CURRICULUM VITAE (Short Version)

Professor Michael A. Hicks

Introduction

Michael Hicks is Professor of Soil Mechanics and head of the Section of Geo-Engineering at Delft University of Technology. He has nearly 40 years of experience in finite elements, specialising in constitutive modelling, coupled processes, soil heterogeneity, static liquefaction, strain localisation, stochastic analysis, adaptive mesh refinement and the material point method. He currently supervises a team of 2 postdocs and 12 PhD students focusing on risk and variability in geotechnical engineering: see page 2 for a statement on current and recent research activities.

He was Chairman of the Organising Committee for *Géotechnique*'s 2005 Symposium in Print, "Risk and Variability in Geotechnical Engineering," and is Editor of a published (2007) Thomas Telford book by the same name. He was Chairman (2006-2010) of the British Geotechnical Association's Working Group on "Numerical Methods in Design," was a member of the Board of Directors of ALERT Geomaterials (2000-2017), was Chairman of ALERT's 2007 Workshop Session on "Inverse and Stochastic Modelling," Chairman of the International Workshop on "Safety Concepts and Calibration of Partial Factors in European and North American Codes of Practice" (Delft, 2011), Chairman of the International Conference on "Installation Effects in Geotechnical Engineering" (Rotterdam, 2013), Chairman of the 8th European Conference on "Numerical Methods in Geotechnical Engineering" (Delft, 2014), and Chairman of the 4th International Symposium on Cone Penetration Testing (Delft, 2018). He is on the Editorial Panels of the international journals "Géotechnique," "Acta Geotechnica," "Georisk" and "Computers and Geotechnics," and was Coordinator of ALERT's 2014 Doctoral School on "Stochastic Analysis and Inverse Modelling." He was awarded the Institution of Civil Engineers' Geotechnical Research Medal in 1999, for a *Géotechnique* paper on the static liquefaction of hydraulic sand fills.

Details

Current Academic Positions:

Professor of Soil Mechanics, Delft University of Technology (2009-Date)
Head of the Section of Geo-Engineering, Delft University of Technology (2011-Date)

Previous Academic Positions:

Lecturer, University of Manchester (1987-1998)
Senior Lecturer, University of Manchester (1998-2009)
Head (interim) of the Department of Geoscience and Engineering, Delft University of Technology (2018)

Current Professional Positions:

Editorial Panel of "Computers and Geotechnics" (2005-Date)
Editorial Board of "Georisk" (2012-Date)
"Géotechnique" Advisory (Editorial) Panel (2019-2021)
Editorial Panel of "Acta Geotechnica" (2020-Date)

Academic Record:

First Class BSc (Honours) in Civil Engineering, University of Manchester (1982) (*top student*)
PhD in Computational Soil Mechanics, University of Manchester (1990)

Awards:

Geotechnical Research Medal, Institution of Civil Engineers, London (1999).
[*Awarded annually for the best contribution in the field of research in geotechnical engineering published by the Institution in the previous year.*]
Georisk 2014 Best Paper Award (2015).
Géotechnique Letters Best Paper (2016, Quarter 2).
Georisk 2017 Most Cited Paper Award (2018).

Current Teaching:

Introduction to Civil Engineering; Soil Mechanics; Risk and Variability in Geo-Engineering; Bachelor Dissertations; Master Dissertations.

Supervision of Research Students/Staff:

13 Postdocs/Associates/Assistants, 37 PhD Students, 5 MPhil Students (including current research team).

External PhD Examinations:

25 (for various universities, including National University of Singapore, University of Western Australia, University of Nantes, Aalto University, Norwegian University of Science and Technology, KTH Royal Institute of Technology (Stockholm), Imperial College London, Trinity College Dublin, Durham University, Cardiff University, Southampton University, Loughborough University, Napier University, National University of Ireland Galway, Glasgow University, Strathclyde University, Oxford University).

Invited/Keynote Lectures:

Numerous, including: 4th Int. Symp. Computational Geomechanics (ComGeo IV), Assisi, 2018; 9th Euro. Conf. Numerical Methods in Geotechnical Engineering (NUMGE IX), Porto, 2018; and Woh Hup Distinguished Lecture, Singapore, 2018.

Funding:

16 industrial, 5 European and 10 EPSRC/STW/NWO projects. Recent/current projects include:

Hicks, M. A. (PI), *with Vardon, P. J., Jommi, C., Askarinejad, A.*, Reliable Dykes: Reliability-based geomechanical assessment tools for dykes and embankments in delta areas; funded by NWO; 1.012 million euros; 3 postdocs and 4 PhDs; 2014-2021.
Hicks, M. A., *with multiple partners*, All-Risk: Implementation of new risk standards in the Dutch flood protection programme; funded by NWO; 0.220 million euros and 1 PhD for Hicks WP; 2017-2022.
Hicks, M. A. (PI), *with Jommi, C., Korff, M.*, SOFTTOP: Investigating heterogeneous soft top soils for wave propagation, cyclic degradation and liquefaction potential; funded by NWO; 1.043 million euros; 2 postdocs and 2 PhDs; 2019-2024.
Hicks, M. A. (co-PI), *with Ghose, R.*, 3DSOIL: 3D soil variability in Groningen for accurate, local site response analysis; funded by NWO; 0.350 million euros; 1 PhD; 2021-2025.
Hicks, M. A. (co-PI), *with Dollevoet, R., Li, Z., Gavin, K., Jommi, C. (and collaboration partners Deltares)*, RESET: Reliable embankments for safe expansion in rail traffic; funded by ProRail; 5 million euros (TU Delft share); 2 postdocs and 8 PhDs; 2021-2026.

Statement on current and recent research activities:

My main research focus for more than 20 years has been risk and variability in geotechnical engineering. Contributions within that domain have broadly come under 3 main areas:

(a) *Stochastic characterization and modelling of soil spatial variability*: This is mainly concerned with the characterization of spatial variability within soil layers using cone penetration test (CPT) data, in order to provide point and spatial statistics as input for random field models of spatial variability. Of particular interest has been the determination of scales of fluctuation, especially in the horizontal plane. For example, Lloret-Cabot et al. (2014) proposed a strategy utilizing conditional random fields for determining the vertical and horizontal scales of fluctuation based on CPT data, and demonstrated its performance for a hydraulically placed sand fill (this paper won the Georisk 2014 Best Paper Award and the Georisk 2017 Most Cited Paper Award). More recently, de Gast et al. (2021a) evaluated a large number of very closely spaced CPTs to derive guidelines for the number and spacing of CPTs as a function of required confidence level in the computed horizontal scale of fluctuation. Meanwhile, other research work has investigated the conditioning of random fields using CPT data. For example, Li et al. (2016) demonstrated how uncertainty in the reliability of an embankment slope (modelled in 3D) was reduced when random fields were conditioned to CPTs located at regular intervals along the embankment crest (i.e., along the third dimension); this was shown to lead to more efficient slope designs for a given target reliability. Another series of papers investigated how data assimilation, for example pore pressure monitoring data, can be used to reduce the uncertainty in an embankment's performance over time (Vardon et al., 2016; Liu et al., 2018).

(b) *Stochastic modelling of slope reliability using the random finite method (RFEM)*: This is mainly concerned with the stochastic (Monte Carlo) modelling of slope stability, using the finite element method to compute structure response and random fields to model spatial variability of properties within soil layers. The emphasis has been on gaining insight into how soil spatial variability influences the initiation and propagation of failure mechanisms in slopes, and how this in turn influences the computed slope reliability. Hicks & Samy (2002a) investigated the influence of depth trend in the point statistics of shear strength on 2D slope stability, and demonstrated that a depth trend generally leads to a greater range of solutions and also to a decrease in reliability. Meanwhile, Hicks & Onisiphorou (2005) used RFEM, together with a sophisticated constitutive model for sand, to investigate the failure of the Nerlerk underwater berm, which failed during construction due to apparent liquefaction even though CPT data had indicated a predominantly dilative fill (Hicks & Boughrarou, 1998). The RFEM analyses demonstrated that failure of the berm was possible through liquefaction of semi-continuous looser zones arising from deposition-induced anisotropy. Hicks & Spencer (2010) investigated the influence of horizontal scale of fluctuation on the stability of embankment slopes, by carrying out 3D RFEM analyses for slopes that were very long in the third dimension. They demonstrated that 3 categories of failure mode were possible, depending on the horizontal scale of fluctuation relative to the embankment dimensions. This was reinforced by Hicks et al. (2014), who computed the distributions of slide volumes associated with the different failure mode categories. They demonstrated that nearly all failures are 3D, even for problems (such as embankments) which appear 2D from a geometric point of view. Hicks & Spencer (2010) highlighted that such problems require 3D analysis and that the reliability of such structures is problem length dependent; i.e., the longer the embankment, the greater the chance of encountering a zone that is weak enough to trigger failure. However, they also demonstrated that a full 3D analysis was not needed for very long embankments; instead, the results of a detailed 3D RFEM analysis for a representative length of embankment (of around 10 times the embankment height) could be combined with simple probabilistic analysis to accurately compute the reliability of embankments of different length (as verified by comparison with full 3D RFEM analyses of embankments of different length). This strategy was used by Hicks & Li (2018) to benchmark existing simpler 3D and 2.5D semi-analytical methods. Recently, the material point method has been linked with random fields for modelling problems involving large deformations. This so-called random material point method (RMPM) was first introduced by Wang et al. (2016) in a paper published in Géotechnique Letters, and was awarded best paper status by the journal in Q2 of 2016.

(c) *Probabilistic assessments of embankment reliability and characteristic values*: The influence of soil spatial variability on geotechnical response, as modelled using RFEM, has been used to provide an interpretation of characteristic values as defined in Eurocode 7. Hicks & Samy (2002b) demonstrated that characteristic values should be a function of not only the point statistics of a material property, but also the scales of fluctuation in the coordinate directions and the geotechnical problem under consideration. Hicks (2012) and Hicks & Nuttall (2012) took this further, and explained how Clause 11 of Section 2.4.5.2, "Characteristic Values of Geotechnical Parameters," in Eurocode 7 could be interpreted through a consideration of the scale of fluctuation relative to the domain of influence of the structure. Recently, this line of research has taken on an increased level of importance in the Netherlands (as outlined below). In brief, climate change, increased external loadings and new design guidelines mean that much of the Dutch flood defense and rail networks (i.e., dykes and embankments, respectively) no longer meet required safety standards. This has prompted research into the use of advanced methods of analysis that explicitly account for uncertainties (Hicks et al., 2019; Varkey et al., 2020).

The above research areas have been central to the major current/recent research projects outlined below. These projects include significant government and industrial funding, thereby highlighting the societal relevance of the research.

Reliable Dykes (2014-2021)

The aim of this project was to develop reliability-based geomechanical assessment tools for rural dykes. More than 1 million euros was awarded by the research council NWO, which included 300 thousand euros from STOWA, the Foundation for Applied Water Management Research, which is the official body representing the water boards and provinces in the Netherlands. In addition, the flood defense industry fully funded a full-scale failure test on a 400 year-old dyke founded on peat to provide validation data for the numerical and probabilistic tools developed in the project; this test was possible because the dyke was protecting a small polder that was to be "returned to nature" (i.e., flooded) to compensate for the loss of free water surface elsewhere in the Netherlands. The project included a site characterization based on an extensive CPT database (de Gast et al., 2021a), an RFEM analysis of the failure test (de Gast et al., 2021b), laboratory testing and constitutive modelling, and the development of various numerical tools, primarily linked to RFEM, including a subset simulation strategy for analyzing very small failure probability events (van den Eijnden & Hicks, 2017) and an extended 3D semi-analytical model benchmarked against RFEM (Varkey et al., 2019). In parallel to the Reliable Dykes project, further funding was obtained through the NWO research programme All-Risk to investigate the residual resistance of dykes, i.e., the resistance of a dyke to flooding following an initial slope failure. This research used RMPM to demonstrate the influence of soil spatial variability on the potential for an initial slope instability to cause a retrogressive failure mechanism leading to flooding; in particular, it developed a probabilistic framework that differentiated between the probability of a slope failure (which might be easily repaired) and the probability of flooding (with potentially massive consequences) (Remmerswaal et al., 2021).

The probabilistic tools developed in Reliable Dykes were used to assess the stability of the Starnmeer dyke in North Holland for the water board Hoogheemraadschap Hollands Noorderkwartier (HHNK) in 2018, and this resulted in mitigation measures that were far less expensive and far less intrusive than had originally been expected based on traditional methods of analysis; specifically, a stabilising berm of much smaller dimensions, as reported in Hicks et al. (2019) and Varkey et al. (2020). Similar assessments were commissioned by the water board Rijnland in 2019, and by the engineering company RPS (on behalf of HHNK) in 2020. Moreover, at the special request of STOWA, NWO agreed to fund Dr Varkey for an additional year as a postdoc, in order to facilitate further transfer of knowledge to industry. This included an assessment of partial factors used in semi-probabilistic design (Varkey et al, 2020), in collaboration with Deltares, as well as further work for the wider Dutch flood defence industry. Meanwhile, the rail operator ProRail commissioned a similar slope stability assessment for the embankment of the Delft-Schiedam line, which formed the basis for a new industry-funded project, RESET (referred to below).

SOFTTOP (2019-2024)

The aim of this project is to investigate the influence of the shallow subsurface (up to 30 m depth) on the transfer of energy (due to induced seismicity) to the ground surface; specifically, what is the influence of the cyclic loading of soft deltaic soils (organic clay, peat and sand) on the site response? This is linked with induced earthquakes in Groningen, in the north of the Netherlands, due to shale gas extraction. The influence of the shallow subsurface on the site response is being quantified probabilistically using coupled RFEM analyses accounting for the spatial variability of the soil properties at 3 scales: (a) small scale heterogeneities, for example in the form of laminations in sand and fibres in peat, are being accounted for through the development of constitutive models incorporating soil anisotropy and fabric; (b) medium scale heterogeneity, which is the spatial variation with material layers, is being accounted for by random fields; and (c) large scale heterogeneity, which is the spatial distribution of geologic layers, is being accounted for using a coupled Markov chain model. The stratification of the Groningen area is being determined from a grid of CPTs with approximately 30 m spacing, using Bayesian updating to account for uncertainty in stratification at the CPT locations and coupled Markov Chain Monte Carlo simulation to predict soil stratigraphy between the CPTs. However, a detailed representation of spatial variability between CPTs, both of soil layering and within individual soil layers, is difficult, and this was the motivation for a new project, 3DSOIL (2021-2025). This project is seeking to use high frequency full-wave immersion geophysics, correlated with CPT data, to generate detailed 3D images of the subsurface. In addition, the intention is to use machine learning to develop a model for predicting CPT data based on geophysical measurements conditioned to known CPT data.

RESET (2021-2026)

This project is funded by Prorail and is in collaboration with Deltares. It is motivated by the need of the Dutch rail network to accommodate (in the future) an increase in rail traffic, both in terms of the magnitude of applied loadings and the frequency of rail traffic, and also by the need to satisfy new safety guidelines and account for climate change. This is a huge project involving numerical and probabilistic modelling, physical modelling, laboratory testing, site investigation and various forms of monitoring, and is worth around 15 million euros over 5 years to all participants (with the possibility of another 15 million euros for years 6-10). The TU Delft share for the first 5 years is around 5 million euros and this will mainly be used to fund 8 PhDs. The main product of the project will be the probability-based framework for quantifying uncertainty and embankment performance: it is expected that 2 PhDs will work on this aspect (under my supervision), while the other 6 PhDs will primarily be involved in obtaining various sources of laboratory, field and numerical model data for calibrating and benchmarking the probabilistic framework. The framework itself will build on developments made in the previous research highlighted above; for example, the stochastic characterisation of sites will utilise multiple data sources, and extend the earlier work on using CPT data in Reliable Dykes and current research on using geophysical measurements and machine learning in 3DSOIL. Meanwhile, the reliability-based framework for embankment performance under train loading will build on the advances made in safety assessments for the flood defence industry in Reliable Dykes, as well as on experience gained in SOFTTOP on the dynamic loading of heterogeneous subsoils.

Publications:

Around 150 technical papers/books, including the following references cited above (in chronological order):

1. Hicks, M. A. & Boughrarou, R., Finite element analysis of the Nerlerk underwater berm failures, *Géotechnique*, **48**(2)**,** 169-185, 1998.
2. Hicks, M. A. & Samy, K., Influence of heterogeneity on undrained clay slope stability, *Quarterly Journal of Engineering Geology and Hydrogeology*, **35**(1)**,** 41-49, 2002a.
3. Hicks, M. A. & Samy, K., Reliability-based characteristic values: A stochastic approach to Eurocode 7, *Ground Engineering*, **35**(12)**,** 30-34, 2002b.
4. **Hicks, M. A. & Onisiphorou, C., Stochastic evaluation of static liquefaction in a predominantly dilative sand fill, *Géotechnique*, **55**(2)**,** 123-133, 2005.
5. **Hicks, M. A. & Spencer, W. A., Influence of heterogeneity on the reliability and failure of a long 3D slope, *Computers and Geotechnics*, **37,** 948-955, 2010.
6. Hicks, M. A., An explanation of characteristic values of soil properties in Eurocode 7. In: Arnold, P., G. A. Fenton, M. A. Hicks, T. Schweckendiek, and B. Simpson (Eds.), Modern Geotechnical Design Codes of Practice: Development, Calibration and Experiences, IOS Press, 36-45, 2012.
7. Hicks, M. A. & Nuttall, J. D., Influence of soil heterogeneity on geotechnical performance and uncertainty: A stochastic view on EC7, Proceedings of the 10th International Probabilistic Workshop, Stuttgart, 215-227, 2012.
8. Hicks, M. A., Nuttall, J. D. & Chen, J., Influence of heterogeneity on 3D slope reliability and failure consequence, *Computers and Geotechnics*, **61,** 198-208, 2014.
9. **Lloret-Cabot, M., Fenton, G. A. & Hicks, M. A., On the estimation of scale of fluctuation in geostatistics, *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, **8**(2)**,** 129-140, 2014.
10. **Li, Y. J., Hicks, M. A. & Vardon, P. J., Uncertainty reduction and sampling efficiency in slope designs using 3D conditional random fields, *Computers and Geotechnics*, **79,** 159-172, 2016.
11. Vardon, P. J., Liu, K. & Hicks, M. A., Reduction of slope stability uncertainty based on hydraulic measurement via inverse analysis, *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, **10**(3)**,** 223-240, 2016.
12. Wang, B., Hicks, M. A. & Vardon, P. J., Slope failure analysis using the random material point method, *Géotechnique Letters*, **6**(2)**,** 113-118, 2016.
13. Hicks, M. A. & Li, Y., Influence of length effect on embankment slope reliability in 3D, *International Journal for Numerical and Analytical Methods in Geomechanics*, **42**(7)**,** 891-915, 2018.
14. Liu, K., Vardon, P. J. & Hicks, M. A., Sequential reduction of slope stability uncertainty based on temporal hydraulic measurements via the ensemble Kalman filter, *Computers and Geotechnics*, **95,** 147-161, 2018.
15. van den Eijnden, A. P. & Hicks, M. A., Efficient subset simulation for evaluating the modes of improbable slope failure, *Computers and Geotechnics*, **88,** 267-280, 2017.
16. Hicks, M. A., Varkey, D., Eijnden, A. P. van den, Gast, T. de & Vardon, P. J., On characteristic values and the reliability-based assessment of dykes, *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, **13**(4)**,** 313-319, 2019.
17. Varkey, D., Hicks, M. A. & Vardon, P. J., An improved semi-analytical method for 3D slope reliability assessments, *Computers and Geotechnics*, **111**, 181-190, 2019.
18. Varkey, D., Hicks, M. A., Eijnden, A. P. van den & Vardon, P. J., On characteristic values for calculating factors of safety for dyke stability, *Géotechnique Letters*, **10(**2)**,** 353-359, 2020.
19. Remmerswaal, G., Vardon, P. J. & Hicks, M. A., Evaluating residual dyke resistance using the Random Material Point Method, *Computers and Geotechnics*, **133,** 104034, 2021.
20. de Gast, T., Vardon, P. J. & Hicks, M. A., Assessment of soil spatial variability for linear infrastructure using cone penetration tests, *Géotechnique*, **71**(11)**,** 999-1013, 2021a.
21. **de Gast, T., Hicks, M. A., van den Eijnden, A. P. & Vardon, P. J., On the reliability assessment of a controlled dyke failure, *Géotechnique*, **71**(11)**,** 1028–1043, 2021b.

** indicates highlighted reference