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# Innovative Techniques To Teach Civil Engineering Materials Laboratory

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## ABSTRACT
At Rowan University, civil engineering (CE) materials laboratory is taught in the junior year as a required course for all CE students. This is a two-credit course with a seventy-five minute class and two-hour forty-minute laboratory every week. The typical enrollment is around 20 to 25 students and no teaching assistants are permitted. The limited laboratory space and equipment does not provide sufficient hands-on experience for all the students. Several universities have a situation similar to that of Rowan University, and this makes teaching core courses like civil engineering materials very challenging. The author re-designed the course to ensure that every student actively participates in the laboratory and understands the material behavior. The number of topics covered in this class was divided into four major areas, timber, aggregates, asphalt concrete and cement concrete. The course was modified to address the concepts required to conduct laboratory experiments and its practical applications. The objectives of the laboratory experiments were well defined, however, the students determined the process. This was done based upon the information taught in statics, structural analysis, solid mechanics and this class. Each of the four groups had to get the process approved from the instructor before conducting the laboratory. The methodology was very effective and the information was organized and flowed better. The information covered was extensive because the rational behind developing standardized laboratory procedure had broad ranging applications on the civil engineering industry as a whole. This technique could be used in primarily teaching institutions that have limited space and equipment resources and do not allow multiple sections of laboratory. This paper, presents a detailed methodology and implementation strategy along with course outline, objectives of each of the four experiments and typical exam questions. Furthermore, the paper also includes the student feedback, and long-term evaluation and certain concerns that the instructor should be aware off when implementing this technique.

## Introduction
Civil engineering material course at Rowan University is a required 2- credit junior-level course that is offered in the fall semester. The course covers civil engineering materials, like wood, aggregates, cement concrete and asphalt concrete. The class of 20 to 25 students is divided into four groups. There are two time slots allocated for this course in a week, one hour-fifteen minute for lecture and two hour-forty minutes for the laboratory.

The civil engineering material laboratory at Rowan University houses equipment for specimen preparation and testing of various civil engineering materials, soils, aggregates, asphalt, cement, asphalt concrete and cement concrete. The space and equipment is adequate to safely and comfortably conduct laboratory experiments for only one group out of the four, a situation that is common for teaching institutions that do not allow teaching assistants and multiple sections in a week. This led to the following problems; (1) the students were not able to correlate the lecture courses with the laboratory and (2) it was difficult for students to understand the significance of laboratory and its application to civil engineering industry as a whole.

After teaching this course for three years, the author has developed a methodology, which optimizes the resources available and provides an opportunity for students to actively participate in the laboratories. The author tried this technique in the past two years and has proved to be successful. The purpose of this paper is to provide a detailed methodology and the implementation strategy along with certain pitfalls, which instructors should be aware off. The paper also includes feedback from the students and long-term evaluation of technique.

**Laboratory Set-up**

It was overwhelming when the author taught the class for the first time using the same course outline and syllabus as the ones in schools with multiple sections and teaching assistants. Even though the laboratory procedure and testing standards were emphasized, there was a need for a link between lectures and laboratories. This was mainly because many of the students did not have an opportunity to actively participate in the laboratory.

In the following year, the author did two modifications; the first modification was to change the focus of the class to the material covered in the laboratory. The information taught in the lectures classes emphasized the theory behind developing these laboratory procedures, its application in construction materials industry and influence on performance. The second modification was two split the laboratory into multiple sections, so that every student in a group had a chance to actively participate in the laboratory.

Each group provided steps to be taken in the laboratory for approval from the instructor before proceeding. The students were not only required to justify the process but explain the concepts involved in developing them. The author has successfully applied this methodology of open-ended laboratory modules in another class[1,2]. However, the syllabus covered was much less because more time was now devoted on ensuring each group actively participated in the laboratory. The lecture classes revolved around the laboratory allowing the author to cover the material in depth. This effort was complimented by evaluating the students on laboratory participation and reports. In addition, the exams included questions on concepts on specifications and their significance. The detail of the course and each laboratory module is explained in the following sections.

**Course Outline**

The course (Table 1) included four laboratories, wood or timber, aggregates, cement concrete and asphalt concrete. When there were no laboratories, a lecture class was conducted for the entire time slot of 160 minutes. The following sections explain the course on a topic basis. The textbook used in the class is titled, "Material for Civil and Construction Engineers" by Mamlouk

and Zaneiwski. 1999. This textbook was easy to teach and complimented the teaching style. It was also well received by the students. The laboratory procedure at the end of the textbook was very helpful in teaching the laboratory.

***Mechanical Properties and Variability***

In the first week of the course, the author explained and reviewed various mechanical properties, responses, modes and behavior of civil engineering materials. In addition, the various sources of variability were explained and its influence on mechanical properties and performance was emphasized. This was followed by the timber or wood module.

***Timber/Wood Module***

Timber was covered in this course beginning from second week (Table 1). The objectives of the timber laboratory was:

1. To determine the compressive strength, flexural strength, and flexural stiffness of various replicates of pine and oak.
2. To compare the mechanical properties and comment on the sources of variability and its influence on mechanical properties and performance.

The lectures were based on the above objectives of the laboratory. The class covered the basics of timber, its chemical composition, the various mechanical properties and its influence on performance. The two groups conducted the laboratory within one allotted time slot of 160 minutes. The other two groups during that time were assigned a series of problems based on the syllabus-covered to-date.

***Aggregates Module***

The aggregates topic was started at the end of the third week. The objectives of the aggregates laboratory was to determine:

1. The rodded unit weight of coarse aggregates (two replicates)
2. The dry and saturated surface dry bulk specific gravity of coarse aggregates (two replicates).
3. To determine the gradation of sand (two replicates).
4. Based on the data collected, the students had to determine the variability of the measured parameters and the influence of the measured parameters on the performance.

The lecture classes included sources of aggregates, physical and mechanical properties, gradation and its influence on aggregate structure and performance in asphalt and cement concrete. Various test procedures required to measure the aggregate properties and concepts involved in designing these experiments.

All groups could finish the laboratory within one period of 160 minutes. The laboratory was divided into two 80-minute slots; two groups conducted the laboratory in each 80-minute time slot. The students in the laboratory were always actively involved because at a given time they were assigned different experiments. The other two groups that were not conducting the laboratory solved review problems in class.

**First Exam**

The first exam included topics of timber and aggregates, the questions included concepts behind the testing procedures; a typical question; "Based on your experience, what steps or measures would you take in the laboratory to ensure accurate and precise measurements of flexural modulus of timber?" The first exam was typically a wake-up call for many students; they realized that the focus of the course was the laboratory. The sincerity and diligence of students in the laboratory improved considerably after the first exam.

**Table 1. Course outline.**

| Week | Day | Session | Class Topic |
|---|---|---|---|
| 1 | 1[1] | Class (160 minutes) | Mechanical Properties-Variability |
| | 2[2] | Class | Mechanical Properties-Variability |
| 2 | 1[1] | Class (160 minutes) | Timber/Wood |
| | 2[2] | Class | Timber/Wood |
| 3 | 1[1] | **Lab 1 (G: I and II)** | **Timber/Wood** |
| | 2[2] | Class | Aggregate |
| 4 | 1[1] | **Lab 1 (G: III and IV)** | **Timber/Wood** |
| | 2[2] | Class | Aggregate |
| 5 | 1[1] | Class (160 minutes) | Aggregates and Review of Exam I |
| | 2[2] | **Exam I Topic covered: Timber and aggregates** | |
| 6 | 1[1] | **Lab 2 (G: I, II, III and IV)** | **Aggregate** |
| | 2[2] | Class | Cement |
| 7 | 1[1] | Class (160 minutes) | Cement |
| | 2[2] | Class | PCC |
| 8 | 1[1] | **Lab 3 (G: III and IV)** | PCC |
| | 2[2] | Class | PCC |
| 9 | 1[1] | **Lab 3 (G: I and II)** | PCC |
| | 2[2] | Class | PCC |
| 10 | 1[1] | Class (160 minutes) | Asphalt and Review of Exam II |
| | 2[2] | **Exam II Topic covered: Portland Cement Concrete** | |
| 11 | 1[1] | Class (160 minutes) | Asphalt |
| | 2[2] | Class | Asphalt |
| 12 | 1[1] | **Lab 4 (G: I and II)** | Asphalt Concrete |
| | 2[2] | Class | Asphalt Concrete |
| 13 | 1[1] | **Lab 4 (G: III and IV)** | Asphalt Concrete |
| | 2[2] | Class | Asphalt Concrete |
| 14 | 1[1] | Presentations (G: I, II, III, IV) | |
| | 2[2] | Review for final exam | |
| Final Week | | **Final Exam: 2-hour Comprehensive** | |

[1]Two hours-forty minute (160 min) time slot; [2]One hour-fifteen minute (75 min) time slot

***Cement and Portland Cement Concrete (PCC) Module***

The topic of cement and PCC was started at the end of sixth week (Table 1). The class focused on chemical, physical and mechanical properties of cement and cement paste. The Portland

cement concrete topic focused on the mixture design, the trends between different parameters in the design. The objectives of the laboratory were:

1. To conduct a cement concrete mixture design using local aggregates and Type I cement for a 3000 psi concrete.
2. Redesign and prepare mixtures using water reducers.
3. Determine 7, 14 and 28-day strength of both the mixtures and a 14-day flexural strength of beams.
4. Comment on the slump, unit weight and the air content of both the mixtures.
5. Compare the compressive strengths, flexural strength of both the mixtures.
6. Compare compressive strength from non-destructive (rebound hammer) testing and destructive (cylinder) testing.

The second exam covered, aggregates, cement and Portland Cement Concrete. The laboratory procedures and concepts of measuring techniques and its application in civil engineering industry were tested in the exam.

***Asphalt and Asphalt Concrete Module***

The topic of asphalt and asphalt concrete was covered beginning of tenth week and continued until the second-to-last week of classes (Table 1). The topic covered in this class was physical, chemical, and mechanical properties of asphalt, asphalt emulsion and cutbacks, asphalt and asphalt concrete mixture design, Superpave versus Marshall mixture design and the influence of these properties on asphalt concrete and pavement performance. The laboratory included the following:

1. To evaluate properties of asphalt cement using Penetration test
2. Develop a Superpave asphalt concrete mixture design for a given traffic and environmental conditions, given the aggregate sources and type of binder. The laboratory set-up in the above two modules was similar to the Wood/Timber module.

***Paper, Presentation and Final Exam***

Each group was required to write a paper and make a 20-minute presentation on a civil engineering material not covered in the class. The guidelines for the paper were similar to that of the laboratory report. The students learnt about non-traditional civil engineering materials that are not typically covered in classes, some of these include, but not limited to, steel, epoxy bars, bamboos, polymers, and recycled materials. The presentations were done in the week before final week of class. The last class was a review before the final exam. The final exam was a comprehensive exam with emphasis on asphalt, aggregates and asphalt concrete.

***Grading***

Each laboratory report was 10% (for a total of 40%), all homework together was weighed 10%, the first and second exam together was 15%, the paper, presentation was weighed 15% and the final exam was weighed 20%. If the student missed a laboratory and only participated in report writing, the student was awarded only 75 percent of the report grade.

**Student Evaluation**

The instructor evaluation (Table 2) was very encouraging and positive. The laboratory evaluation clearly showed that 18 out of the 20 students felt that the laboratory complimented

well with the courses. The comments (Table 3) clearly showed that the students perceived the class positively. Even though the lecture class included primarily the concepts of the laboratory, none of the students felt that the syllabus covered was insufficient. Since all the students actively participate in the laboratory they could relate to the course material easily. The most critical comments (**in bold**) were that the workload was very extensive and not representative of a two-credit course. The author believes that the assigned workload is essential for the students to understand the subject and prepare them for the future classes, not only in civil engineering materials, but also in presentation and report writing. The author has discussed the issue of increasing the credit load with the department. The department is currently reviewing the author's request.

**Table 2. Student Evaluations on Instructor and Laboratory**

| | | Student Scores (20 students) | | | | |
|---|---|---|---|---|---|---|
| | **Question** | **1 (poor)** | **2** | **3** | **4** | **5 (excellent)** |
| | **Instructor** | | | | | |
| 1 | Was the professor enthusiastic about the subject? | | | | 2 | 18 |
| 2 | Did the professor stimulate thinking? | | | 3 | 6 | 11 |
| 4 | Did the professor require a high level of student performance? | | | | 1 | 19 |
| 5 | Did the professor encourage questions and comments during the class? | | | | 3 | 17 |
| 6 | Did the professor actively involve students in teaching and learning? | | | 3 | 10 | 7 |
| | **Laboratory** | | | | | |
| 7 | Do you think the material covered in the lecture and the lab was sufficient to perform and understand the labs that were conducted? | | | 2 | 13 | 5 |
| 8 | Do you think that the experiments in this lab helped your understanding of the material covered in the lecture portion of the course? | | | 1 | 14 | 5 |
| 9 | Do you think that the lab reports you prepared were adequate to explain the results of your experiment to practicing civil engineers? | | | 2 | 9 | 9 |

The feedback on the optimum use of laboratory time and space was very positive after the author modified the methodology. This also made teaching a lot easier for the author, because the laboratory material was the common connecting point. However, the author will continue to improvise its pedagogical techniques to provide a more conducive learning environment.

**Long Term Evaluation**

The civil engineering faculty teaching laboratory in other courses have commented that student reports were very organized and thorough. In addition, they also observed that this class laid a good foundation for classes like geotechnical and structural design. The author also taught the same group of students in the advanced class of Pavement Materials Design the following year.

The author observed that they had a significant retention of the material and understood pavement material behavior reasonably well.

**Table 3. Student Comments**

| No | Comments |
|---|---|
| 1. | Really enjoyed the class |
| 2. | I learned a lot & understood more material with him as the instructor than I probably would have if another professor taught the class. |
| 3. | In think Dr. Mehta's teaching style was extremely effective. |
| 4. | He was very thorough & demanded much from the students. He graded very strictly regarding the laboratory reports. The tests were very exhaustive but fairly graded. |
| 5. | Dr. Mehta did an excellent job & tests were challenging yet fair. I look forward to having him in other classes. |
| 6. | I think Dr. Mehta was an excellent teacher **but this course is only a two-credit class and he needs to calm down on the level of work.** |
| **7.** | **This is only a 2-credit course so the workload doesn't have to be so heavy.** |

**Scheduling Concerns**

The author found that this technique created a few unexpected problems, which were especially in scheduling. Initially, the groups that were not conducting the laboratory were under utilizing precious class time. After the first two laboratories the author decided to provide a review tutorial session. In these sessions, higher-level thinking and design problems were assigned. The students could work on those individually or as a group, but had to finish it in class and submit it to the instructor. This appeared to work well because it gave an opportunity for the instructor to encourage students to think on practical (design) problems in construction materials design industry, beyond the topics covered in lecture classes.

**Conclusions**

Based on the three classes, the author strongly believes that the new technique is beneficial for both the instructor and the students. The methodology has been very effective; the information is more organized and flows better. The information covered was extensive and very relevant to civil engineering applications. This can be attributed to the fact that the rational behind developing standardized laboratory procedure have broad ranging applications on the civil engineering industry as a whole.

This technique could be used in primarily teaching institutions that have limited space and equipment resources and that do not allow multiple sections of laboratory in a week. The author strongly believes that teaching is a learning process for the faculty. The author is continuously evolving and improvising the technique to ensure that the students stay current with the latest developments and have a fruitful learning environment.

**BIBLIOGRAPHICAL INFORMATION**

1. Mehta, Y. and Najafi, F **"**Teaching Methodology of Flexible Pavement Materials and Pavement Systems**",** Manuscript Accepted for Publication at Journal of SMET Education, 2003.

2. Mehta, Y. A, Orlins, J. and Lubelski, D. **"** Innovative Teaching Methods for Surveying and Engineering Graphics"**,** Proceedings of Mi-Atlantic Conference**,** Kean University, NJ 2003.

**BIOGRAPHICAL INFORMATION**

Dr. Mehta is an Assistant Professor at the Department of Civil and Environmental Engineering at Rowan University. Dr. Mehta has extensive experience in teaching pavement materials and pavement systems. Dr. Mehta has published several technical and educational papers in leading professional organizations.