Vibration-based monitoring of a five-storey building

Introduction

Complaints regarding excessive vibrations were received by the owners of a business renting office space on the third floor of a five-storey building. The rest of the building houses a number of apartments, with a small gym located on the fourth floor. A vibration assessment was commissioned, and sensitive accelerometers were placed at different locations on the structure to record its response during night-time, when the excitation consists only of ambient loading.

The building in question is constructed from reinforced concrete, and is founded on rock. Concrete with different specifications (M40, M35, and M30) has been used for the columns, lower two floors, and upper three floors, respectively. You have been provided with a simplified, but dynamically compatible 2D FE model of this structure.

The dimensions of the columns and floors are specified in the provided FE code. All structural components are modelled using 2-node Euler Bernoulli beam elements having three degrees of freedom (DOF) at each node: translations in the x and y direction and rotation around the z axis. From the original technical drawings of the building it is not completely clear how the floors are connected to the walls. To account for this uncertainty kinematic constraints have been defined to model flexibility in the floor-to-wall connections. These constraints linearly relate the kinematics of the rotational DOF's of the floor to those of the columns (at their intersection). A kinematic constraint factor of 1 signifies a clamped connection, whereas a factor of ±30 and above can be used to model a hinged connection. It is assumed that the floor-to-wall connections of respectively the bottom 2 and top 3 floors are similar, so that only two kinematic constraint factors are defined for each of these floor groups. Some uncertainty also exists regarding the floor mass, especially since (only) the bottom 2 floors were retrofitted with modern construction materials and floor coverings in 2014. This uncertainty has been modelled by defining additional floor masses per unit length for each of the two floor groups.

Instructions

You are asked to:

- Identify the dynamic properties of the building;
- Update the FE model, where it is assumed, for simplicity, that **only two model parameters require calibration**;
- Advise on a redesign of the measurement set-up, in case of future testing on this or similar buildings;
- Suggest retrofitting options for alleviating the vibrations.

Resources

Each group receives:

1. The initial FE model: *FE_model.py*
2. A file to assist you mapping degrees of freedom to indices: *get_dof.py*

3. A file to assist you in collecting and plotting identified eigenvectors: *get_identified_eigenvectors.py*
4. A number of Python files, as well as a pdf document, to guide you through the model updating: *CEGM2008_Model_Updating_Case_Study.pdf*, *RunOptim.py*, *ObjFun.py*, *FE_fun.py*, *modematching.py*.
5. A data pack containing the measured accelerations and corresponding time axis, and the sensor locations.

Additional resources to use are the lecture materials, including the recorded lectures.

Products

Your results and findings can either be presented in a (concise) report, or in a well-documented Jupyter notebook. For both options, it is important to *ensure that all subcomponents listed under assessment criteria are included in your final deliverable.*

Assessment criteria & feedback

Your work will be assessed with attention to the components defined here below, where a relative weighting has been assigned to each component.

Approach (methodology, creativity):	40%
Results (visualization, interpretation):	40%
Evaluation (critical thinking):	20%

For this case study, these components are subdivided into the following subcomponents for assessment:

Operational modal analysis:
Estimation of the spectral density matrix [2 pts] - (Approach)
Figure showing singular values of spectral density matrix as function of frequency [1 pts] - (Results)
Interpretation of the abovementioned figure [2 pts] - (Evaluate)
Identified modal parameters (eigenfrequencies *as well as* mode shapes) [4 pts] - (Results)
Validation of the set of identified modal parameters [2 pts] - (Results)

Model updating:
Pairing of the identified and calculated modal parameters [3 pts] - (Approach)
Selection of updating parameters [4 pts] - (Results, Evaluate)
Cost function definition and plot [4 pts] - (Approach, Results)
Comparison between dynamic properties of initial and updated model [2 pts] - (Approach, Results)
Analysis of the updating procedure and the quality of the updated model [2 pts] - (Evaluate)

Redesign of the measurement setup and retrofitting
Suggestions for improvements in sensor selections and/or placement [2 pts] - (Approach)
Retrofitting advice for reducing vibrations [2 pts] – (Approach)

Feedback on your progress, results, and the presentation of results will primarily be given during the scheduled workshops. Additional feedback is possible by appointment: e.lourens@tudelft.nl.

Submission

The deadline for the final deliverable is 30 January 2025, at the end of the day. Deliverables can be uploaded to Brightspace. If you choose to submit a Python notebook, it is your responsibility to ensure (and test) that the files you submit will run without errors when downloaded.