British PhD Theses: 2004

The purpose of these summaries is to bring to the notice of readers topics in geotechnical engineering that 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 2005 should be submitted to The Director (Engineering), The Institution of Civil Engineers, 1 Great George Street, London SW1P 3AA by 31 January 2006.

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

M. H. A. Mohamed, University of Bradford
Migration of light non-aqueous phase liquids in an unsaturated and saturated sand

Groundwater aquifers are a resource of immense importance, and their quality is vital for worldwide pollution-free water supply. Accidental spills and leakage from underground storage tanks of light non-aqueous phase liquids have been identified as common causes of LNAPL contamination of subsurface environment. A detailed experimental programme was undertaken using fully instrumented two- and three-dimensional tanks to investigate the influence of various spill conditions, such as spill volume, spill area and spill rate, and fluctuations of water table, on the likely migration pattern of LNAPLs in the geoenvironment as well as the hydraulic relations of different phases.

Sponsored by University of Bradford.

Contact: Dr R. S. Sharma.

A. Gajo, University of Bristol
Instability phenomena in sand samples

A new constitutive model describes the behaviour of granular materials including evolving elastic anisotropy, drained collapse, strain localisation and post-localisation phenomena. Drained collapse in loose sand samples is considered in relation to the existence of energetically possible paths for the whole mechanical system, involving homogeneous sample deformations. Localisation is sensitive to features of mechanical behaviour and testing conditions. Post-localisation analysis shows a new saturation mechanism where shear bands unload, encouraging new bands to appear. Saturation is persistent in loose sand but not in dense sand, where it precedes the formation of a new band within the material transformed by previous localisation.

Sponsored by University of Bristol, University of Trento.

Contact: Professor D. M. Wood.

T. Kalasin, University of Bristol
Dynamic macroelement model for gravity retaining walls

A wall–foundation–backfill macroelement model is developed to provide a numerically efficient means of parametric study of interaction of geotechnical and seismic non-linearities. The foundation of the wall is modelled by a kinematic hardening model incorporating interaction of vertical load, horizontal load and moment. The backfill model introduces an elastic–plastic interaction at each level of the wall, so that there are nine regimes of wall–backfill response. The backfill macroelement also incorporates some modest kinematic hardening. Numerical time integration is used to study the response of the macroelement models to harmonic horizontal base motion and to recorded histories of earthquake motion.

Sponsored by Government of Thailand.

Contact: Professor D. M. Wood.

A. J. Brennan, University of Cambridge
Vertical drains as a countermeasure to earthquake-induced soil liquefaction

An option for protecting against earthquake-induced soil liquefaction is the installation of gravel drains to relieve generated excess pore pressures. A series of centrifuge tests were carried out on level sand beds to investigate the effect of changing drain parameters and the geometry of drain groups. It was seen that fluid draining from depth caused a delay in the time for near-surface soil to begin draining. Limiting the influx of fluid from regions that are not to be protected was seen to be crucial to the success of small groups of drains.

Sponsored by EPSRC.

Contact: Dr S. P. G. Madabhushi, Department of Engineering.

Yi Pik Helen Cheng, University of Cambridge
Micromechanical investigation of soil plasticity

This research investigates the plasticity of crushable soil using the discrete element method (DEM), with the computer code PFC^{3D}. The DEM enables plastic soils to be modelled not as a continuum but as an aggregate of discrete grains. This study differs, however, from conventional DEM studies by including grain crushing as a crucial granular characteristic of soils. This is based on evidence from a literature study concerning soil crushing and an experimental study using a mini-oedometer installed with a digital camera. The experiments recorded real-time images of sands when compressed one-dimensionally. A relationship between grain crushing and macroscopic soil deformation was found.

Supported by Croucher Foundation, Hong Kong.

Contact: Professor M. Bolton.

B. Chitambira, University of Cambridge
Accelerated ageing of cement stabilised/solidified contaminated soils with elevated temperatures

Lack of adequate long-term data contributes to poor acceptance of stabilisation/solidification techniques in the UK. Laboratory samples were subjected to accelerated ageing using elevated temperatures to attempt to model the long-term behaviour of cement stabilised/solidified treated contaminated soils using the Arrhenius relationship. The

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cement-based binders also contained pulverised fuel ash, alone or with lime, and bentonite. The results were correlated with site-treated samples from the West Drayton site, Middlesex, UK. The results showed a possibility for modelling long-term behaviour of cement stabilised/solidified treated soils using elevated temperatures in terms of unconfined compressive strength, permeability, durability, leachability and microstructure.

Sponsored by Cambridge Commonwealth Trust, EPSRC.

Contact: Dr A. Al-Tabbaa.

C. K. Choy, University of Cambridge

Installation effects of diaphragm walls on adjacent piled foundations

A series of small-scale model tests in the geotechnical centrifuge was carried out to investigate the installation effects of diaphragm walls on an adjacent loaded pile in dry dense fine sand. The study focused mainly on the effects of pile–wall distance, wall length, and construction sequence of multiple walls. This required the development of two technologies – an in-flight 'concreting' technique and instrumented model piles to measure axial load, bending moment and normal stress distributions. Distinct soil failure zones were identified, and a progressive failure mechanism for this complex soil–structure interaction problem has been proposed.

Sponsored by Nishimatsu Construction Ltd.

Contacts: Dr J. R. Standing, Professor R. J. Mair.

B. Ghosh, University of Cambridge

Behaviour of rigid foundation in layered soil during seismic liquefaction

The seismic soil–structure interaction of a rigid foundation embedded in non-homogeneous, layered and liquefiable soil was analysed in this thesis. This boundary value problem was investigated using dynamic centrifuge modelling and numerical modelling based on finite elements. In this thesis, it was shown that these methods can complement each other in providing an insight into the SSI interaction during earthquake shaking. The model test data obtained from the present centrifuge tests can be used to improve the design of the foundation of a high-risk structure such as a nuclear containment in an earthquake zone founded in inhomogeneous soil. These results are equally relevant for other heavy foundation structures such as power plants, industrial structures and buildings resting on raft foundations.

Sponsored by: Cambridge Commonwealth Trust.

Contact: Dr S. P. G. Madabhushi.

A. S. Merritt, University of Cambridge

Conditioning of clay soils for tunnelling machine screw conveyors

Earth pressure balance tunnelling machines are commonly used for the construction of tunnels in soft soils ranging from coarse sands and gravels to stiff clays. A screw conveyor is used to discharge controlled volumes of soil from the machine, and to dissipate the pressure in the head chamber. Index tests were performed to investigate the effects of foam and polymer conditioning treatments on clay samples. Soil flow rates, pressure gradients and casing shear stresses were measured along an instrumented 1/10 scale model screw conveyor, and the screw torque was measured, during tests with varying soil properties and conveyor operating conditions. A theoretical model describing the screw conveyor operation is proposed.

Sponsored by EPSRC, Pipe Jacking Association.

Contact: Professor R. J. Mair.

A. Waduge, University of Cambridge

Source zone remediation by air sparging and soil vapour extraction

Physical and numerical modelling of contaminant source zone remediation by air sparging was conducted to investigate the interaction between air sparging and light non-aqueous phase liquid contaminants entrapped in the subsurface. Column experiments were performed to investigate the effects of flow interruption, flow rate and different entrapments on source zone mass removal. Two-dimensional tank experiments and numerical analysis were conducted to examine the effect of different entrapments, fluctuation of water table and subsurface heterogeneity on mass removal efficiency, and to develop an upscaling method that models the mass transfer processes observed at different scales.

Sponsored by Kajima Technical Research Institute, Cambridge Commonwealth Trust, Overseas Research Scholarship.

Contact: Dr K. Soga.

O. Hamza, University of Dundee

The effect of climate change on rock slope stability in permafrost regions

The stability of rock slopes in high mountain regions is vulnerable to climate change because of the ice in the rock joints. The mechanism by which temperature rise influences the factor of safety of these frozen slopes is not fully understood. The investigation centred on the thermo-mechanical process of 'ice-strengthened' rock slope (susceptible to warming) using the geotechnical centrifuge technique and numerical modelling of heat transfer. Experimental characterisation of the shear strength behaviour of ice-filled rock joints was also conducted using direct-shear box tests. The results will help to identify mechanisms triggering failure of rock slopes in permafrost, and have been used to validate analytical techniques to assess the stability of these slopes.

Sponsored by The University of Aleppo.

Contact: Professor M. C. R. Davies.

B. Palananthakumar, Heriot-Watt University

A finite element analysis of the migration and generation of landfill gas through unsaturated soil

This research has developed a two-dimensional, two-phase flow numerical model to simulate the migration of landfill gas through partially saturated soil. The model treats liquid, heat, air, methane and carbon dioxide transfer in parallel with five independent system variables of pore water pressure, temperature, pore air pressure and the concentrations of methane and carbon dioxide. The governing system of fully coupled non-linear partial differential equations was solved spatially by the finite element method and temporally by the finite difference method. The proposed model also includes exponential landfill gas generation and microbial methane oxidation functions. The model applications show robust capability and trustworthiness in the prediction of

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landfill gas concentrations when compared with experimental data.

Sponsored by Millennium Scholarship, Department of Civil and Offshore Engineering.

Contact: Dr W. J. Ferguson.

J. Bird, Imperial College, London

Earthquake loss estimations: modelling losses due to ground failures

Current practice for incorporating liquefaction into earthquake loss estimations is shown, through case studies, to be problematic in its application. How liquefaction impacts on the built environment in a regional context is not well covered by our present modelling capabilities: hence an improved framework is proposed. This deals with issues of spatial uncertainty and variability in ground conditions and exposed building stock. Building damage scales that incorporate modes of liquefaction-related damage are presented. Building vulnerability to liquefaction-induced ground deformations is analytically and empirically defined, considering the relative uncertainties associated with each level of input data and each stage of the analysis.

Sponsored by EPSRC, Arup Geotechnics, Marie Curie Fellowship from the ROSE School, Italy.

Contact: Dr J. J. Bommer.

P. Bourne Webb, Imperial College, London

Ultimate limit state analysis for embedded retaining walls

The thesis presents the results of a study using the finite element method to examine the potential use of structural plasticity in the analysis and design of embedded retaining walls. The work was undertaken within a larger, pan-European project that looked at the introduction of plasticity into the design of steel sheet pile embedded walls and involved both centrifuge testing and numerical simulation. Calculations covering a range of ground conditions and structural forms were undertaken to test how the response of the wall system might be modified by the occurrence of wall plasticity, oblique bending and the influence of flexural stiffness. It was concluded that allowing for plastic hinges and accounting for the effect of wall flexibility leads to more economic wall design. Design charts that fully comply with both the structural and geotechnical Eurocodes were established.

Sponsored by CORUS.

Contact: Professor D. M. Potts.

J. N. Franzius, Imperial College, London

Behaviour of buildings due to tunnel induced subsidence

Recent tunnelling research at Imperial College has developed a new design approach, based on the relative stiffness of a building and the underlying soil, to account for the effect of building stiffness when predicting its deformation and potential damage due to tunnel construction. This thesis has extended the applicability of this approach both by performing a series of two- and three-dimensional finite element analyses, and by reviewing field data obtained during the construction of the Jubilee Line Extension. In particular, the effects of building weight, of the nature of the contact between the building and the soil, and of the geometry of the building with respect to the tunnel approach have been investigated. The results have led to an improved understanding of the tunnel–soil–building interaction, and have provided greater confidence for the use of this approach in engineering practice.

Sponsored by EPSRC.

Contact: Professor D. M. Potts.

A. Grammatikopoulou, Imperial College, London

Development, implementation and application of kinematic hardening models for overconsolidated clays

This thesis presents developments made for the improvement of existing two- and three-surface kinematic hardening models used for simulating the pre-failure behaviour of overconsolidated clays. These include the formulation of the models in general stress space, different shapes of the yield surface in the deviatoric plane, and changes in the hardening modulus to account for the smooth transition from elastic to elasto-plastic behaviour. The models were implemented and validated in the Imperial College Finite Element Program (ICFEP). Their performance was then evaluated through finite element simulations of a series of laboratory tests, as well as two boundary value problems, for which comparisons were made between the predictions and measurements.

Sponsored by EPSRC; Soil Mechanics Section, Imperial College.

Contacts: Dr L. Zdravkovic, Professor D. M. Potts.

M. L. Melgarejo Corredor, Imperial College, London

Laboratory and numerical investigations of soil retention curves

The soil water retention curve (SWRC) was established for eight soils. Comprehensive drying and wetting paths were followed to model a number of conditions that occur in nature. Distinct characteristics of the SWRC related to soil type were found and described. Various mathematical formulations to model the SWRC, its hysteresis and different components were reviewed, and the van Genuchten equation and Luckner formulation were selected to model the experimental data. These were shown to reproduce the experimental SWRCs well in most cases. Relationships were investigated between the van Genuchten parameters ($\forall$, n and m) and soil characteristics, and trends were established. Numerical analyses were performed implementing the SWRC using the van Genuchten equation (without hysteresis). Very good agreement was found with the field data modelled. A numerical parametric study indicated that the van Genuchten n value, controlling the slope of the SWRC, and the saturated permeability have the greatest influence on the analysis.

Sponsored by Universidad Nacional de Colombia, ORS award scheme.

Contact: Professor D. M. Potts.

S. J. Arnold, University of Loughborough

Load transfer across cracks and joints in concrete slabs on grade

This research has investigated the behaviour of joints and cracks in concrete slabs on grade under single and multiple cycles of load. This provides an increased understanding of concrete slab on grade performance, enabling more effective design and long-term behaviour assessment. The research has incorporated a series of small-scale laboratory tests, site monitoring using dynamic plate equipment, and finite element modelling. A variety of crack geometries, reinforcement types (both steel fibre and traditional fabric), load

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magnitudes, concrete material constituents and site foundations have been assessed during testing to enable key factors in the deterioration of cracks and joints to be determined.

Sponsored by EPSRC, Association of Concrete Industrial Flooring Contractors.

Contact: Dr P. Fleming.

S. Likitlersuang, University of Oxford

A hyperplasticity model for clay behaviour: an application to Bangkok clay

A constitutive model was developed, using the 'continuous hyperplasticity' method, in which smooth transitions between elastic and plastic behaviour are modelled. The kinematic hardening model, specified by two scalar functionals, describes the effects of stress history on stiffness. A rate-dependent calculation is used for the incremental response. The model uses eight parameters, and is calibrated against triaxial tests from the Asian Institute of Technology and cyclic tests from Chulalongkorn University. It is then implemented in the OXFEM finite element program. Two projects in Bangkok (a road embankment and a tunnel in soft ground) are analysed under plane-strain conditions, and compared with field data. The effects of factors such as stress history on the results are investigated.

Supported by Royal Thai Government Scholarship.

Contact: Professor G. T. Houlsby.

M. J. Brown, University of Sheffield

The rapid load testing of piles in fine-grained soils

The interpretation of rapid load (Statnamic) pile tests in clays has been examined using an instrumented model pile in a large clay calibration chamber and a full-scale instrumented pile in glacial lodgement till. The effect of rate of loading on the pile's shaft and tip resistance was quantified using different pile penetration rates, and a new analysis method incorporating non-linear rate-dependent soil behaviour and a soil inertial component was developed. Results from full-scale pile load testing showed that the stiffness measured during Statnamic and static tests was very similar up to 50% of the ultimate static pile capacity.

Sponsored by EPSRC, PMC Ltd, Expanded Piling Co. Ltd.

Contact: Dr A. F. L. Hyde.

E. H. Jones, University of Sheffield

Non-invasive imaging of NAPL/partitioning tracer interaction in porous media

This laboratory-based study employed a 2-D porous medium of nominal thickness and a non-invasive imaging technique in conjunction with a fluorescent tracer to monitor partitioning tracer behaviour and interaction in porous media in continuous real time. Simple numerical and mathematical models were developed and compared with experimental results. Results indicated that a fluorescein partitioning tracer was able to detect and quantify sorption of partitioning tracers to NAPL in the homogeneous porous medium, though its performance was affected by both flow rate and NAPL distribution.

Sponsored by EPSRC.

Contact: Dr C. C. Smith.

J. B. Meca, University of Sheffield

Rate effects of rapid loading in clay soils

The relationship between the shear strength of the clay and the rate of shearing is relevant to the interpretation of new rapid load pile-testing techniques. Triaxial tests were carried out at 0·001–200 mm/s on reconstituted kaolin and undisturbed glacial clay. Using these test results, and a back-analysis of data from model and full-scale pile tests, a non-linear model was proposed for the static resistance of a pile taking into account the rate effects and the inertia of the pile. This was used to develop a new multistage interpretation method for the analysis of rapid load tests in clays.

Sponsored by TNO (Netherlands), Berminghammer Foundation Equipment (Canada).

Contact: Dr A. F. L. Hyde.

S. Srisakthivel, University of Sheffield

Laboratory measurement of the permeability of clay soils assisted by a self-boring device

A miniature self-boring instrument was used to measure the permeability of various clay soils in a cylindrical test cell. Flow was injected into a central unsupported cylindrical cavity and collected at the peripheral cell boundary. In reconstituted specimens, predominantly kaolin, the cavities were observed to degrade and partially fill with softened material, and this had a complex effect on the measured permeability. Data from pore water pressure probes suggested that hydraulic fracturing was taking place around the cavities, even though applied pressure heads were very small. However, in natural Oxford Clay specimens the cavities remained stable, and satisfactory measurements were possible.

Sponsored by: University of Sheffield.

Contact: Dr C. C. Hird.

I. Watson, University of Sheffield

Modelling of natural attenuation processes in groundwater using adaptive and parallel numerical methods

Biodegradation is an important process contributing to the natural attenuation of organic contaminants in groundwater. A numerical model was created to describe anaerobic phenol biodegradation data from an aquifer-derived laboratory scale microcosm. The laboratory-scale biodegradation model was transferred to a field-scale reactive transport model, and the simulations suggest that plume core processes are much more important than previously thought, possibly with a greater impact than plume fringe processes. It appears, in general, that relatively complex models are required for the realistic, quantitative assessment of natural attenuation at field scale, and that parallel, adaptive numerical methods provide appropriate efficiency benefits for such simulations.

Sponsored by EPSRC.

Contact: Professor D. N. Lerner.

R. Nikolova, University of Southampton

Performance of granular drainage systems permeated by low organic strength leachate

Potential mechanisms of biological and chemical clogging of drainage systems in in-ground repositories for low-level radioactive wastes were investigated, by means of large-scale column tests. The columns were operated to mimic saturated drainage layers, permeated by two different types of synthetic leachate. Rates of clogging were monitored by meas-

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uring changes in the drainable porosity of the aggregate, section by section within each column. The role of sulphates dissolved in the leachate was studied, with a particular focus on the competition for organic substrate between the sulphate-reducing and methanogenic bacteria. A common framework explaining the significance of different factors on the microbially mediated clogging of waste drainage systems in general was established with reference to both the new experiments and previous work. The clog material remained relatively porous and permeable while its nature was mainly biological, but became cemented and impermeable with the accumulation of calcium carbonate precipitates.

Sponsored by BNFL, University of Southampton.

Contact: Professor W. Powrie.

J. A. Priest, University of Southampton

The effects of methane gas hydrate on the dynamic properties of a sand

The project involved the development of a high-pressure (20 MPa), low-temperature ($-20^{\circ}C$) testing facility, incorporating a resonant column apparatus testing in both torsion and flexure, to synthesise and test methane hydrate. Specimens were formed from uniform Leighton Buzzard sand, with a range of hydrate contents. Resonant column testing was used to determine torsional and flexural resonant frequencies, from which the shear and bulk moduli were then derived. Damping characteristics were also determined. It was found that, for the method of hydrate formation used, the addition of small percentages of hydrate had a very large impact on shear modulus, during which effective stress dependence fell virtually to zero.

Sponsored by EU HYDRATECH project.

Contacts: Professor C. R. I. Clayton, Dr A. I. Best.

J. Smethurst, University of Southampton

The use of discrete piles for infrastructure slope stabilisation

A review of the literature revealed few well-documented case histories but a plethora of proposed methods for the analysis of discrete piles for infrastructure slope stabilisation. Piles used to stabilise a railway embankment near Tonbridge, Kent, were instrumented with strain gauges and inclinometer tubes to measure pile bending moments and displacements over a period of two years. Analysis of the piles was carried out using both the elastic analysis program ALP and the finite difference program FLAC3D. The elastic analyses were used to back-analyse the measured profile to investigate the effect of varying the soil stiffness. The finite difference analysis was able to model the effects of the construction process and slope regarding pile behaviour. Despite there often being no site-specific soil stiffness data available, the elastic method was found to be more effective at reproducing the observed pile behaviour (bending moments and displacements) than the modified limit equilibrium methods generally used at present.

Sponsored by EPSRC, Skanska Cementation Foundations, Mott MacDonald.

Contact: Professor W. Powrie.

M. Theron, University of Southampton

The influence of fine platy particles on the behaviour of a rotund sand

The behaviour of gold mine tailings can display the characteristics of either (dilative) sand or (contractive) clay, depending upon grading. The fines contain very little clay, but have been shown to be predominantly platy in shape, in contrast to the more bulky and angular coarse fraction. A series of triaxial tests were carried out using specimens made up with different proportions of fine-sand-sized mica mixed with coarse-sand-sized Leighton Buzzard sand. Isotropic compression and shear stiffness were determined using local strain measurement and side-mounted bender elements. Good correlations were observed between the behaviour of the mica/sand mixes and that previously found for South African gold tailings.

Sponsored by ORS.

Contact: Professor C. R. I. Clayton.

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