Dynamics of Mechanical Systems

Railway arc bridge

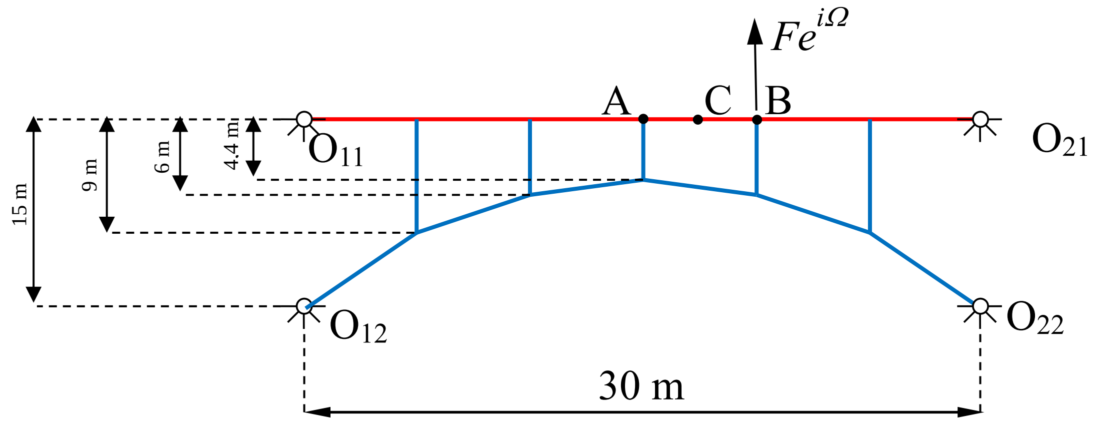
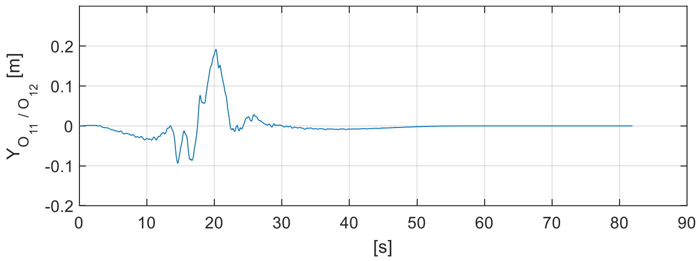
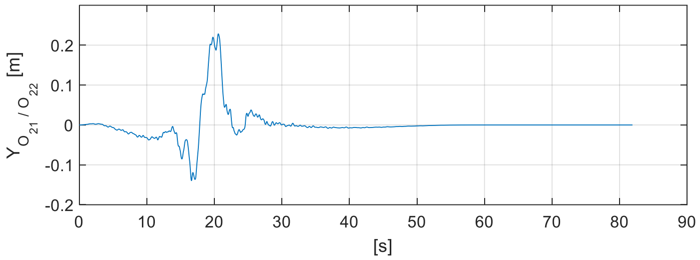


Fig.1

Consider the railway bridge shown in Fig.1. All beams are made of steel (E=2.06e11 N/m^2, ρ=7800 kg/m^3). Beams in blue have IPE300 cross section (A=5.381e-3m^2, I=8.356e-5 m^4) and beams in red have IPE400 cross section (A=8.446e-3 m^2, I=2.313e-4 m^4). Damping is defined according to the "proportional damping" assumption: [C]=α[M]+β[K], with α=0.8 s^{-1} and β=3.0e-5 s.

1. Define a FE model of the structure suitable for analysing its dynamic response in the **0-24 Hz** frequency range (***using a safety coefficient 2***). Plot the undeformed structure.
2. Compute the structure's natural frequencies and modes of vibration. Plot the modal shapes associated to the natural frequencies of the bridge up to **24 Hz**.
3. Compute the natural frequencies of the damped structure up to **24 Hz** and the related non-dimensional damping ratios .
4. Compute the structure frequency response functions between an input force applied at position B in vertical direction and the output **vertical acceleration** evaluated at points A and B. Assume the input force to vary in the 0-24 Hz frequency range and set the frequency resolution to 0.01 Hz. Plot the Bode diagrams (in linear scales).
5. Compute the same FRF as point 4 developing a model in modal coordinates limited to the first three modes. Plot the Bode diagrams superimposed (with two different colours) to those of point 4.
6. For the same input described at point 4, compute the FRF of the bending moment at point C, located on the bridge deck at mid-distance between points A and B.
7. Compute the bridge response due to a seismic motion of the ground, represented as a vertical displacement of points O_{11}/O_{12} (same displacement for these two points) and O_{21}/O_{22} (same displacement for these two points). The time histories of the displacements at these points are shown in the figure below:





The two time histories are provided in file *seismic_displ.txt*, available on WeBeeP. The file has three columns containing respectively: time, vertical displacement of points O_{11}/O_{12}, vertical displacement of points O_{21}/O_{22} displacement respectively. The outputs to be produced are:

6.1) Vertical displacement of point A

6.2) Vertical acceleration of point A

8. Define a change in the structure to reduce **<u>by 30% at least</u>** the maximum amplitude of the FRF of the vertical acceleration of point B for a unit force applied at B (see point 4.) **<u>without increasing the total mass of the system by more than 5%</u>**. The following modifications are not allowed: any change in the length of the span or vertical distance between points A and C; any change of material properties; use of additional constraints. If the section of one or more beam is changed, unified beam sections such as IPE, HPE etc. shall be used.

Have with you at the oral exam **<u>a printed copy</u>** of the following:

1) all plots mentioned above
2) the .inp input file of the system (and of the modified system at point 8, if needed)
3) any .m script used to answer points 3, 5, 6, 7 (8 if needed)