displacement Response Spectrum - NODE 01 - Amplification Factor: {P3: .3f}' )
    plt.legend()

    # Displacement - NODE 02
    plt.subplot(8, 1, 3)
    P1 = displacement_n2x_undamped
    P2 = displacement_n2x_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Displacement X')
    if KIND == 1:
        plt.title(f'Displacement Time History - NODE 02 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Displacement Response Spectrum - NODE 02 - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    plt.subplot(8, 1, 4)
    P1 = displacement_n2y_undamped
    P2 = displacement_n2y_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Displacement Y')
    if KIND == 1:
        plt.title(f'Displacement Time History - NODE 02 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Displacement Response Spectrum - NODE 02 - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Velocity - NODE 01
    P1 = velocity_n1_undamped
    P2 = velocity_n1_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(8, 1, 5)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Velocity')
    if KIND == 1:
        plt.title(f'Velocity Time History - NODE 01 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Velocity Response Spectrum - NODE 01 - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Velocity - NODE 02
    P1 = velocity_n2_undamped
    P2 = velocity_n2_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(8, 1, 6)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Velocity')
    if KIND == 1:
```

```python
        plt.title(f'Velocity Time History - NODE 02 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Velocity Response Spectrum - NODE 02 - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()


    # Acceleration - NODE 01
    P1 = acceleration_n1_undamped
    P2 = acceleration_n1_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(8, 1, 7)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Acceleration')
    if KIND == 1:
        plt.title(f'Acceleration Time History - NODE 01 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Acceleration Response Spectrum - NODE 01 - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Acceleration - NODE 02
    P1 = acceleration_n2_undamped
    P2 = acceleration_n2_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(8, 1, 8)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Acceleration')
    if KIND == 1:
        plt.title(f'Acceleration Time History - NODE 02 - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Acceleration Response Spectrum - NODE 02 - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Display the plot
    plt.show()

    plt.figure(figsize=(18, 20))
    # Spring Force - SHEAR
    P1 = spring_force_H_undamped
    P2 = spring_force_H_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(4, 1, 1)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Horizontal Axial Spring Force')
    if KIND == 1:
        plt.title(f'Spring Force Time History - SHEAR - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Spring Force Response Spectrum - SHEAR - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Spring Force - AXIAL
    P1 = spring_force_V_undamped
    P2 = spring_force_V_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(4, 1, 2)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Vertical Axial Spring Force')
    if KIND == 1:
        plt.title(f'Spring Force Time History - AXIAL - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Spring Force Response Spectrum - AXIAL - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Spring Force - MOMENT
    P1 = spring_force_M_undamped
    P2 = spring_force_M_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(4, 1, 3)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Moment Spring Force')
    if KIND == 1:
        plt.title(f'Spring Force Time History - MOMENT - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Spring Force Response Spectrum - MOMENT - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Element Force
    P1 = ele_force_undamped
    P2 = ele_force_damped
    P11 = np.max(np.abs(P1))
    P22 = np.max(np.abs(P2))
    P3 = P11/P22
    plt.subplot(4, 1, 4)
    plt.plot(time_undamped, P1, label=f'Undamped: {P11:.5e}', color='black')
    plt.plot(time_damped, P2, label=f'Damped: {P22:.5e}', color='red')
    plt.xlabel('Time [s]')
    plt.ylabel('Element Force')
```

```python
    if KIND == 1:
        plt.title(f'Element Force Time History - BASE REACTION - Amplification Factor: {P3: .3f}')
    if KIND == 2:
        plt.title(f'Element Force Response Spectrum - BASE REACTION - Amplification Factor: {P3: .3f}')
        plt.semilogy()
    plt.legend()

    # Display the plot
    plt.show()


# --------------------------------

def SECTION_REC(sectionID, matID, B, H, numY, numZ):
    # numY , numZ = 1000, 1
    # Define fiber rectangular section
    op.section('Fiber', sectionID)
    #patch rect $matTag $numSubdivY $numSubdivZ $yI $zI $yJ $zJ
    op.patch('rect', matID, numY, numY, -0.5*H, -B, 0.5*H, B)  # Core

# --------------------

"""
When OK equals -1, it generally indicates that the command or operation was not executed
because it was already in progress or had already been completed. This can happen if you
try to run a command that is already running or has been completed in a previous step.

When OK equals -2, it typically indicates that the command or operation was not executed
because it was not recognized or not implemented. This could mean that the command
is either misspelled, not available in the current version of OpenSees, or not applicable to the current context.

When OK equals -3, it typically means that the command or operation failed.
This could be due to various reasons, such as incorrect input parameters,
syntax errors, or issues with the model setup.
"""
def ANALYSIS(OK, INCREMENT, TOLERANCE, MAX_ITERAIONS):
    import openseespy.opensees as op
    test = {1:'NormDispIncr', 2: 'RelativeEnergyIncr', 4: 'RelativeNormUnbalance',5: 'RelativeNormDispIncr', 6: 'NormUnbalance'}
    algorithm = {1:'KrylovNewton', 2: 'SecantNewton' , 4: 'RaphsonNewton',5: 'PeriodicNewton', 6: 'BFGS', 7: 'Broyden', 8: 'NewtonLineSearch'}

    for i in test:
        for j in algorithm:
            if OK != 0:
                if j < 4:
                    op.algorithm(algorithm[j], '-initial')

                else:
                    op.algorithm(algorithm[j])

                op.test(test[i], TOLERANCE, MAX_ITERAIONS)
                OK = op.analyze(INCREMENT)
                print(test[i], algorithm[j], OK)
                if OK == 0:
                    break
            else:
                continue

# --------------------
```

In [26]:
```python
import openseespy.opensees as ops
import numpy as np
import matplotlib.pyplot as plt

# Set up variables
Ea = 210.0e3  # [N/mm^2] Modulus of elasticity (Young's modulus)
B = 100 # [mm] Section Width
H = 200 # [mm] Section Height
Le = 3000.0  # [mm] Length of the column element
A = B * H # [mm^2] Cross-sectional area of the element
I = (B * H**3) / 12 # [mm^4]
KE = (3 * Ea * I) / Le**3 # [N/mm] Lateral column Effective Stiffness
print(f'Lateral column Stiffness: {KE:.3f} (N/mm)')
iv0 = 0.005                   # [mm/s] Initial velocity applied to the node
st_iv0 = 0.0                  # [s] Initial velocity applied starting time
damping_ratio = 0.05          # [%] Damping ratio
soil_damping_ratio = 0.015    # [%] Damping ratio for Stony soils
MS = 10000                    # [kg] mass values for node 1

# Define masses for multiple nodes
mass_values = [1000.0, 5000.0]  # [kg] mass values for node 1 and 2

# Set analysis parameters
duration = 50.0 # [s] 50 Seconds
dt = 0.01

# Define ReinforcingSteel material properties
fy_m = 400.0    # [N/mm^2] Yield strength of steel
Es_m = 210.0e3  # [N/mm^2] Modulus of elasticity
fu_m = 600.0    # [N/mm^2] Ultimate strength
Esh_m = 20.0e3  # [N/mm^2] Hardening modulus
esh_m = 0.03    # [mm/mm] Strain at start of hardening
esu_m = 0.1     # [mm/mm] Ultimate strain

# Section Fibers
numY , numZ = 1000, 1

MAX_ITERATIONS = 5000 # convergence iteration for test
TOLERANCE = 1.0e-10   # convergence tolerance for test

# Define soil-structure interaction springs at base (Node 1)
# [1] ELASTIC SOIL & [2] ELASTIC-NO TENSION SOIL:
# Spring constants for soil-structure interaction
k_horizontal = 210.0e4  # [N/mm] Horizontal spring constant
k_vertical = 150.0e4    # [N/mm] Vertical spring constant
k_rotational = 550.0e4  # [N.mm/Rad] Rotational spring constant

# [3] ELASTO-PLASTIC SOIL:
# Horizontal spring parameters
fy_h = 400.0      # [N] Yield force
Es_h = 21000.0    # [N/mm] Lateral Siffness in Horizental Direction
fu_h = 410.0      # [N] Ultimate force
Esh_h = 200.0     # [N/mm] Hardening modulus
```

```python
esh_h = 0.4       # [mm] Displacement at start of hardening
esu_h = 1.1       # [mm] Ultimate displacement

# Vertical spring parameters
fy_v = 450.0      # [N] Yield force
Es_v = 20000.0    # [N/mm] Lateral Siffness in Vertical Direction
fu_v = 460.0      # [N] Ultimate force
Esh_v = 180       # [N/mm] Hardening modulus
esh_v = 0.5       # [mm] Displacement at start of hardening
esu_v = 1.8       # [mm] Ultimate displacement

# Rotational spring parameters
fy_r = 50e3       # [N.mm] Yield force
Es_r = 50e5       # [N.mm/Rad] Rotational Siffness in Horizental Direction
fu_r = 70e3       # [N.mm] Ultimate force
Esh_r = 50e4      # [N.mm/Rad] Hardening modulus
esh_r = 0.06      # [Rad] Rotation at start of hardening
esu_r = 0.12      # [Rad] Ultimate rotation

# [4] Define the MultiLinear material properties for springs
kh = np.array([[0.05, 22.0], [0.15, 27.0], [0.25, 27.0], [0.3, 25.5], [0.5, 21.5]])                   # k horizontal
kv = np.array([[0.15, 18.5], [0.3, 27.0], [0.4, 29.0], [0.5, 30.5], [1.1, 24.4]])                     # k vertical
kr = np.array([[0.01, 10500.0], [0.04, 29000.0], [0.06, 30000.0], [0.09, 30500.0], [0.15, 15000.0]])  # k rotational

# Create a DataFrame
import pandas as pd
data = {
    "Displacement_X": kh[:, 0],
    "Force (kh)": kh[:, 1],
    "Displacement_Y": kv[:, 0],
    "Force (kv)": kv[:, 1],
    "Rotation_Z": kr[:, 0],
    "Force (kr)": kr[:, 1]
}

#df = pd.DataFrame(data)
PLOT_SPRING()
def INTERACTION_ANALYSIS(MASS_ONE,  ii, iMAX, DAMPING, SOIL_DAMPING, periodTF, LINEAR, SPRING_KIND, CONTACT, CONTACT_DISP):
    import openseespy.opensees as ops
    import numpy as np

    KE = (3 * Ea * I) / Le**3; # [N/mm] Lateral column Effective Stiffness
    MASS = mass_values[1] * ((ii+1) / iMAX)
    print('MASS: ', MASS)
    #GMfact = 9810 # standard acceleration of gravity or standard acceleration
    GMfact = 1
    # Set up the model
    ops.wipe()
    ops.model('basic', '-ndm', 2, '-ndf', 3)

    # Define nodes
    ops.node(1, 0.0, 0.0)
    ops.node(2, 0.0, Le)
    ops.node(200, 0.0, 0.0)  # SOIL NODE
    ops.node(400, 0.0, Le)   # CONTACT NODE

    # Define boundary conditions (modified to include springs)
    ops.fix(200, 1, 1, 1)  # Node 200 is Fixed in all directions initially - SOIL
    ops.fix(400, 1, 1, 1)  # Node 400 is Fixed in all directions initially - CONTACT

    # Assign masses to nodes
    if MASS_ONE == True:
        ops.mass(2, MASS, MASS, 0.0) # COLUMN TOP MASS
        print('ONE MASS')

    if MASS_ONE == False:
        ops.mass(1,  0.05 * MASS, 0.05 * MASS, 0.0) # FOUNDATION MASS
        ops.mass(2, 0.95 * MASS, 0.95 * MASS, 0.0)  # COLUMN TOP MASS
        print('TWO MASSES')

    # Define material
    matID = 1
    if LINEAR == True:
        ops.uniaxialMaterial('Elastic', matID, Es_m)
    if LINEAR == False:
        ops.uniaxialMaterial('ReinforcingSteel', 1, fy_m, Es_m, fu_m, Esh_m, esh_m, esu_m)

    # Define fiber rectangular section
    sectionID = 1
    ops.section('Fiber', sectionID)
    #patch rect $matTag $numSubdivY $numSubdivZ $yI $zI $yJ $zJ
    ops.patch('rect', matID, numY, numZ, -0.5*H, -B, 0.5*H, B)  # Core

    # Define geometric transformation
    ops.geomTransf('Linear', 1)

    # Define elements
    # element nonlinearBeamColumn $eleTag $iNode $jNode $numIntgrPts $secTag $transfTag
    eleID =  1
    ops.element('nonlinearBeamColumn', eleID, 1, 2, 5, sectionID, 1)

    # OUTPUT DATA
    ops.recorder('Node', '-file', f"{SALAR_DIR}DTH_DYN_{ii}.txt",'-time', '-node', 2, '-dof', 1,2,3, 'disp')         # Displacement Time History Node 2
    ops.recorder('Node', '-file', f"{SALAR_DIR}VTH_DYN_{ii}.txt",'-time', '-node', 2, '-dof', 1,2,3, 'vel')          # Velocity Time History Node 2
    ops.recorder('Node', '-file', f"{SALAR_DIR}ATH_DYN_{ii}.txt",'-time', '-node', 2, '-dof', 1,2,3, 'accel')        # Acceleration Time History Node 2
    ops.recorder('Node', '-file', f"{SALAR_DIR}BTH_DYN_{ii}.txt",'-time', '-node', 1, '-dof', 1,2,3, 'reaction')     # Base Shear Time History Node 1
    ops.recorder('Element', '-file', f"{SALAR_DIR}DEF_DYN_{ii}.txt",'-time', '-ele', 1, 'section', 1, 'deformations')# Curvature Time History

    # Define soil-structure interaction springs at base (Node 1)
    if SPRING_KIND == 1:
        # Elastic Material:
        # uniaxialMaterial Elastic $matTag $E <$eta> <$Eneg> -> (Eneg:  tangent in compression (optional, default=E))
        ops.uniaxialMaterial('Elastic', 2, 0.3 * k_horizontal, 0, k_horizontal)  # Horizontal spring
        ops.uniaxialMaterial('Elastic', 3, 0.3 * k_vertical, 0, k_vertical)      # Vertical spring
        ops.uniaxialMaterial('Elastic', 4, 0.3 * k_rotational, 0, k_rotational)  # Rotational spring
        KS = k_horizontal # Soil Lateral Stiffness
    if SPRING_KIND == 2:
        # Define horizontal spring
        ops.uniaxialMaterial('ReinforcingSteel', 2, fy_h, Es_h, fu_h, Esh_h, esh_h, esu_h)
        # Define vertical spring
        ops.uniaxialMaterial('ReinforcingSteel', 3, fy_v, Es_v, fu_v, Esh_v, esh_v, esu_v)
        # Define rotational spring
```

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        ops.uniaxialMaterial('ReinforcingSteel', 4, fy_r, Es_r, fu_r, Esh_r, esh_r, esu_r)
        KS = Es_h # Soil Lateral Stiffness
    if SPRING_KIND == 3:
        # Elastic-No Tension Material:
        # uniaxialMaterial ENT $matTag $E
        ops.uniaxialMaterial('ENT', 2, k_horizontal)  # Horizontal spring
        ops.uniaxialMaterial('ENT', 3, k_vertical)    # Vertical spring
        ops.uniaxialMaterial('ENT', 4, k_rotational)  # Rotational spring
        KS = k_horizontal # Soil Lateral Stiffness
    if SPRING_KIND == 4:
        # Define soil-structure interaction springs at base (Node 1)
        #                                       STRAIN    STRESS
        # uniaxialMaterial MultiLinear $matTag $u1 $f1 $u2 $f2 $u3 $f3 $u4 $f4
        ops.uniaxialMaterial('MultiLinear', 2, *kh.flatten()) # Horizontal spring
        ops.uniaxialMaterial('MultiLinear', 3, *kh.flatten()) # Vertical spring
        ops.uniaxialMaterial('MultiLinear', 4, *kh.flatten()) # Rotational spring
        KS = kh[0][1] / kh[0][0] # Soil Lateral Stiffness


    # Soil Natural frequency (rad/s)
    wns = (KS / MS) ** 0.5
    # Soil Damping coefficient (Ns/m)
    CS = 2 * wns * MS * soil_damping_ratio if SOIL_DAMPING else 0.0
    # Define materials for Soil damper
    ops.uniaxialMaterial('Elastic', 5, 0.0, CS)

    if SOIL_DAMPING == False:
        # element zeroLength $eleTag $iNode $jNode -mat $matTag1 $matTag2 ... -dir $dir1 $dir2
        ops.element('zeroLength', 2, 200, 1, '-mat', 2, '-dir', 1) # Horizontal spring for soil stiffness
        ops.element('zeroLength', 3, 200, 1, '-mat', 3, '-dir', 2) # Vertical spring for soil stiffness
        ops.element('zeroLength', 4, 200, 1, '-mat', 4, '-dir', 3) # Rotational spring for soil stiffness
    if SOIL_DAMPING == True:
        ops.element('zeroLength', 2, 200, 1, '-mat', 2, 5, '-dir', 1, 1) # Horizontal spring for soil stiffness and damping
        ops.element('zeroLength', 3, 200, 1, '-mat', 3, 5, '-dir', 2, 2) # Vertical spring for soil stiffness and damping
        ops.element('zeroLength', 4, 200, 1, '-mat', 4, '-dir', 3) # Rotational spring for soil stiffness

    # Dynamic analysis setup
    ops.constraints('Transformation')
    ops.numberer('RCM')
    ops.system('UmfPack')
    ops.test('EnergyIncr', TOLERANCE, MAX_ITERATIONS)
    #ops.integrator('CentralDifference')
    ops.integrator('HHT', 0.9)
    #ops.integrator('Newmark', 0.5, 0.25)
    ops.algorithm('ModifiedNewton')

    # Define analysis type
    ops.analysis('Transient')

    # Define time series for input motion (Acceleration time history)
    ops.timeSeries('Path', 1, '-dt', 0.01, '-filePath', 'OPENSEES_SPRING_SEISMIC_01.txt', '-factor', GMfact, '-startTime', st_iv0) # SEISMIC-X
    ops.timeSeries('Path', 2, '-dt', 0.01, '-filePath', 'OPENSEES_SPRING_SEISMIC_02.txt', '-factor', GMfact) # SEISMIC-Y

    # Define load patterns
    # pattern UniformExcitation $patternTag $dof -accel $tsTag <-vel0 $vel0> <-fact $cFact>
    ops.pattern('UniformExcitation', 1, 1, '-accel', 1, '-vel0', iv0, '-fact', 1.0) # SEISMIC-X
    ops.pattern('UniformExcitation', 2, 2, '-accel', 2)                             # SEISMIC-Y

    # Perform eigenvalue analysis to determine modal periods
    if periodTF == True:
        #eigenvalues01 = ops.eigen('-genBandArpack', 1) # eigenvalue mode 1
        eigenvalues01 = ops.eigen('-fullGenLapack', 1) # eigenvalue mode 1
        #eigenvalues01 = ops.eigen('-symmBandLapack', 1) # eigenvalue mode 1
        #Omega = np.power(eigenvalues01, 0.5)
        #Omega = np.power(max(min(eigenvalues01), min(eigenvalues02), min(eigenvalues03)), 0.5)
        Omega = np.power(min(eigenvalues01), 0.5)
        modal_period = 2 * np.pi / np.sqrt(Omega)  # [Second]
        frequency = 1 / modal_period               # [Hertz]

    if periodTF == False:
        modal_period = 0.0            # [Second]
        frequency = 0.0               # [Hertz]


    if DAMPING == True:
        # Calculate Rayleigh damping factors
        omega1 = np.sqrt(KE / mass_values[1])
        omega2 = 2 * omega1  # Just an assumption for two modes
        a0 = damping_ratio * (2 * omega1 * omega2) / (omega1 + omega2)
        a1 = damping_ratio * 2 / (omega1 + omega2)
        # Apply Rayleigh damping
        ops.rayleigh(a0, a1, 0, 0)

    ops.analysis('Transient')

    if CONTACT == True:
        # CONTACT SPRING STIFFNESS PROPERTIES:
        PY_C = 114e10    # [N] Yield force capacity
        K_C = PY_C / 7  # [N/mm] Axial Rigidity Stiffness
        ops.uniaxialMaterial('Steel02', 300, PY_C, K_C, 0.1, 18.0, 0.925, 0.15) # NONLINEAR CONTACT
        #ops.uniaxialMaterial('Elastic', 300, K_C)                                 # LINEAR CONTACT
        #CONTACT_STEPS = int(np.abs(CONTACT_DISP / DtAnalysis))

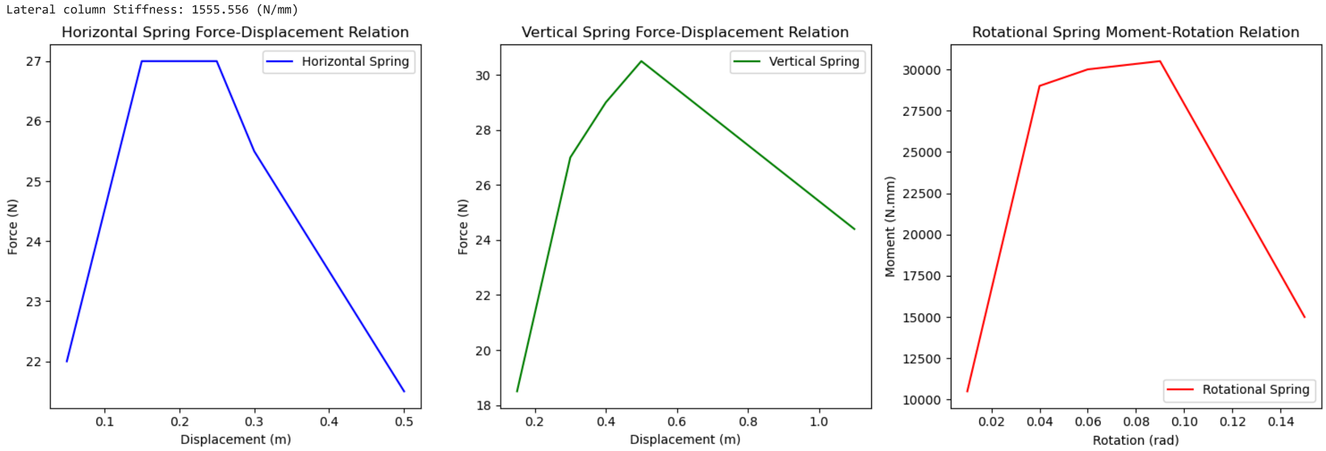
    # Perform transient analysis and store results
    time = []
    displacement_n1x = []
    displacement_n1y = []
    velocity_n1 = []
    acceleration_n1 = []
    displacement_n2x = []
    displacement_n2y = []
    velocity_n2 = []
    acceleration_n2 = []
    spring_force_H = []
    spring_force_V = []
    spring_force_M = []
    ele_force = []
    stable = 0
    current_time = 0.0
    NN = 0; # [0] CHECK JUST ONE TIME THIS LATERAL SPRING -> Contact is not applied [1] Contact is applied
    while stable == 0 and current_time < duration:
        stable = ops.analyze(1, dt)
```

```
        if SPRING_KIND != 3 or SPRING_KIND != 4: # if Elastic-No Tension Material
            ANALYSIS(stable, 1, TOLERANCE, MAX_ITERATIONS) # CHECK THE ANALYSIS
        current_time = ops.getTime()
        time.append(current_time)
        displacement_n1x.append(ops.nodeDisp(1, 1))            # FUNDATION DISPLACEMENT-X
        displacement_n1y.append(ops.nodeDisp(1, 2))            # FUNDATION DISPLACEMENT-Y
        velocity_n1.append(ops.nodeVel(1, 1))                  # FUNDATION VELOCITY-X
        acceleration_n1.append(ops.nodeAccel(1, 1))            # FUNDATION ACCEL-X
        displacement_n2x.append(ops.nodeDisp(2, 1))            # COLUMN TOP DISPLACEMENT-X
        displacement_n2y.append(ops.nodeDisp(2, 2))            # COLUMN TOP DISPLACEMENT-Y
        velocity_n2.append(ops.nodeVel(2, 1))                  # COLUMN TOP VELOCITY-X
        acceleration_n2.append(ops.nodeAccel(2, 1))            # COLUMN TOP ACCEL-X
        spring_force_H.append(-ops.eleResponse(2, 'force')[0]) # SOIL REACTION - SHEAR
        spring_force_V.append(-ops.eleResponse(3, 'force')[1]) # SOIL REACTION - AXIAL
        spring_force_M.append(-ops.eleResponse(4, 'force')[2]) # SOIL REACTION - MOMENT
        ele_force.append(-ops.eleResponse(1, 'force')[0])      # COLUMN REACTION
        KE =  ele_force[-1] / displacement_n2x[-1]             # Effective Lateral Stiffness
        if CONTACT == True:
            if displacement_n2x[-1] >= CONTACT_DISP: # CHECK FOR CONTACT
                if NN == 0:
                    print(f'IN TIME {current_time} CONTACT DONE!')
                    ops.element('zeroLength', 500, 400, 2, '-mat', 300, '-dir', 1) # DOF[4] LATERAL CONTACT SPRING
                    ops.element('zeroLength', 600, 400, 2, '-mat', 300, '-dir', 2) # DOF[5] LATERAL CONTACT SPRING
                NN = 1; # WE WANT TO ADD ONE TIME THIS LATERAL SPRINGS -> Contact is applied before

    ops.wipe()
    print("Period: ", modal_period)
    print("Frequency: ", frequency)
    if DAMPING == False:
        print(f'{ii+1} Undamping Structure Dynamic Analysis Done.')
    if DAMPING == True:
        print(f'{ii+1} Damping Structure Dynamic Analysis Done.')

    return modal_period, time, displacement_n1x, displacement_n1y, displacement_n2x, displacement_n2y, velocity_n1, velocity_n2, acceleration_n1, acceleration_n2, spring_force_H, sprir
```

Lateral column Stiffness: 1555.556 (N/mm)



In [27]:
```
### SOIL-STRUCTURE INTERACTION WITH TWO MASSES:
## UNDAMPED DATA
time_undamped = []
uMA_period_undamped = []
uMA_displacement_n1x_undamped = []
uMA_displacement_n1y_undamped = []
uMA_velocity_n1_undamped = []
uMA_acceleration_n1_undamped = []
uMA_displacement_n2x_undamped = []
uMA_displacement_n2y_undamped = []
uMA_velocity_n2_undamped = []
uMA_acceleration_n2_undamped = []
uMA_spring_force_H_undamped = []
uMA_spring_force_V_undamped = []
uMA_spring_force_M_undamped = []
uMA_ele_force_undamped = []
## DAMPED DATA
time_damped = []
MA_period_damped = []
MA_displacement_n1x_damped = []
MA_displacement_n1y_damped = []
MA_velocity_n1_damped = []
MA_acceleration_n1_damped = []
MA_displacement_n2x_damped = []
MA_displacement_n2y_damped = []
MA_velocity_n2_damped = []
MA_acceleration_n2_damped = []
MA_spring_force_H_damped = []
MA_spring_force_V_damped = []
MA_spring_force_M_damped = []
MA_ele_force_damped = []

starttime = time.process_time()
# Perform analysis
Imax = 50 # Number of Iterations
for II in range(Imax):
    print('STEP: ', II+1)
    ### UNDAMPED CO,NDITIONS:
    period_undamped, time_undamped, displacement_n1x_undamped, displacement_n1y_undamped, displacement_n2x_undamped, displacement_n2y_undamped, velocity_n1_undamped, velocity_n2_undamp
    uMA_period_undamped.append(period_undamped)
    uMA_displacement_n1x_undamped.append(np.max(np.abs(displacement_n1x_undamped)))
    uMA_displacement_n1y_undamped.append(np.max(np.abs(displacement_n1y_undamped)))
    uMA_displacement_n2x_undamped.append(np.max(np.abs(displacement_n2x_undamped)))
    uMA_displacement_n2y_undamped.append(np.max(np.abs(displacement_n2y_undamped)))
    uMA_velocity_n1_undamped.append(np.max(np.abs(velocity_n1_undamped)))
    uMA_velocity_n2_undamped.append(np.max(np.abs(velocity_n2_undamped)))
    uMA_acceleration_n1_undamped.append(np.max(np.abs(acceleration_n1_undamped)))
    uMA_acceleration_n2_undamped.append(np.max(np.abs(acceleration_n2_undamped)))
    uMA_spring_force_H_undamped.append(np.max(np.abs(spring_force_H_undamped)))
    uMA_spring_force_V_undamped.append(np.max(np.abs(spring_force_V_undamped)))
```

```python
    uMA_spring_force_M_undamped.append(np.max(np.abs(spring_force_M_undamped)))
    uMA_ele_force_undamped.append(np.max(np.abs(ele_force_undamped)))
    ### DAMPED CONDITIONS:
    period_damped, time_damped, displacement_n1x_damped, displacement_n1y_damped, displacement_n2x_damped, displacement_n2y_damped, velocity_n1_damped, velocity_n2_damped, acceleration
    MA_period_damped.append(period_damped)
    MA_displacement_n1x_damped.append(np.max(np.abs(displacement_n1x_damped)))
    MA_displacement_n1y_damped.append(np.max(np.abs(displacement_n1y_damped)))
    MA_displacement_n2x_damped.append(np.max(np.abs(displacement_n2x_damped)))
    MA_displacement_n2y_damped.append(np.max(np.abs(displacement_n2y_damped)))
    MA_velocity_n1_damped.append(np.max(np.abs(velocity_n1_damped)))
    MA_velocity_n2_damped.append(np.max(np.abs(velocity_n2_damped)))
    MA_acceleration_n1_damped.append(np.max(np.abs(acceleration_n1_damped)))
    MA_acceleration_n2_damped.append(np.max(np.abs(acceleration_n2_damped)))
    MA_spring_force_H_damped.append(np.max(np.abs(spring_force_H_damped)))
    MA_spring_force_V_damped.append(np.max(np.abs(spring_force_V_damped)))
    MA_spring_force_M_damped.append(np.max(np.abs(spring_force_M_damped)))
    MA_ele_force_damped.append(np.max(np.abs(ele_force_damped)))

totaltime = time.process_time() - starttime
print(f'\nTotal time (s): {totaltime:.4f} \n\n')
```

```
STEP:  1
MASS:  100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  234.589470261006
Frequency:  0.00426276592417977
1 Undamping Structure Dynamic Analysis Done.
MASS:  100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  234.589470261006
Frequency:  0.00426276592417977
1 Damping Structure Dynamic Analysis Done.
STEP:  2
MASS:  200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  278.97546713910754
Frequency:  0.003584544584708457
2 Undamping Structure Dynamic Analysis Done.
MASS:  200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  278.97546713910754
Frequency:  0.003584544584708457
2 Damping Structure Dynamic Analysis Done.
STEP:  3
MASS:  300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  308.7371055228015
Frequency:  0.0032390016687713808
3 Undamping Structure Dynamic Analysis Done.
MASS:  300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  308.7371055228015
Frequency:  0.0032390016687713808
3 Damping Structure Dynamic Analysis Done.
STEP:  4
MASS:  400.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  331.75961043303454
Frequency:  0.0030142306915984557
4 Undamping Structure Dynamic Analysis Done.
MASS:  400.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  331.75961043303454
Frequency:  0.0030142306915984557
4 Damping Structure Dynamic Analysis Done.
STEP:  5
MASS:  500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  350.79307844212707
Frequency:  0.0028506833841790793
5 Undamping Structure Dynamic Analysis Done.
MASS:  500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  350.79307844212707
Frequency:  0.0028506833841790793
5 Damping Structure Dynamic Analysis Done.
STEP:  6
MASS:  600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  367.1523625530615
Frequency:  0.002723664892270653
6 Undamping Structure Dynamic Analysis Done.
MASS:  600.0
TWO MASSES
WARNING can't set handler after analysis is created
```

```
IN TIME 19.520000 CONTACT DONE!
Period:  367.1523625530615
Frequency:  0.002723664892270653
6 Damping Structure Dynamic Analysis Done.
STEP:  7
MASS:  700.0000000000001
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  381.57773394765206
Frequency:  0.002620697988990071
7 Undamping Structure Dynamic Analysis Done.
MASS:  700.0000000000001
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  381.57773394765206
Frequency:  0.002620697988990071
7 Damping Structure Dynamic Analysis Done.
STEP:  8
MASS:  800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  394.53088919749564
Frequency:  0.002534655783312866
8 Undamping Structure Dynamic Analysis Done.
MASS:  800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  394.53088919749564
Frequency:  0.002534655783312866
8 Damping Structure Dynamic Analysis Done.
STEP:  9
MASS:  900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  406.3208814127306
Frequency:  0.002461109053817554
9 Undamping Structure Dynamic Analysis Done.
MASS:  900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  406.3208814127306
Frequency:  0.002461109053817554
9 Damping Structure Dynamic Analysis Done.
STEP:  10
MASS:  1000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  417.1656247770852
Frequency:  0.002397129438779515
10 Undamping Structure Dynamic Analysis Done.
MASS:  1000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  417.1656247770852
Frequency:  0.002397129438779515
10 Damping Structure Dynamic Analysis Done.
STEP:  11
MASS:  1100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  427.22502691863195
Frequency:  0.0023406868441498327
11 Undamping Structure Dynamic Analysis Done.
MASS:  1100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  427.22502691863195
Frequency:  0.0023406868441498327
11 Damping Structure Dynamic Analysis Done.
STEP:  12
MASS:  1200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  436.62020183815935
Frequency:  0.0022903200442627868
12 Undamping Structure Dynamic Analysis Done.
MASS:  1200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  436.62020183815935
Frequency:  0.0022903200442627868
12 Damping Structure Dynamic Analysis Done.
STEP:  13
MASS:  1300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  445.4452709554558
Frequency:  0.0022449446996149597
13 Undamping Structure Dynamic Analysis Done.
MASS:  1300.0
TWO MASSES
WARNING can't set handler after analysis is created
```

```
IN TIME 19.520000 CONTACT DONE!
Period:  445.4452709554558
Frequency:  0.0022449446996149597
13 Damping Structure Dynamic Analysis Done.
STEP:  14
MASS:  1400.0000000000002
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  453.7749561371632
Frequency:  0.002203735544404369
14 Undamping Structure Dynamic Analysis Done.
MASS:  1400.0000000000002
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  453.7749561371632
Frequency:  0.002203735544404369
14 Damping Structure Dynamic Analysis Done.
STEP:  15
MASS:  1500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  461.6696544277395
Frequency:  0.002166050963950718
15 Undamping Structure Dynamic Analysis Done.
MASS:  1500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  461.6696544277395
Frequency:  0.002166050963950718
15 Damping Structure Dynamic Analysis Done.
STEP:  16
MASS:  1600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  469.178940522012
Frequency:  0.002131382962089885
16 Undamping Structure Dynamic Analysis Done.
MASS:  1600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  469.178940522012
Frequency:  0.002131382962089885
16 Damping Structure Dynamic Analysis Done.
STEP:  17
MASS:  1700.0000000000002
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  476.34405008049845
Frequency:  0.0020993229574947096
17 Undamping Structure Dynamic Analysis Done.
MASS:  1700.0000000000002
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  476.34405008049845
Frequency:  0.0020993229574947096
17 Damping Structure Dynamic Analysis Done.
STEP:  18
MASS:  1800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  483.19968315019605
Frequency:  0.0020695377809036427
18 Undamping Structure Dynamic Analysis Done.
MASS:  1800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  483.19968315019605
Frequency:  0.0020695377809036427
18 Damping Structure Dynamic Analysis Done.
STEP:  19
MASS:  1900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  489.7753399818343
Frequency:  0.0020417524492700877
19 Undamping Structure Dynamic Analysis Done.
MASS:  1900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  489.7753399818343
Frequency:  0.0020417524492700877
19 Damping Structure Dynamic Analysis Done.
STEP:  20
MASS:  2000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  496.09632911946517
Frequency:  0.0020157375519688427
20 Undamping Structure Dynamic Analysis Done.
MASS:  2000.0
TWO MASSES
WARNING can't set handler after analysis is created
```

```
IN TIME 19.520000 CONTACT DONE!
Period:  496.09632911946517
Frequency:  0.0020157375519688427
20 Damping Structure Dynamic Analysis Done.
STEP:  21
MASS:  2100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  502.18453956980505
Frequency:  0.0019912998533500197
21 Undamping Structure Dynamic Analysis Done.
MASS:  2100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  502.18453956980505
Frequency:  0.0019912998533500197
21 Damping Structure Dynamic Analysis Done.
STEP:  22
MASS:  2200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  508.0590417188661
Frequency:  0.0019682751764771244
22 Undamping Structure Dynamic Analysis Done.
MASS:  2200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  508.0590417188661
Frequency:  0.0019682751764771244
22 Damping Structure Dynamic Analysis Done.
STEP:  23
MASS:  2300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  513.7365602257606
Frequency:  0.0019465229407861333
23 Undamping Structure Dynamic Analysis Done.
MASS:  2300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  513.7365602257606
Frequency:  0.0019465229407861333
23 Damping Structure Dynamic Analysis Done.
STEP:  24
MASS:  2400.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  519.2318505798632
Frequency:  0.0019259219150043062
24 Undamping Structure Dynamic Analysis Done.
MASS:  2400.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  519.2318505798632
Frequency:  0.0019259219150043062
24 Damping Structure Dynamic Analysis Done.
STEP:  25
MASS:  2500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  524.5580023092748
Frequency:  0.001906366875727136
25 Undamping Structure Dynamic Analysis Done.
MASS:  2500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  524.5580023092748
Frequency:  0.001906366875727136
25 Damping Structure Dynamic Analysis Done.
STEP:  26
MASS:  2600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  529.726685564543
Frequency:  0.0018877659503490464
26 Undamping Structure Dynamic Analysis Done.
MASS:  2600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  529.726685564543
Frequency:  0.0018877659503490464
26 Damping Structure Dynamic Analysis Done.
STEP:  27
MASS:  2700.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  534.7483529472462
Frequency:  0.0018700384853708033
27 Undamping Structure Dynamic Analysis Done.
MASS:  2700.0
TWO MASSES
WARNING can't set handler after analysis is created
```

```
IN TIME 19.520000 CONTACT DONE!
Period:  534.7483529472462
Frequency:  0.0018700384853708033
27 Damping Structure Dynamic Analysis Done.
STEP:  28
MASS:  2800.0000000000005
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  539.6324064483622
Frequency:  0.0018531133194568269
28 Undamping Structure Dynamic Analysis Done.
MASS:  2800.0000000000005
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  539.6324064483622
Frequency:  0.0018531133194568269
28 Damping Structure Dynamic Analysis Done.
STEP:  29
MASS:  2900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  544.3873363475782
Frequency:  0.0018369273736403085
29 Undamping Structure Dynamic Analysis Done.
MASS:  2900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  544.3873363475782
Frequency:  0.0018369273736403085
29 Damping Structure Dynamic Analysis Done.
STEP:  30
MASS:  3000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  549.0208378263152
Frequency:  0.001821424490843012
30 Undamping Structure Dynamic Analysis Done.
MASS:  3000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  549.0208378263152
Frequency:  0.001821424490843012
30 Damping Structure Dynamic Analysis Done.
STEP:  31
MASS:  3100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  553.5399089625419
Frequency:  0.0018065544756731718
31 Undamping Structure Dynamic Analysis Done.
MASS:  3100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  553.5399089625419
Frequency:  0.0018065544756731718
31 Damping Structure Dynamic Analysis Done.
STEP:  32
MASS:  3200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  557.9509342782151
Frequency:  0.0017922722923542284
32 Undamping Structure Dynamic Analysis Done.
MASS:  3200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  557.9509342782151
Frequency:  0.0017922722923542284
32 Damping Structure Dynamic Analysis Done.
STEP:  33
MASS:  3300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  562.2597556513996
Frequency:  0.0017785373929910056
33 Undamping Structure Dynamic Analysis Done.
MASS:  3300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  562.2597556513996
Frequency:  0.0017785373929910056
33 Damping Structure Dynamic Analysis Done.
STEP:  34
MASS:  3400.0000000000005
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  566.4717335449413
Frequency:  0.001765313149417127
34 Undamping Structure Dynamic Analysis Done.
MASS:  3400.0000000000005
TWO MASSES
WARNING can't set handler after analysis is created
```

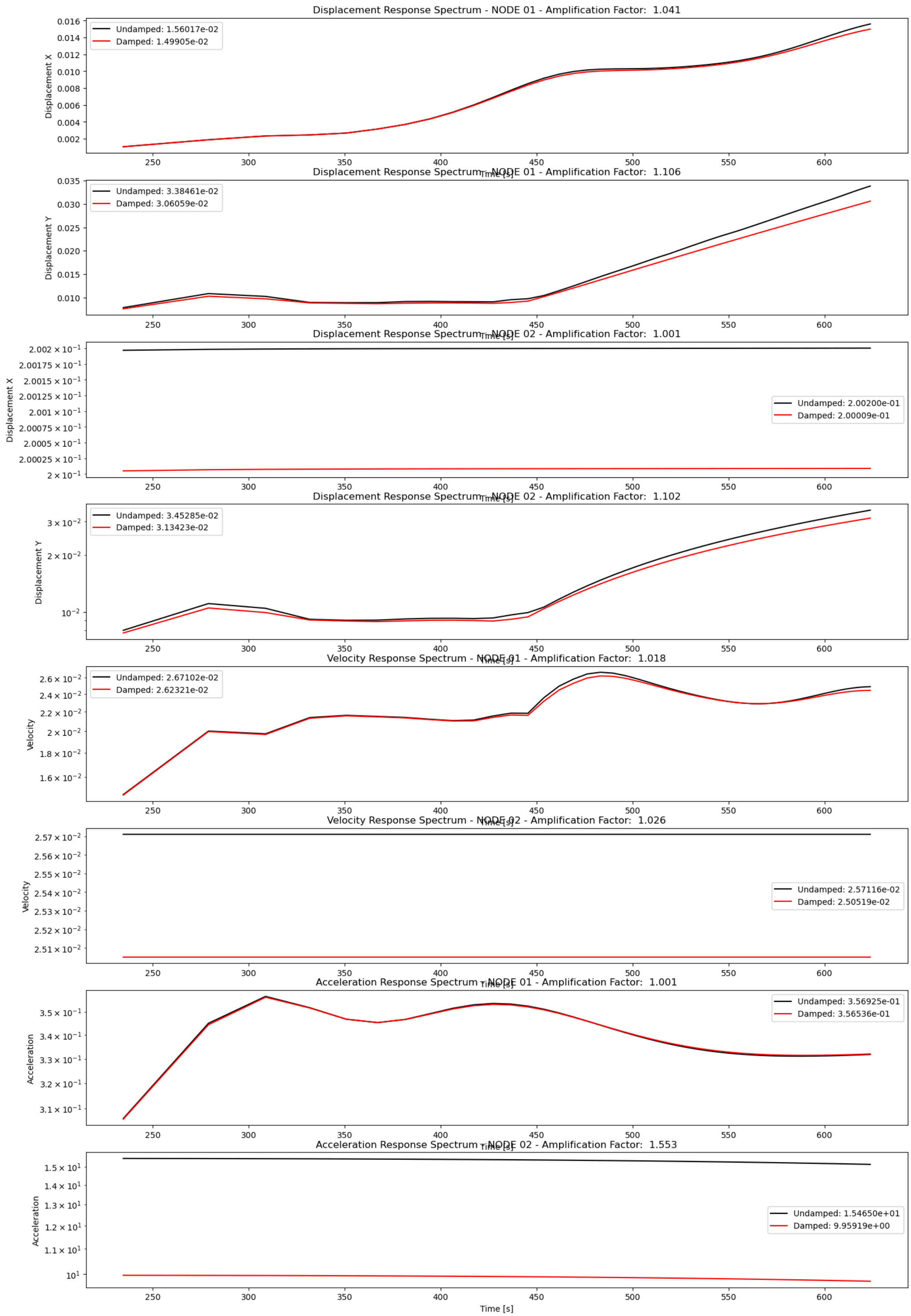
```
IN TIME 19.520000 CONTACT DONE!
Period:  566.4717335449413
Frequency:  0.001765313149417127
34 Damping Structure Dynamic Analysis Done.
STEP:  35
MASS:  3500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  570.5917993997767
Frequency:  0.0017525663724083157
35 Undamping Structure Dynamic Analysis Done.
MASS:  3500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  570.5917993997767
Frequency:  0.0017525663724083157
35 Damping Structure Dynamic Analysis Done.
STEP:  36
MASS:  3600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  574.6245011692736
Frequency:  0.0017402669011940004
36 Undamping Structure Dynamic Analysis Done.
MASS:  3600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  574.6245011692736
Frequency:  0.0017402669011940004
36 Damping Structure Dynamic Analysis Done.
STEP:  37
MASS:  3700.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  578.5740428276032
Frequency:  0.0017283872520668343
37 Undamping Structure Dynamic Analysis Done.
MASS:  3700.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  578.5740428276032
Frequency:  0.0017283872520668343
37 Damping Structure Dynamic Analysis Done.
STEP:  38
MASS:  3800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  582.444319059274
Frequency:  0.0017169023154267084
38 Undamping Structure Dynamic Analysis Done.
MASS:  3800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  582.444319059274
Frequency:  0.0017169023154267084
38 Damping Structure Dynamic Analysis Done.
STEP:  39
MASS:  3900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  586.2389452544554
Frequency:  0.0017057890952058
39 Undamping Structure Dynamic Analysis Done.
MASS:  3900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  586.2389452544554
Frequency:  0.0017057890952058
39 Damping Structure Dynamic Analysis Done.
STEP:  40
MASS:  4000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  589.9612843155995
Frequency:  0.001695026481542898
40 Undamping Structure Dynamic Analysis Done.
MASS:  4000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  589.9612843155995
Frequency:  0.001695026481542898
40 Damping Structure Dynamic Analysis Done.
STEP:  41
MASS:  4100.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  593.6144699106703
Frequency:  0.0016845950540095229
41 Undamping Structure Dynamic Analysis Done.
MASS:  4100.0
TWO MASSES
WARNING can't set handler after analysis is created
```

```
IN TIME 19.520000 CONTACT DONE!
Period:  593.6144699106703
Frequency:  0.0016845950540095229
41 Damping Structure Dynamic Analysis Done.
STEP:  42
MASS:  4200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  597.2014275007776
Frequency:  0.0016744769083772793
42 Undamping Structure Dynamic Analysis Done.
MASS:  4200.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  597.2014275007776
Frequency:  0.0016744769083772793
42 Damping Structure Dynamic Analysis Done.
STEP:  43
MASS:  4300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  600.7248926115377
Frequency:  0.00166465550587173
43 Undamping Structure Dynamic Analysis Done.
MASS:  4300.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  600.7248926115377
Frequency:  0.00166465550587173
43 Damping Structure Dynamic Analysis Done.
STEP:  44
MASS:  4400.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  604.1874272535399
Frequency:  0.0016551155401324862
44 Undamping Structure Dynamic Analysis Done.
MASS:  4400.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  604.1874272535399
Frequency:  0.0016551155401324862
44 Damping Structure Dynamic Analysis Done.
STEP:  45
MASS:  4500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  607.5914348052587
Frequency:  0.0016458428192301848
45 Undamping Structure Dynamic Analysis Done.
MASS:  4500.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  607.5914348052587
Frequency:  0.0016458428192301848
45 Damping Structure Dynamic Analysis Done.
STEP:  46
MASS:  4600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  610.9391726574985
Frequency:  0.0016368241631161777
46 Undamping Structure Dynamic Analysis Done.
MASS:  4600.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  610.9391726574985
Frequency:  0.0016368241631161777
46 Damping Structure Dynamic Analysis Done.
STEP:  47
MASS:  4700.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  614.2327646126676
Frequency:  0.0016280473097696044
47 Undamping Structure Dynamic Analysis Done.
MASS:  4700.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  614.2327646126676
Frequency:  0.0016280473097696044
47 Damping Structure Dynamic Analysis Done.
STEP:  48
MASS:  4800.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  617.474211045603
Frequency:  0.0016195008343856904
48 Undamping Structure Dynamic Analysis Done.
MASS:  4800.0
TWO MASSES
WARNING can't set handler after analysis is created
```

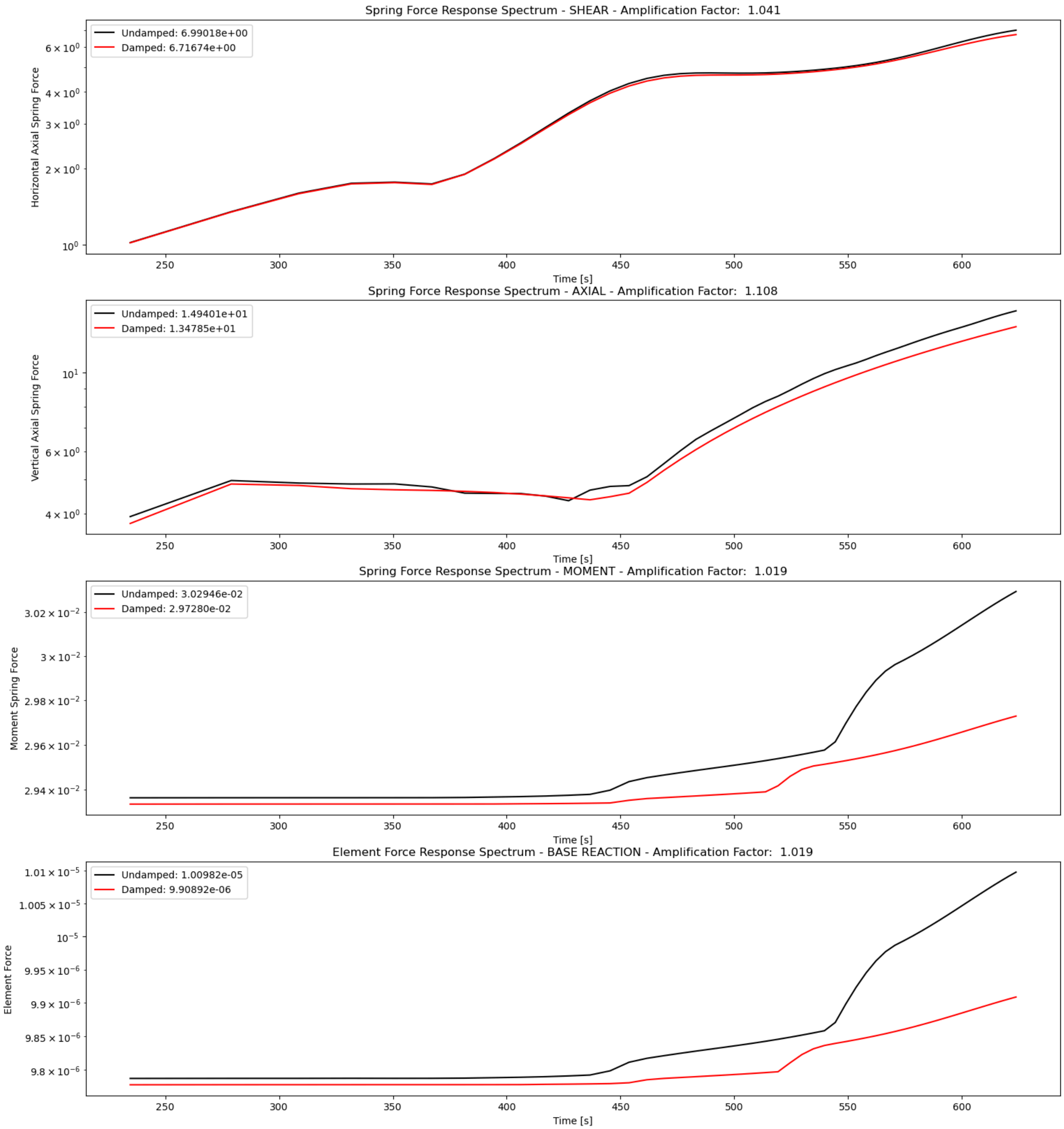
```
IN TIME 19.520000 CONTACT DONE!
Period:  617.474211045603
Frequency:  0.0016195008343856904
48 Damping Structure Dynamic Analysis Done.
STEP:  49
MASS:  4900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  620.6653985050045
Frequency:  0.0016111740760942981
49 Undamping Structure Dynamic Analysis Done.
MASS:  4900.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  620.6653985050045
Frequency:  0.0016111740760942981
49 Damping Structure Dynamic Analysis Done.
STEP:  50
MASS:  5000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 16.860000 CONTACT DONE!
Period:  623.8081085778033
Frequency:  0.0016030570719573723
50 Undamping Structure Dynamic Analysis Done.
MASS:  5000.0
TWO MASSES
WARNING can't set handler after analysis is created
IN TIME 19.520000 CONTACT DONE!
Period:  623.8081085778033
Frequency:  0.0016030570719573723
50 Damping Structure Dynamic Analysis Done.

Total time (s): 2742.2031
```

In [28]:

```
### PLOT TWO MASSES RESPONSE SPECTRUM:
PLOT_4_CHART(uMA_period_undamped, MA_period_damped,
             uMA_displacement_n1x_undamped, MA_displacement_n1x_damped,
             uMA_displacement_n1y_undamped, MA_displacement_n1y_damped,
             uMA_displacement_n2x_undamped, MA_displacement_n2x_damped,
             uMA_displacement_n2y_undamped, MA_displacement_n2y_damped,
             uMA_velocity_n1_undamped, MA_velocity_n1_damped,
             uMA_velocity_n2_undamped, MA_velocity_n2_damped,
             uMA_acceleration_n1_undamped, MA_acceleration_n1_damped,
             uMA_acceleration_n2_undamped, MA_acceleration_n2_damped,
             uMA_spring_force_H_undamped, MA_spring_force_H_damped,
             uMA_spring_force_V_undamped, MA_spring_force_V_damped,
             uMA_spring_force_M_undamped, MA_spring_force_M_damped,
             uMA_ele_force_undamped, MA_ele_force_damped, KIND=2)
```

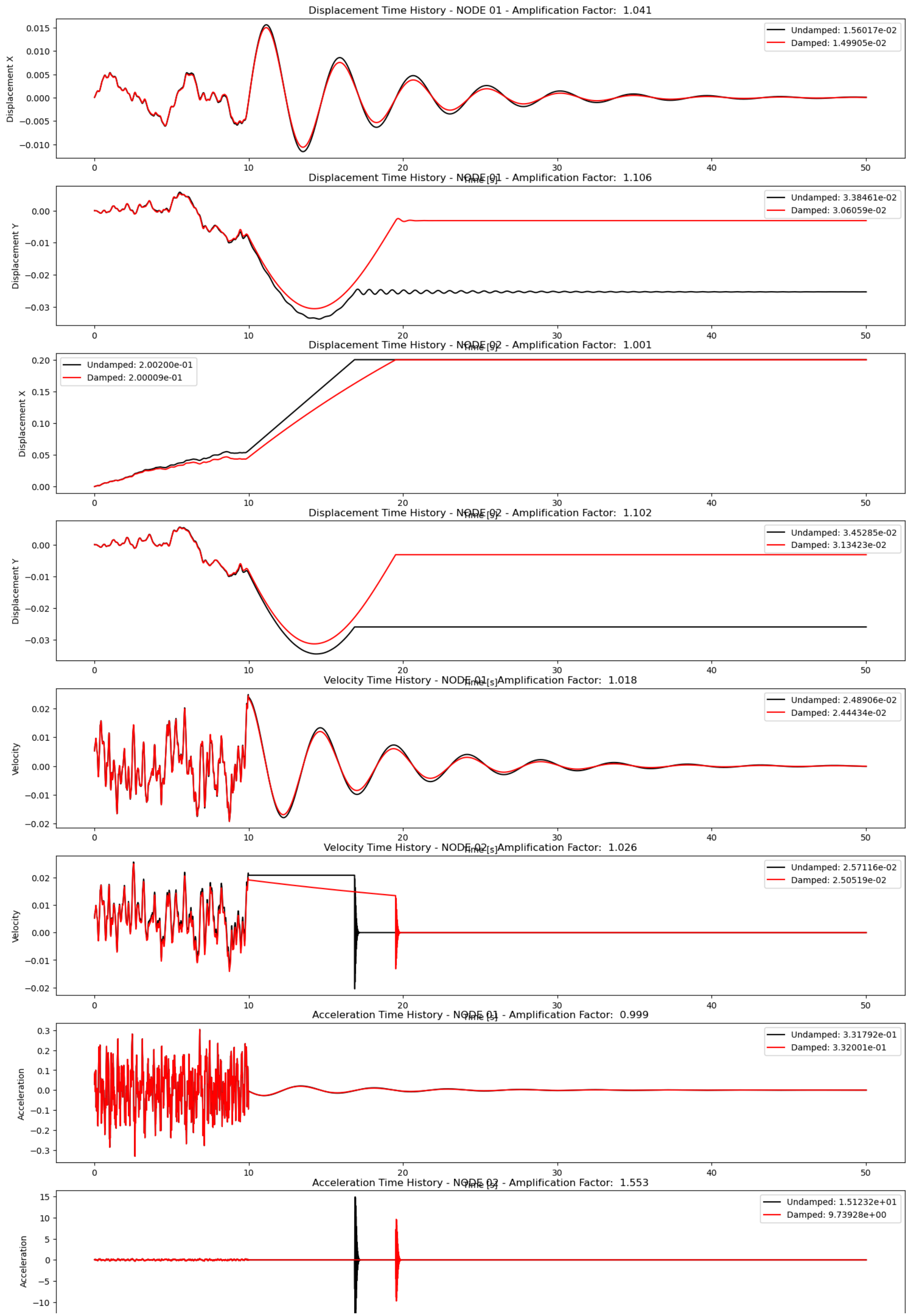


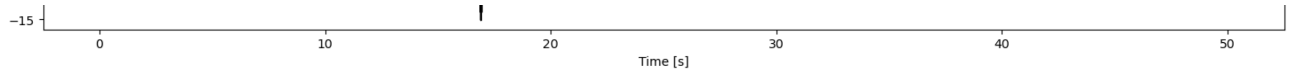
Displacement Response Spectrum - NODE 01 - Amplification Factor: 1.041
Undamped: 1.56017e-02
Damped: 1.49905e-02
Displacement X
Time [s]
Displacement Response Spectrum - NODE 01 - Amplification Factor: 1.106
Undamped: 3.38461e-02
Damped: 3.06059e-02
Displacement Y
Time [s]
Displacement Response Spectrum - NODE 02 - Amplification Factor: 1.001
Undamped: 2.00200e-01
Damped: 2.00009e-01
Displacement X
Time [s]
Displacement Response Spectrum - NODE 02 - Amplification Factor: 1.102
Undamped: 3.45285e-02
Damped: 3.13423e-02
Displacement Y
Time [s]
Velocity Response Spectrum - NODE 01 - Amplification Factor: 1.018
Undamped: 2.67102e-02
Damped: 2.62321e-02
Velocity
Time [s]
Velocity Response Spectrum - NODE 02 - Amplification Factor: 1.026
Undamped: 2.57116e-02
Damped: 2.50519e-02
Velocity
Time [s]
Acceleration Response Spectrum - NODE 01 - Amplification Factor: 1.001
Undamped: 3.56925e-01
Damped: 3.56536e-01
Acceleration
Time [s]
Acceleration Response Spectrum - NODE 02 - Amplification Factor: 1.553
Undamped: 1.54650e+01
Damped: 9.95919e+00
Acceleration
Time [s]

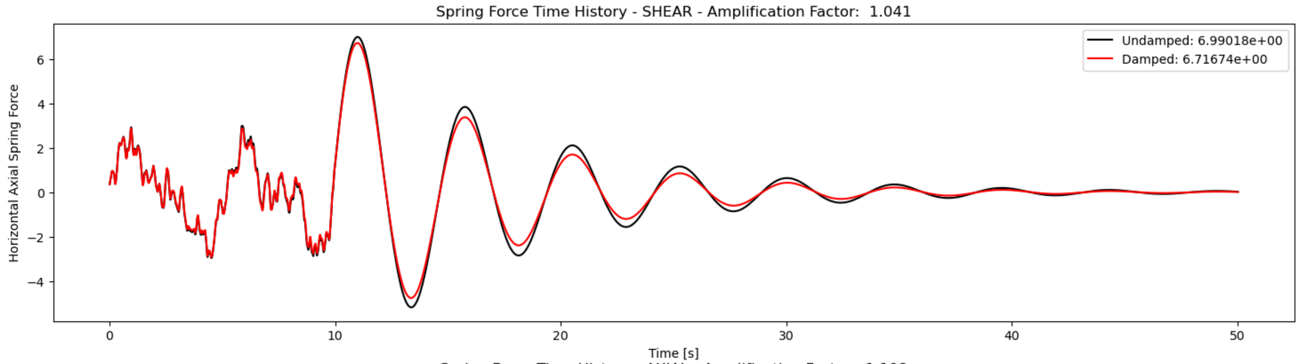


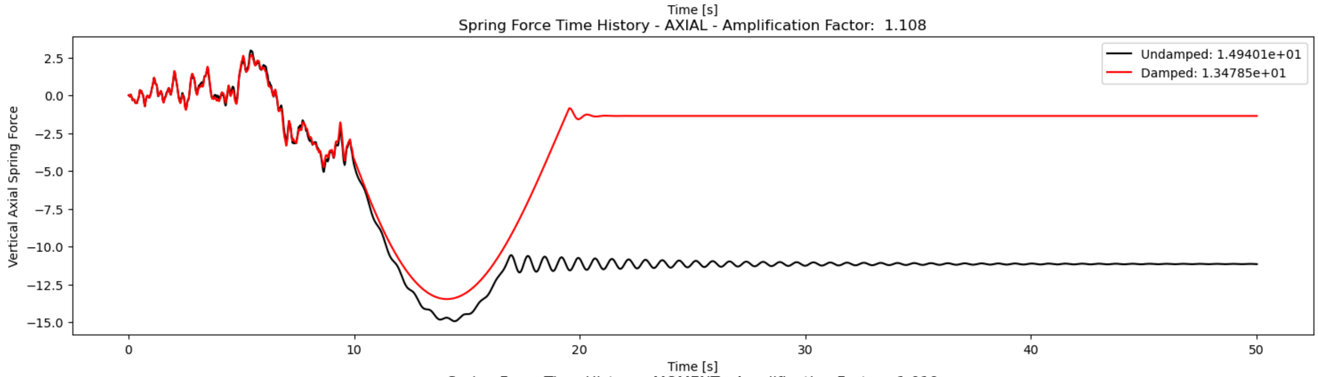
In [29]:

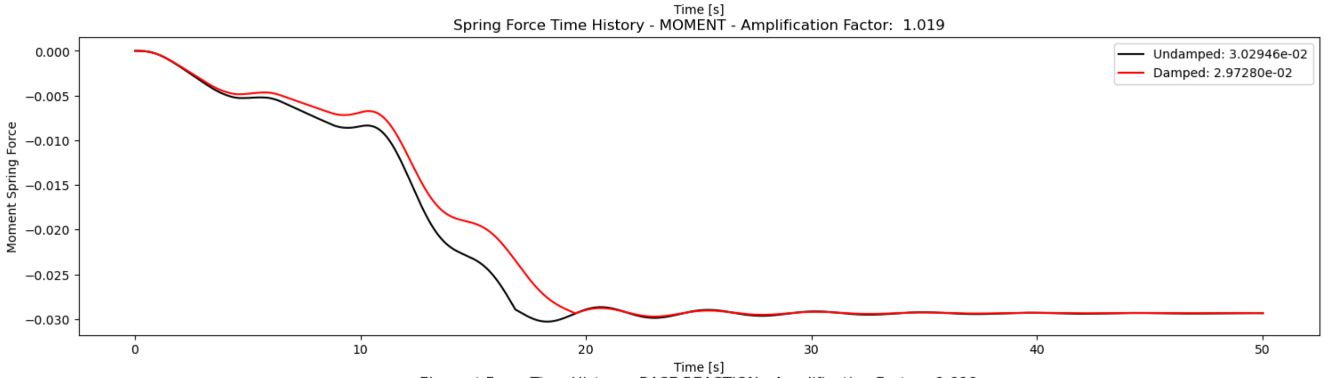
```
### PLOT TWO MASSES LAST ANALYSIS TIME HISTORY:
PLOT_4_CHART(time_undamped, time_damped,
             displacement_n1x_undamped, displacement_n1x_damped,
             displacement_n1y_undamped, displacement_n1y_damped,
             displacement_n2x_undamped, displacement_n2x_damped,
             displacement_n2y_undamped, displacement_n2y_damped,
             velocity_n1_undamped, velocity_n1_damped,
             velocity_n2_undamped, velocity_n2_damped,
             acceleration_n1_undamped, acceleration_n1_damped,
             acceleration_n2_undamped, acceleration_n2_damped,
             spring_force_H_undamped, spring_force_H_damped,
             spring_force_V_undamped, spring_force_V_damped,
             spring_force_M_undamped, spring_force_M_damped,
             ele_force_undamped, ele_force_damped, KIND=1)
```

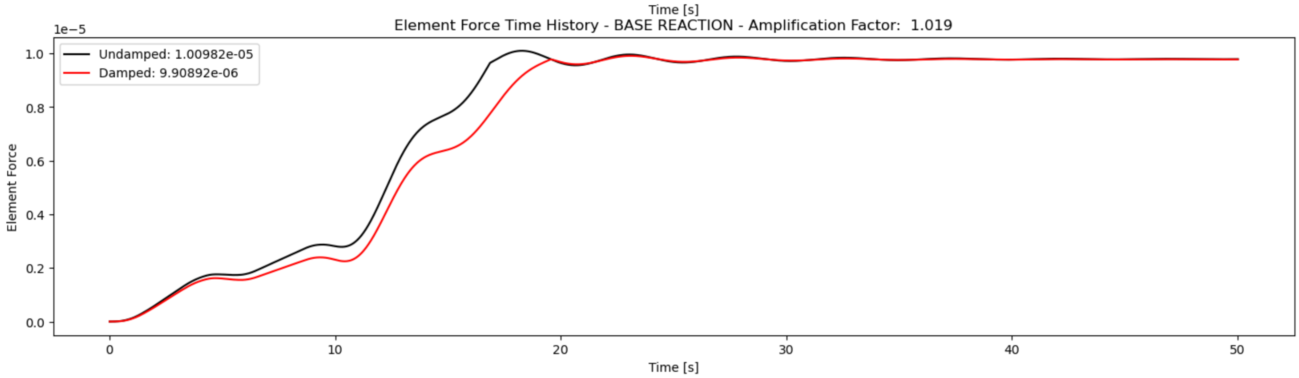

Displacement Time History - NODE 01 - Amplification Factor: 1.041
Displacement X
Undamped: 1.56017e-02
Damped: 1.49905e-02
Time [s]
Displacement Time History - NODE 01 - Amplification Factor: 1.106
Displacement Y
Undamped: 3.38461e-02
Damped: 3.06059e-02
Time [s]
Displacement Time History - NODE 02 - Amplification Factor: 1.001
Displacement X
Undamped: 2.00200e-01
Damped: 2.00009e-01
Time [s]
Displacement Time History - NODE 02 - Amplification Factor: 1.102
Displacement Y
Undamped: 3.45285e-02
Damped: 3.13423e-02
Time [s]
Velocity Time History - NODE 01 - Amplification Factor: 1.018
Velocity
Undamped: 2.48906e-02
Damped: 2.44434e-02
Time [s]
Velocity Time History - NODE 02 - Amplification Factor: 1.026
Velocity
Undamped: 2.57116e-02
Damped: 2.50519e-02
Time [s]
Acceleration Time History - NODE 01 - Amplification Factor: 0.999
Acceleration
Undamped: 3.31792e-01
Damped: 3.32001e-01
Time [s]
Acceleration Time History - NODE 02 - Amplification Factor: 1.553
Acceleration
Undamped: 1.51232e+01
Damped: 9.73928e+00



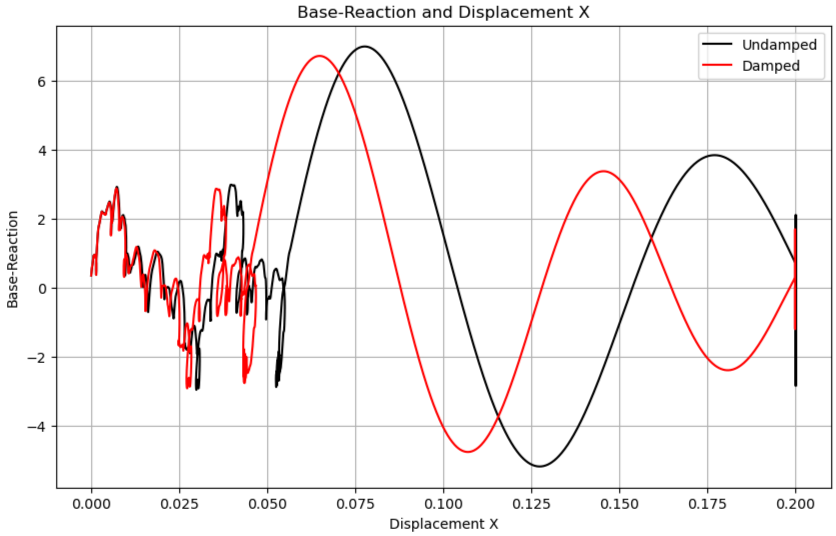




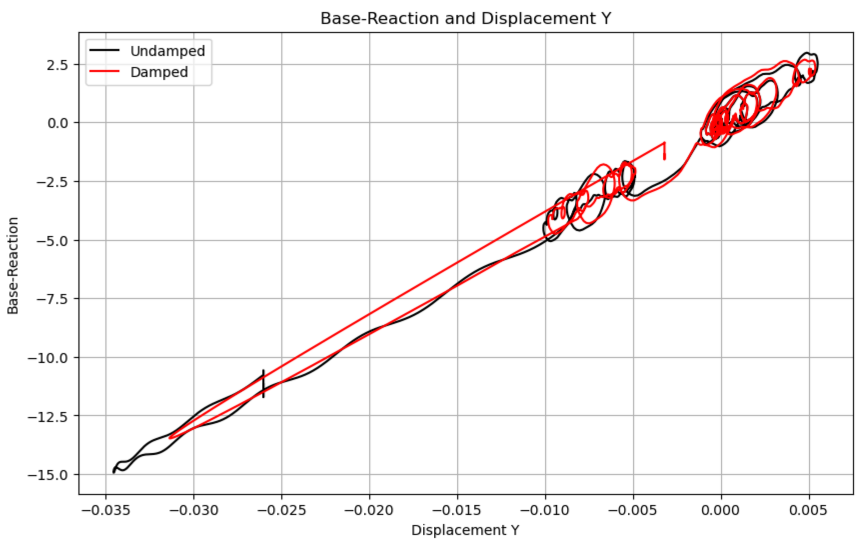




In [30]:
```
### TWO MASSES BASE REACTION & DISPALCEMENT:
X1 = displacement_n2x_undamped
X2 = displacement_n2x_damped
#Y1 = ele_force_undamped
#Y2 = ele_force_damped
Y1 = spring_force_H_undamped
Y2 = spring_force_H_damped
XLABEL = 'Displacement X'
YLABEL = 'Base-Reaction'
TITLE = 'Base-Reaction and Displacement X'

PLOT_2D(X1, Y1, X2, Y2, XLABEL, YLABEL, TITLE)
```



In [31]:
```
### TWO MASSES BASE REACTION & DISPALCEMENT:
X1 = displacement_n2y_undamped
X2 = displacement_n2y_damped
#Y1 = ele_force_undamped
#Y2 = ele_force_damped
Y1 = spring_force_V_undamped
Y2 = spring_force_V_damped
XLABEL = 'Displacement Y'
YLABEL = 'Base-Reaction'
TITLE = 'Base-Reaction and Displacement Y'

PLOT_2D(X1, Y1, X2, Y2, XLABEL, YLABEL, TITLE)
```



In [ ]: