

British PhD Theses: 1995

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 1996 should be submitted to The Director (Engineering), The Institution of Civil Engineers, 1 Great George Street, London SW1P 3AA, by 31 January 1997.

D. Luo, University of Glasgow

Image processing and pattern recognition applied to soil structure

Numerical shape description of soil particles was achieved using an efficient and reliable new algorithm, SPCH, which finds the convex hull of either a binary object or a cluster of points in a plane. The roundness/shape of the particles was measured using the Circular Hough Transform (with a simple extension): three new algorithms, Centre, Gradient Centre, and Radius method of this transform were compared with traditional methods. Orientation analyses were made using the Directed Vein, Convex Hull, Principal Components, and Moments methods; the first method appeared to be the fastest with the special property of measuring 'internal preferred orientation' rather than 'elongation direction'. This represents collaborative research between the Department of Electronics and Electrical Engineering and the Department of Civil Engineering, University of Glasgow.

Supported in part by SERC.

Contact: Dr P. Smart, University of Glasgow.

C. M. Martin, Oxford University

Physical and numerical modelling of offshore foundations under combined loads

Environmental loads on offshore structures result in horizontal forces and moments on the foundations, as well as vertical loads. Model tests of spudcan footings of jack-up platforms on clay are reported. The tests are interpreted using plasticity theory: expressions are obtained for the yield surface in V:H:M space and a flow rule for footing displacements. The plasticity model also uses theoretical elastic stiffness factors and bearing capacity factors to define the size of the yield surface in terms of vertical penetration. The numerical model is evaluated by simulation of footing tests. Structural analyses of a jack-up are described, incorporating the numerical model of spudcan behaviour.

Contact: Professor G. T. Houlsby, Oxford University.

D. Kelly, Napier University

The effect of anchorage of geosynthetics upon the performance of unpaved roads

Geosynthetics used in unpaved roads on weak subgrades reduce rutting by a combination of separation, filtration, reinforcement and drainage. Reinforcement arises from either the membrane effect or lateral restraint, each requiring different in situ placement techniques; anchorage of the geosynthetic is required for the membrane effect while lateral restraint theory relies on interface friction for strength and stiffness. Cyclic load tests examined various geosynthetics at the subbase-subgrade interface. Finite element analysis was used to assess the effects of various material properties upon the road's performance. The principal conclusion was that reinforcement occurred without the need for manual anchorage.

Sponsored by Napier University.

Contact: Dr C. A. Fairfield, Napier University.

D. M. Armstrong, Napier University

Integrity assessment of structures using modal testing

Several structures were subjected to non-destructive testing, including slabs and plates representing bridge decks or road pavements, brickwork sewers, piled foundations, and backfilled arch bridges. The impact hammer method and modal analysis were used to assess structural integrity. Slabs and plates were tested with various support conditions providing dynamic stiffness measurement and void location in the underlying soil. Tests on brickwork sewers detected cross-sectional defects and soil damping effects. Modal pile tests also showed similar damping effects from surrounding soils; these effects were quantified for future NDT-based assessments. Tests on backfilled arches showed the feasibility of NDT for assessment purposes.

Sponsored by Napier University.

Contact: Professor A. Sibbald, Napier University.

J. R. McDowell, Napier University*Pipe-soil interaction in trench reinstatements*

A study of the interaction between flexible pipes and the surrounding soil is described. Dominant modes of interactive behaviour were stress dispersal, lateral earth pressure mobilization at the pipe haunches, and pipe bedding effects. The following were investigated by laboratory and field tests: pipe stiffness, diameter and profile; soil stiffness, cover depth and trench geometry. The principal parameters were pipe stiffness, soil stiffness and cover depth. Finite element analysis provided calibrated reinstatement design charts. The basis for a unified trench reinstatement code of practice was established.

Sponsored by Argival Plastics Limited and Napier University.

Contact. Dr C. A. Fairfield, Napier University.

M. Laman, Liverpool University*The moment carrying capacity of short pier foundations in clay*

A study of the moment carrying capacity of short rigid pier foundations in saturated clay soil is described. The work includes both conventional and centrifugal model tests and numerical investigations using the finite element method. Empirical relationships are derived between moment carrying capacity and pier geometry and predictions using these compared with those using existing design formulae. It is shown that, for the same pier rotations, the moment carrying capacities observed in centrifugal model tests are significantly larger than those in conventional model tests and the reason for this is clarified using non-linear finite element analyses of both models.

Contact: Dr G. J. W. King, Liverpool University.

K. O'Connor, City University*Swelling behaviour of unsaturated fine-grained soils*

The swelling behaviour of unsaturated fine-grained soils of different plasticity was investigated using both laboratory tests (stress path triaxial cell and computer-controlled oedometer apparatus) and centrifuge models. The influence of initial state (dry density and water content) and boundary conditions (stress or displacement controlled) was observed. The centrifuge experiments produced data of lateral stress change on a model retaining wall consistent with the laboratory tests and results from a full-scale prototype wall. The implication of the findings on the specification for the use of fine-grained soils as backfill material is discussed.

Sponsored by EPSRC and TRL.

Contacts: Dr K. O'Connor, Sir William Halcrow and Partners; Dr R. N. Taylor, City University.

A. Khakbazan, University of Glamorgan*Swelling, shrinkage and shear strength of unsaturated expansive clays*

The swelling, shrinkage and shear strength properties of unsaturated expansive clays were examined. Swell and consolidated drained tests were conducted on artificially constituted mixtures of kaolinite and 10%, 20% and 30% sodium montmorillonite. To eliminate the effects of creep on the perspex testing chamber, a double-walled triaxial cell was developed. Quantitative relationships were established which demonstrated the influence on swelling of moisture, air and montmorillonite content. In addition, the results illustrate the effect on the total or effective angle of internal friction of the percentage content of montmorillonite and of pore water and pore air pressure.

Contact: Dr R. Delpak, University of Glamorgan.

M. Srbulov, Imperial College of Science, Technology and Medicine*The prediction of ground sliding induced by strong earthquakes*

Attenuation relations are derived for the assessment of sliding displacements in soil during strong earthquakes as a function of magnitude and distance of the earthquake. Displacements are computed for horizontal and sloping ground in five types of soil. The shear strength of soil is modelled as a function of shear displacement and shearing rate. The results indicate that sliding in partially saturated clay and till could be one order of magnitude smaller in comparison with that computed using strength associated with slow shear rate. For submerged clay and till, the displacements could be similarly small on average but could be even greater sometimes.

Contact: Professor N. N. Ambraseys or Dr S. K. Sarma, Imperial College.

E. Porovic, Imperial College of Science, Technology and Medicine*Investigation of soil behaviour using a resonant-column torsional shear hollow cylinder apparatus*

The thesis presents an experimental study into the effects of principal stress rotation on the small and large strain behaviour of soils. A newly commissioned resonant-column torsional shear hollow cylinder apparatus has been used whose

development is described before presenting the results. Experiments were also performed with bender element equipment. The testing programme involved a systematic study of Ham River sand under a wide range of stress conditions, and research on a natural clay-silt and two stiff intact clays. The interpretation identifies the key controlling parameters and describes the results in terms of kinematic regions of stiff behaviour at small strains and anisotropic large strain yield surfaces.

Sponsored by EPSRC, Amoco and HSE.

Contact: Dr R. J. Jardine, Imperial College of Science, Technology and Medicine.

M. Skempas, Imperial College of Science, Technology and Medicine

Dam abutment stability with particular reference to the Thisavros Dam

A world-wide database of dams with abutment stability problems is used to highlight the most frequent causes and types of dam abutment instability. Most failures are during construction, are less frequent once construction is complete, and become relatively uncommon once five years has elapsed since construction. These studies are complemented by a detailed review of the particular problems encountered at the Thisavros Dam, Greece. The residual strength of the abutment materials was measured with a new technique, using the direct shear apparatus.

Contact: Professor R. J. Chandler, Department of Civil Engineering, Imperial College of Science, Technology and Medicine.

A. N. Parathiras, Imperial College of Science, Technology and Medicine

Displacement rate effects on the residual strength of soils

A modified version of the Imperial College/Norwegian Geotechnical Institute ring shear apparatus was used to examine the effect of displacement rates of up to 100 mm/s on the residual strength of a range of soil types. A modified design of the confining rings allowed large displacements without excessive loss of material, so that a reliable steady-state residual strength could be established, even at the highest displacement rates. The results showed that both 'positive' residual strengths (where the strength increased with increasing strain-rate), and 'negative' strengths (where the strength reduced with increasing strain-rate) could be obtained, depending on the degree of irregularity of the sliding surface.

Contact: Professor R. J. Chandler, Imperial College of Science, Technology and Medicine.

M. R. Sansom, Cardiff School of Engineering, University of Wales Cardiff

A fully coupled numerical model of moisture, air and heat transfer in unsaturated soil

The development of a fully coupled moisture, air and heat transfer model, applicable to unsaturated soil, is presented. An approximate numerical solution to the theoretical model is then developed. A verification and validation programme is implemented to assess the integrity of the theory, discretization approach and the computer software. As part of a collaborative European Union research programme investigating the modelling and testing of the hydration of clay backfilling and sealing systems, the proposed model has been applied to simulate a series of controlled heating and hydration experiments performed on three types of unsaturated soil; two candidate clay buffer materials and medium sand. Good agreement between the experimental and numerical results has been achieved.

Sponsored by the Commission of the European Union.

Contact: Professor H. R. Thomas, Cardiff School of Engineering, University of Wales, Cardiff.

C. B. Setjadinigrat, Manchester University

Finite element analysis of reinforced embankments on soft clays

The constitutive model 'MONOT' was calibrated for various natural and reconstituted clays. A composite FE model of the 'geocell' synthetic mattress system was developed and analysed to illustrate the sharing of load between geocell and infilled sand. A geocell-reinforced embankment in Kent was analysed by FEM and reasonable agreement between computation and performance obtained. Various other embankments on soft soils were analysed. Results were presented as computer animations.

Sponsored by Netlon Ltd.

Contact: Professor I. M. Smith, Manchester University.

K. Hachouf, Queen Mary and Westfield College, University of London

Geotextile soil reinforcement in retaining walls

A study of the frictional behaviour of sand and sand-geotextile interfaces at low vertical effective stress applicable to laboratory models is described. The study investigates the distribution of strain along extensible geotextile reinforcement as it is pulled out of sand. A new approach for determining soil-reinforcement shear stresses and reinforcement tensile loads is developed. The sand-

geotextile friction and the sand–sand friction are represented by combined hyperbolic exponential decay functions solved by the finite difference method. When compared to experimental results and earlier models the new model was found to be superior.

Contact: Dr N. W. M. John, Queen Mary and Westfield College, University of London.

Ahmed Saadi, South Bank University

The behaviour of strip footings on stone columns

The performance of strip footings supported on ground improved with stone columns has been investigated. Field results, including structural bending strains, settlements and contact pressure distributions have been obtained from a full-scale trial on an inhomogeneous fill. This comprised two identical strip footings on treated and untreated ground. Comprehensive site investigation data was also obtained to facilitate associated numerical studies. The results have given a valuable insight into stress ratios, settlement reduction and induced bending moments. The last of these is of particular significance in the design of strip footings on stone columns.

Sponsored by Bauer (U.K.) Limited and BRE.

Contact: Professor L. A. Wood, South Bank University.

Zura Jivakhishvili, South Bank University

The coupled finite-boundary element method applied to the analysis of geotechnical engineering problems

A numerical model utilizing a coupled finite and boundary element method has been developed. The boundary element region which is modelled as an inhomogeneous elastic continuum is condensed onto the interface with the finite element region which is treated as an inhomogeneous elasto-plastic material. The validity of the model and the associated non-linear solution techniques are demonstrated with reference to a series of classical test examples. Finally the method has been used to back-analyse the behaviour of the concrete gravity dam of Bratski power station and the earth retaining walls associated with the Limehouse Link in East London.

Contact: Professor L. A. Wood, South Bank University.

Li Zheng, South Bank University

Temperature-dependent visco-elastic-plastic analysis of permanent deformation in bituminous pavements

An FEM program 'VISPER' has been developed which is able to model elastic, plastic, visco-elastic

and visco-plastic strains in bituminous pavements, and calculate permanent and recoverable deformations at any point in an uncracked pavement, under any conditions of loading, time of loading and temperature. Temperature gradients in the pavement can also be modelled, and combinations of loading conditions handled. The plastic properties of the asphalt mixture are the most important factors in calculating the permanent deformation of flexible pavements, particularly at the upper end of the temperature spectrum. Elastic parameters alone are not sufficient to enable comprehensive, reliable analysis and design of flexible pavements. Suggested further work, includes modelling of actual pavements under realistic environmental conditions.

Sponsored by South Bank University.

Contact: Peter Wright, South Bank University.

K. Nesnas, University of Sheffield

Numerical implementation of a critical state model for the drained behaviour of an unsaturated soil

A critical state model for unsaturated soil has been implemented in the finite element program CRISP. The program has been verified by comparing the results with those obtained using a direct stress–strain integration technique for both axis-symmetric and plane-strain stress paths. These ranged from changes to one of the stress variables to more complex stress paths including the transition from saturated to unsaturated conditions and vice versa. The program was subsequently used to analyse a variety of strip footing problems, including a fluctuating groundwater table. Simultaneous swelling and collapse may occur as the water table rises.

Sponsored by the Algerian Government.

Contact: Professor I. C. Pyrah, Napier University.

P. C. F. Ng, University of Sheffield

Behaviour of buried pipelines subjected to external loading

Data from a number of full-scale field tests were used in the validation of a two-stage analysis technique for modelling laterally loaded pipelines. Stage 1 uses plane-strain finite element analysis to relate the restraining effect of the soil to the pipe displacement; stage 2 uses an elastic beam on an elastic foundation program to model the lateral pipe–soil behaviour. The introduction of a soil–pipe interface element in stage 1 significantly affects the predicted pressure–displacement relationship. A parametric study was carried out to study the influence of the natural ground, backfill, trench width and angle of the trench sides. Present

empirical relationships have been extended to include the effect of the trench backfill.

Supported by a British Gas Research Scholarship and an Overseas Research Student Award.

Contact: Dr P. C. F. Ng, The Queen's University of Belfast, or Professor I. C. Pyrah, Napier University.

T. H. Salman, University of Sheffield

Triaxial behaviour of partially saturated granular soils at low stress levels

A new double-wall triaxial cell, capable of making separate measurements and control of the pore air and pore water pressures, has been designed for testing partially saturated granular specimens, with height/diameter equal to 375 mm/150 mm, at low stress levels. The results of tests on partially saturated limestone chippings showed that suctions in the range 25 kPa to 75 kPa have an effect on the soil stiffness and shear strength at low stress levels. The results also showed that at failure there was a relationship between q , $(p - u_a)$, suction, specific volume and water content.

Sponsored by SERC.

Contact: Dr W. F. Anderson, University of Sheffield.

Wei Hu, Glasgow University

Physical modelling of ground behaviour of stone column foundations

The work investigated the behaviour of soft clay beds reinforced by a large group of stone (sand) columns. Displacement controlled vertical loading tests were carried out on rigid circular footings. The deformed shape of the sand columns after loading was obtained by removing the sand and forming a plaster cast from the clay bed. Area replacement ratio and column length were the main parameters investigated. The results clearly show that the group behaviour of the columns leads to a deepening of the zone of bulging, with the deepest bulging taking place on the central columns in the group.

The work was supported by SERC.

Contact: Dr Bill Stewart, Glasgow University.

M.-W. Gui, Cambridge University

Centrifuge and numerical modelling of pile and penetrometer in sand

Cone penetration tests (CPT) have been performed in a centrifuge, contributing to a European collaboration on in-flight measurements. The influences of container size, particle size and a sloping ground surface were investigated. Numerical mod-

elling with FLAC, based on plastic hardening fitted to triaxial data for the sand in question, was compared with experimental CPT profiles. The penetration process was simulated by continuous re-meshing. Good comparisons required the elimination of peak soil strengths. Penetration was then seen to be taking place at stress ratios either smaller than or equal to the critical state stress ratio, even in dense sands.

Sponsored by Cambridge Commonwealth Trust and Fugro Ltd.

Contact: Dr M. D. Bolton, Cambridge University.

D. C. Evans, Cambridge University

Contaminant migration through intact and damaged clay liners

The passage of salt solution through a clay layer, which had been consolidated in situ in the prototype mini-drum centrifuge, was studied and the results were in agreement with those predicted by the one-dimensional advection-dispersion equation. The effects of tensile cracking on the integrity of the liner and on the contaminant plume was also examined. A new triaxial apparatus was designed which incorporated the flow-pump method of permeability measurement and was used to induce tensile cracking around an expanding cylindrical cavity. Tensile cracking caused a dramatic reduction in the clay permeability and occurred at zero effective stress. The formation of pock-marks during the centrifugal consolidation of clay slurry can be avoided by applying an external downward hydraulic gradient.

Sponsored by EPSRC.

Contact: Professor A. N. Schofield, Cambridge University.

M. F. Bransby, University of Cambridge

Piled foundations adjacent to surcharge loads

The behaviour of a pile group laterally loaded by an adjacent surcharge loading was investigated. Understanding of undrained clay deformation behaviour at pre-failure loads was achieved by studying systems at varying geometrical scales and levels of complexity. Results from 2-D finite element analyses gave insight into the deformation of soil surrounding single piles and groups. Non-linear 3-D finite element analysis was used together with results from a series of centrifuge model tests to gain understanding of both component systems and global behaviour. A design method was presented. Finally, the new 'buttonhole' foundation technique designed to shield piles from lateral loading was studied.

Sponsored by EPSRC, EC Science Programme.

Contact: Dr S. M. Springman, Cambridge University.

E. E. R. Boyce, University of Cambridge***Modelling of transport processes in heterogeneous soils***

This work studied the transport processes involved in migration of a conservative pollutant through a layered soil (silt and sand) due to flow perpendicular to the layers. The relationship between the dispersivity and characteristic heterogeneity scale of the medium was considered. Physical modelling was carried out using a geotechnical centrifuge, and test data was compared with both analytical solutions and a finite element analysis. Instabilities in the pollutant interface occurred, increasing the apparent macrodispersivity of the medium. The onset of instabilities was thought to be caused by the heterogeneous nature of the soil matrix.

Sponsored by SERC and Golder Associates UK Ltd.

Contact: Dr C. Savvidou, Cambridge University.

I. Zakaria, University of Sheffield***Yielding of unsaturated soil***

Controlled-suction triaxial tests were performed to investigate the shape of an idealized single yield surface for compacted speswhite kaolin with an isotropic stress history. After unloading to stress states inside the yield surface, samples were reloaded (at three different values of suction) either isotropically or by drained triaxial shearing. Yield points were identified from the volumetric behaviour, whereas it was difficult to identify clear yield points from the shear behaviour. Constant-suction cross-sections of the yield surface were approximately elliptical in shape in the q - p plane, with the size of the ellipses increasing with increasing suction. Plastic strain increment vectors for the post-yield behaviour were consistent with an associated flow rule.

Sponsored by the Public Services Department, Government of Malaysia.

Contact: Professor S. J. Wheeler, University of Glasgow.

R. J. Chandler, Queen Mary and Westfield College, University of London***Field studies, analysis and numerical modelling of retaining walls propped at formation level***

Field instrumentation was installed behind a bored pile retaining wall, supported by a stabilizing base at formation level, on the A406 North Circular Road at South Woodford. The field measurements, together with a series of finite element analyses, are used to assess the factors influencing the performance of this class of retaining wall, with particular

emphasis on the type of prop and the sequence of construction. In order to carry out more realistic analyses with strain-dependent soil stiffness, the Simpson Brick model – together with a modified Newton–Raphson iteration technique – was incorporated into the finite element program CRISP. The changes made to CRISP were fully tested and calibrated.

Sponsored by EPSRC and TRL.

Contacts: Dr R. J. Chandler, SAGE Engineering, Bath; Professor W. Powrie, University of Southampton; Dr M. D. Bolton, University of Cambridge.

D. J. Richards, Queen Mary and Westfield College, University of London***Centrifuge and numerical modelling of twin propped retaining walls***

Centrifuge model tests and finite element analyses (using CRISP) were carried out to investigate the soil movements, prop loads and bending moments associated with embedded walls retaining clay, propped at two levels. Various embedment depths, pre-excavation lateral earth pressure coefficients and construction sequences were modelled. Wall bending moments, and the loads in the upper props, were found to be greater in the short term (i.e. soon after excavation) than in the longer term. Increasing the depth of embedment beyond that required for stability during excavation reduces the load in the lower props and increases wall bending moments but, unless the stiffness of the wall is also increased, it seems to have little effect in reducing ground movements.

Sponsored by TRL.

Contacts: Dr D. J. Richards, University of Southampton; Professor W. Powrie, University of Southampton.

G. Holmes, Queen Mary and Westfield College, University of London***Early age volume change and pore pressure development in cement pastes***

When constructing an oil, gas or water well, it is usually necessary to seal the annulus between the well casing and the well bore. This is achieved by pumping a cement slurry into the annulus and allowing it to set. However, the cement seal may become ineffective due to the effects of shrinkage, fluid or gas invasion, or excessive bleed during setting. In the context of this problem, the physical processes that occur during the initial setting of the cement have been investigated by tests in which the effects of the water/cement ratio, sample size, surface condition, pressure, temperature and various additives in the mix on the development of negative

pore water pressures, the surface settlement and the volume reduction on hydration were explored.

Sponsored by EPSRC and British Gas.

Contacts: Professor W. Powrie, University of Southampton; Dr S. A. Jefferis, Golder Associates, Maidenhead.

J. Page, Queen Mary and Westfield College, University of London

Changes in lateral stress during slurry trench wall installation

The processes involved in the installation of a slurry trench or diaphragm wall are examined and a consolidation-based model for estimating the lateral stresses exerted on the side of the trench during concreting is proposed. This model gives results that are consistent with those obtained using other more empirical theories, and with previous field measurements. A commercially available miniature total stress transducer was adapted for use in clay samples in centrifuge model tests. In-soil calibrations were carried out to establish that the transducer was capable of measuring changes in total stress with a repeatability of $\pm 15\%$. A series of centrifuge tests was then carried out in which the changes in lateral stress within the soil during the simulated installation of a slurry trench wall were measured.

Sponsored by EPSRC.

Contacts: Professor W. Powrie, University of Southampton.

V. Malandraki, School of Engineering, University of Durham

The engineering behaviour of a weakly bonded artificial soil

The properties of an artificially weakly bonded sand have been examined. The effects of bonding on the soil's behaviour have been investigated using undrained and drained triaxial tests, including probing tests following unconventional stress paths. Particular attention has been given to yield of the bonds, identified from the loss in tangential stiffness. The soil's behaviour was found to be represented by four main zones in stress space, identified by the relative position of the yield surface and the failure envelope. In triaxial drained probing tests different yield loci were observed for each stress path direction. It was found that a sample which has yielded following one stress path direction may show a further yield if the direction of shear is changed.

Partially supported by European Union Human Capital and Mobility programme.

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

A. Giolas, School of Engineering, University of Durham

A knowledge-based system for the estimation of geotechnical properties

A knowledge-based system has been developed to provide a tool for storing and using correlations and 'typical' values for the estimation of ground properties. The system developed is intended to provide geotechnical engineers with a decision-support tool to assist with the ground property evaluation problem. It was implemented using the ProKappa software and runs under X windows on a Sun workstation. The development of this system involved the identification and collection of the domain knowledge (knowledge associated with the ground, ground properties, 'typical' values and correlations) which was elicited from the relevant technical literature. Generic forms for the representation of correlations and 'typical' values in the system were developed which provide a consistent form for the representation of such knowledge.

Supported by NATO.

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

A. Oliver, School of Engineering, University of Durham

A knowledge-based system for the interpretation of site investigation information

This thesis describes the development of a knowledge-based system (SIGMA) for the interpretation of site investigation information. SIGMA has as its core a relational database to store all aspects of a site investigation. It also contains a number of knowledge bases which hold knowledge about the ground, geotechnical tests and correlations between geotechnical parameters. SIGMA provides two aspects of interpretation: (i) interpretation of design parameters from laboratory and field test results, or engineering descriptions of the ground; and (ii) the interpretation of ground conditions from borehole records. The system generates an interpretation from the borehole logs by tracing layers across a site and building up a picture of the ground conditions on a borehole-to-borehole level.

Supported by EPSRC and Scott Wilson Kirkpatrick & Partners.

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