Geo-engineering Education in Australia

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ABSTRACT: This paper presents an overview of education, both undergraduate and postgraduate, in the geo-engineering disciplines of civil and environmental engineering, engineering geology and mining engineering. Treatment of education related to pure, or non-engineering, geology is beyond the scope of this paper.

1 SYSTEM OF ENGINEERING EDUCATION IN AUSTRALIA

1.1 *Admission requirements for higher education*

In Australia, it is compulsory for students to attend school (primary and secondary) between the ages of 6 and 15 to 17 depending on the state. Students wishing to undertake tertiary study complete a total of 13 years education; 7 primary and 6 secondary (NSW, Victoria, Tasmania, ACT, NT) and 8 primary and 5 secondary (Queensland, Western Australia, South Australia). In the final year of their secondary education (Year 12), students wishing to study in the tertiary sector are required to sit a public examination, although continual assessment throughout the final and, in some states, penultimate years, also contributes to their grade. Their performance in Year 12, as well as quotas within the various programs, dictates whether the student is successful or not in gaining entry to their chosen field of study.

1.2 *Types of higher education institutions offering engineering education*

In Australia, tertiary education typically adopts two forms – university and TAFE (technical and further education). In general, undergraduate and postgraduate engineering degrees are offered by universities and associate degrees, diplomas and certificates are available from the TAFE sector. In 2007, there were 39 universities in Australia, 37 of which were public and 2 private (DEEWR 2007), and over 70 institutes of TAFE (NCVER 2006).

1.3 *Number and distribution of programs offered*

Of the 39 universities, 26 currently offer civil engineering undergraduate degrees, 17 in civil and environmental engineering, and 7 in mining engineering. Each of these degree programs includes education in geotechnical engineering.

Almost exclusively, engineering undergraduate degree programs, which have been accredited by Engineers Australia (EA) as having met the requirements of the Washington Accord, involve 4 years of full-time study. Generally, the program core contains strands in structures, water and geotechnical engineering, and graduates are sufficiently equipped to pursue careers in any of these areas.

Similar to the UK system, Australian undergraduate programs offer an embedded Honours, i.e. within the 4-year program, where students who perform well throughout their studies are granted Honours degrees at either first or second class, with the latter being subdivided into Class 2A or 2B. Students who do not qualify for Honours are granted an 'ordinary' degree.

Presently unique in the Australian context, in 2008 the University of Melbourne introduced a new approach to higher education in Australia, known locally as the 'Melbourne Model.' Instead of the conventional four-year Bachelor of Engineering, the Melbourne Model offers students a pathway to a career in Engineering based on a two-cycle study program, similar in structure to that proposed by the Bologna Process. In the first cycle of the new model, a student will select from one of the broad undergraduate degrees (3 years) that will later lead to a Master of Engineering (second cycle of 2 years). Examples of such broad undergraduate degrees that can lead to the Master of Engineering include Science, Environments, Commerce and Biomedicine. In the new model the emphasis on academic breadth and disciplinary depth aims to provide professional engineers with the capacity to succeed in a world where knowledge boundaries are shifting.

The new Melbourne Model has significant implication in the teaching and learning of geo-engineering. In the first cycle, geo-engineering is introduced to a more general student body who will be enrolled in a broad undergraduate degree rather than with a focus on engineering. The curriculum will be different with the majority of the contact hours in geo-engineering allocated in the second cycle of postgraduate study. Instead of teaching conventional courses such as *Geomechanics* and *Engineering Geology*, the first cycle program involves newly integrated geo-subjects such as *Earth Processes* which involves both earth systems and basic soil mechanics. The topics cover broader areas including the solid earth; atmosphere, land and water systems; land and water movement; the composition, classification and properties of soils; soil-water interactions; and the basic strength and engineering properties of soil. The more specialized geo-engineering content will be introduced in the second cycle of the two-year postgraduate study.

The disadvantage of the Melbourne Model is that it requires an additional year to complete an accredited qualification, as the first cycle is insufficient to gain relevant accreditations from professional engineering bodies such as EA. However, the advantage is the model provides breadth in the first cycle and depth in the second.

2 GEO-ENGINEERING SUBJECTS IN DIFFERENT PROGRAMMES

2.1 *Geo-engineering subjects in first cycle programs*

In the majority of Australian civil engineering and civil & environmental engineering programs geo-engineering instruction is included in courses involving both geology and geotechnical engineering. This usually involves 2, 3 or 4 core (compulsory) courses and the opportunity for 1 or 2 elective courses. Usually, an introduction to earth processes is given in first year by academic staff from schools of geology, followed by courses in soil mechanics in Years 2 and 3 and geotechnical engineering in Years 3 and 4. Typical example syllabi of such courses include:

- *Introductory Geology for Engineers* includes treatment of mineralogy, the major rock groups, plate tectonics and the major geological processes, geophysics, structural geology, the fundamentals of ore deposit geology and metallic and non-metallic exploration, the geology of energy deposits, and environmental matters associated with mining.
- *Level 1 Geotechnical Engineering* courses generally include: the origin and composition of soils; mineralogy of clays; phase relationships; soil classification; total and effective stresses; soil shear strength and Mohr circles of stress; consolidation and settlement; permeability and seepage; soil compaction and ground improvement.
- *Level 2 Geotechnical Engineering* courses include: foundation analysis and design; site investigations, in situ and laboratory testing; lateral earth pressures and retaining wall design; slope stability; pavement design; and environmental geotechnics.

These courses also generally include laboratory practical sessions on soil classification, triaxial and direct shear testing, consolidation and compaction and, in the case of introductory geology courses, field trips. Optional and compulsory advanced level courses vary between institutions. Some examples of these include: *Advanced Geomechanics*, *Deep Foundation Engineering and Design*, *Expansive Soils and Footing Design*, *Foundation Engineering Design*, *Ground Hazards and Environmental Geotechnics*, *Offshore Geomechanics*, and *Rock Mechanics and Rock Slopes*.

In order to qualify for Honours, students must also successfully complete a substantial research project which accounts typically for one-quarter of their final year of study. Students wishing to undertake a career in geo-engineering or proceed to postgraduate study generally undertake a geo-engineering-related research project.

Most Australian engineering programs require students to complete a 12-week period of industrial experience before a degree can be awarded.

Despite the resources boom that has driven the Australian economy for the past decade, there has generally been a strong decline in support for first cycle programs in pure geology, with direct consequences for the teaching of engineering geology. At present, of the 37 Australian Universities, around 20 have Geoscience departments (SET 2007), but only around 7 of these can offer a program which includes a full range of geology courses (e.g. sedimentology, igneous geology, structural geology, economic geology, palaeontology and mineralogy). There are no first cycle programs dedicated to engineering geology, and only two dedicated engineering geologists working in Australian Universities, and these are based in engineering faculties.

As a consequence, engineering geology courses are either being taught by engineers, or by pure geologists. Accordingly, their content varies widely between institutions, ranging from mostly pure geology to applied geology with an emphasis on mining or resources.

Of the 37 Australian universities, 7 full programs in mining engineering are offered, with two more universities offering the first two years of a generic program with "feeder" arrangements for students to complete their programs in one or more of the universities offering the 7 full programs. Three larger mining programs, based in different states of Australia, have formed a collaboration called Mining

Education Australia (MEA 2007) wherein there is a common program for years 3 and 4, allowing students seamless transfer between their institutions.

The course content of the mining programs varies significantly between institutions, depending upon staffing levels, staffing expertise and regional needs. Typical mining programs include basic courses on mathematics, geotechnical, water and structural engineering (mostly in the first 2 years), with specialist courses on geology, rock mechanics, environmental management, resource estimation, mining economics, mine design, safety management and finance in later years. Specialist/elective courses vary according to regional needs (mostly coal-related on the east coast and metals-related in the south and west) and include mine water, mine ventilation, petroleum geology, minerals processing, surveying, geostatistics, spatial information and finance.

2.2 *Geo-engineering subjects in second cycle study programs, including specializations*

There are relatively few Australian Universities that offer coursework programs in geo-engineering at masters level. Those that are available, have particular structures and course selections, reflecting the institution's approach to postgraduate education and to a lesser extent, research expertise in geotechnical/mining disciplines. In most cases, they involve some measure of specialization.

Available programs include masters degrees (1 year full-time), graduate diplomas 0.1–1year full-time) and graduate certificates (0.5 year full-time). One of the widest selections is offered at The University of New South Wales, which offers a Master of Engineering Science in Geotechnical Engineering and Engineering Geology; a Master of Mining Engineering specializing in Mine Geomechanics or Mine Management; a Graduate Diploma specializing in Mining Engineering, Mine Ventilation or Coal Mine Strata Control, and a Graduate Certificate in Mining Engineering. The courses offered, which mostly cover aspects not covered in Cycle 1, are offered as a mixture of 5-day intensive short courses and full semester courses. Most programs are a mixture of core units and electives. Similar arrangements, although generally with fewer program offerings, are available at the Universities of Wollongong, Western Australia, Queensland and Sydney, and Curtin University.

Masters by Research in geomechanics and geotechnical engineering are available at most of the larger universities offering a civil engineering program. Masters by Research in engineering geology and mining engineering are only available at institutions which have Schools of Mining Engineering, although it is not unusual that masters research on a mining-related topic is undertaken by geotechnical researchers in universities without formal mining programs.

2.3 *Geo-engineering subjects in integrated programs*

There are currently no integrated programs available in Australia.

2.4 *Specializations in first cycle programs*

The first cycle programs in civil engineering all contain some component of geological and geotechnical training, as discussed in §2.2 above. Currently, no Australian university offers formal specializations within geotechnical engineering at this level. In mining there are some related specializations in the first cycle, but these are diverse and generally relate to mining activities that are removed from geo-engineering.

3 DOCTORATE PROGRAMS IN GEO-ENGINEERING SCIENCES

Most Australian universities offer study programs that lead to Doctorates specializing in geo-engineering. The most common is the Doctor of Philosophy by Research or commonly known as PhD. The entry requirements for this research-only program generally includes a four-year honours degree with Class 2A or above. However, other qualifications such as research- or coursework-based master's degrees and professional experience are also considered favourably in judging the suitability of a candidate to undertake a PhD. Usually, candidates are enrolled first on probation and the candidature is confirmed only after having successfully completed the probationary period. The program can be undertaken full-time or part-time and the allocated time depends on the chosen mode of study. Generally, full-time PhD programs take 3-4 years to complete, whereas part-time studies can take twice as long.

Examinations of research-only PhD studies are undertaken through a thesis, which is normally examined by two external specialist examiners, who in many cases, are from overseas. Examiners' names remain confidential throughout the process, unless the examiner indicates otherwise. The examiners evaluate the thesis on a range of measures, the main ones being the assessment of a candidate's knowledge of the discipline and evidence of their ability to complete a rigorous research project.

In addition to the Doctor of Philosophy, various universities offer other doctorate programs. For example, the University of Sydney offers a Doctor of Engineering Practice which involves obtaining credit points from both coursework and research components. Other variations include obtaining a PhD by

submission of a series of published papers (Monash University) and double-badged PhD degrees (e.g. the University of Adelaide), where the degree certificate will show recognition from two institutions and the candidate may spend time in the both institutions during the candidature. Finally, most of the universities offer higher doctorates, which are normally through the submission of a collection of work leading to a substantial contribution to knowledge by established researchers.

4 CONTINUING EDUCATION AND TRAINING ACTIVITIES IN GEO-ENGINEERING SCIENCES

Professional engineers who are chartered members of EA are required to undertake and document a minimum of 150 hours of continuing professional development (CPD) over a 3-year period. This can be achieved in the following ways: (i) formal postgraduate study and individual tertiary courses not undertaken for award purposes; (ii) short courses, workshops, seminars, conferences and technical meetings; (iii) learning activities in the workplace that extend the member's area of practice competence base; (iv) private study which extends the member's knowledge and skills in their area of practice including risk management, business and management skills; (v) service to the engineering profession; (vi) the preparation and presentation of material for courses, conferences, seminars and symposia; (vii) chartered members employed in tertiary teaching and/or academic research; and (viii) any other structured activities not covered above that meet the objectives of the CPD policy.

4.1 *Formal education*

In geo-engineering in Australia there are currently no formal coursework masters or masters-type programs available after the second cycle.

4.2 *In-house training provided by companies*

In order to meet the current international skills shortage in geotechnical engineering all professional and responsible companies operating in geo-engineering are heavily focused on training and development of their staff. Many companies run internal training seminars and technical development programs that may range from regular one-hour discussions, often during lunchtime, in a local office, to 3- or 4-day structured training sessions delivered by in-house senior personnel.

Longer term structured training, particularly in association with EA's CPD and graduate development programs, as mentioned above, include attendance at external technical courses and conferences, and support in the form of time and payment of fees for employees to study for relevant masters degrees and other postgraduate qualifications.

Close industry and university liaison and cooperation leads to access to special focus training sessions, workshops and seminars provided by the universities on a commercial basis or in conjunction with EA and the Australian Geomechanics Society (AGS) and the Australasian Institute of Mining and Metallurgy (AusIMM) or other relevant professional bodies. Attendance at these valuable and often very cost-effective training opportunities is actively encouraged by most geo-engineering companies.

Finally, probably the most common and effective form of training is that which occurs 'on-the-job' under the formal or informal mentoring of junior staff by senior geotechnical professionals.

4.3 *Other continuing education activities*

Professional bodies such as EA, AGS and AusIMM offer regular technical meetings, seminars, workshops and conferences and the majority of practicing geo-engineers attend such meetings in order to develop their skills and expertise. In addition, such bodies publish technical journals which further facilitate continuing professional development.

A relatively recent and particularly important AGS initiative is the *Geology for Engineers* course, which is presented and developed by a group of eminent, industry-based, engineering geologists, and is aimed at addressing the shortcomings in engineering geology education in Australian universities. Over the past decade this course has been delivered on three occasions in a one-week intensive, residential, field-based format.

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