Research news and notes

EARTHQUAKE ENGINEERING RESEARCH AT THE UNIVERSITY OF AUCKLAND

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1. Introduction

Earthquake Engineering Research at the University of Auckland Engineering School was initiated by Professor N. A. Mowbray in 1960. Since this date a number of research projects have been completed, the results of which have been published in M.E. or Ph.D theses, or summarised in published papers. Many of the more recent theses are available from the school in report form.

This report gives a brief outline of completed and current research projects, the projects being grouped under headings representing particular fields of interest. More detailed information on any of the projects listed, may be obtained by writing to the associated or supervising members of staff. In addition, the report is supplemented by a brief review of lectures or coursework related to earthquake engineering, which are at present introduced into undergraduate or postgraduate course.

Engineering School staff members currently active in various fields of earthquake engineering research, and their major fields of interest, include:

Prof. N.A. Mowbray	-	Structural Dynamics
Mr P.W. Taylor	-	Soil Dynamics
Dr G.R. Martin	-	Soil Dynamics
Dr B.H. Falconer	-	Structural Design
Dr M.J. O'Sullivan	-	Wave Propagation

2. Dynamic Properties of Soils

A knowledge of the physical properties of soils under earthquake conditions, is an essential feature of many aseismic design problems.

Dynamic triaxial compression test apparatus has been under progressive development at the school since 1961. The first equipment developed was of the strain controlled type, where a sinusoidally varying deformation of controlled amplitude is applied to the soil sample. Such apparatus is suitable for studying deformation and damping characteristics of soils, information which is essential for the purpose of examining the effects of foundation compliance on the dynamic response of structures, and for determining the effects of site characteristics on earthquake ground motions. For the purpose of studying soil strength

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under dynamic loading, stress controlled dynamic triaxial equipment has been recently developed. With this apparatus, a static axial load may be applied to a soil sample, while a sinusoidal cyclic load is superimposed. The following research projects have involved the use of the above equipment:

"Damping in Cohesive Soils" by B.K. Menzies
(M.E. Thesis, 1963 - supervised by P.W. Taylor)

This project describes the initial development of the strain controlled dynamic triaxial equipment, reviews the nature of damping characteristics in soils, and describes a limited number of experimental results on selected cohesive soils. Some of the essential aspects of the work have been published in a paper by Taylor and Menzies (1963).

"Dynamic Properties of Cohesive Soils" by J.M.O. Hughes
(M.E. Thesis, 1965 - supervised by P.W. Taylor)

This investigation extended the scope of Menzies work and describes further experimental work on dynamic deformation and damping characteristics of clays. In addition, a method is described of using measured soil characteristics for assessing the effects of rotational foundation compliance on the dynamic response of structures. Aspects of the research are discussed in a paper by Taylor and Hughes (1965).

"Cyclic Deformation of a Clay" by D.R. Bacchus
(Ph.D. Thesis, 1969 - supervised by P.W. Taylor)

This study describes the development and use of a more refined dynamic strain controlled triaxial cell, designed to study in particular, variations in pore water pressure during cyclic loading of saturated clays. A specific study of a kaolin clay is described, where the effects of consolidation pressure and strain amplitude on deformation characteristics, induced pore water pressures, and deviator and mean effective stresses are examined in detail. Some of the more significant results of the research, are presented in a paper by Taylor and Bacchus (1969).

"Cyclic Deformation and Damping Characteristics of Some Auckland Clays"
(Current M.E. Thesis - graduate research student: R.Smith - supervised by P.W. Taylor)

This thesis is based on an extension of Bacchus's investigation with particular emphasis on studying the nature of the dynamic characteristics of some typical Auckland clays. The use of the commonly used concept of equivalent viscous damping, as a means of approximating the energy loss resulting from the non-linear hysteretic characteristics observed for cyclicly loaded clays, is being critically examined.

"Stress Controlled Dynamic Tests on Soils"
(Current Research Project - P.W. Taylor)

Initial research with the stress controlled dynamic equipment has been aimed at studying the relationship between dynamic strength and test conditions, as defined by combinations of static load, dynamic load and number of load cycles to failure, for a range of cohesive soils. The application of tests results to the design of spread footings has been presented in a paper by Taylor (1967).

3. Foundation Interaction Problems

Foundation interaction affects both the frequency characteristics of structures, and the magnitude of energy dissipated during vibration, and hence should be an important facet of any earthquake response analysis. To date, three masters research projects have been completed in this general area, and a further project initiated.

"Foundation Vibrations" by G.R. Martin
(M.E. Thesis, 1962 - supervised by Professor N.A. Mowbray)

This investigation presents an extensive background to general foundation vibration theory, and reviews the effects of foundation compliance on building response and on earthquake records recorded in basements of buildings. Results of an experimental investigation are also given, where concrete footings were subjected to forced vibration in a rocking mode over a range of frequencies, and the resulting response curves analysed.

"The Dynamic Response of Pile Foundations" by R.J. Granwall
(M.E. Thesis 1966 - supervised by P.W. Taylor)

This investigation was based on a model study of the dynamic response of a "mass-point bearing pile system" passing through a layer of soft clay. A shaking table was used to excite a free standing clay block (bentonite), and observed differences in response of the pile system and the "free field" motion of the clay examined.

"Ground Compliance and Building Design" by D.J. Palmer
(M.E. Thesis, 1967 - supervised by Professor N.A. Mowbray)

A study was made of the effects of both rotational and horizontal ground compliance on the natural periods and modes of vibration of multistoried buildings. Foundations were represented by strip footings on a semi-infinite elastic half space, and buildings assumed to deform elastically in shear only. Significant results from the investigation, have been presented in a paper by Palmer (1969).

"Foundation Interaction Studies"
(Current Ph.D. Thesis - graduate research student: G. Ramsay - supervised by Professor N.A. Mowbray and G.R. Martin)

This study, which was recently initiated, is aimed at examining the effects of foundation compliance during earthquakes, with particular emphasis on examining the nature and magnitude of energy losses resulting from interaction.

4. Effects of Site Characteristics on Earthquake Motion

It has been recognised for many years that site characteristics (depth and nature of soils overlying bedrock) play an important role in determining the frequency characteristics and intensity of earthquake ground motions. Recently, a research project was initiated to develop methods of recording and analysing microtremors, and to assess the usefulness of microtremor characteristics as a basis for "microzoning". One project has been completed in this field and a further study initiated. An examination of earthquake focussing effects is also currently in progress.

"Microtremor Studies" by P.E. Salt
(M.E. Thesis, 1969 - supervised by P.W. Taylor)

This study describes the development of equipment to record microtremors, and the results of some preliminary analyses. The recording system comprised a Wilmore seismometer, a dc amplifier and slow motion tape recorder. Frequency analysis of records made use of an audio-analyser, tape speeds being increased for the purpose of analysis. Use was also made of a computer program to model site characteristics for correlation purposes.

"Microtremor Analysis"
(Current Ph.D. Thesis - graduate research student : I. Parton - supervised by P.W. Taylor)

This investigation is essentially an extension of Salt's preliminary study. The recording and analysing equipment is being modified to improve accuracy. The availability of a PDP12 data-logger in 1970 will permit digital analysis of tape records to supplement audio-analysing techniques. In addition, laboratory equipment to measure the elastic shear modulus of soil samples is being developed.

"Earthquake Focussing"
(Current M.E. Thesis - graduate research student " P. Jackson - supervised by M.J. O'Sullivan)

Problems concerned with selective intensification of earthquake ground motion, produced by focussing of earthquake waves as a result of site inhomogenity and geological stratification are being analysed. The methods developed are being applied to an investigation of the seismic response of the Hutt Valley and the Caracas region.

5. Structural Response Analyses

Dynamic response analyses of idealized elastic or elastoplastic structures are an essential feature of the aseismic design of buildings. With the increasing availability of digital computers, there has been more widespread use of such analyses by design engineers in recent years. With this in view, the following projects aimed at studying the more fundamental aspects of dynamic analyses, have been completed or initiated:

"A Study of the Maximum Transient Response of Simple Fully Yielding Structures" - by G.R. Walker
(Ph.D. Thesis, 1965 - supervised by Professor N.A. Mowbray)

This study involved an analytical investigation of the transient response of fully yielding single-degree-of-freedom elasto-plastic systems subjected to a dynamic exciting force. In particular, attention was focussed on the relationship between the characteristics of the largest pulses of an earthquake and the maximum response of fully yielding structures to the earthquake motion. Significant aspects of the thesis have been presented in a paper by Walker (1965).

"A Study of the Maximum Transient Response of a Two Degree of Freedom Elasto-Plastic System" by D.J. Collecutt
(M.E. Thesis, 1966 - supervised by Professor N.A. Mowbray)

This investigation extended the scope of Walker's study to include an analysis of the maximum transient response of a two-degree-of-freedom elasto-plastic system. Unfortunately, the project was limited by the computer facilities available at the time. However, preliminary results were obtained showing the effects of variation of system parameters.

"Effects of Hysteretic Damping on Response Spectra"
(Current Ph.D. Thesis - graduate research student: R. Mayes, - supervised by Professor N.A. Mowbray)

This project is currently aimed at studying response spectra for single-degree-of-freedom systems, where damping forces respresentative of those encounted in practice are introduced in place of the conventional viscous damping forces. Response spectra are at present being obtained using the N-S component of the 1940 El Centro earthquake.

6. Dynamic Properties of Prestressed Concrete

As prestressed concrete is being increasingly used for multi-storied structures, it is essential to establish the deformation and failure characteristics of structural components manufactured from prestressed concrete, when subjected to cyclic loading. Two Ph.D. projects have been completed to date, where the behavior of prestressed concrete beams in particular have been examined.

"The Damping and Flexural Properties of Prestressed Concrete Members Subjected to Reversed Cyclic Loading" by R.A. Soencer
(Ph.D. Thesis, 1966 - supervised by Professor N.A. Mowbray)

The development of apparatus to subject 6" x 4" x 13' prestressed concrete beams to reversed cyclic loading by means of alternating end moments is described, end rotations and moments being measured by electrical transducers. Preliminary test results are presented and a method of computing the response of an idealized prestressed concrete structure developed using material characteristics based on test results. Aspects of the research have been presented in a paper by Spencer (1969).

"The Fatigue of Prestressed Concrete Beams Under Reversed Cyclic Loading" By M.L. Jacobs
(Ph.D. Thesis, 1968 - supervised by Professor N.A. Mowbray)

This study furthered the work initiated by Spencer In particular the fatigue life and energy absorption characteristics of prestressed concrete beams subjected to cyclic loading at different moment levels was investigated. Failure modes, the influence of shear reinforcement and changes in member properties with number of cycles were also noted.

7. Dynamic Stability of Earth Slopes and Embankments

It is now generally accepted that the effects of earthquakes on slope stability should be assessed in terms of the deformations produced, rather than the computation of a minimum factor of safety based on conventional limiting equilibrium methods of analysis used in conjunction with a pseudostatic seismic coefficient. The development and practical application of such deformation methods is currently under investigation by G.R. Martin and P.W. Taylor. Background to the development of these methods for the case of earthdams, is given in papers by Seed and Martin (1966) and Martin (1967).

8. Lectures or Coursework in Earthquake Engineering

Although in the syllabus for the B.E. degree, there is no subject specifically in the field of earthquake engineering, general aspects or comments on basic seismology, dynamic response analyses for structures, principles of aseismic design, and the behaviour of structural components, concrete and soils under dynamic loads are introduced in the various undergraduate courses. In particular, the Advanced Structures option in the final year considers in some detail dynamic response analyses for multi-degree-of-freedom systems using matrix methods, and coursework in Design during the final year, introduces criteria for earthquake resistant design, in so far as the limited time permits. One design project for 1969 paid special attention to design of reinforced concrete frameworks for moment ductility. In this project, the relevant latest requirements of the Structural Engineers

Association of California (SEAOC) and of the New Zealand Ministry of Works were followed.

Candidates for an M.E. Degree are required to pass examinations in three subjects selected from a prescribed list, and to present a thesis on a research topic, the latter being given equal weight to the examination papers in assessing the overall grade of pass. Postgraduate courses which involve a study of aspects of earthquake engineering include the Structures Seminar, which in 1969 included a study of random vibration theory and structural damping, and the Soil Mechanics Seminar, which in 1969 included work on seismic stability of earth slopes and analysis of earthquake records.

In 1968 a postgraduate course on earthquake engineering of three hours per week, (two lectures and one seminar,) was introduced. The prescription covered the fundamentals of seismology, the damaging effects of earthquake upon land and upon the constructions of man, with study of some relevant historical earthquakes, and extended to review the fundamentals of earthquake resistant design of engineering structures. Four masters degree students took the course in 1968, but none in 1969. Three of the four students were taken on a three day field observation at Inangahua two weeks after the earthquake of May 1968. The course will be continued in 1970.

9. Publications

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