Summary of ISC6 Workshop

Dissipation testing: Hydraulic fracturing, modelling and model fitting "Towards standardisation"

Organizer: ISSMGE HNC
Location: Hungarian Academy of Sciences or Budapest / Budapest Congress Centre / ONLINE

Date: September 26, 2021

Chair: Dr. K Rainer Massarsch

Secretary: Zbigniew Bednarczyk, Nadaprapha Binsaaeteh and dr. habil. Emőke Imre

WORKSHOP TOPICS

The evaluation of various kinds of dissipation tests, including:

- modelling of penetration and dissipation
- the hydraulic fracturing during pushing before pore water pressure dissipation tests
- partly drained penetration, dissipation test results in silt, sand, and OC clays
- the similarity of DMT and qc dissipation test
- standards, evaluations and new types of dissipation tests, simultaneous dissipation tests
- soil parameters.

WORKSHOP PROGRAM

Prof. János Józsa: Opening of Workshop on behalf of the Hungarian Academy of Sciences

Joek Peuchen, Fugro: Pore presssure dissipation tests for offshore geohazards - discussion

isc6 0926 1 - YouTube www.youtube.com/watch?v=bre2owHeHN8

The focus is on sharing experience with offshore deployment of a step-tapered piezoprobe in clays. Piezoprobes have a track record of about 25 years. This includes operation in water depths of >1100m and push-in deployment to more than 400m below seafloor. The Fugro piezoprobe is 10mm, which is small compared to a piezocone. For clays, this step-tapered piezoprobe thus allows acquisition of t90 dissipation data within a fair amount of time, typically within 6 hours per test. Test interpretation for in situ equilibrium pore pressure in clay is based on 1/t or 1/√t data processing methods. Interpretation of results requires verification for possible soil-related data anomalies including: (1) stratification affecting pore pressure migration along the axis of the tool, (2) gas in soil interfering with pore pressure measurement and (3) distinction between excess pore pressure and measurement uncertainty.

K. Rainer Massarsch: Pore water dissipation following pile driving in clay

isc6 0926 2 - YouTube https://www.youtube.com/watch?v=0Aaoq4dGn5g

The presentation describes different types of in-situ measurements with the aim of studying the effect of pile driving in soft clay. The topics discussed are:

- In-situ measurements at Skå-Edeby test site.
- Measurement of rapid pore water pressure changes at multiple levels.
- Horizontal earth pressure before, during and after pile driving.
- Estimation of pore water pressure increase due to pile driving.
- Hypothesis describing the rapid pore water dissipation after pile driving.

Diego Marchetti: The dissipation test performed with the standard DMT, with the Medusa DMT, partial drainage

isc6 0926 3 - YouTube https://www.youtube.com/watch?v=gtzei6BepUs

The Medusa DMT system allows the precise recording of the stress changes. The record after the stop of the penetration, in case of partial drainage, needs special procedure which is treated. The A reading is needed to be taken differently in this case.

Laurin Hauser, Helmut Schweiger: Numerical study on cone penetration and the dissipation afterwards

isc6 0926 4 - YouTube https://www.youtube.com/watch?v=fvsrDrTOPz0

The contribution to the workshops deals with the numerical simulation of cone penetration testing and the subsequent dissipation phase using the Particle Finite Element Method. Based on the successful recalculation of in-situ CPTu in silty deposits the dissipation behavior at the u1 and u2 position was investigated under different drainage conditions highlighting the relevance of the obtained t50 for the characterization of the occurring drainage behavior.

Osman, Ashraf: Modelling of penetrometers

The presentation gave an overview of recent developments in predicting pore water pressure around CPTs. The presentation started with a brief introduction to recent analytical solutions and discusses some of their limitations. The presentation finishes by introducing an Eulerian-based finite element approach and shows its success in simulating CPTs.

Emoke Imre - Stephen Fityus - Lachlan Bates – Márton Hegedűs: Dissipation tests in partly drained soils - evaluation of truncated data, real-time evaluation in embedded system

isc6 0926 6 - YouTube https://www.youtube.com/watch?v=M3cQw7LoD3M

The pore water pressure dissipation test data of various sites, various types, both with relatively large and small t_{50} times were evaluated. Long and truncated tests with various filter positions were considered. The result indicates that the identification of coefficient of consolidation in "real time" is possible. The value c may become steady after a while, therefore, at a value being less than t_{50}, it could theoretically be possible to stop the test, earlier than time t_{50}. Results indicate that for filter position u_3, t_{min} is the shortest.

Summaries of PowerPoint Presentation

Joek Peuchen: Pore pressure dissipation tests for offshore geohazards

This workshop contribution is about pore pressure dissipation tests for offshore geohazards, particularly for estimation of in situ equilibrium pore pressure – test type PPDT1 according to ISO 19901-8:2014. The focus is on sharing experience with offshore deployment of a step-tapered piezoprobe in clays.

Piezoprobes have a track record of about 25 years. This includes operation in water depths of >1100m and push-in deployment to more than 400m below seafloor.

The piezoprobe method has an inherent trade-off between deployment robustness and deployment time, compared to a piezocone penetrometer. Particularly, the diameter of the lower end of a Fugro piezoprobe is 10mm, which is small compared to a piezocone. For clays, this step-tapered piezoprobe thus allows acquisition of t90 dissipation data within a fair amount of time, typically within 6 hours per test.

Test interpretation for in situ equilibrium pore pressure in clay is based on 1/t or 1/√t data processing methods. Interpretation of results requires verification for possible soil-related data anomalies including: (1) stratification affecting pore pressure migration along the axis of the tool, (2) gas in soil interfering with pore pressure measurement and (3) distinction between excess pore pore pressure and measurement uncertainty.

Peuchen, J., Santos, R., Yetginer, A.G., Eckart, W.S., Carrington, T.M. & Lunne, T. (2020). CPT data showing anomalies – assessment and potential postprocessing. In Z. Westgate (ed.). 4th International Symposium on Frontiers in Offshore Geotechnics (ISFOG 2020): proceedings (pp. 1026-1035). Deep Foundations Institute.

Peuchen, J., Meijninger, B.M.L. & Drummen, T.W.A. (2015). Reassessment of geotechnical conditions after an offshore well incident. Invited lecture. In Proceedings of the XVI ECSMGE: geotechnical engineering for infrastructure and development (pp. 195-206). ICE Publishing.

Peuchen, J. & Terwindt, J. (2014). Introduction to CPT accuracy. In 3rd International symposium on cone penetration testing CPT14: May 12-14 (2014) - Las Vegas, Nevada.

Tervoort, E., Peuchen, J. & Humphrey, G. (2011). Gas hydrate quantification by combining pressure coring and in-situ pore water sampling tools. In Proceedings of the 7th International Conference on Gas Hydrates (ICGH 2011), Edinburgh, Scotland, United Kingdom, July 17-21, 2011.

Peuchen, J. & Klein, M. (2011). Prediction of formation pore pressures for tophole well integrity. In OTC2011: Offshore Technology Conference, 2-5 May 2011, Houston, Texas, OTC Paper 21301. https://doi.org/10.4043/21301-MS

Kortekaas, S. & Peuchen, J. (2008). Measured swabbing pressures and implications for shallow gas blowout. In OTC.08: Proceedings 2008 Offshore Technology Conference, 5-8 May, Houston, Texas, USA, OTC Paper 19280 https://doi.org/10.4043/19280-MS

Peuchen, J. & Raap, C. (2007). Logging, sampling, and testing for offshore geohazards. In OTC.07: Proceedings 2007 Offshore Technology Conference, 30 April-3 May, Houston, Texas, USA, OTC Paper 18664 https://doi.org/10.4043/18664-MS.

Tervoort, E.P.P. & Peuchen, J. (2007). An improved tool for in situ pore water and gas sampling. In Offshore site investigation and geotechnics: confronting new challenges and sharing knowledge: proceedings of the 6th international conference, 11–13 september 2007, London, UK (pp. 73-80). Society for Underwater Technology.

K. Rainer Massarsch: Hydraulic fracturing in clay due to pile driving

Summary

The presentation describes different types of in-situ measurements with the aim of studying the effect of pile driving in soft clay. The topics discussed are:

- In-situ measurements at Skå-Edeby test site.
- Measurement of rapid pore water pressure changes at multiple levels.
- Horizontal earth pressure before, during and after pile driving.
- Estimation of pore water pressure increase due to pile driving.
- Hypothesis describing the rapid pore water dissipation after pile driving.

Geotechnical Conditions

The geotechnical conditions at the Skå-Edeby test site (Swedish Geotechnical Institute, SGI) has been investigated extensively and are typical for Swedish soft clay deposits, cf. geotechnical profile:

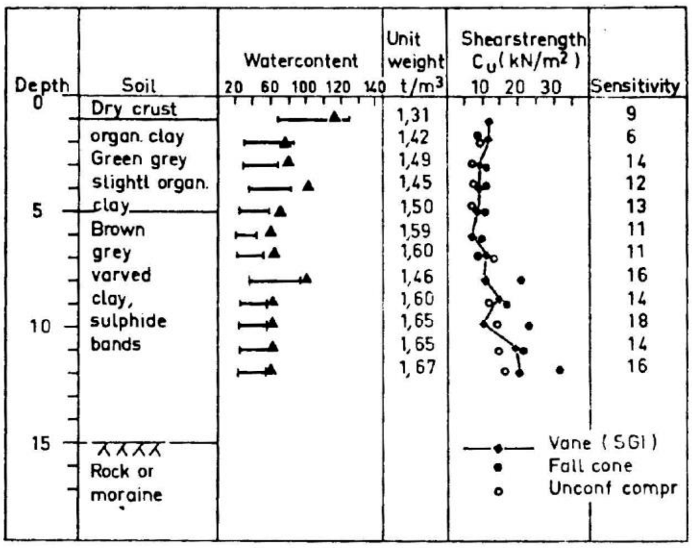

Figure 1. Geotechnical profile at Skå-Edeby.

In order to investigate horizontal stresses in soft clay prior to, during and following driving of pre-formed piles, the following tests were performed:

a) Hydraulic fracturing tests
b) Total lateral earth pressure using push-in cells
c) Simultaneous measurement of pore water pressure at several levels by multiple piezometer.

Examples of the testing equipment are shown in Figure 2.

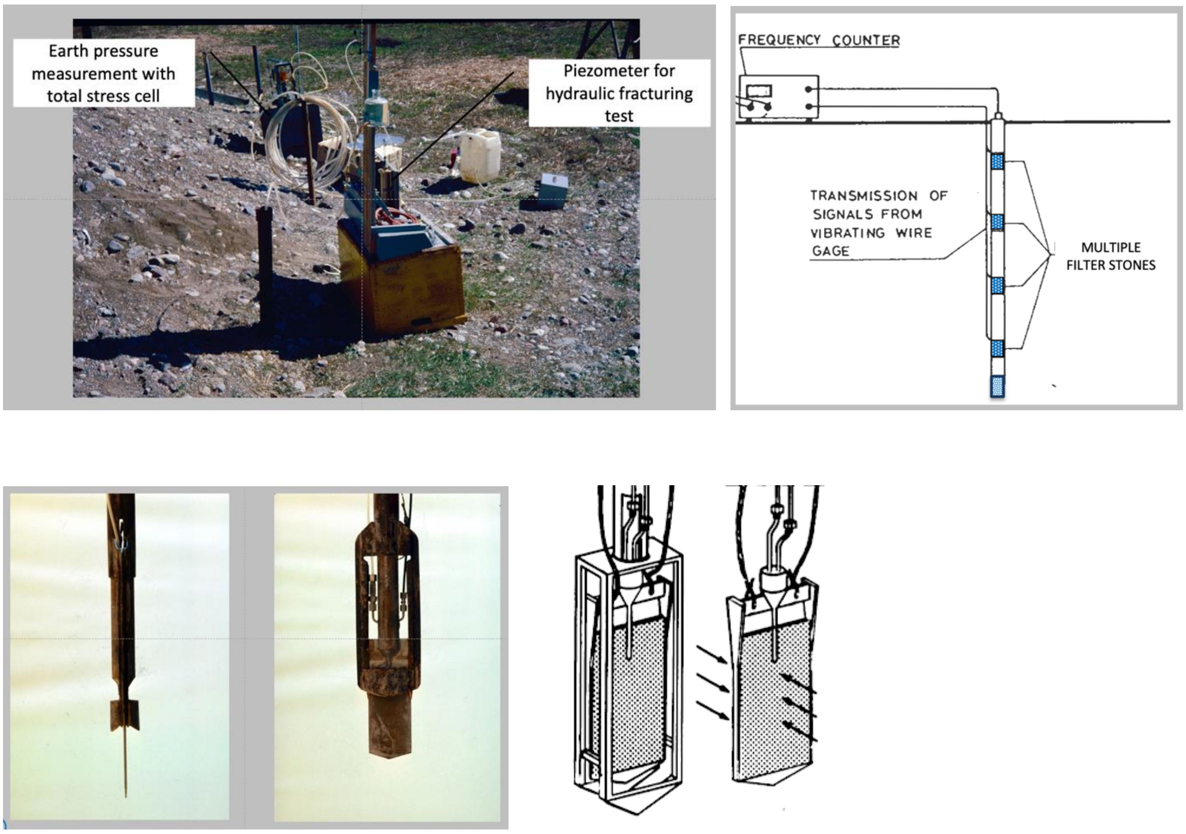

Figure 2. Testing methods for determination of pore water pressure and total horizontal stress.

An example of the pore water pressure dissipation rate during a hydraulic fracturing test by Lefebvre et al. (1991). The fracturing pressure was determined at a reduction of the water flow, Figure 3.

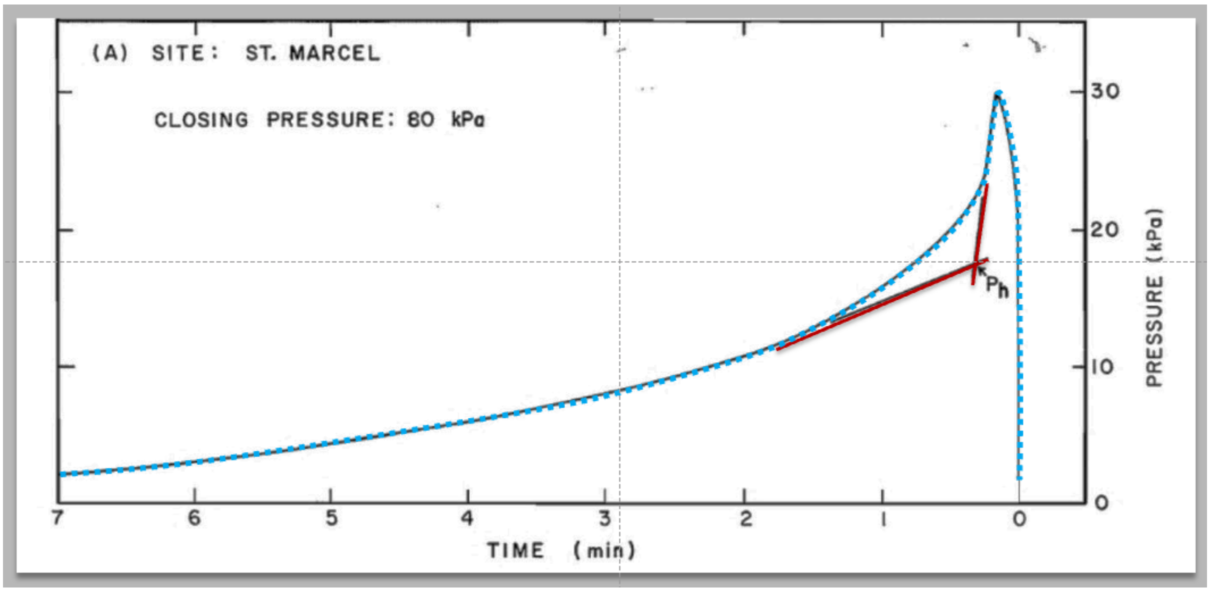

Figure 3. Measurement of water pressure and water flow during test.

Pore Water Pressure during Pile Driving in Clay

In Sweden, a common foundation method for buildings and other structures on soft clay is driving of pre-formed piles. Extensive field measurements were performed during the driving of preformed piles for an embankment (timber piles) and bridge abutment (concrete piles) at Nol, north of Gothenburg, Sweden, Figure 4.

Figure 4. In-situ measurements during pile driving in clay at Nol, Sweden.

The results of pore water pressure measurements during pile driving at different depths and distances from piles are shown in Figure 5. The pore water pressure response at 6 m depth at a lateral distance of 0.9 m from the pile is marked in red. During pile driving, the pore water pressure rose to very high levels but dissipated rapidly within hours. This pore water pressure response is similar to other field investigations, e.g. as reported by Lambe and Whitman (1969).

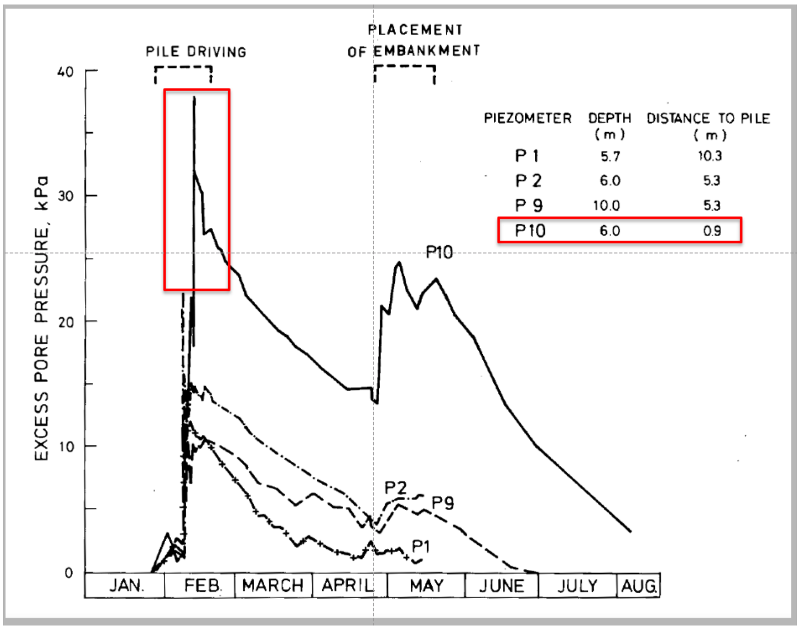

Figure 5. Pore water pressure measurements during pile driving at Nol, cf. Figure 4.

It is interesting to note that the pore water pressure response is similar to the results reported in the literature, e.g., Lambe and Whitman (1969).

Field Observations of Soil Fracturing

At the Skå-Edeby test site, driven sand drains were installed as part of a research study on the influence of driven sand drains on the consolidation of soft clay (Hansbo, 1960). Holtz and Holm (1972) excavated some sand drains to determine the change of geotechnical parameters adjacent to the driven sand drains.

Figure 6. Sand-filled cracks adjacent to sand drains driven into soft clay, Holtz and Holm (1972).

Holtz and Holm made the following observations: "The shape of the drain at 2 m depth was highly irregular and showed evidence of rather severe disturbance. Cracks filled with sand were observed 20 cm away from the drain face and large pieces of clay were found within the sand cylinder".

These observations are consistent with similar investigations by e.g., Boutsma and Horvat (1967): "*Driven and jetted sand drains were installed to 8 m depth. A network of vertical sand-filled cracks could be observed in the soft clay. The width of the cracks varied from a few mm up to 20 mm. Most of them extended to the adjacent sand drains and were completely filled with sand*."

Conclusions

Based on field observations of pore water pressure generation during driving of piles into soft clay deposit and the rapid dissipation of excess pore water pressure shortly after driving, the following conclusions can be drawn:

- High pore water pressures can be generated during driving of piles into soft clay.
- Due to the high rate of loading – clay behaves more as a brittle material.
- Pore water pressures dissipation immediately after driving cannot be explained by consolidation theory.
- The dissipation rate is similar to that during a hydraulic fracturing test.
- Excavated, driven sand drains show sand-filled cracks in the clay.

It can thus be concluded that primarily vertical cracks occur due to tensile stresses, developing in the zone surrounding the driven pile. The sand-filled cracks are evidence of this phenomenon.

References

Most of the information shown in the presentation has been published in the following references:

Boutsma, K. and Horvat, E. 1967. "The advantages and disadvantages of the application of sand drains and preloading at an excavation in Rotterdam". Proceedings of the geotechnical conference Oslo 1967. Vol. 1, pp. 9-11.

Hansbo, S. 1960. "Consolidation of Clay with Special Reference to Influence of Vertical Drains - A Study made in Connection with Full-scale investigations at Skå-Edeby". Swedish Geotechnical Institute (SGI). Report No. 18.

Holtz, R.D. and Holm, B.G. 1972. "*Excavation and Sampling around some Sand Drains at Skå-Edeby*". Sweden. Nordisk Geotekniker-möte (Nordic Geotchnical Meeting) Trondheim, 24-26 August 1972. Publisher: Norwegian Geotechnical Institute, Oslo, pp. 79-85.

Lambe, T.W. and Whitman, R.V. 1969. "*Soil Mechanics*". Wiley Series in Geotechnical Engineering. January 1991. ISBN: 978-0-471-51192-2, 576 p.

Lefebvre et al. (1991). "*Evaluation of K_0 in Champlain clays with hydraulic fracturing tests*". Canadian Geotechnical Journal. 28(3): 365-377.

Massarsch. K.R. 1975. "*New Method for Measurements of Lateral Earth Pressure*". Canadian Geotechnical Journal, Vol. 12, 1975, pp. 142-146.

Massarsch, K.R., Holtz, R.D. Holm, B.G. and Frederikson, A. 1975. "*Measurements of Horizontal In-situ Stresses*". Proc. of the Specialty Conference on In-situ Measurements of Soil Properties, ASCE, Raleigh, N.C. June 1-4, 1975, Vol. 1. pp. 266-286.

Massarsch, K.R., and Broms, B.B. 1976. "*Lateral Earth Pressure at Rest in Soft Clay*". Proc. of the Am. Soc. of Civil Engineering, Journal of the Geotechnical Engineering Division, 0ctober 1976, pp.1041-1047.

Massarsch, K.R. 1976. "*Soil Movements Caused by Pile Driving in Clay*". Dept. of Soil and Rock Mechanics, Royal Institute of Technology (KTH), Thesis in partial fulfillment of the requirements for the Degree Doctor of Engineering, 261 p.

Massarsch, K.R., and Broms, B.B. 1977. "*Fracturing of Soil Caused by Pile Driving in Clay*". IX Intern. Conf. on Soil Mechanics and Foundation Engineering, Tokyo 1977, Session I, pp. 197-199.

Massarsch, K.R. 1978. “*New Aspects of Soil Fracturing in* Clay”. ASCE Journal of the Geotechnical Division, Vol. 104, GT8, pp. 1109-1123; also published in: University of Kentucky Soil Mechanics Series No 25. April 1978.

Massarsch, K.R. 1980. “*New Aspects of Soil Fracturing in Clay*”. Closure to Discussion, Journal of the Geotechn. Engineering Division, ASCE, GT6, pp. 715-716.

Massarsch, K.R. and Broms, B.B. 1981. “*Pile Driving in Clay Slopes*”. Proceedings of the Tenth International Conference on Soil Mechanics and Foundation Engineering, Stockholm, (also VBB Special Report 21:80.7), Vol. 3. pp. 469-474.

Massarsch, K.R. and Kamon, M. 1983. “*Performance of Driven Sand Drains*”. 8th European Conference on Soil Mechanics and Foundation Engineering, Helsinki, 23 - 26 May, 1983, Proceedings, Volume 2, pp. 659-662.

Compilation of Curricula Vitae

Dr. K Rainer Massarsch

Dr. K Rainer Massarsch is a consultant in geotechnical and earthquake engineering, as well as soil dynamics, working on assignments worldwide. During his professional career as an academic, researcher, consultant, and contractor, he became involved in many aspects of geotechnical and foundation engineering. He was responsible for the design and execution of major foundation projects in Europe, the Middle East, the Far East, Australia, South, and North America. Dr. Massarsch is the author of over 200 scientific and technical publications. He was invited to lecture at conferences and symposia in more than 40 countries.

Dr. Massarsch has been involved in the design, implementation, and supervision of many major foundation projects, such as earth dams, airports, and harbors, tunnels, and industrial projects. He has been responsible for planning, implementation, and evaluation of advanced field investigations, such as different types of penetration tests, seismic field and laboratory testing, and determination of design parameters. He specializes in advanced foundation design, vibration analyses and mitigation measures, risk assessment of different types of construction work such as blasting, pile driving, traffic vibrations. An area of special interest has been soil treatment for the reduction of settlements and liquefaction analysis. He was responsible for the development and standardization of several ground improvement methods, such as vibratory compaction, deep mixing, vertical drainage.

He is past Chairman of ISSMGE Technical Committee 10, Geophysical Testing, Chairman of the Swedish Committee on Ground Vibrations and Chairman of two European Standardisation Committees (CEN/TC 288), which prepared standards on Deep Soil Mixing (WG 10) and Vertical Drainage (WG 11). Dr. Massarsch has been involved in the organization of several international conferences, such as ESOPT, ICSMFE 81, CPT'95, and two Deep Mixing Conferences.

Joek Peuchen

Joek Peuchen is a geotechnical engineer at Fugro, Netherlands. He has over 30 years of experience in geotechnical site characterization, geohazards, special foundation solutions, offshore & onshore, mainly for the global energy sector and major infrastructure. His main technical interests are in integrated site characterization, with a particular focus on geotechnical parameter value determination. Other areas include innovative development of in-situ test equipment and generation of synthetic geotechnical data from integrated geological and geophysical data. Mr. Peuchen is author or co-author of more than 70 publications on geotechnical topics, invited speaker at international specialty conferences including keynotes, and peer reviewer of journal and conference publications. Professional memberships include geotechnical societies and ISO standardization.

Diego Marchetti

Engineer Diego Marchetti has worked since 2001 in association with Professor Silvano Marchetti, the inventor of the Flat Plate Dilatometer (DMT) in 1980, used in over 80 countries worldwide. Together they developed and patented the Seismic Dilatometer (SDMT) in 2004 and the fully automated Dilatometer (Medusa DMT) completed in 2019 and employed today in four continents. In 2009 they founded Studio Prof. Marchetti, the company where Diego became director in 2016 after Silvano passed away.

The main activities of the company consist of the design, production, and distribution of patented geotechnical and geophysical equipment for in situ testing. In particularly challenging surveys, such as offshore DMT and SDMT surveys, Diego provides coordination and assistance on-site for ensuring high-quality testing with the supplied equipment.

His research activities are mainly in cooperation with the University of L'Aquila and also with other worldwide universities and institutes. He is the author/co-author of over 70 publications in technical journals and conference proceedings. Diego was invited and delivered technical presentations in over 60 countries at national and international conferences and to universities, Research Institutes, and private companies.

Dr. Laurin Hauser

Computational Geotechnics Group, Institute for Soil Mechanics and Foundation Engineering, Graz University of Technology.

As part of the ongoing research at the institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics dealing with the characterization of postglacial silty deposits in Austria we are working on the numerical simulation of CPTu in these soils considering effects of partial drainage and microstructural bonding using the application G-PFEM. Apart from developing some features of the numerical model, such as the implementation of the constitutive model, the research focuses on the recalculation of in-situ CPTu for validation. Laurin Hauser is currently working at Graz University of Technology as a research and teaching assistant under the supervision of Prof. Helmut F. Schweiger.

Professor Ashraf Osman

Department of Engineering - Durham University

Professor Osman obtained an MPhil in 2002 and a PhD in 2005 from Cambridge University, both in geotechnical engineering. Professor Osman's research focuses on developing analytical and numerical solutions for soil-structure interaction problems. His research has been funded by UKRI, the Royal Society, the Royal Academy of Engineering and the British Council. He is the PI for 8 GCRF and Newton Fund grants. He is leading the ?1.27M GCRF/EPSRC (EP/P029434/1) project "Developing performance-based design for foundations of WIND turbines in AFRICA (WindAfrica)". This project aims to accelerate the deployment of wind turbines in Africa by designing foundations suitable for African unsaturated soils. He is also leading the Newton Fund international consortium on Unsaturated Soils Mechanics for Engineering Practice (UnsatPractice). Professor Osman is a member of two Technical Committees (TCs) of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE): TC219 System Performance of Geotechnical Structures and TC308 Energy Geotechnics. Professor Osman was a past member of the editorial board of the ICE proceedings - Geotechnical Engineering (Nov 2014- Oct 2020), the Géotechnique Advisory Panel (Jan 2011-Jan 2014) and the Executive Committee of the UK Association for Computational Mechanics (2012-2014).

Research interests

- Performance-based design methods
- Soil-structure-atmosphere interaction
- Large-strain deformation analysis
- Urban data systems

Research groups

- Sustainable Infrastructure

Awarded Grants

- 2020: Shallow Landslide Susceptibility Mapping in Rize, Turkey (40000.00 from Royal Academy of Engineering)
- 2019: Integrated Modelling of Landslides due to Hydrometeorological Impact in Langat Basin, Peninsular

Malaysia (iModelLandslides) (380825.00 from Natural Environmental Research Council)

- 2018: CACTUS: Climate Adaptation Control Technologies for Urban Spaces(?349758.00 from Engineering and Physical Sciences Research Council)
- 2017: Increasing Climate Resilience of Urban Infrastructure(?37200.00 from British Council Yemen)

• 2015: Predicting collapse of sinkholes using an unsaturated soil mechanics framework(?12000.00 from Royal Academy of Engineering)

• 2015: Unsaturated Soils Mechanics for Engineering Practice (UnsatPractice) (152219.56 from ESRC).

Dr. habil Emőke

Associate Professor, Bánki Faculty, Óbuda University , HBM EKIK Research Center, Óbuda University.

Dr. habil Emőke Imre obtained her habilitation degree in 2015 from BME in civil engineering. Her research focuses – among others - on model fitting and developing analytical and numerical solutions for coupled consolidation; moreover, on granular matter, unsaturated soils and applied mathematics (nonlinear parameter identification).

Her research was funded by OTKA (NKTH), Norwegian Fund, Industrial partners and National Research Fund Jedlik. She participated on the „Development of Biodegradation Landfill Technology” (as project vice-leader), “In situ soil tests” (as project leader, with honour), in “Complex geotechnical examination of river dykes” (as project vice-leader) and in “Examination of rheological processes of soils” (as project vice-leader) and in 10 industrial reports. She made several computer evaluation software for lab and in-situ tests in fortran.

She is a member of three Technical Committees (TCs) of the

International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE):

’Unsaturated Soils Technical Committee’, ’In situ testing Technical Committee’,

’Dikes and Leeves Committe’.

She organised 3 Young Engineers Conference on Soil Mechanics and Foundation Engineering in Hungary, 3 Unsaturated Soil Symposia in Hungary with BME Geotechnical Department and with the RISSAC, the 1st Middle European Conference on Landfill Technology in Budapest, Hungary. She participated in the organisation of ISC6. She is a past member of the editorial board of the ENVGEO and preparing 2 special issues in relation to ISC6.

Research group: She is one of the founders of HBM Systems Research Center BGK-EKIK, Obuda University (in 2020).

Dr. Zbigniew Bednarczyk

Head of Geotechnical Engineering Laboratory at Institute of Opencast Mining in "Poltegor-Institute" Institute of Opencast Mining, Wroclaw Poland.

Graduate in Geology at University of Wroclaw (1985), PhD in Technical Sciences - Mining and Geotechnical Engineering, AGH University of Science and Technology, Krakow (1997).

Post-doc Geotechnical Engineering NTNU University of Science and Technology Trondheim - Interpretation of CPTU tests in comparison to laboratory testing (2002).

Over 150 geotechnical engineering documentations for industrial and civil engineering infrastructure, 23 landslide stabilization projects, specialization in landslide monitoring. Member of TC-203 ISSMGE. Over100 publications and 3 monographs published.