British PhD Theses: 2002

The purpose of these summaries is to bring to the notice of readers topics in geotechnical engineering which are currently or have recently been subjects of research at universities in the United Kingdom.

Details comprising author, thesis title and brief summary (not to exceed 100 words), of doctoral theses published in 2003 should be submitted to The Director (Engineering), The Institution of Civil Engineers, 1 Great George Street, London SW1P 3 AA by 31 January 2004.

The summaries are arranged in alphabetical order, firstly by university and then by surname.

H. Bin-Chen Benson, University of Bristol

Engineering performance of deep excavations in Taipei

Geotechnical performance data have been collected around several excavations in soft clay in Taipei. The movements have been compared with those predicted using empirical methods. Effectiveness of methods to improve safety of excavations and nearby structures has been explored.

Nonlinearity and anisotropy of small strain shear stiffness of soil are important factors for the prediction of ground response around excavations in Taipei. A simple, strain-dependent shear stiffness model, BRISTAIPEI, has been implemented in a finite difference code. This model has been used to simulate standard soil tests and to back analyse the excavation at Taipei National Enterprise Centre (TNEC).

Contact: Mr D. F. T. Nash.

E. Bowman, University of Cambridge

The Ageing and Creep of Dense Granular Materials

'Ageing' in granular materials and 'set up' of displacement piles in sands are investigated by relating macro-behaviour to micro-structural change. Triaxial creep experiments were conducted on a range of pluviated dense granular materials. A stress path was chosen to mimic that felt by an element of soil near to a displacement pile. The change in microstructure during one-dimensional creep was investigated, using resin injection and optical microscopy of sections. An alternative hypothesis for the pile set up and soil ageing was proposed, involving creep at macro- and micro-level.

Sponsored by EPSRC.

Contact: Dr K. Soga.

H. Coumoulos, University of Cambridge

Centrifuge and Numerical Modelling of Dense Non Aqueous Phase Liquid Contaminants Migration

A DNAPL was injected in two-dimensional soil models with an inclined interface in the centrifuge. A unique pattern of pore pressure changes was registered indicating the DNAPL saturation level and the plume velocity. Numerical parametric analyses examined the effects of the sand interface angle, the permeability contrast at the interface and the DNAPL injection type on DNAPL spreading and penetration at the soil layer interface.

It was shown that for a given volume of released DNAPL, slower releases resulted in deeper DNAPL penetration in layered soil systems, whereas for the same injection rate, increased spreading was observed with increasing angles of interface and permeability contrast at the interface.

Sponsored by European Commission, EPSRC.

Contact: Dr K. Soga.

S. K. Haigh, University of Cambridge

Effects of Earthquake-induced Liquefaction on Pile Foundations in Sloping Ground

Centrifuge modelling and numerical studies were carried out on the behaviour of liquefiable slopes and their interaction with pile foundations.

The experiments highlighted the importance of the dilation of liquefied soil in the behaviour of liquefiable slopes. Slope movements were limited by dilation during each cycle of the earthquake preventing significant soil flow velocities from building up and large pressures were applied to piles from the liquefied soil owing to dilation of soil close to the piles.

The data from these experiments was compared with numerical models and showed reasonable agreement both for slope displacements and induced stresses in piles.

Sponsored by EPSRC and Shimizu Corporation, Japan.

Contact: Dr S. P. G. Madabhushi.

S. Jacobsz, University of Cambridge

The effects of tunnelling on piled foundations

The effects of tunnelling on piled foundations were investigated using geotechnical centrifuge modelling. A model tunnel surrounded by dense dry fine sand, capable of inducing plane-strain deformation, was used to impose tunnelling-related ground loss on loaded driven instrumented model piles. Ground loss caused a reduction in pile base load, resulting in the mobilisation of shaft capacity. Once the maximum shaft capacity had been mobilised large pile settlement followed. The behaviour of single piles and pile groups were investigated. A zone of influence was defined around the tunnel in which a potential for large tunnelling-related pile settlement exists.

Sponsored by Cambridge Commonwealth Trust, Nishimatsu Construction.

Contact: Dr J. Standing (Imperial College Science Technology & Medicine).

S. Ratnam, University of Cambridge

Development of a novel self-boring permeability measurement technique

Using a modified Cambridge self-boring pressuremeter, a new insitu permeability measurement technique was developed. The technique attempts to determine both the horizontal and vertical components of permeability. Field tests were conducted at three clay (soft and stiff) and one slurry cut-off wall sites. To interpret the test, new geometry constants (shape factors) were developed using the finite element method (FEM). A general expression for simple infinite boundary conditions was obtained and preliminary work for complex finite boundary conditions conducted.

Sponsored by Malaysian Prime Minister's Fellowship Exchange Programme (Perdana Scholar), Cambridge Insitu.

Contact: Dr K. Soga.

B. Teymur, University of Cambridge

The Significance of Boundary Conditions in Dynamic Centrifuge Modelling

A series of centrifuge tests involving loose, dense, dry and saturated homogeneous horizontal sand layers has been carried out to investigate the effects of the end-walls of the Equivalent Shear Beam model container on soil behaviour. It was observed that when the relative density was around 50%, close to that of the design soil layer, the change in behaviour towards the end-wall was minimal. It was concluded that the boundary of the ESB functions best with dense dry sand models whose response changes little with time.

Sponsored by Istanbul Technical University.

Contact: Dr S. P. G. Madabhushi and Professor R. Mair.

D. White, University of Cambridge

An investigation into the behaviour of pressed-in piles

An investigation into the behaviour of pressed-in piles was conducted, comprising a laboratory study of press-in pile installation using a plane strain calibration chamber, and field tests to examine the behaviour of pressed-in piles at full scale. A deformation measurement system for plane strain modelling was developed, combining Particle Image Velocimetry (PIV) and photogrammetry. This technique was used to measure displacement and strain paths during pile installation. Field tests were conducted to investigate the relief of hard driving using driving shoes, the evolution of plug capacity, and a technique by which high plug capacity can be 'switched on' after installation to create an efficient foundation structure.

Sponsored by Giken Seisakusho Co. Ltd. EPSRC Cambridge Newton Trust.

Contact: Professor M. D. Bolton.

S. Yimisiri, University of Cambridge

Pre-failure deformation characteristics of soils: anisotropy and soil fabric

The pre-failure deformation characteristics of soils were investigated with particular attention to anisotropy and soil fabric. A new model for the interaction between rough-surface particles was developed and micromechanics theory was employed to simulate the stress-strain behaviour of soils at small strains. The microscopic investigation was then extended to the intermediate strain level using the Distinct Element Method. The anisotropy, non-linearity and time effects of London Clay were investigated for a wide range of strain levels by triaxial testing.

Sponsored by Royal Thai Government Scholarship, Cambridge Insitu and EPSRC.

Contact: Dr K. Soga.

J. C. Martin, University of Durham

The Development of a Knowledge-Based System for the Preliminary Investigation of Contaminated Land

A prototype knowledge-based system (ATTIC: Assessment Tool for The Investigation of Contaminated Land) has been developed to assess information collected during the preliminary stage of the investigation of contaminated land (past use, geological maps, hydrological maps etc). It assists with the risk assessment process, with the prediction of potential contaminants, hazards and risk to neighbouring areas. The system was developed using CLIPS software, consisting of four knowledge-bases (source, pathway, target and health and safety) containing 1600 rules. The system was validated against a number of case studies and predicted the likely contaminants with a reasonable match to those observed, even though the input data was limited.

Sponsored by EPSRC studentship.

Contact: Dr D. G. Toll, School of Engineering, University of Durham.

C. L. Ramshaw, University of Durham

Computation of Ground Waves from Pile Driving and their Effects on Structures.

Ground surface vibrations due to impact and vibratory pile driving have been modelled using a finite element program. New multi-stage procedures using finite element/infinite element transient analyses estimated the ground vibrations. Results were validated against UK piling site measurements.

Some common building forms were incorporated into the models. Slender frames can be analysed by imposition of transient ground displacements. However, stiffer structures require full 3D transient analysis with soil-structure interaction. The techniques developed in the project could be extended to piling vibrations on geotechnical structures, and to other sources of excitation such as tunnelling or vibro-compaction.

Sponsored by EPSRC.

Contact: Dr A. Selby.

I. Tsaparas, University of Durham

Field Measurements and Numerical Modelling of Infiltration and Matric Suctions within Slopes

This work presents an analysis of the pore-water pressures (suctions) and seepage conditions within two residual soil slopes in Singapore. The analysis is based on field measurements and on numerical modelling using finite element software capable of modelling transient unsaturated flow. The field measurements consist of rainfall data, runoff data and pore-water pressure changes during infiltration at several depths and locations on the two slopes. The numerical modelling was used to couple all the available field information into one complete model that could describe the seepage conditions during infiltration. It was seen that a slope has a limiting capacity for how much rainfall water can infiltrate the slope surface.

Sponsored by University of Durham.

Contact: Dr D. G. Toll, School of Engineering, University of Durham.

J. E. Colmenares, Imperial College

Suction and volume changes of compacted sand-bentonite mixtures

A laboratory investigation of the volume changes in compacted sand-bentonite mixtures during controlled wetting was undertaken using an oedometer apparatus with radial stress sensors. Detailed studies were made of the influence of hydration time, compaction method, initial density, sand grading and bentonite content on the soil water characteristic

curve. Comparisons were made of suction measurements were made using filter papers and Imperial College Suction Probes. Significant conclusions were drawn about the practicality of controlling suction in granular materials, which contain a small quantity of clay. An extensive study was made of the soil fabric using and environmental scanning electron microscope and a mercury intrusion porosimeter. The results were examined in the context of a void ratio–total stress–suction framework.

Sponsored by EPSRC and Universidad Nacional de Columbia.

Contacts: Dr A. M. Ridley and Prof J. B. Burland Imperial College.

John Douglas, Imperial College

A critical reappraisal of some problems in engineering seismology

Estimation of earthquake ground motion characteristics is important for engineering design purposes. Potential sources of scatter, from each stage of the derivation of relationships to estimate ground motions are highlighted, and many of these are critically examined to assess their importance. This thesis assesses the inherent uncertainty of the input strong-motion data including that arising from accelerogram processing, examines the importance of independent parameters and the effect of uncertainties and errors in these variables and investigates the effect of the data distribution with respect to the independent variables. Also presented are updated relations for horizontal and vertical near-field strong-motion characteristics.

Sponsored by Engineering and Physical Sciences Research Council (EPSRC) and European Commission Sd1 Framework Programme.

Contact: Dr J. Douglas.

Z. Fang, Imperial College

A local degradation approach to the numerical analysis of brittle fracture in heterogeneous rocks

This thesis develops elemental degradation in order to simulate microstructural breakdown in heterogeneous rock. The degradation index parameter is introduced, and is defined as the ratio of degradation occurring at a particular confining stress to that occurring under uniaxial conditions. This is combined with an elasto-plastic constitutive relation to produce the degradation model, which has been implemented using a finite difference scheme.

Among other phenomena, the model reproduces the complete stress-strain curve and corresponding strain energy dissipation, and shows the dependence of the stress-strain curve and fracture patterns on confining pressure. In the analysis of mine pillars, the model produces results that concur with field observations. This suggests that the degradation model is a powerful approach to the study of macroscopic brittle behaviour encountered in rock mechanics and rock engineering.

Sponsored by Imperial College.

Contact: Dr J. P. Harrison, Imperial College.

S. D. Lee, Imperial College

A study of the influence of surface and void geometry on the hydro-mechanical behaviour of rock fractures

A coupled hydro-mechanical program is used to study the influence of surface geometry on fluid flow through rough rock fractures. The program uses statistical fracture models, separate conceptual models for normal and shear behaviour, and a finite difference solution to the local cubic law for flow.

The significance of both spatial variation and anisotropy ratio of the void geometry are shown. For fractures subjected to normal stress, the void geometry is shown to be the principal factor controlling fracture closure and hydraulic behaviour. Preferential flow paths develop as void spatial correlation increases, and these persist under high normal stress. Under shear, as surface spatial correlation parallel to the shearing direction increases, shear stress behaviour becomes less brittle, and the dilation gradient reduces. It is also shown that as surface roughness increases, preferential flow paths disappear more rapidly.

Sponsored by the Government of Korea.

Contact: Dr J. P. Harrison, Imperial College.

A. L. Pellew, Imperial College

Field investigations into pile behaviour in clay

Two aspects of pile behaviour in London clay were investigated, the first being the effective stress regime developed around bored piles. A procedure was devised in which a highly instrumented core was placed in grout within a 120 mm diameter, 6 m deep, augered pile shaft. Special attention was given to the grout design and to minimising measurement errors regarding pore water pressures, shear stress transfer and radial stresses made during installation, equalisation and load testing. Deep block samples were also taken for fabric and mechanical properties studies. New insights were obtained into the radial effective stress regime and failure criteria that control shaft capacity. The effects of long term ageing were also addressed. Pile re-tests to failure, and block sample studies, were performed at Canons Park on a suite of driven, jacked and bored piles that were installed 18 years earlier, with the steel displacement piles showing marked capacity gains which were found to be related to corrosion processes involving sulphate reducing bacteria.

Sponsored by EPSRC Stent Foundations and BRE.

Contact Professor R. J. Jardine.

V. Rasouli, Imperial College

Application of Riemannian multivariate statistics to the analysis of rock fracture surface roughness

The development of roughness determination based on the distribution of unit normal vectors to a rock surface is presented, with Riemannian geometry and Mahalanobis distances being used to develop a multivariate technique.

For linear profiles, the 1D Riemannian dispersion parameter is proposed for roughness determination. For surfaces, the 2D Riemannian dispersion and isotropy parameters are proposed for roughness and anisotropy, respectively.

These parameters are used to analyse various synthetic profiles, the exemplar JRC profiles, and several linear rock profiles and rock surfaces. The analyses show, among other things, how the principal geometry of a surface (i.e. roughness, periodicity and aspect ratio) can be recovered. The results demonstrate the advantages of the proposed method over customary methods of surface characterisation.

Sponsored by the Government of Iran.

Contact: Dr J. P. Harrison, Imperial College.

E. E. Saldivar Moguel, Imperial College
Investigation into the behaviour of displacement piles under cyclic and seismic loads

The Thesis concerns the seismic capacity of friction piles, focusing on the Mexico City soft clays. A first key step was to validate the local application of the Jardine and Chow (1996) effective stress static capacity methodology, which was proven to match a data base of 26 field tests very well; the exercise included new interface shear tests and other supporting laboratory experiments. A series of full scale instrumented building case histories was then analysed, with a non-linear dynamic structural programme being used to deduce the loads imposed on the buildings' piles from tri-dimensional accelerometer records made at several levels during earthquakes. The deduced loads could then be compared with the capacities is often assumed to apply to seismic pile capacity is smaller than had been thought. Interaction Diagrams were developed to provide a rational effective stress based tool for seismic and cyclic design.

Sponsored by the Government of Mexico and UK Health and Safety Executive.

Contact: Professor R. J. Jardine.

L. Margetts, University of Manchester
Parallel Finite Element Analysis

In this thesis it is shown how to parallelise well-written Fortran 90/95 code. The parallel programs, using MPI, are only slightly longer than their serial equivalents. Coupled problems involving several million "degrees of freedom" have been solved on various parallel computers with up to 512 processors. Excellent scaling means that computing speeds 512 times faster than serial have been achieved. Computer hardware issues of cache re-use have been addressed and algorithmic problems of iterative solvers in a parallel environment exposed.

Sponsored by EPSRC, Manchester Computing.

Contact Professor I. M. Smith, Centre for Civil and Construction Engineering, Manchester.

T. Y. Yap, University of Manchester
A study of strain localization in geomaterials using standard and non-standard continuum models

The thesis compares standard and non-standard (Cosserat) continua in finite element computations of progressive failure. For a standard continuum, there is no convergence of the shearband thickness with decreasing element size, although convergence of the peak and residual loads may be possible, especially for larger problems in which the failure mechanism develops more gradually. For the Cosserat continuum, the shearband thickness and load-displacement response both converge. However, very small elements are needed to trigger the Cosserat effect, and this, along with the extra rotational degrees of freedom, leads to significant increases in computer requirements. Moreover, although relatively simple to implement, Cosserat theory can only be used with circular yield and failure surfaces.

Sponsored by CVCP (ORS), University of Manchester, and Manchester School of Engineering.

Contact: Dr. M. A. Hicks, Manchester School of Engineering, University of Manchester.

H. Miller, Nottingham Trent University
Modelling the Collapse of Metastable Loess Soils

An artificial collapsible loess soils was developed enabling effects of the constituents on the behaviour to be determined. The artificial material was tested in the oedometer and triaxial equipment and behaviour compared well with natural loess soil. The artificial material was used in a small-scale test of a strip footing. Rising ground water was simulated in the test and the settlement of the footing was monitored. The strip footing test was further modelled using finite element techniques and compared with the laboratory results. A simple but effective method of estimating collapse below a strip footing on a collapsible loess soil was determined.

Sponsored by Nottingham Trent University.

Contact: Dr Ian Jefferson, School of Property and Construction, Nottingham Trent University.

W. Huang, University of Sheffield
The role of transverse mixing of electron acceptors and carbon substrates in natural attenuation

The supply of electron acceptor by transverse dispersion can be a controlling factor of biodegradation. The vertical dispersivity of the Four Ashes field is 0·4–1·2 mm and this small dispersivity implied that molecular diffusion might be a main factor accounting for vertical dispersion. Non-reactive transport experiments in the laboratory confirmed that transverse dispersivity is dependent on grain size and molecular diffusion. Reactive transport experiments showed that at the core of the plume oxygen was rapidly exhausted and main biodegradation occurred at the fringe of the plume where carbon substrate and electron acceptors mixed together. Different reactive models were also compared.

Sponsored by Environment Agency/ORS.

Contact: Dr J. A. Chambers.

A. Oram, University of Sheffield
Physical Modelling of Solute Transport in Fractured Porous Media

Investigating flow and transport phenomenon of soluble contaminants in fractured porous media (FPM) is troublesome. The development of a novel physical modelling method employing sintered glass beads as an analogue of fractured sandstone is described. Together with digital imaging techniques two-dimensional solute concentration data can be extracted from any co-ordinate within a model. The method has been used to compare solute transport in non-fractured and discretely-fractured porous media models with simulations produced by the FRACTRAN code and the correspondence between these suggests that physical model fidelity is good. Further experiments indicate a divergence of physical phenomena from theoretical transport modes.

Sponsored by University of Sheffield.

Contact Dr C. C. Smith.

S. Trowsdale, University of Sheffield
The depth of penetration of contamination in urban groundwater

Recent studies have shown that groundwater quality at depth in many urban aquifers is better than expected with water quality close to the surface being poor. The objectives were to establish the depth and extent to which the aquifer beneath the conurbation of Nottingham is contaminated, and

to establish the potential for shallow industrial abstractions to scavenge poorer quality waters, protecting the deeper aquifer. Depth specific groundwater field measurements were input into a transient 3-dimensional computer model.

Sponsored by NERC.

Contact: Dr J. A. Chambers.

F. Wakida, University of Sheffield

Potential nitrate leaching from house building to groundwater

Nitrate pollution has been identified as a major water quality issue in the UK. Agricultural practices have been researched to understand the quantity and behaviour of nitrate inputs to groundwater. However, there are other potential non-agricultural sources that can increase nitrate concentration in groundwater, such as leaching from construction works. The rate of nitrate leaching to groundwater is measured by analysis of soil water from cores taken from residential sites with different ages of construction and geologies in the urban area of Nottingham.

Sponsored by National Council of Technology and Science, Mexico.

Contact: Dr J. A. Chambers.

G. Wealthall, University of Sheffield

Predicting DNAPL source zones in fractured rock

Dense non-aqueous phase liquids (particularly chlorinated solvents) have been identified as one of the most common organic pollutants of groundwater in aquifers beneath major industrial areas of the UK. Their mobility in the subsurface is controlled mainly by a combination of physio-chemical properties and geological structure – where fractures are present they will provide pathways for migration. This research focuses on the delineation of potential DNAPL migration pathways through an extensive review of existing data on fracture distributions, site-specific fracture mapping, novel field experimental techniques and includes development of a validated fracture network model.

Sponsored by EPSRC Waste and Pollution Programme.

Contact: Dr J. A. Chambers.