Experimental Structural Dynamics

Project: Determining Dynamic Properties of Metsovo Bridge (1:100 scale physical model)

Group 4	
Aayush Sigdel	Sudan Shakya
121825	121571
Country: Nepal	Country: Nepal

July 17, 2020

Bauhaus University Weimar

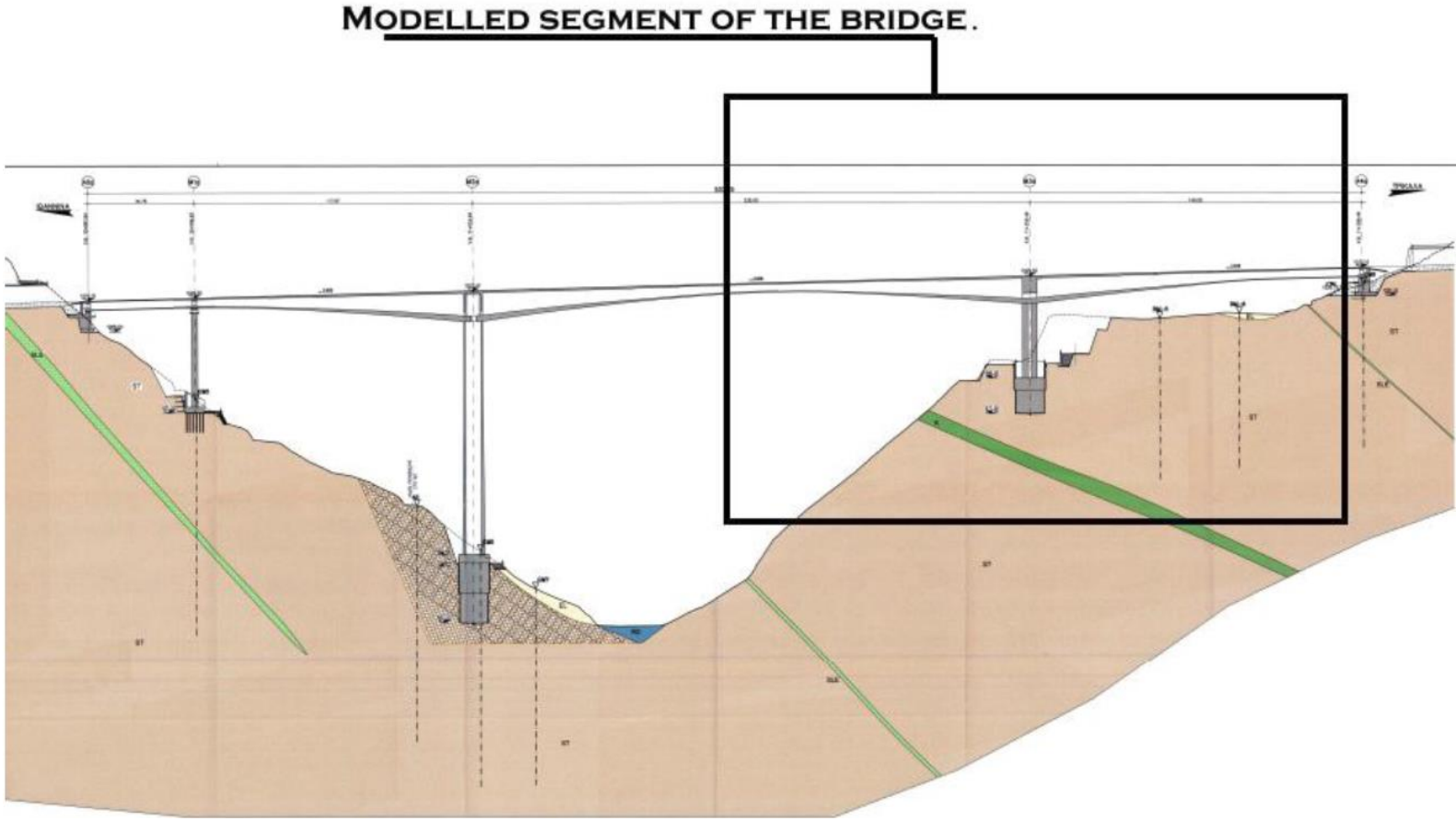
Introduction

- Objectives:
  - Compare the numerical model of Metsovo bridge with the experimental model
  - Determine the dynamic parameters: frequencies, damping and mode shapes from Operational Modal Analysis

Source: Stathopoulos et al.

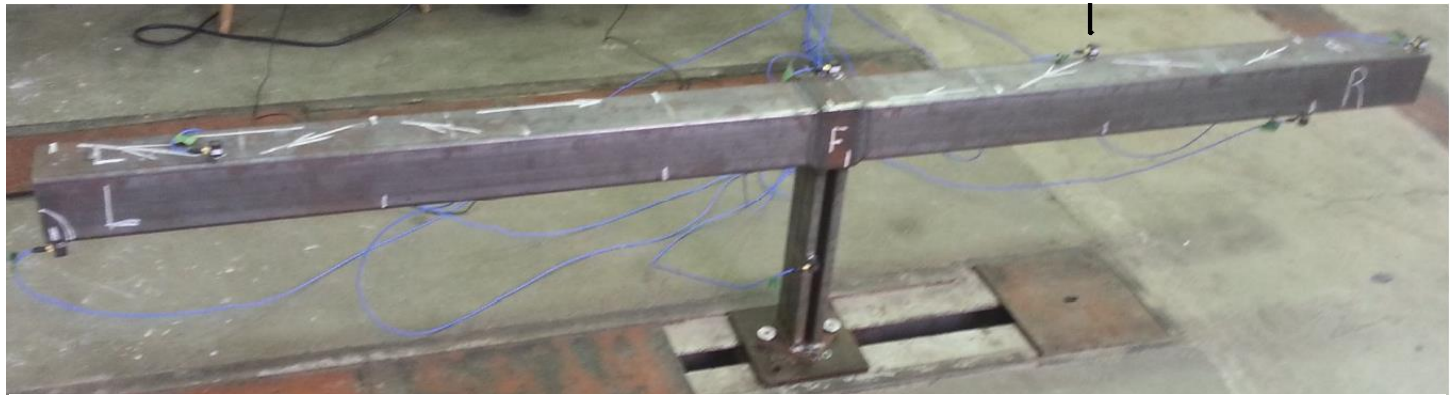
Introduction

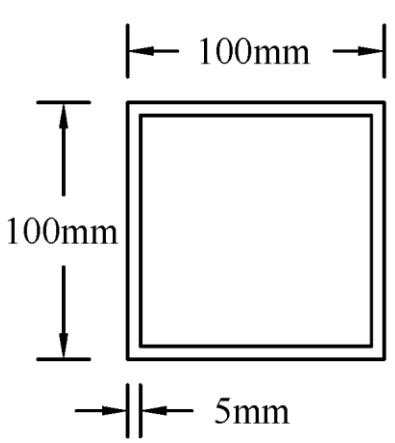
- Structure: Metsovo Bridge
- Location: Egnatia Highway in the city of Thessaloniki, Greece
- Structure: Four Spans of pre-stressed concrete box girder with RC piers
- Modal parameter tests were carried out for a single span of the cantilever.
- Physical Model: 1:100 scale rectangular hollow steel section keeping the dynamic behavior of the real system.



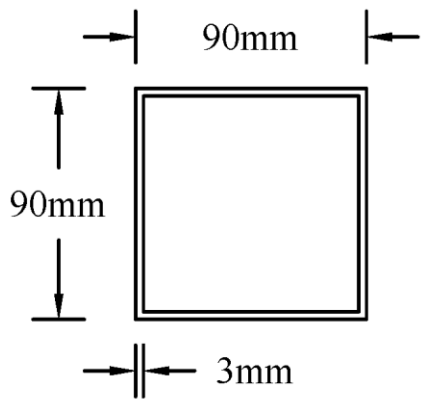
Materials and Sections

- Material: Steel
- Material Properties:
  - Modulus of Elasticity, E=210Gpa
  - Density, ρ=77 KN/m^3
- Sections
  - Deck: Hollow rectangular tube: 90mm x 90mm x 3mm
  - Central Part of the Deck: Hollow rectangular tube: 100mm x 100mm x 5mm
  - Piers: 2 numbers of hollow rectangular tubes: 80mm x 20mm 3mm
- Support conditions: Manually fixed to the ground by means of bolts (Fixed end support)

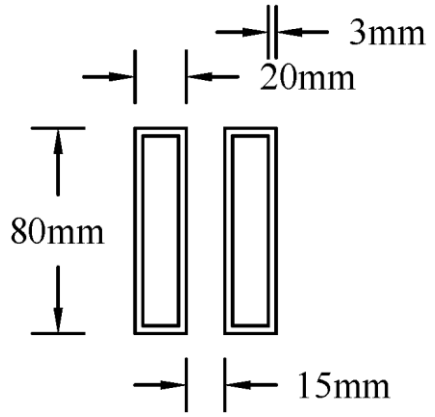




Central Part of Deck



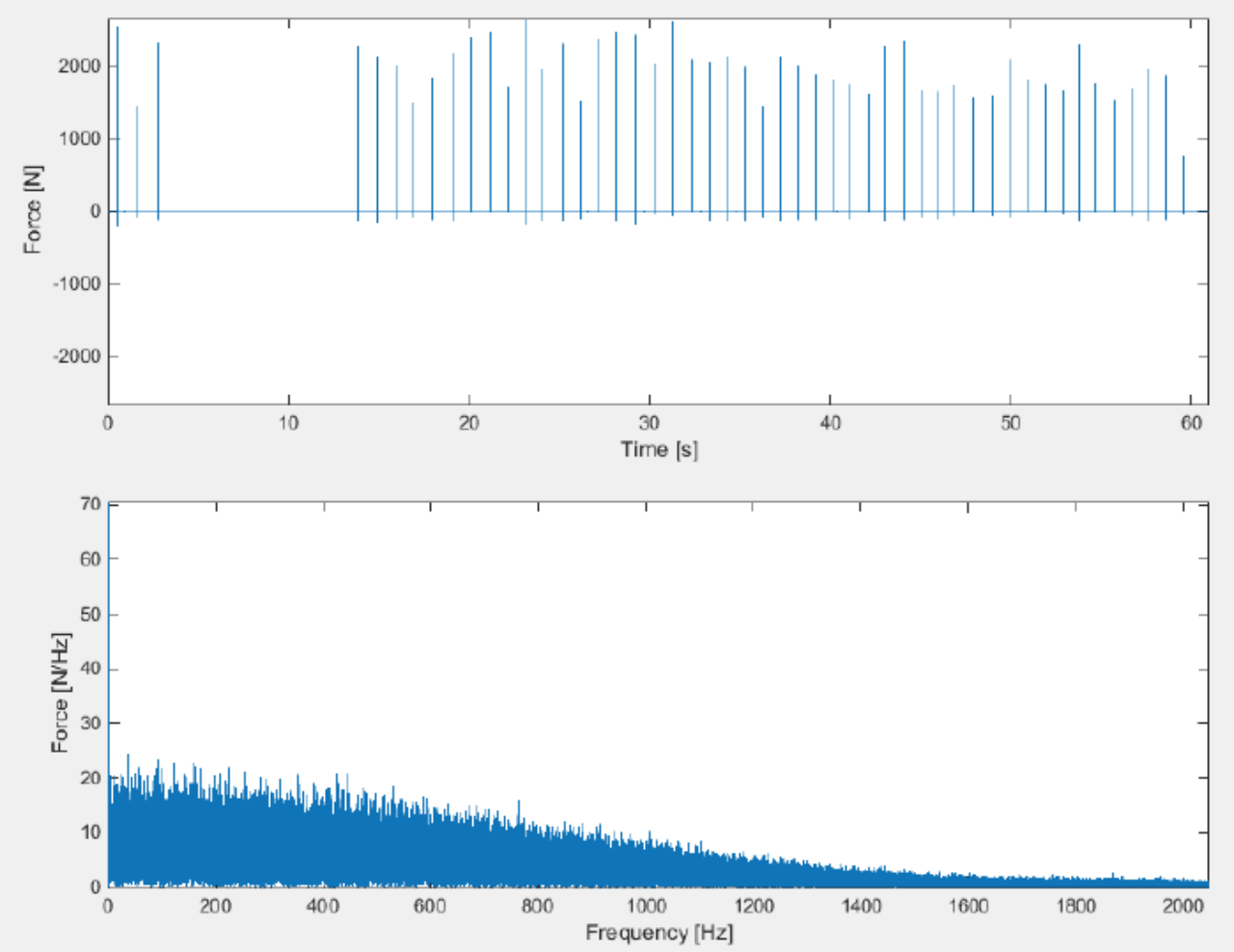
Deck Section



Pier Section

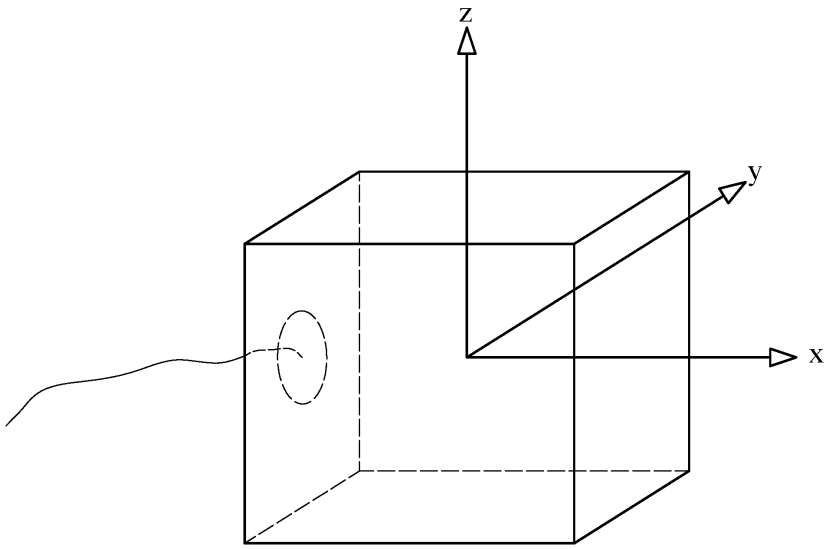
Excitation Mechanism

- Excitation was carried out by means of a specific hammer used to manually apply a series of impulsive loads.
- Loads were applied on the free edge of the structure.
- Hammer tip consists of a force transducer, with a load cell that can log the time history of the loading to the analyzer.



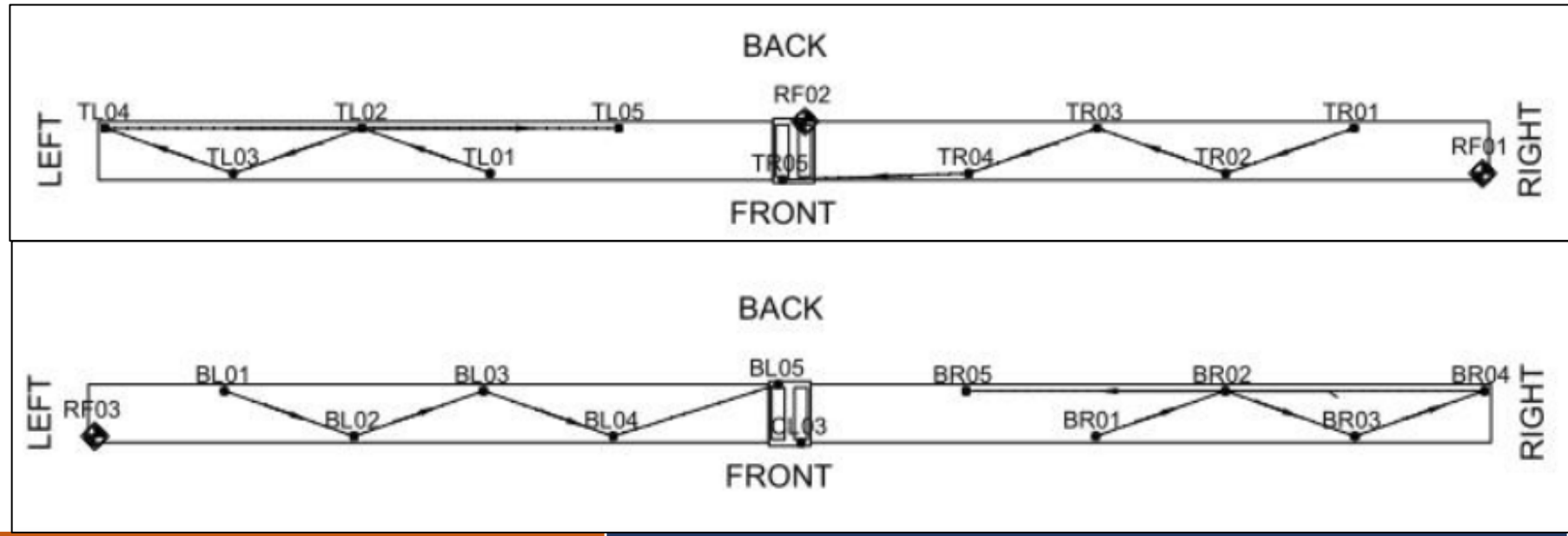
Sensors

- Type of sensors: Triaxial Accelerometers (Model 356A16 by PCB Piezotronics Inc.)
- Number of sensors: 8
- Fixed on the system by means of magnetic force.
- The real time recorded data is arranged in columns of data channels as per respective local co-ordinate axis.
- Sampling Frequency: 4096 Hz

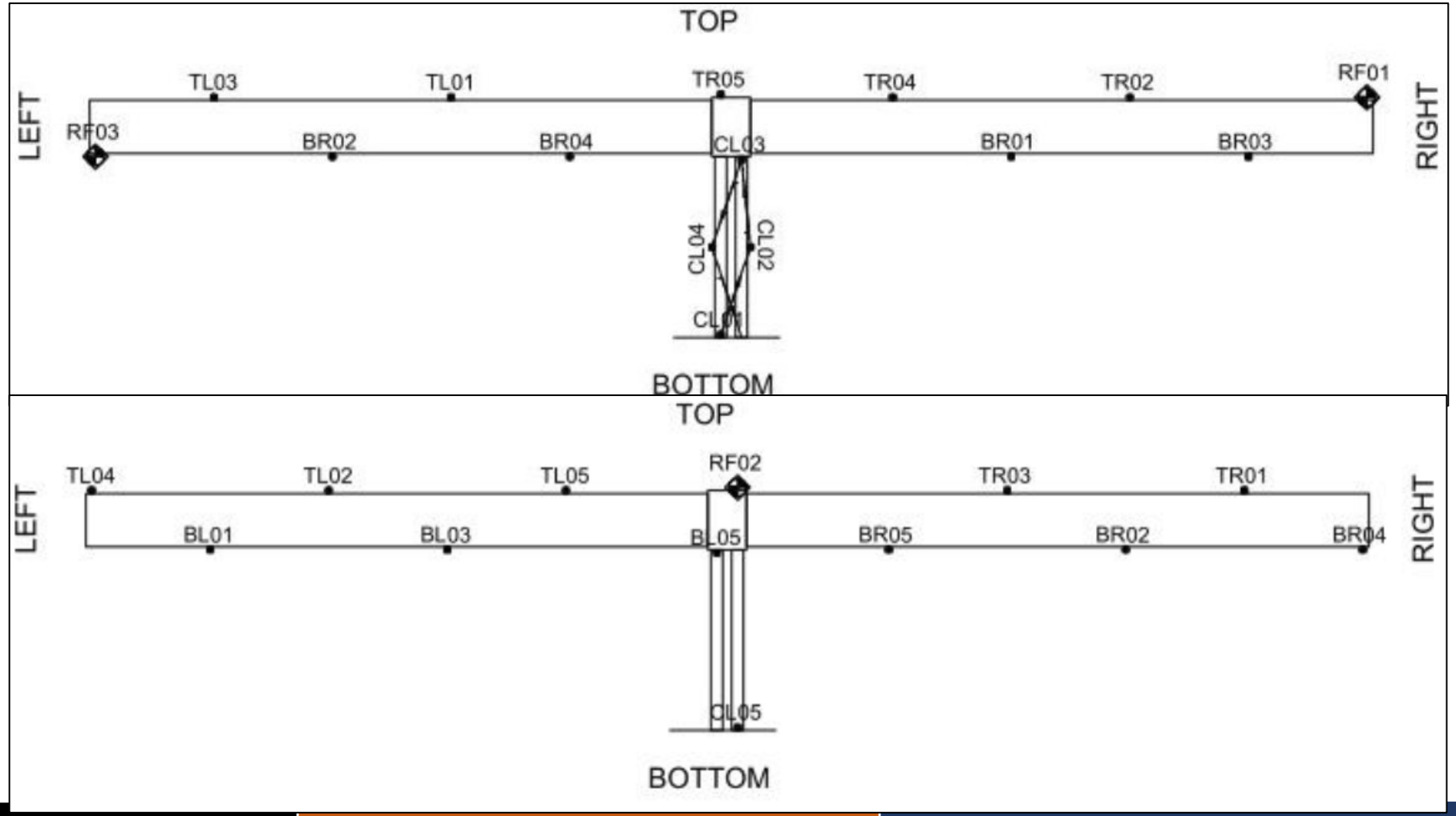


Test Structure and Sensor Arrangement

- Number of Experimental Configurations: 5
- Total Number of Measurements: 13
- Number of sensors used: 8
  - 3 Master Sensors: Reference Sensors (RF01, RF02, RF03)
  - Five Moving Sensors: Position changed in each configuration (TL, TR, BL, BR, CL)
- Spacing of sensors: 200mm



Test Structure and Sensor Arrangement



Test Structure and Sensor Arrangement

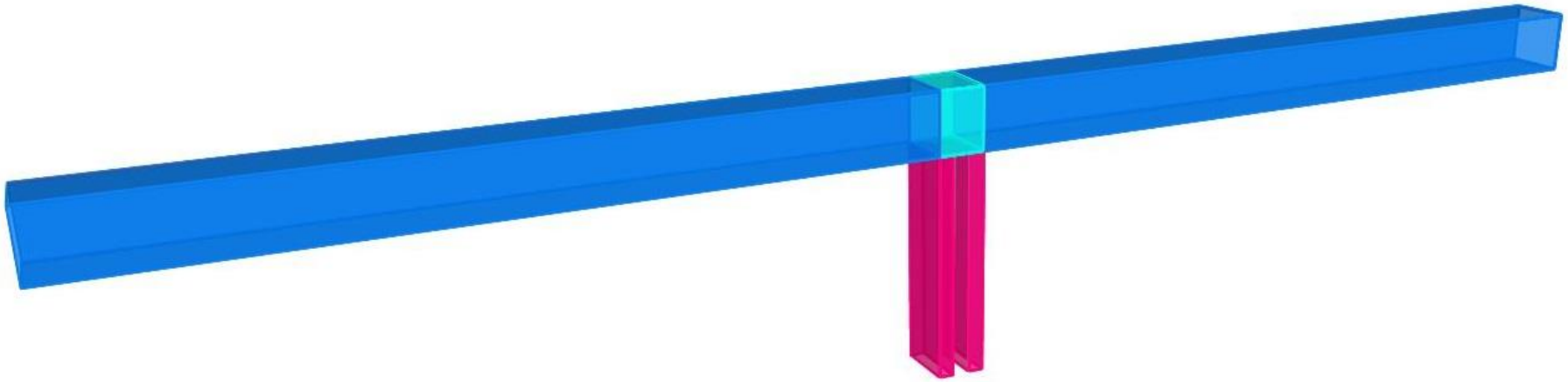
Measurement No.	Configuration	Duration (s)	Excitation
1	1	61	Vertical at left end
2	1	61	Vertical at left end
3	2	71	Vertical at right end
4	2	60	Vertical at left end
5	3	60	Vertical at left end
6	3	60	Vertical at right end
7	4	61	Vertical at left end
8	4	60	Vertical at right end
9	5	60	Vertical at left end
10	5	60	Vertical at right end
12	3	16	Vertical at left end
13	3	10	Vertical at left end
14	3	20	Vertical at left end

Analyzer

- In each measurement, the excitation force and recorded acceleration time history in real time are logged into the analyzer.
- Total 25 channels of data for each set of measurement
  - 24 from the acceleration time history (in 3 local coordinate directions of 8 sensors)
  - 1 load channel
- Data is stored in ASCII format

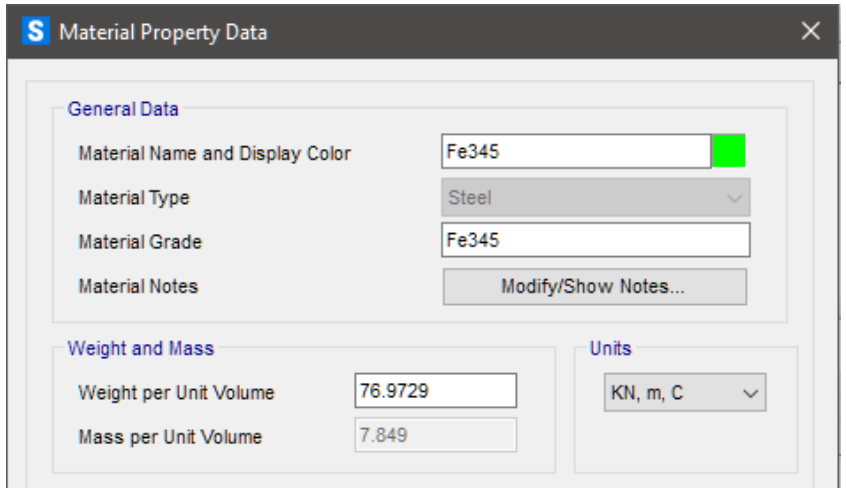
Numerical Model

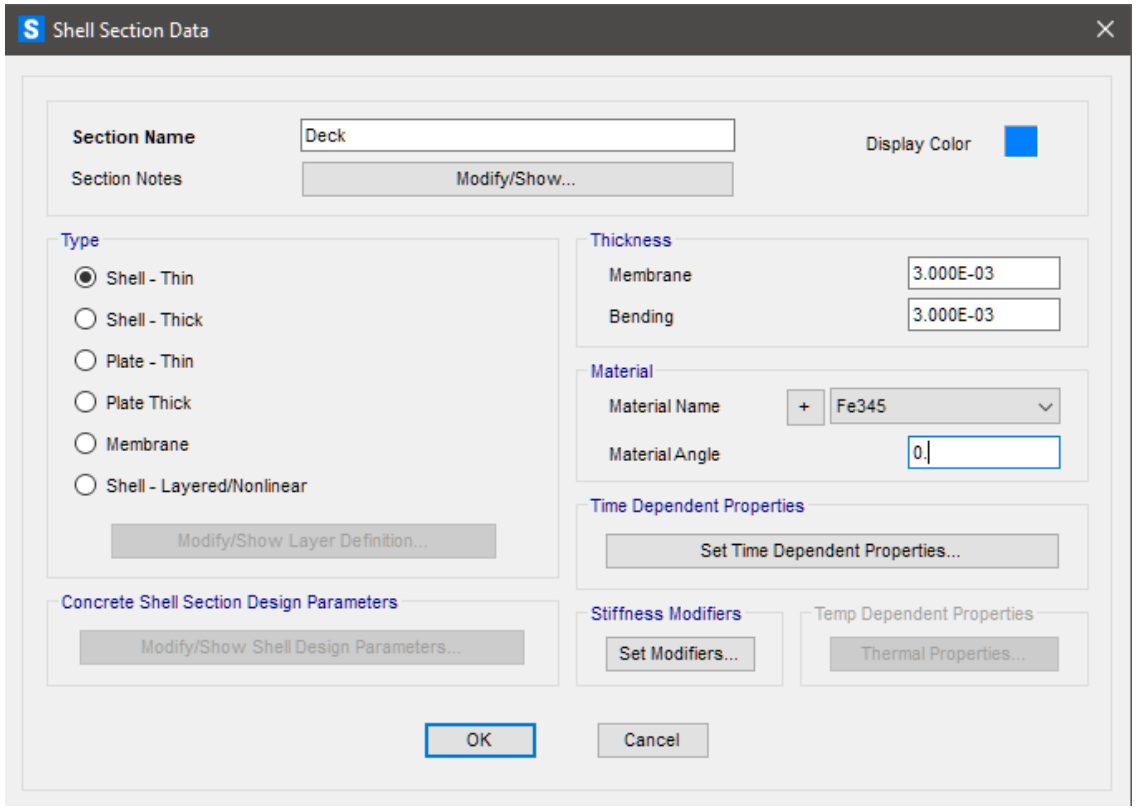
- Model Created in SAP 2000
  - Shell model is used
  - Fixed support is assumed



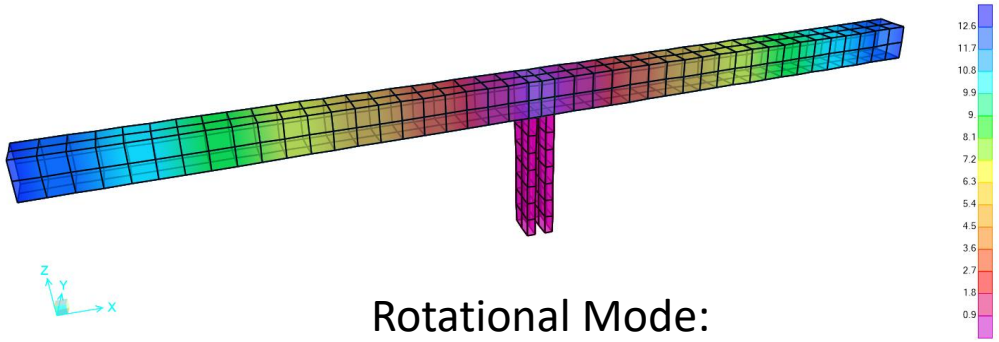
Material and Section Definition

- Material definition: Unit Weight of 77KN/m^3
- Modulus of Elasticity: E=210 Gpa
- Shell thickness: 3mm

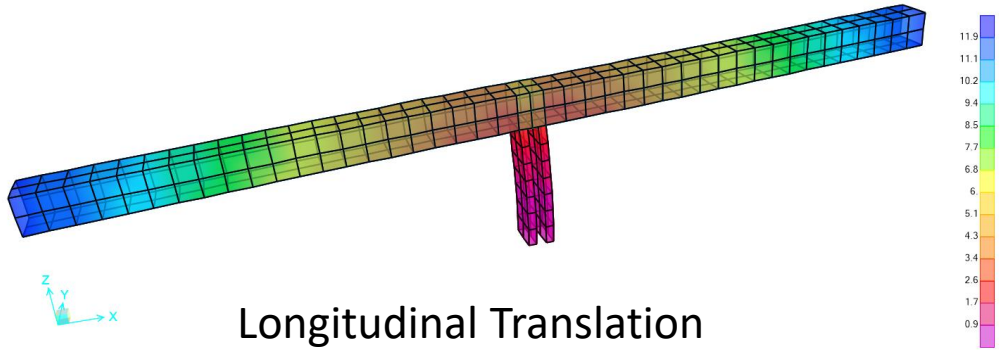




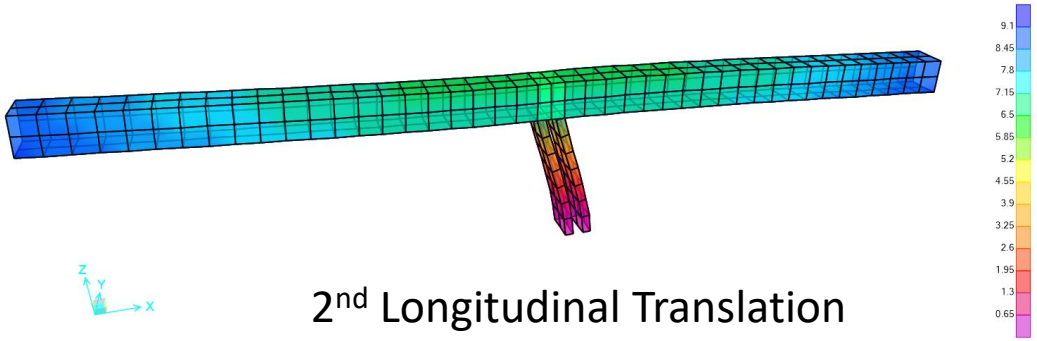
Results of Numerical Model



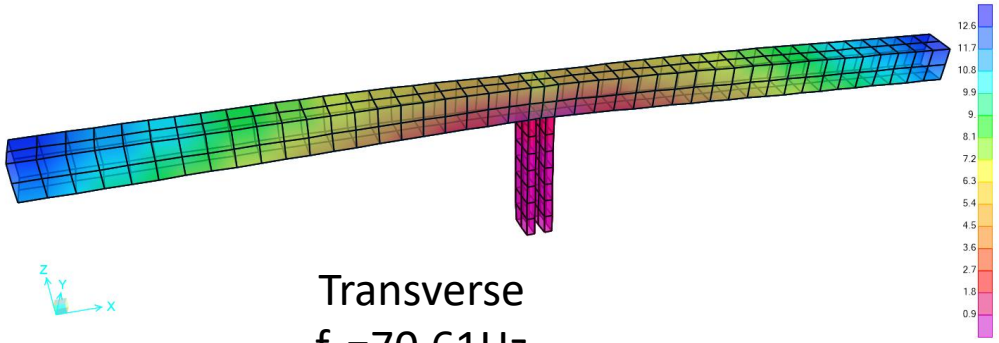
Rotational Mode:
f_1=15.37Hz



Longitudinal Translation
f_2=27.83Hz

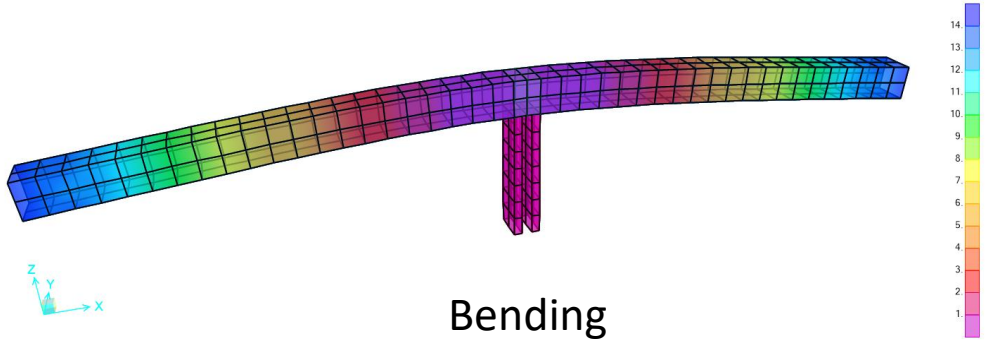


2nd Longitudinal Translation
f_3=62.11Hz

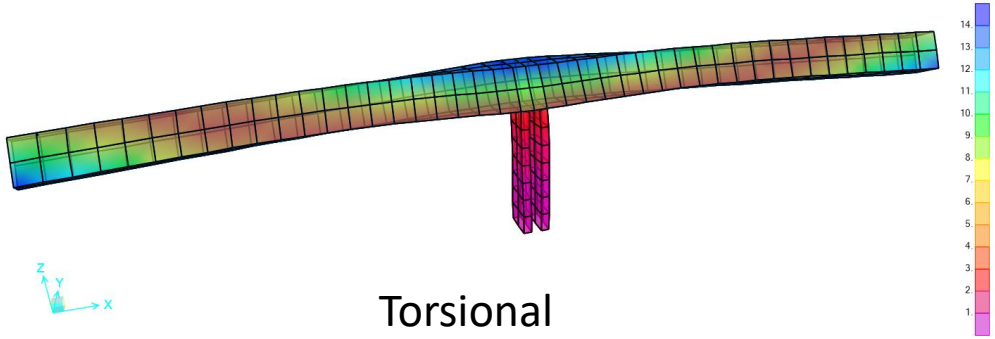


Transverse
f_4=70.61Hz

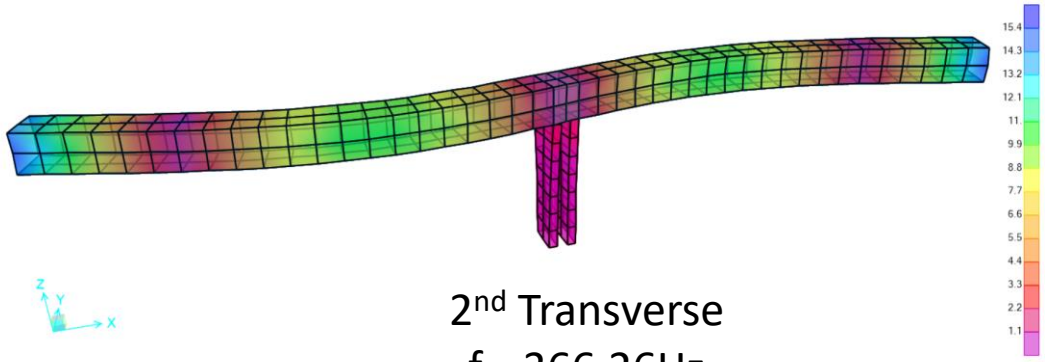
Results of Numerical Model



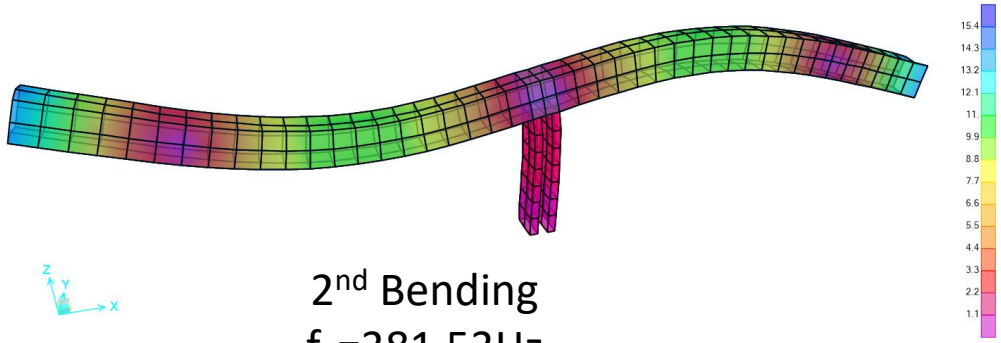
Bending
f_5=86.29Hz



Torsional
f_6=169.61Hz

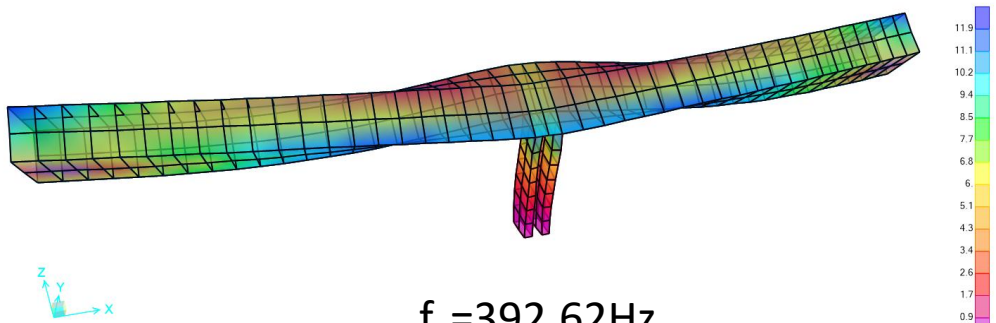


2nd Transverse
f_7=366.26Hz

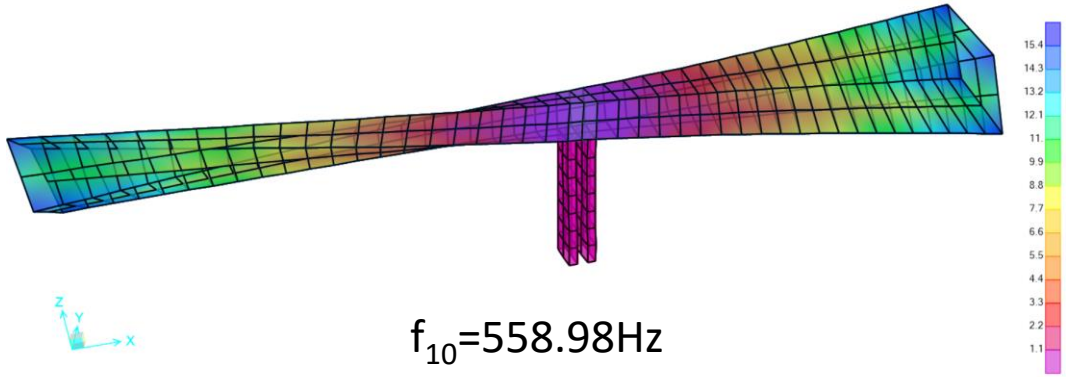


2nd Bending
f_8=381.53Hz

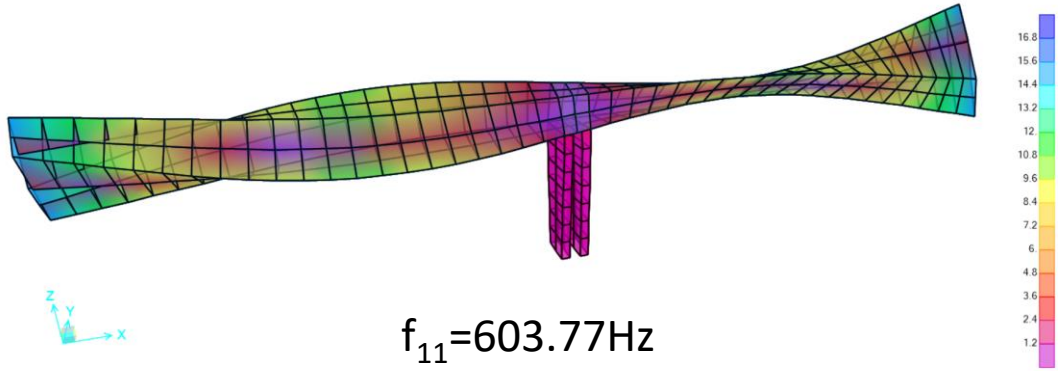
Results of Numerical Model



f_9=392.62Hz



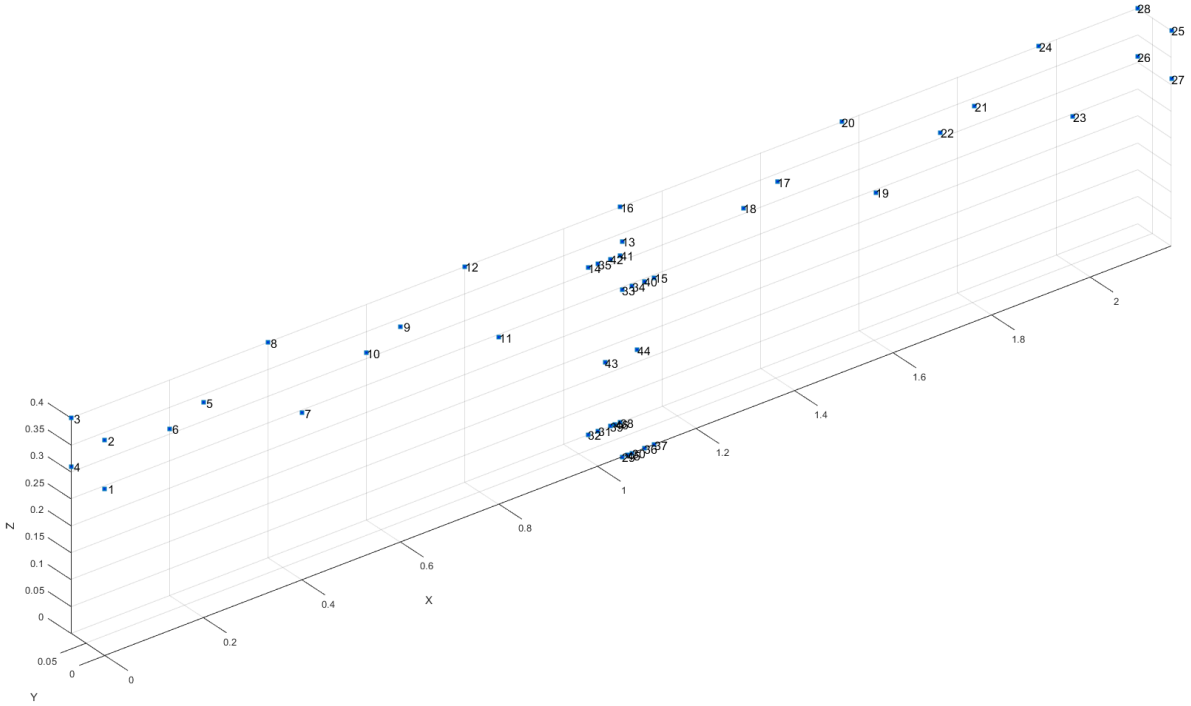
f_{10}=558.98Hz



f_{11}=603.77Hz

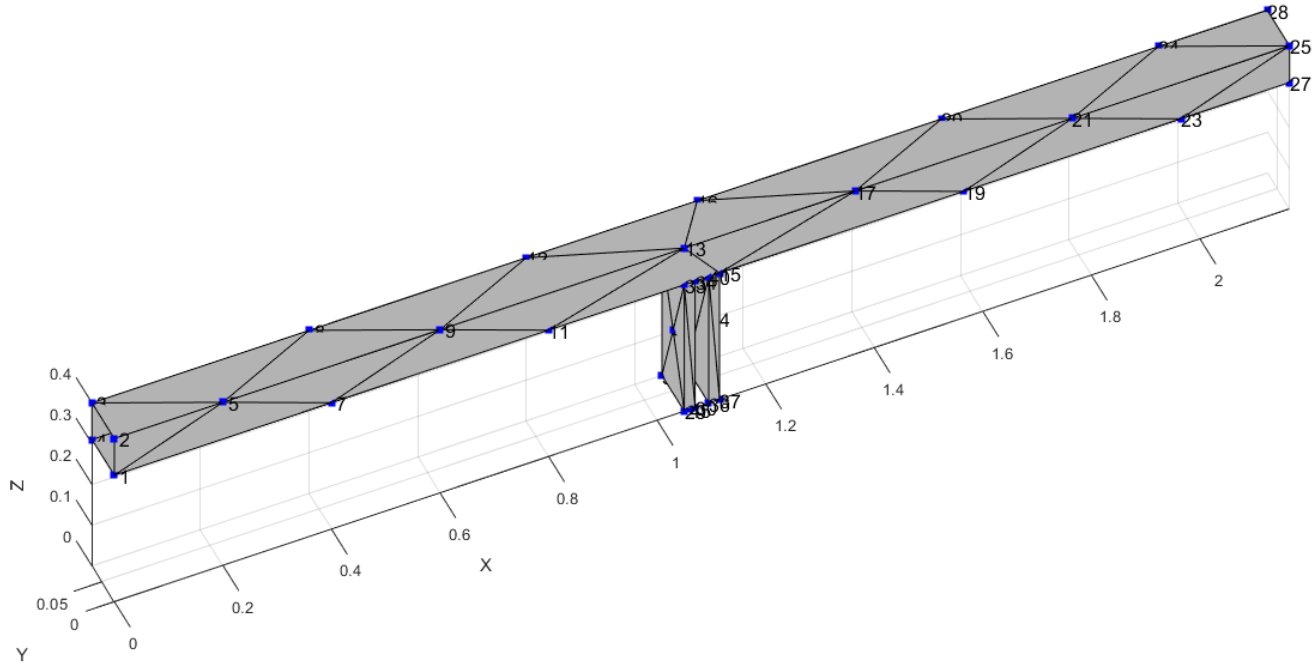
Geometry Definition

- Grid Definition
  - Coordinate Definition in x,y and z plane.
  - Grid of the nodes where measurements were taken was created.
  - The grid will later be used to create surface of the model.



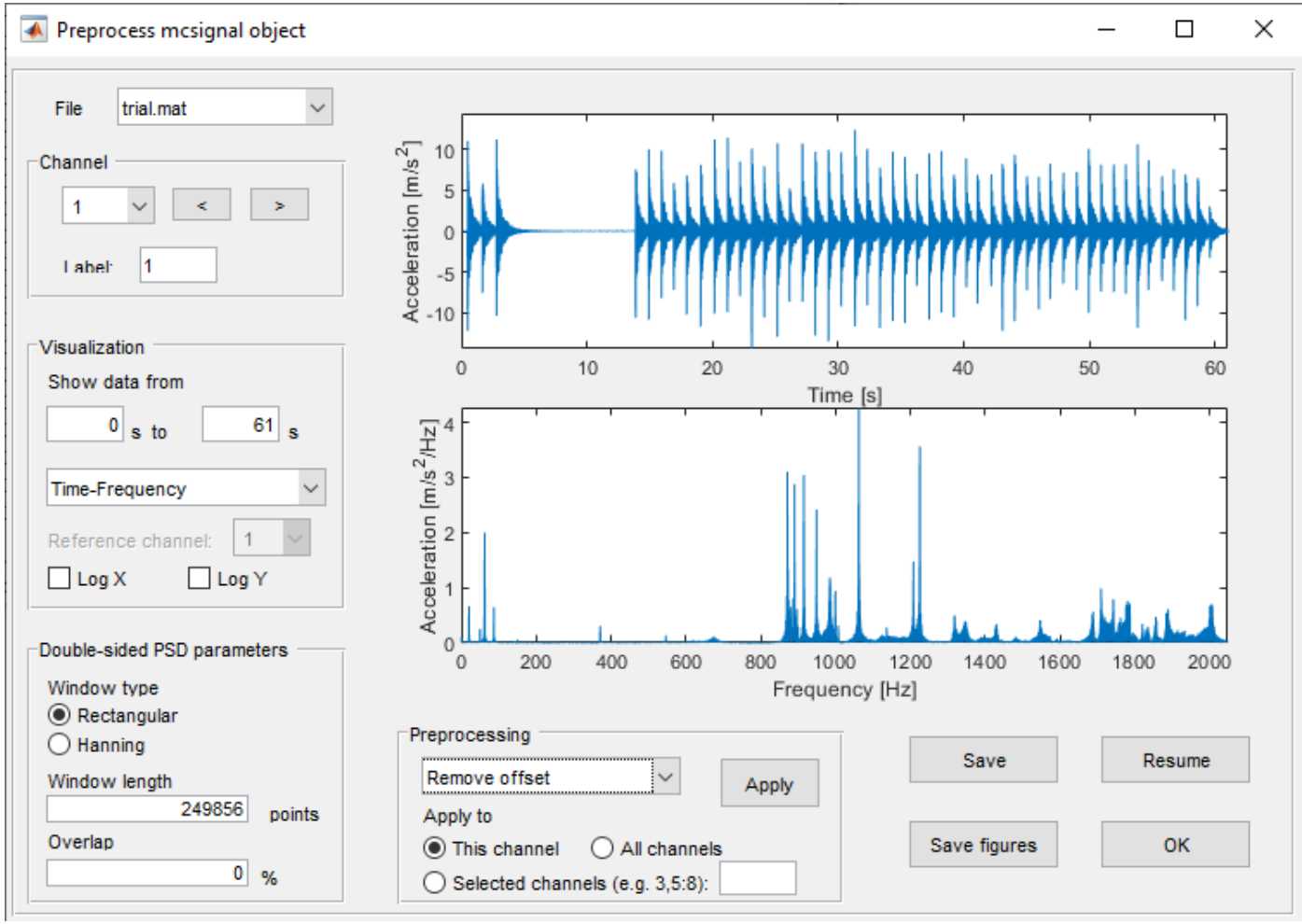
Geometry Definition

- Surface Definition
  - The surface was generated in the form of triangles by joining three points of the grid.
  - The combination of triangles resulted in final surface of the structure.
- Slave Definition
  - Slave nodes are defined for those nodes which are not measured but required for geometry definition.



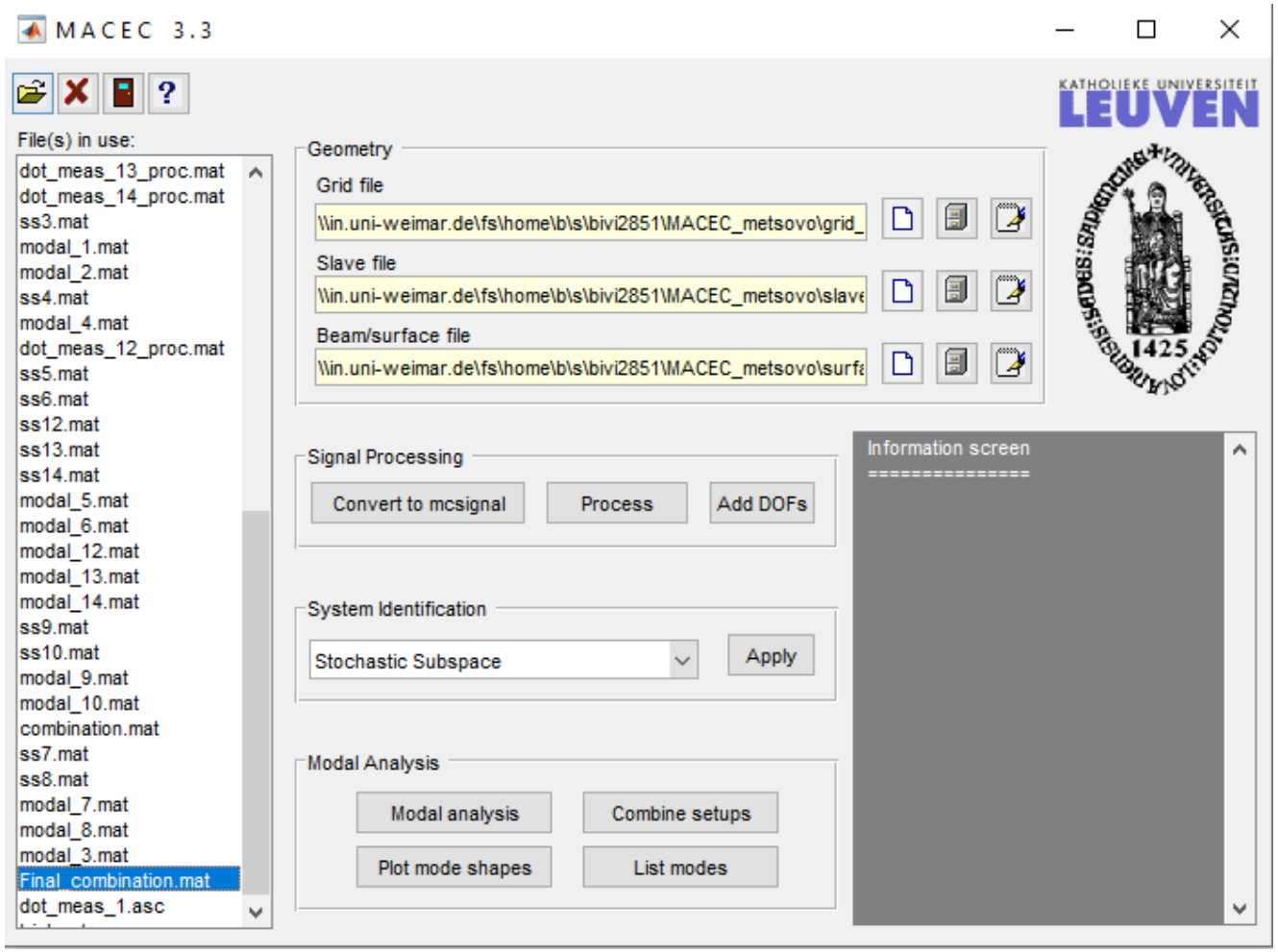
Signal Processing

- Conversion to mcsignal
  - Data in ASCII format obtained from the analyzer is converted to mcsignal format to be used as input for MACEC.
  - Sampling frequency of 4096Hz is used.
- Offset removal
- Delete channel
  - The last channel is the force channel which is removed as we are using operational modal analysis
- Decimate
  - Aliasing would occur after 2048 Hz
  - Decimation is done by a factor of 3, which would result in frequencies upto 682 Hz.



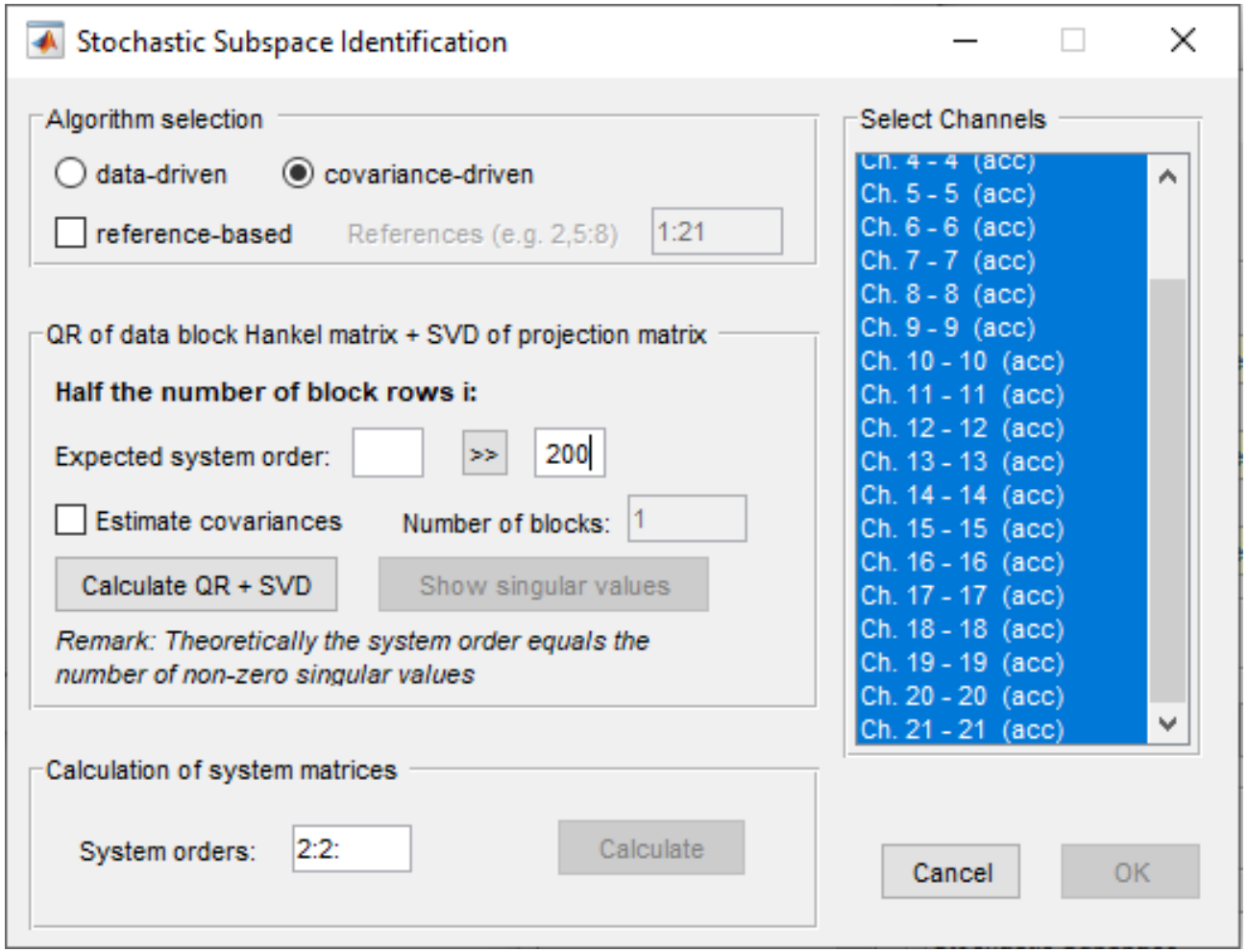
Signal Processing

- Addition of DOFs
  - The Degree of Freedom (DOF) was assigned for each acceleration channel based on the local coordinate of the sensor and global coordinate for the whole structure.



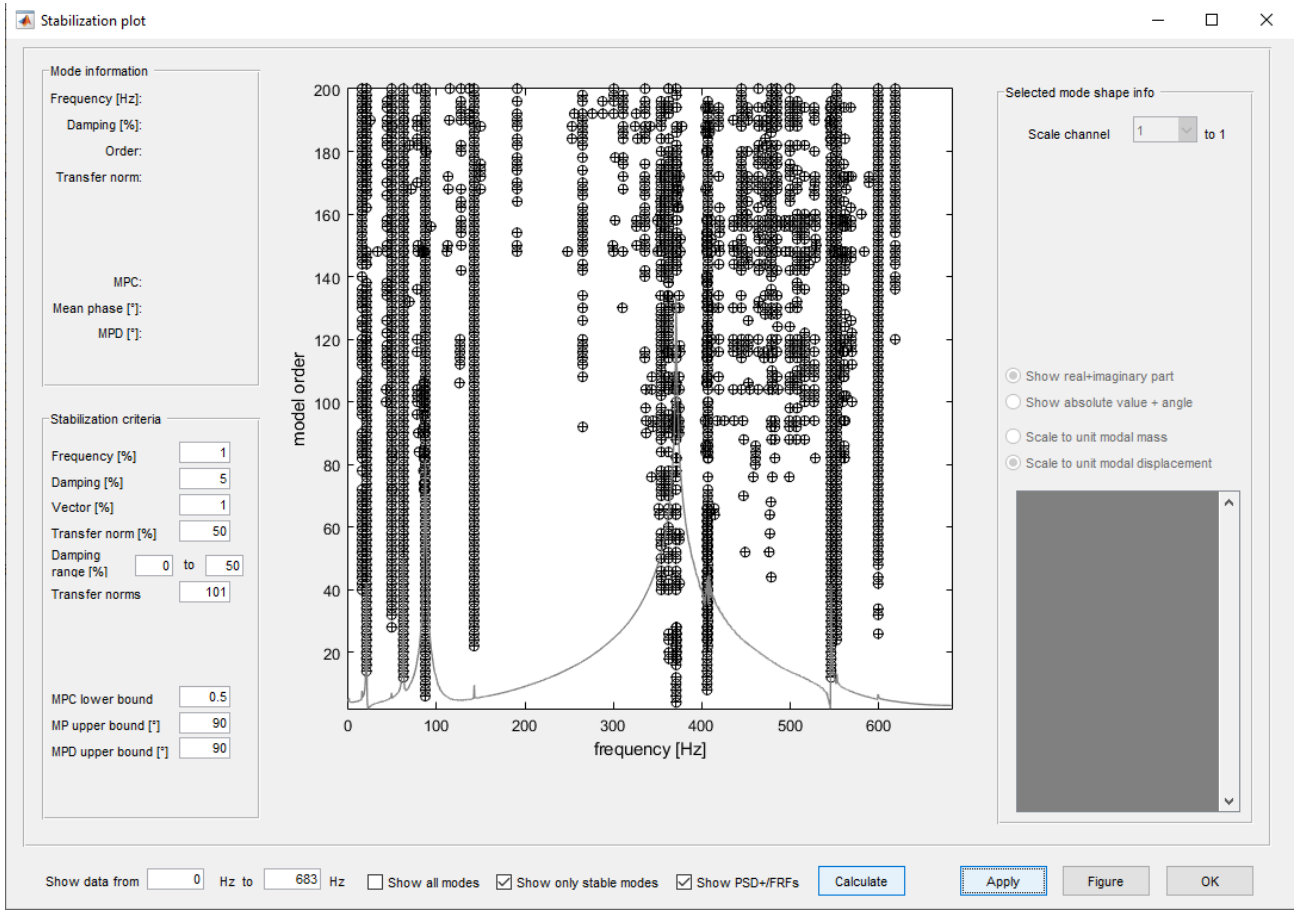
System Identification

- Covariance-driven Stochastic Subspace Identification was used for system Identification.
- Expected system order: 200
- Calculation of Singular Value Decomposition
- Calculation of system matrices: System orders 2:2:200
- Output saved as .mat format.



Modal Analysis

- The file created from system identification is used for modal analysis.
- Stabilization plot is used and visualization of Power-spectral density(PSD) and Frequency Response Function (FRF) is done.
- Frequencies are selected from the stabilization plot having Modal Phase Collinearity (MPC) close to 1 (>0.95).
- A total of 11 modal frequencies upto 600 Hz are selected.
- The process is repeated for each measurement and all the modal analysis are combined to get the combined results for the frequencies, damping and mode shapes.

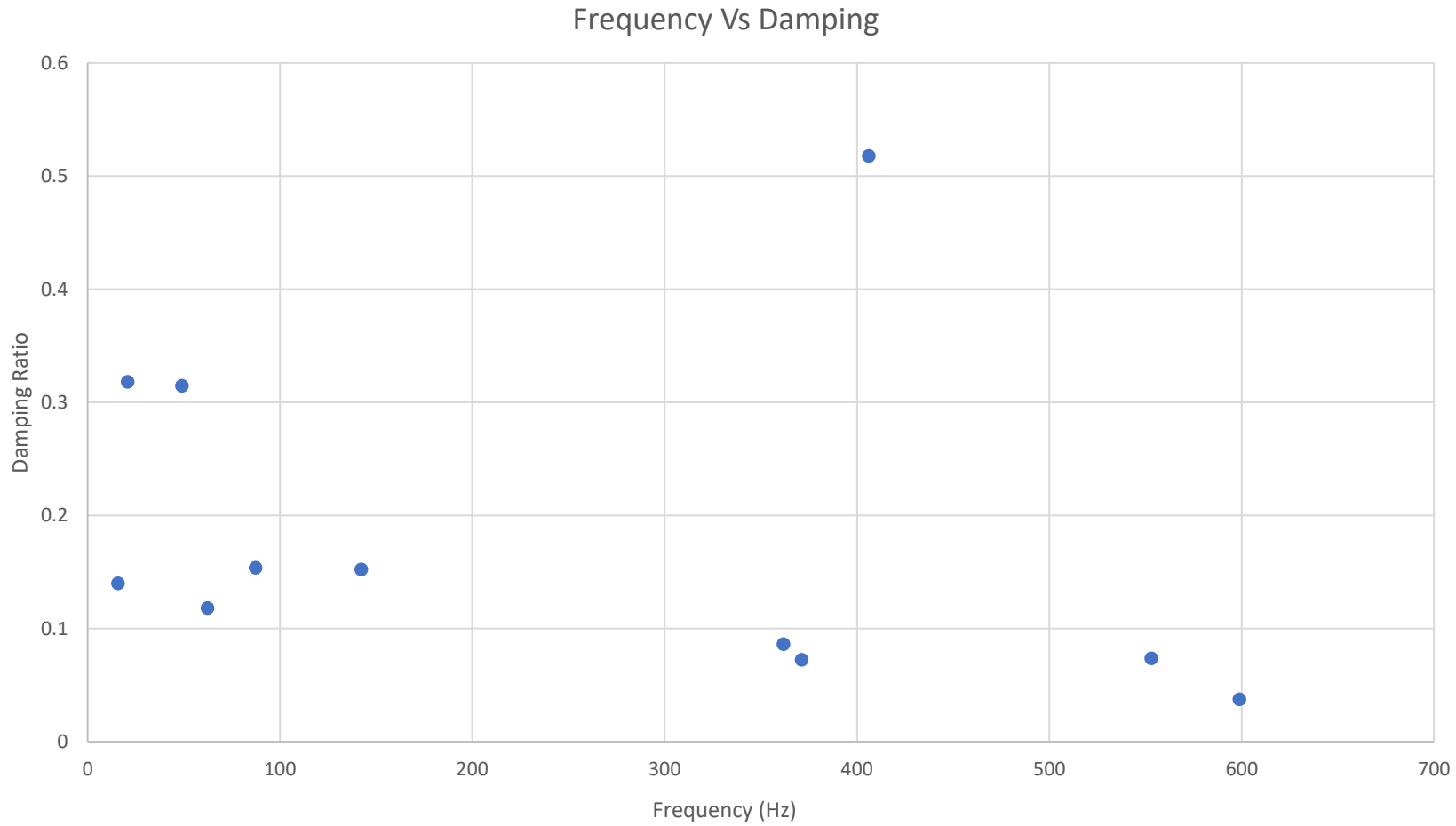


Results

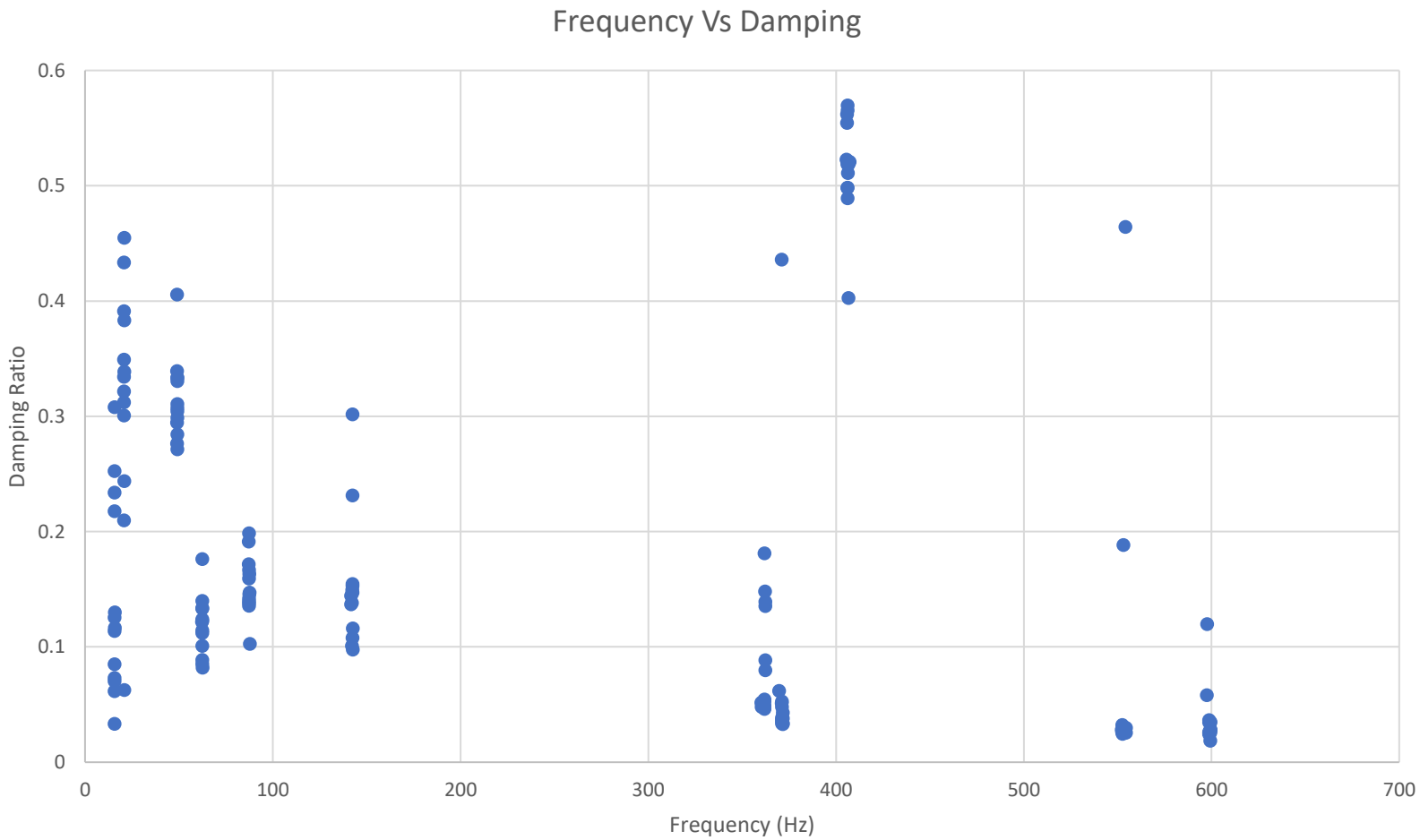
Natural Frequencies and damping ratios (obtained from experimental analysis)

SN	Frequency (Hz)	Damping Ratio (%)
1	15.72	0.140
2	20.80	0.318
3	49.06	0.315
4	62.39	0.118
5	87.34	0.153
6	142.26	0.152
7	361.77	0.086
8	371.17	0.072
9	406.13	0.518
10	552.99	0.074
11	598.82	0.037

Results


Frequency Vs Damping
Damping Ratio
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
Frequency (Hz)

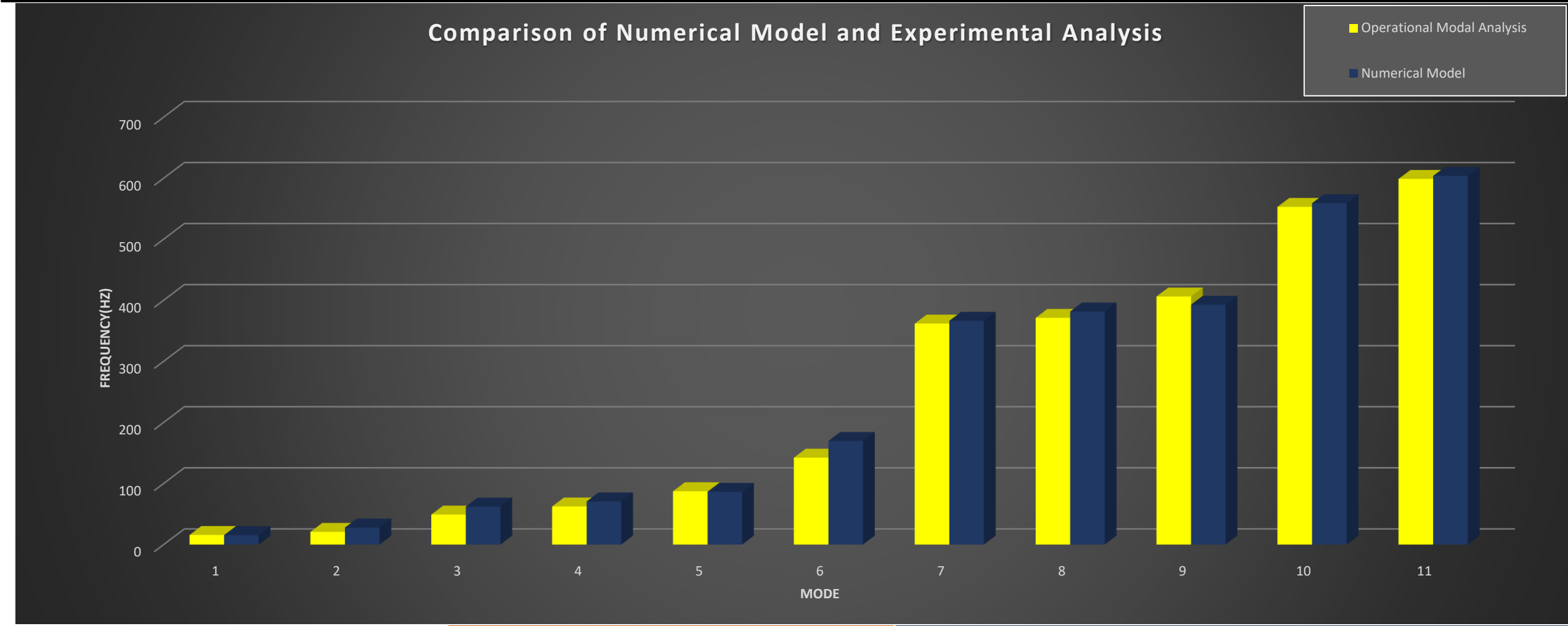
Results


Frequency Vs Damping
Damping Ratio
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
Frequency (Hz)

Comparison of Numerical Model with Experimental Analysis

SN	Frequency from Experimental Analysis (Hz)	Frequency from Numerical Model (Hz)	Change in Frequency (%)
1	15.72	15.37	2.25%
2	20.80	27.83	33.80%
3	49.06	62.11	26.60%
4	62.39	70.611	13.18%
5	87.35	86.29	1.21%
6	142.26	169.61	19.23%
7	361.77	366.26	1.24%
8	371.17	381.53	2.79%
9	406.14	392.62	3.33%
10	552.99	558.98	1.08%
11	598.82	603.77	0.83%

Comparison of Numerical Model with Experimental Analysis



Limitations

- Mode shapes could not be determined from the MACEC software because the sensor configuration used during the experiment was unknown.
- The support condition was supposed to be a fixed support, where the experiment was carried out by bolting the structure to the ground. The fixation may not be completely fixed.

References

- Faraonis, P., Sextos, A., Zabel, V., Wuttke., F. (2014) Dynamic Characteristics of Bridge-Foundation-Soil Systems Based on Laboratory and On-Site Measurements. IBSBI 2014, October 16-18, 2014, Athens, Greece.

Thank you!