Research Field And Department	Structural mechanics and mechanical waves propagation in metamaterials Department of Continuum Mechanics and Structural Analysis
Supervisor	Francisco Gómez Silva
Title of the Work	Design and numerical analysis of mechanical metamaterials and quasi-zero stiffness structures for elastic wave and vibration isolation

Abstract:
Mechanical metamaterials are artificial structures with tailored geometry that allow unprecedented control of elastic wave propagation. By carefully designing periodic unit cells, it is possible to create frequency band gaps in which mechanical waves cannot propagate, enabling advanced solutions for vibration and noise isolation.
In this project, the student will be introduced to the fundamentals of mechanical metamaterials and to the numerical analysis of periodic structures for elastic wave and vibration isolation. The work will focus on the design and simulation of simple periodic lattices (unit cells) and on the study of their dynamic response. Using numerical tools (e.g., finite element or dispersion analysis software, depending on lab availability), the student will compute dispersion curves and identify band gaps, and will relate them to the geometry and material properties of the unit cell.
In addition, the project may explore quasi-zero stiffness (QZS) configurations, i.e., structures whose effective stiffness is very low around an equilibrium position, making them attractive for low-frequency vibration isolation. The student will analyse how geometric nonlinearity and internal mechanisms can be used to tailor the effective stiffness and dynamic response of these systems.
This project follows one of the research lines of the group "Dynamics and Fracture of Structural Elements", and is suitable for students with an interest in solid mechanics, vibrations and numerical methods. At the end of the six-week period, the student is expected to understand the basic concepts of band-gap formation in mechanical metamaterials, the principle of quasi-zero stiffness for vibration isolation, and to be able to perform and interpret simple numerical studies on these structures.

Main Tasks to Carry Out:

- Conduct a brief literature review on mechanical metamaterials quasi-zero stiffness (QZS) structures for elastic wave and vibration isolation .
- Become familiar with the numerical tools used in the lab (e.g., MATLAB, COMSOL Multiphysics, Abaqus or similar) for modal and/or dispersion analysis of periodic structures.
- Define one or more baseline unit-cell geometries (e.g., lattice with resonators or voids, or mechanisms that can exhibit quasi-zero stiffness behaviour) and their material properties.
- Set up and run numerical simulations to obtain the dynamic response of the unit cell (eigenfrequencies, mode shapes and/or dispersion relations).

- Perform a parametric study on selected geometric or material parameters and analyse their influence on:
    a) the position and width of band-gaps, and
    b) the effective stiffness and vibration isolation performance of QZS-inspired configurations.
- Post-process and interpret the results, relating physical mechanisms to the observed band gap behaviour.
- Prepare a short-written report summarizing the methodology, results and main conclusions of the work.

References/Bibliography if required

- Gómez-Silva, F. (2022). Non-standard continualization of 1D and 2D lattices with next-nearest-neighbour interactions for enhanced modelling of their vibratory behaviour (Doctoral dissertation, University Carlos III of Madrid).
- Gómez-Silva, F., Zaera, R., Ortigosa, R., & Martinez-Frutos, J. (2025). Topology optimization of lattice structures for target band gaps with optimum volume fraction via Bloch-Floquet theory. Computers & Structures, 307, 107601.
- Song, X., Yan, S., Wang, Y., Zhang, H., Xue, J., Liu, T., ... & Li, D. (2025). Genetic algorithm-enabled mechanical metamaterials for vibration isolation with different payloads. Journal of Materiomics, 11(3), 100944.