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The use of case studies to teaching Soil Mechanics

B. Courcelles[1], L. Forest[2], A. Kozanitis[2]
[1]Dept of Civil, Geological and Mining Engineering, Polytechnique Montreal
[2]Center for teaching and learning, Polytechnique Montréal, Polytechnique Montreal

Abstract: As case studies constitute the essence of civil engineering education, a detailed study of the Teton Dam disaster has been implemented in the course of Soil Mechanics given at Polytechnique Montreal. This case study aims to provide practical applications to theoretical lectures, and to sensitize the students to economic, social and ethical issues encountered on construction sites. Based on a course evaluation performed by the students, the paper intends to point out the advantages/disadvantages of the use of a single case study throughout the semester, the format of presentation and focuses on the perception of the case study by the students. A detailed examination of the course evaluation demonstrated the utility of case studies as an initiation to multidisciplinary problems and confirmed students' interest in real-life applications, particularly as regards ethical and economical aspects.

1 Introduction

Most of civil engineering courses are based on case studies to illustrate both design and engineering concepts (Chinowsky & Robinson, 1997), to provide a better understanding of interrelated aspects (Fitzgerald, 1995), and to prepare the students to multidisciplinary problems (Fruchter, 1994, Pohl et al., 1991). Moreover, such case studies constitute a source of active learning, shifting the emphasis from teacher-centered to more student-centered activities as outlined by Grant (1997). Based on these observations, a recent reorganization of the course of Soil Mechanics given at Polytechnique Montreal has been focused on the use of the Teton Dam disaster (1976) to support the lectures. A detailed description of the case study is provided in "Students as forensic engineers: an innovative approach to teaching soil mechanics" (Courcelles et al., 2013), and the present paper is focused on the perception of the case study by the students.

2 Case studies in the course of Soil Mechanics

2.1 Course in the curriculum

The course of Soil Mechanics is given in the third year among four composing the civil engineering curriculum. Deep understanding of notions such as stress, deformation, tensile, compressive and shear strength, principal stresses, and Mohr's circles is mandatory to succeed in this course. As an introduction to geotechnical engineering and a prerequisite to the course of foundations, this course has to be attractive for the students, particularly for those who do not intend to choose the geotechnical engineering specialty.

2.2 Case study principle

When preparing the course, we noticed that case studies deal often with a single element of a project, which is usually a technical aspect. Hence, these single-focus case studies do not illustrate the interdisciplinary problems encountered by engineers and provide an inadequate understanding of the civil engineering profession (Smith, 1990). For this reason, we choose a complex case study, bearing a multitude of technical and non-technical aspects, presented throughout the semester. As the course is an introduction to geotechnical engineering, the degree of complexity of the case study constituted the most important challenge in the preparation of the lectures. Indeed, the notions had to be complex enough to represent the reality, but also had to deal with the limited background of the students in this area.

Regarding its format, the case study was regularly treated at the end of the lectures during a 10 to 15 min presentation. As a support of the theory, the case study illustrates different technical notions such as soils classification, mechanical and hydraulic behaviors, compaction, shear strength, but "non-engineering maters", such as ethics, safety and security also constitute an important aspect of the case study. This multidisciplinary approach intends to present "real-world problems" as an initiation to real-life professional situations.

2.3 Case study of the Teton Dam

A detailed description of the case study is provided in "Students as forensic engineers: an innovative approach to teaching soil mechanics" (Courcelles et al., 2013), but a short summary of the disaster is provided hereafter. The Teton Dam was located in the south-east of Idaho, approximately 64 km northeast of Idaho Falls, and was designed for flood control, power generation, recreation and irrigation. This earth fill dam had a maximum height of 122 m, was 940 m long and was supporting a reservoir with a capacity of 333 Mm^3. Its construction started in June, 1972, and the first filling up began in October 3rd, 1975. Unfortunately, the dam failed during this first filling up on June 5, 1976, and caused the death of 14 people.

Two independent groups were constituted to investigate the failure: the Independent Panel (IP) and the Interior Review Group (IRG). The first one stated that two mechanisms could most likely explain the failure: seepage under the grout cap in unsealed joints of the rock, and hydraulic fracturing or differential settlement resulting in a piping failure. The second group concludes that the Teton Dam was constructed as specified and failed as a result of inadequate protection of the impervious core from internal erosion. The cracking of the core material was pointed out as the most probable mode of failure, but interface erosion at the contact between the core and the rock was mention as another probable mode.

3 Course and case study evaluation

3.1 Method of evaluation

In Polytechnique Montreal, all courses can be evaluated by the students at the end of each semester. As the Teton Dam case study was implemented for the first time in the fall 2012 semester, a special form was provided to the students as part of the evaluation of the course. The aim of this dedicated evaluation was to verify the acceptance of the case study and to verify if the objectives were attained. These objectives were (1) to present practical applications of theoretical lectures, and (2) to sensitize the students to economic, social and ethical issues encountered on construction sites.

The questionnaire provided to the students was composed of closed questions in which an assumption had to be ranked (From "I strongly agree" to "I strongly disagree"), but also contained some open-ended questions where students were invited to explain their views, propose some modifications and/or justify their choices. A total of 42 students participated to the evaluation. The questionnaire is given in Appendix of the present paper and the results are provided by themes in the next section.

3.2 Results of students' evaluations

When looking at the results of the course evaluation, 94% of the students thought appropriate to use a case study in the course of soil mechanics and 85% found the Teton Dam case interesting. This observation is consistent with our expectation and confirms that case studies increase student motivation and interest in a subject (Mustoe and Croft, 1999).

The format of presentation was a big challenge in the preparation of the course. Indeed, we wanted to dedicate a sufficient space to the case study, but we also had to keep enough time for the presentation of totally new subject matter for the students. To satisfy these two constrains, we chose to refer to the case study as much as possible and systematically during a 15 min presentation at the end of the lectures. This organization satisfied 75% of the students who found this organization adapted to the objectives. Nevertheless, several comments were done with respect to the position of the case studies presentations at the end of the lectures, arguing some problems of concentration and fatigue. These comments constitute a concern for succeeding semesters and, as suggested by several students, a position at the beginning of each lecture as a reminder of the previous one is under study.

The Teton Dam disaster was studied during the whole semester, even though punctual references to other real cases were done during the lectures. This single case study throughout the semester seems to please students, as 70% of them found that this single case can meet the objectives. This observation comforted our idea of using a complex case study to illustrate multidisciplinary problems, instead of dealing with separate examples devoted to every single problem. Finally, we noted that 39% of the students whished the course devoted more time to the case study, which confirms their interest to such real-life situations.

The themes and questions treated during the presentations of the case study were not given in advance to the students and this methodology seems to be the main disadvantage of the retained format. Indeed, 90% of the students found that it would have been preferable to formulate the questions before the lecture and 74% found appropriate to read expert opinions before discussing the case study in class. These responses confirmed and explained the lack of active participation during several case study presentations. As it is now documented that students can learn more effectively when actively involved in the learning process (Bonwell and Eison, 1991, Sivan et al., 2000), a special effort has to be done for the next semesters. Nevertheless, we should mention that 62% of the students thought that the questions during the presentation were clearly stated and allowed for a deep reflection.

Another challenge of the case study was the technical content. Indeed, the course of Soil Mechanics is just an introduction to geotechnics and is limited to soil description and classification, elementary soil behaviors and groundwater flows. Thus, the students are not able to design an earth dam at the end of the session, and the themes treated in the case study were consequently limited to general problems such as the choice of material, and its compaction. Despite the absence of design calculations, 93% of the students found that the technical content of the case study was sufficiently thorough.

As regards to their self-evaluation of knowledge, only 43% of the students were able to cite the major themes of the case study. Nevertheless, an open-ended question regarding the case study was asked in the final exam and the number of right responses demonstrated that they were severe when evaluating themselves.

Concerning the link with the course, 66% of the students thought that the case study helped them to better understand the theoretical aspects of the course and their applications, and 77% thought that the professor made sufficient connections between the course material and the case study. This observation confirmed the utility of case studies to connect the theory to real-life applications. Nevertheless, 87% of the students mentioned that exercises and homework assignments based on the case study would have

improved the links with the course content, which demonstrated the need to keep some classic teaching tools as usually used in their previous education.

Finally, 83 % of the students pointed out that the ethical aspects in relation to the case study could have been more extensively developed, and 69% of them had the same feeling regarding other technical, economic or human aspects, which confirmed their interest towards non-engineering aspects. Nonetheless, the case study succeeded in partially addressing these concerns as 80% of the students found that the Teton Dam disaster allowed them to recognize and better understand the scope of responsibilities of engineers.

4 Conclusion

The use of the Teton Dam disaster in the course of soil mechanics demonstrated the utility of case studies as an initiation to multidisciplinary problems and confirmed students' interest in such real-life applications, particularly as regards to ethical and economical aspects. The course evaluation also tended to show that case studies constitute a source of motivation for the students, but also pointed out that a good balance between the theoretical content and examples, as well as the format of presentation, remain a challenge. A particular attention should be devoted to the place of the case study in the course and, if placed at the end of a course, a more dynamic behavior should be adopted to catch students' attention. To conclude, the implementation of the case study seems to have been a success in spite of a few adaptations to be done for the next semester.

According to David and Wilcock's statement (2003), we should nevertheless keep in mind that lessons learned from an initial course offering should always be viewed with caution because the extra enthusiasm generated by an experimental offering. The success of future semesters resides in the involvement of students, particularly in the next course evaluations.

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APPENDIX

Table 1: Results of the course evaluation

FORMAT / CONTENT	- -	-	+	+ +	X	N	Agreement	Disagreement
The professor makes enough connections between the course material and the case study.	3	5	15	12	0	35	77%	23%
The case study helps us to better understand the theoretical aspects of the course and their applications.	2	10	14	9	0	35	66%	34%
The format of presentation (15 min at the end of the lecture) is adapted to the objectives.	4	5	17	10	0	36	75%	25%
The study of a single case throughout the session can meet the objectives.	3	8	14	12	0	37	70%	30%
The questions to students during the presentation are clearly stated and allow a deep reflection.	1	10	10	8	2	29	62%	38%
It would be preferable to formulate these questions before the theoretical lecture.	0	3	13	15	1	31	90%	10%
It would have been appropriate for students to read expert opinions on the failure before discussing the case study in class.	2	7	12	13	1	34	74%	26%
The course devotes sufficient space for the case study.	7	7	12	10	0	36	61%	39%
The selected case is interesting.	0	4	10	13	6	27	85%	15%
TECHNICAL CONTENT								
The technical content of the case study is sufficiently thorough.	1	1	16	12	1	30	93%	7%
Other technical, economic or human aspects could have been developed in the case study.	1	7	8	10	3	26	69%	31%
Exercises from the case study would have improved links with the course content.	2	2	7	19	3	30	87%	13%
I am able to cite the major themes of the case study.	7	9	7	5	2	28	43%	57%
RESPONSIBILITY/ETHICS								
The case study allows us to recognize and better understand the scope of responsibilities of engineers.	3	3	12	12	2	30	80%	20%
Ethical aspects connected to the case could have been more developed.	3	2	11	14	2	30	83%	17%
GENERAL ASPECT								
Generally speaking, do you think it is appropriate to use a case study in the course of soil mechanics?	0	2	10	19	3	31	94%	6%

Legend:

- ++ I strongly agree with the statement
- + I somewhat agree with the statement
- - I somewhat disagree with the statement
- -- I strongly disagree with the statement
- X I don’t know
- N number of answers