



Figure 1. Soil Mechanics laboratory at TCD.



Figure 2. The TCD Geotechnics Research Group's mobile research laboratory.

GEOTECHNICAL TEACHING AND RESEARCH REACHES FIFTY YEAR MILESTONE AT TCD

Brendan O’Kelly, Trevor Orr and Eric Farrell describe the development of geotechnical engineering, one of the youngest branches of civil engineering, and in particular the development of the curriculum and research laboratories in soil mechanics at the School of Engineering, Trinity College Dublin, from the initial stages just over 50 years ago, right up to the present day.

Soils differ in many important aspects from other construction materials. In particular, the shear strength and deformation response of a given soil are not constant but can alter appreciably according to the construction sequence, applied stress and also as a function of time. Stress analyses in soil masses are complex and previously accepted theories must often be modified in light of new experimental evidence. Soil mechanics applies the principles of engineering mechanics and dynamics, engineering geology, fluid mechanics, hydrogeology, clay mineralogy and colloidal chemistry to predict the mechanical behaviour of soils. Geotechnical engineering is concerned with any design and construction involving the ground, including foundations, retaining walls, dams and earth structures, deep excavations, underground openings and pavement engineering. It investigates the existing subsurface conditions and materials; determines the pertinent physical, mechanical and chemical properties from laboratory and field tests; assesses the risks posed by the site conditions; the design of earthworks and foundations for structures, and monitoring of the site conditions, earthworks and foundation construction. Sustainability, engineering economics and judgement derived from past experience are central to successful geotechnical design.

Early development

Until the 18th century, no theoretical basis had been developed for geotechnical design and the discipline was more of an art than a science, relying heavily on past experience. Several foundation-related engineering problems prompted engineers to begin taking a more scientific-based approach to studying the subsurface. Early advances occurred in 1776 with Charles Coulomb's development of earth pressure theory relating to the construction of retaining walls. Using the laws of friction and cohesion to determine the true sliding surface behind a retaining wall, Coulomb inadvertently defined a limit-equilibrium failure criterion for soil. The Mohr–Coulomb failure criterion (a very useful graphical construction technique that is still in use today) was subsequently developed by combining Coulomb's theory with

Christian Otto Mohr's theory of a 2D stress state in 1882. Other major developments around this period included Henry Darcy defining hydraulic conductivity during the 1850s; Joseph Boussinesq's theory of stress distribution in 1885 and William Rankine's development of earth pressure theory based on the stress state in 1857. However, it is generally recognised that the birth of modern geotechnical engineering as a separate discipline within civil engineering began in 1925 with the publication of *Erdbaumechnik* by Karl Terzaghi (1883–1963). *Erdbaumechnik*, which freely translated from German, gave the English-speaking world the term 'soil mechanics', contained the theory of one-dimensional consolidation that allows reliable predictions of the time-dependent settlement response of clay foundations under an applied surface load. Geotechnical engineering was formally established as an important discipline within civil engineering practice following the First International Conference on Soil Mechanics and Foundation Engineering in 1936. The conference proceedings included an important paper by Terzaghi on the principle of effective stress, which gave rise to a proper understanding of the shear strength and deformation response of the ground, and led to the development of new laboratory methods, including the triaxial test, in order to determine pertinent soil properties. Later developments included, for example, Albert Atterberg's studies on clay consistency in 1948 and Alec Skempton's studies on the fundamentals of the effective stress and pore pressures in clays, bearing capacity and slope stability.

Early years of soil mechanics at Irish universities

Foundation engineering and the design of retaining walls has been taught in one form or another from the early years of the engineering schools in Irish universities. However, soil mechanics did not enter the syllabus as a separate subject of civil engineering courses until about the 1950s, and since then, soil mechanics and geotechnical engineering have developed rapidly and are now established as core subjects of university degree programmes in civil engineering. In 1948, Professor Reginald Kirwan (1920–2001) joined the School of Engineering, Trinity College Dublin (TCD),



Brendan O'Kelly.



Trevor Orr.



Eric Farrell

to begin a long and fruitful association with this new engineering science of soil mechanics. As well as lecturing in surveying and the strength of materials, Professor Kirwan was responsible for developing the soil mechanics curriculum which was formally added to the civil engineering programme at TCD in 1955. A Soil Mechanics laboratory (Figure 1) was established shortly afterwards, and within ten years, a programme of research that regularly contributed technical papers to international conferences, particularly in the area of road pavement design. A series of seminars featuring leading international speakers was held at TCD, a tradition that has continued to the present day, for the benefit of Irish practising civil engineers.

Geotechnics Research Group at TCD

The Geotechnics Research Group at TCD has steadily expanded over the years with the addition of Trevor Orr in 1977, Eric Farrell in 1982, Barry Lehane in 1993, and most recently Brendan O'Kelly in 2002, all of whom gained many years of international experience with major consulting engineering firms before joining TCD. At present, the Research Group includes Eric Farrell, Trevor Orr, Brendan O'Kelly and the very experienced Chief Experimental Officer, Martin Carney, along with an energetic team of eight PhD researchers. Eric Farrell assumed the responsibility for the development of teaching and research when his mentor, Professor Kirwan, retired in 1984. In 2005, Barry Lehane was appointed as Associate Professor at the School of Civil and Resource Engineering, University of Western Australia, where he was promoted to a full Professorship in Geotechnical Engineering the following year.

Test facilities

The test facilities at TCD have been developing continuously and today include a modern, well-equipped laboratory in which to carry out all of the standard soil mechanics tests as well as more sophisticated apparatus, including miniature probes for soil-suction measurements and state-of-the-art stress path cells with instrumentation fitted directly on the specimen to accurately measure its local strain response, bender elements, direct simple shear apparatus and many other facilities for specialised commercial and research work. The laboratory also has vertical and lateral plate-load test

facilities and miscellaneous devices, including a power auger, in situ density meters and facilities for determining the structural properties of geomembranes. Relatively large-scale testing can be carried out in the main test hall of the Structures Laboratory at TCD, which includes a large purpose-built test chamber that can accommodate model piles and stabilised soil columns. The Geotechnics Research Group is also fortunate to have a mobile research laboratory consisting of a specialised 20 tonne truck (Figure 2) that facilitates standard cone penetration testing, as well as seismic cone and enviro-cone testing of the ground and is the only such investigation unit owned by a university in Ireland. Collaborative research and commercial work are regularly carried out using this mobile laboratory, including, for example, field tests in collaboration with Dr. Kenneth Gavin (UCD) to determine the load-deformation response of instrumented reduced-scale piles that were driven and jacked into sandy ground. Φ

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In future issues, the Journal will highlight some of the School's major geotechnical research achievements over the years, as well as showcasing some current R & D in construction innovation and the drive for sustainability in the ground engineering sector being championed by the Geotechnics Research Group at Trinity College.

The Geotechnics Research Group welcomes new links with industry and enquiries from individuals wishing to undertake postgraduate research. Interested parties are welcome to contact Brendan O'Kelly at bokelly@tcd.ie.