# Design, construction and investigation of an earth retaining structure – a foundation for active learning

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## CONTEXT

An increasingly evident tenet in engineering education, particularly in geo-engineering is that engineering students must be equipped to 'do' (Atkinson, 2012). How do we train them to 'do'? By doing. Bloom et al. (1971) and more recently others (Biggs and Tang (2007), Jaksa (2012) etc.) have further evidenced the positive impact that active learning or 'doing' can have on student outcomes. This paper presents an undergraduate engineering initiative at the University of the Sunshine Coast, Queensland, where 3rd year geotechnical engineering students 'did' a semester long project that incorporated the design, construction, testing and analysis of a campus-sited earth retaining structure.

## PURPOSE

The purpose for this initiative was to provide geotechnical engineering students with an immersive semester-long 'doing' experience that would expose them to all necessary professional engineering facets of the course, within a 'real-world' project based environment.

## APPROACH

At course commencement students were grouped and designated as Project Engineers. They were then tasked with the requirement to manage a small onsite geotechnical engineering project, that being the construction of a small 1m high earth retaining structure. Each group carried complete responsibility for the project including: risk analysis, budget and project planning, site investigation (laboratory and field based), project design, contractor engagement, construction and proof testing of the earth retaining structure. Throughout this process, a different Project Engineer from each group was required to provide a weekly verbal briefing to the Project Manager (Lecturer) on project progress and at the end of the semester, a final project report was submitted and a summative verbal briefing delivered.

## RESULTS

This approach resulted in a self-motivated and engaged student cohort. After recognising the responsibility that had been granted to them in assuming management of the project, students generally self-organised their groups, allocated tasks and devised timelines to ensure successful project completion in a timely manner. Destructive testing of the wall did not occur and the Engineering Test Precinct within which the structure was constructed continues to be utilised for additional 'doing' based geotechnical engineering learning.

## CONCLUSIONS

In this initiative discrete 'doing' tasks were not prescribed, but a complete semester-long geotechnical engineering construction project was allocated to student groups to manage from inception to completion. This project enabled the students to 'do' many things, beyond those that may have been discretely defined for the project. This exposed them to necessary 'real-world' construction and project management issues. By transferring project 'ownership' to them, their self-assertiveness and confidence was increased, enabling them to serve more effectively as graduate civil engineers.

## KEYWORDS

Active learning, earth retaining structure, geotechnical engineering.

# Introduction

Tertiary pedagogical methods are evolving rapidly. The ubiquity of the internet and wireless technologies has driven the implementation of many digital techniques such as ‘blended learning’, Massive Online Open Courses (MOOCs) and Problem Based Learning (PBL). However, developing alongside these initiatives is the realisation that professional degrees, such as Engineering, need to produce graduates that are `work ready’. This realisation is not new; Seidel et al. (1994) outlined a PBL approach for a soil engineering course in the 1990s, but amidst the plethora of digital teaching technologies now available and employed, this awareness is being re-emphasised by the profession.

In response to this, recent engineering pedagogical methods have moved towards subject/course-long project-based or “active” learning, sometimes based on frameworks such as Conceiving, Designing, Implementing and Operating (CDIO). These methods are consistent with Atkinson’s thesis (Atkinson, 2012) that in the workplace, engineers are required to `do’ things and thus any engineering teaching and assessment should be founded upon a student engineer’s ability to `do’ things. Bloom et al. (1971) and more recently others (Biggs and Tang (2007), Jaksa (2012) etc.) have further evidenced the positive impact that active learning or ‘doing’ can have on student outcomes.

In this paper we describe a third year geotechnical engineering initiative, founded upon this principle of `doing’ where students were supported to design, manage, construct and assess a simple geotechnical engineering structure, an earth retaining wall.

# Method

## Preliminary preparation

This method of instruction was possible because of the small staff/student ratio of the course. The third year students had completed a pre-requisite soil mechanics course prior to commencing the project and so had attained a basic understanding of the theories involved.

Discussion with the Facilities Management section of the University identified a small portion of unused on-campus land that could be used in the short to medium term as an `engineering test precinct’ where large-scale engineering structures could be constructed.

Appropriate surveys were conducted to identify the location of utilities/services and access conditions and a risk assessment were considered to ensure student and staff site safety. Negotiation with the Head of School, Science and Engineering realised a small amount of funds that could be used to purchase materials for use within the construction project.

After these administrative procedures had been completed, the site was handed over to the student cohort.

## Management

We designated the Course Coordinator (staff member) as the Project Manager, ultimately responsible for the progression of the construction project. Each of the six students were assigned as Project Engineers and an initial planning meeting was conducted to identify project tasks, timelines and responsibilities. The activities for which students were responsible included:

1. Generation of Risk Assessment for work on site,
2. Management of visiting contractors,
3. Preparation of project timeline (Gantt chart),
4. Preparation of project budget,
5. Site investigation,
6. Structure design,

7. Procurement of materials,
8. Site preparation,
9. Wall construction, and
10. Post-construction stability analysis.

Students were responsible for acquiring access to the equipment, either via in-kind support or via a financial transaction, after approval from the Project Manager. Students were also responsible for negotiating with Facilities Management for site access via a locked boom-gate for supporting contractors.

Student learning was supported by weekly technical lectures and ongoing technical advice and assistance as requested by the student team throughout the semester.

## Assessment

Construction and analysis of the retaining wall as described above incorporated all assessment for the Geotechnical Engineering Course. The course ran over a period of 13 weeks, utilising a four hour `block' per week. Students were assessed on the following items:

1. Group Project Plan (Week 3) comprising project plan, budget, timeline, risk assessment, communications strategy etc.,
2. Individual client briefing (Week 13) comprising an oral presentation describing one aspect of the task in detail, and
3. Group final Project Report (Week 15) encapsulating all work that was completed in constructing and assessing the wall, including results from the geotechnical site investigation, design considerations, envisaged modes of failure etc.

Additionally, formative assessment tasks included a weekly verbal briefing from one of the Project Engineers to the Project Manager, reporting on project progress.

## Design and Construction

Prior to commencing design of the earth retaining structure, students were required to conduct a geotechnical assessment of the site, in accordance with AS 1726 (Geotechnical Site Investigations) or a similar document. Laboratory or field tests that were conducted independently by students to characterise site materials included:

1. Triaxial test,
2. Direct shear box test,
3. Drop Cone Penetrometer (DCP), and
4. Shear Vane.

Additionally, soil friction angle was estimated using the angle of repose, pre-existing Cone Penetration Test (CPT) data from the site was used to generate a shear strength profile with depth and the geological context of the site and a contemporary flooding assessment were undertaken for design considerations.

Upon completion of the site geotechnical assessment, students completed a preliminary design of the envisaged earth retaining structure shown in Figure 1.

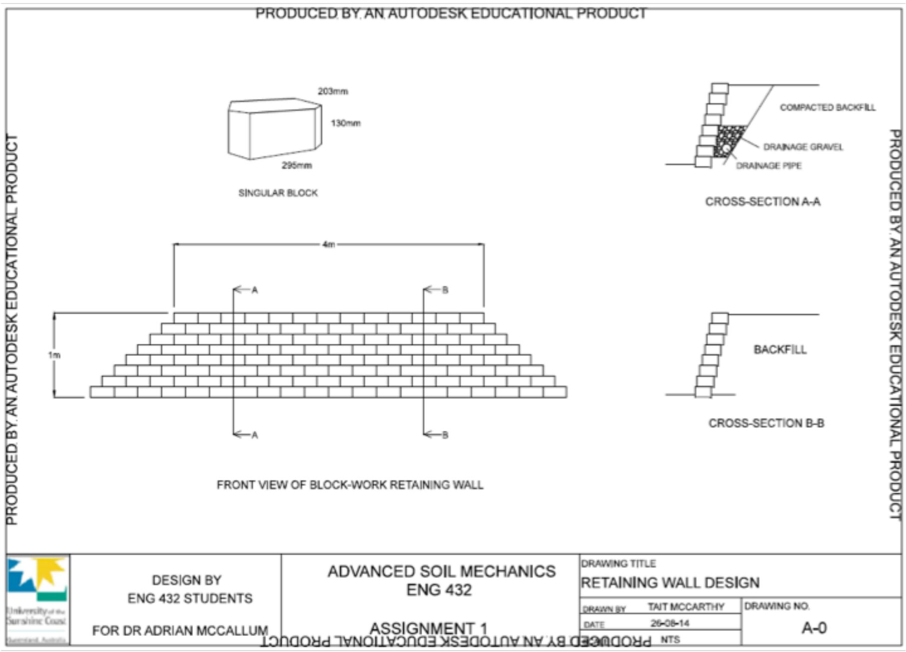


**Figure 1: Basic retaining wall design incorporating block detail, retained soil and drainage.**

Approximately 20 $m^3$ of donated fill was imported onsite and then distributed by excavator. This fill was then compacted in multiple 100 - 200 mm lifts using a vibratory compactor (Figure 2). Students were responsible for ensuring that sufficient compaction was achieved.


**Figure 2: Student compacting site of earth retaining structure using a vibratory compactor obtained via in-kind support.**

Remaining facets of the wall including a shallow strip foundation composed of road-base, drainage, particulate and blocks were then constructed over following weeks, enabling construction of the completed wall (Figure 3).

**Figure 3: Completed earth-retaining structure, approximately 1 m high.**

Drainage as per the preliminary design was only installed along half of the wall length to enable comparison between a drained and un-drained wall in subsequent stability assessments.

### Analysis

After completing construction of the wall, the students were tasked with assessing the stability of the wall, addressing both typical retaining wall failure mechanisms and specifically the potential for rotational slip failure. This mechanism was assessed using geotechnical engineering software of their choice using inputs derived from their preliminary site investigation and their construction methods.

It was originally envisaged that the students would predict failure loads and mechanisms for the wall and that the wall would then be failed. However, ultimately this was decided against, because of the cost and effort that has been invested in construction of the structure.

## Results and Discussion

The intention of this initiative was to enable students to manage a `real' engineering project over the course of a university semester, thereby exposing them not only to the particular technical facets under consideration (geotechnical engineering), but to the broader issues of engineering project management such as time and budget management, site safety, stakeholder management and project communication and reporting.

Was it successful?

The students were motivated by the project and took responsibility for learning necessary theory and practices to complete the project. In particular, they showed evidence of learning in the following topics, which were not taught in the traditional lecture/tutorial mode:

- Laboratory techniques for determining soil strength
- Theory of lateral earth pressures
- Design requirements for retaining walls
- Design theory for shallow & deep foundations
- Theory of slope failure
- Methods of ground improvement
- Impacts of earthquakes & liquefaction, and
- Critical State Soil Mechanics

Evidence of students' technical capacity was evident in the group report that was submitted for assessment at semester completion. Unfortunately, assessment of `real-world' skill attainment as desired in a `work ready' engineering graduate is more difficult. No post-graduation skill-assessment tools were used to assess such attainment, however, the implementation of such measures will be incorporated within future courses.

On this occasion, the acquisition of `doing' skills as desired via this initiative was simply assessed by examining the percentage of graduates employed after completion of this course. Of the six course attendees, five are now in full-time engineering employment.

The wall remains today as a structure that subsequent University of the Sunshine Coast Geotechnical Engineering students can use to practise their site investigation techniques and it serves as a local `real-world' structure that we continue to use to assess students' application of retaining wall stability, shallow foundations and slope stability theories. Because of the cost of constructing the wall, both real and in-kind, it is impractical to destroy the wall and therefore whilst soil samples are annually retrieved for testing purposes, we attempt to retain the integrity of the structure for future use.

# Conclusion

In this initiative discrete 'doing' tasks were not prescribed, but a complete semester-long geotechnical engineering construction project was allocated to a student group to enable them to creatively manage an engineering project from inception to completion.

This project enabled the students to learn geotechnical engineering skills and knowledge by 'doing' many things, beyond those that could have been discretely defined for the project. They were exposed to necessary 'real-world' construction and project management issues, such as site safety, contractor management and time and budgetary constraints.

Although the efficacy of this approach was difficult to assess, we qualitatively assess that by transferring project 'ownership' to them, their self-assertiveness and confidence was increased, preparing them to serve more effectively as graduate civil engineers.

## References


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