CE402 STRUCTURAL DYNAMICS

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Status: Elective

Lecturers:	Dr K. Ramachandran (KR) Dr D. Lloyd Smith (DLS)(Room 426)
Structure:	36 lectures, 12 tutorial hours, 12 project hours.
Links:	see below

Introduction

Civil Engineers are now building tall, slender and lighter structures for economical and aesthetic reasons. Sometimes they had to build these structures in areas prone to seismic shocks. Until recently structures, except long span bridges and sky scrapers, had been usually analysed for static loading with some allowance for dynamic effects in the form of a 'dynamic factor'. With the availability of cheap, fast computers it is now easy to perform dynamic analysis and many consulting firms are in fact using computer packages to perform dynamic analysis of structures. It is therefore essential that civil engineers should have a sound understanding of and familiarity with the methods available for the dynamic analysis of structures (buildings, bridges, masts, offshore structures, geotechnical and hydraulic structures).

Aims

The aim of this course is to provide sufficient in-depth understanding of the basic principles in structural dynamics and to give adequate knowledge of dynamic analysis procedures required for the design of structures subjected to dynamic loading.

Links with other course modules

The course requires the application of mathematical techniques taught in the first two years of the course. Students are expected to have some understanding of stiffness and flexibility analysis from the first and second year modules (CE 104, CE 206).

Students are expected to be familiar with the structural dynamics topics taught in the third year Structural Mechanics module (CE 301). Students taking the module CE 413 (Earthquake Engineering) may find this course helpful; however the Earthquake Engineering module is self-contained and does not depend on this module.

SYLLABUS

Single-degree-of-freedom elastic structures (SDOF) *(KR)* (8 Hours)
Revision on damped and undamped free vibrations. Harmonic loads and resonance. Evaluation of damping. Response due to an impulse and the Convolution (Duhamel) Integral. Pulse loads and blast load. Response spectra. Motion of supports and earthquake loading. Earthquake response spectra. Ductility factor method and Equal energy method; Earthquake resistant design.

Numerical methods *(KR)* (7 Hours)
Numerical evaluation of Duhamel integral; Explicit-implicit schemes; Newmark method; Wilson θ method,Nonlinear response; Extension to multi-degree-of-freedom systems; The Finite Element Method in Structural Dynamics.

Multi-degree-of-freedom elastic structures (MDOF) *(KR)* (8 Hours)
Stiffness and flexibility matrices; Free, undamped vibrations; Natural frequencies and natural modes, normalization and orthogonality; Generalised mass, stiffness matrices and force vector. Response by modal superposition method; Use of response spectra for Square root sum square estimates of maximum response; Earthquake resistant design. Vibration analysis by matrix iteration (Stodola method).

Energy methods *(KR)* (6 Hours)
Rayleigh's principle; Approximate analysis of continuous mass system using Rayleigh's technique; Improved Rayleigh's method; Rayleigh's method in discrete coordinates; Rayleigh-Ritz method.

Analysis of distributed parameter systems *(KR)* (5 Hours)
Partial differential equation for straight, non-uniform beam; free undamped vibration, mode shapes and frequencies of uniform beams; Application to simply-supported and cantilever beams; Orthogonality conditions; Modal analysis of forced response.

Random vibrations *(KR)* (4 Hours)
Introduction to random processes. Stochastic response of linear, SDOF systems. Wind loading and gust effects.

Vibration of elastic structures in a fluid stream *(DLS)* (9 Hours)
Film: Wind-induced vibrations; Vortex-induced vibrations: vortex shedding frequency and Strouhal Number; Lift and drag forces on stationary cylinder; Elastically supported cylinder and entrainment or "lock-in" of vibrations; Prediction of amplitude; Methods of alleviating vibrations; Galloping: Glauert-den Hartog stability criterion; Effect of angle of attack; Examples of cables, river piles and bridges; Classical flutter: aerodynamic centre; Aerodynamic coupling of bending and twisting oscillations; Rocard criterion for critical wind speed; Examples of bridges.

Coursework and submission dates (under revision)
Non-linear response of a structure due to a given earthquake (Direct Integration).
In this project, students will first discuss various techniques available for the direct integration of the equation of motion for a given dynamic loading. They will then apply a suitable technique to determine the non-linear response of a given structure subjected to a given loading. *Submission date: Week 10*

Linear dynamic analysis of a multi-storey building (Modal Analysis).
This project will enable students to explore various methods available for calculating and /or estimating the natural frequencies and modes of vibrations of structures.
Submission date: Week 22

Assessment
35% of the allotted mark for this module will be given for the two projects described above and 65% for a 3-hour written examination in April/May. The written examination paper will have seven or eight questions covering the whole syllabus and students have to answer five questions to get full credit.

Recommended reading/textbooks:
Detailed handouts during lectures
CLOUGH, R.W. & PENZIEN, J., Dynamics of Structures, *Second Edition, McGraw Hill*
J.L. Humar. Dynamics of Structures,Second Edition, A.A. Balkema Publishers

Learning Outcomes
At the end of the course students are expected to be able to analyse simple structures subjected to

- earthquake
- blast
- wave and wind loading