Doctoral Course
Academic Year 2020-21

PROPAGATION OF MECHANICAL WAVES IN DEFORMABLE SOLIDS

Institutions:	University of Pavia: Department of Civil and Architectural Engineering and Department of Earth and Environmental Sciences; IUSS Pavia: UME School Doctoral Programme
Term:	Winter 2021 (Academic Year 2020-21)
Instructor:	Prof. Carlo G. Lai (E-mail: carlo.lai@unipv.it)
Class duration:	January 11, 2021 – February 26, 2021 (28 hours)
Class schedule*:	Wednesday and Thursday 4–6 PM. Classroom: TBA

SCOPE

The purpose of the course is to impart in-depth theoretical knowledge and innovative methodological approaches to the participants in the study of the phenomena associated with the propagation of mechanical waves in deformable solids for the solution of relevant problems in structural and geotechnical engineering, seismology and applied geophysics. The course is addressed to scholars with different background however sharing a common interest in the subject of propagation of vibratory waves in deformable continua of different nature including soils, rocks and construction materials. It is expected that at the end of the course, the attendees will have mastered the tools of analysis introduced to them so as to be able to independently investigate research topics of interest not covered in class.

COURSE OUTLINE

The course begins with a review of a few mathematical concepts including Fourier and Laplace transforms, Bessel and Hankel functions, spherical harmonics. Then, the two main classes of wave motion represented by hyperbolic and dispersive waves are introduced as they constitute the theoretical framework for the remaining of the course. The next subject to be discussed is wave propagation in elastic waveguides; problems examined include vibrations in strings, longitudinal and flexural waves in beams and in thin plates. A selected number of both free and forced vibration problems will be analysed with reference to infinite and finite 1D and 2D structural members. The second part of the course focuses on problems of wave propagation in unbounded continua and half-spaces. Topics include wave motions with polar and axial symmetry, propagation of waves in non-homogeneous media, surface Love and Rayleigh waves, the solution of the Lamb problem including a discussion of the differences between 2D versus 3D radiation (Huyghens' principle). The dispersive properties of surface waves will be illustrated with examples borrowed from geophysics and seismology in the solution of relevant forward and inverse problems. Next subject to be studied is wave propagation in linear dissipative continua; this includes Boltzmann equations, the elastic-viscoelastic correspondence principle for time-invariant boundary conditions and a discussion on the implications of the principle of physical causality for determining damping in soils (Kramers-Kronig equations). The course ends with an introduction to wave propagation in fully-saturated poroelastic media (Biot's theory) and with the analysis of moving loads applied at the free-surface of an elastic half-space under subcritical and supercritical regimes. This subject is closely related to the study of the vibrational impact induced by fast and super-fast trains.

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*in case classes are regularly held in classroom. If this will not be possible, lectures will be delivered *via* live streaming

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COURSE REQUIREMENTS

Basic knowledge of Calculus and Mechanics of Deformable Body

COURSE NOTES

The course material is posted at the KIRO web site accessible at the link: https://elearning2.unipv.it/ingegneria/

REFERENCES

- Achenbach, J.D. (1984). Wave Propagation in Elastic Solids, North-Holland, 425 pp.
- Graff, K.F. (1991). Wave Motion in Elastic Solids, Dover Publications, 649 pp.
- Kausel, E. (2006). Fundamental Solutions in Elastodynamics, Cambridge Press, 251 pp.
- Aki, K. & Richards P.G. (2002). Quantitative Seismology, University Science, 700 pp.
- Verruijt, A. (2010). An Introduction to Soil Dynamics. Springer, New York, 431 pp.
- Lecture notes, scientific articles will be provided throughout the course

ASSESSMENT

Assignments will be handed over and graded during the course. The final examination will consist of a two hours written test. The final-exam format is closed-book. An equation-sheet will be provided, if needed. Grading: 40% assignments, 60% final exam.

FINAL EXAMINATION

March 5, 2021 from 2:00 PM to 4 PM subject to changes due to contingent situations.

SCHEDULE OF LECTURES

SCHEDULE OF LECTURES	HOURS	# LECTURES
1. Review of Fourier and Laplace transforms. Special functions	6	1–3
2. Classification of wave motion: hyperbolic and dispersive waves	2	4
3. Waves in elastic waveguides: vibrations of strings, beams, plates	6	5–7
4. Wave propagation in unbounded media and half-spaces. Surface waves	6	8–10
5. Wave motion in linear dissipative continua. Physical causality	4	11–12
6. Poroelasticity and Biot theory. Waves in saturated porous materials	2	13
7. Elastic vibrations induced by moving loads: fast and super-fast trains	2	14
TOTAL	**28**	

ASSIGNMENTS

1. Solution of an initial/boundary value problem on free/forced vibrations of waveguides
2. Solution of an initial/boundary value problem on propagation of elastic surface waves
3. Solution of an initial/boundary value problem on wave motion in viscoelastic continua