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CRITERION 3-(b) OF 'ABET' FOR LABORATORY PRACTICES IN CIVIL ENGINEERING EDUCATION

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Abstract

The Accreditation Board for Engineering and Technology (ABET), 2003-2004 General Engineering Criteria for Basic Level Program Outcomes and Assessments, requires engineering programs to demonstrate that their graduates have an ability to design and conduct experiments, as well as to analyze and interpret data (ABET 2003-2004/Criterion-3b). The goal of this requirement is to deviate from "go-through-the-motions" style ASTM procedures, and allow a team of students to design, develop and conduct integrated laboratory experiments. The outcome of this effort is to move from the basic goal of an established test (e.g." a given material characteristic, or property) to devising new equipment and experimental procedures that will bring out student creativity and establish interest in research throughout their education in the future. This paper will document the recent approach used at Boise State University, the College of Engineering, in the Engineering Properties of Construction Materials Laboratory where teams of students design their own experiments to investigate the particle shape and surface texture analyses of coarse aggregates.

Keywords: ABET, Engineering Education, Enhancing Laboratory Testing Practices, Outcomes and Assessments, Criterion 3-(b).

1. Introduction

The quality of the performance of the students and graduates is one of the most important considerations in the evaluation of an engineering program. [1] The Accreditation Board for Engineering and Technology, Inc. (ABET) has established a 'General Criteria for Basic Level Programs', and the Criterion 3-(a) through (k), 'Program Outcomes and Assessments', outlines the requirements for engineering programs to demonstrate for their graduates. Specifically, the Criterion 3-(b), 'an ability to design and conduct experiments, as well as to analyze and interpret data,' addresses the assessment of the following skills of the students and graduates of the program:

- Recognition of the need for experimental work;
- Ability to plan and formulate an appropriate experimental program;

- Ability to setup, design, manage and conduct engineering tests and laboratory experiments;
- Capability to analyze and interpret data; and,
- Demonstration of the knowledge and experimental techniques with appropriate conclusions and recommendations.

During the Spring 2003 Semester, the above indicated program outcomes and assessment goals were evaluated for the 'Engineering Properties of Construction Materials Laboratory' Course (CE 341) in the Civil Engineering Department at Boise State University.[2] The junior and senior level civil engineering students were asked to perform a special laboratory test assignment. With this work, it is intended to allow students to develop more relevant cognitive structure for laboratory experiments, and give them just the basic goal of an established test (e.g. a given material property or characteristic), and ask them to devise their own experiment and equipment, rather than the kind of specialty apparatus that might be encountered in an engineering laboratory. They were also expected to report about the following 'critical thinking' steps during and upon completion of their experiment:

- What the students are investigating
- How the students are designing and developing the experimental laboratory testing procedure
- Why the students are interested in finding out about that given material property
- How the laboratory testing works
- How the experimental data are analyzed and interpreted
- How the entire testing process is being assessed
- What the requirements are for reporting
- How the conclusions and recommendations about the testing assignment are reached
- What the uses of this test are in Civil Engineering

2. The Chosen Topic For Material Property Or Characteristic

The chosen topic for this special laboratory test assignment and report was "Particle Shape and Surface Texture Analyses of Coarse Aggregates." The following information from Portland Cement Association [3] was provided to the students of four teams, a total of seventeen students, as a topic to be tested in the laboratory:

> "The particle shape and surface texture of an aggregate influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, elongated particles require more water to produce workable concrete than do smooth, rounded, compact aggregates. Hence, aggregate particles that are angular require more cement to maintain the same water-cement ratio. However, with satisfactory gradation, both crushed and noncrushed aggregates (of the same rock types) generally give essentially the same strength for the same cement factor. Angular or poorly graded aggregates can also be more difficult to pump.
>
> The bond between cement paste and a given aggregate generally increases as particles change form smooth and rounded to rough and angular. This increase in

bond is a consideration in selecting aggregates for concrete where flexural strength is important or where high compressive strength is needed.

Void contents of compacted coarse or fine aggregate can be used as an index of differences in the shape and texture of aggregates of the same grading. The mixing water and mortar requirement tends to increase as aggregate void content increases. Voids between aggregate particles increase with aggregate angularity.

Aggregates should be relatively free of flat and elongated particles. Flat and elongated aggregate particles should be avoided or at least limited to about 15% by weight of the total aggregate. This requirement is equally important for coarse and for crushed fine aggregate, since fine aggregate made by crushing stone often contains flat and elongated particles. Such aggregate particles require an increase in mixing water and thus may affect the strength of concrete, particularly in flexure, if water-cement ratio is not maintained." [3]

Students, as a group, were asked to design and conduct an experiment, and analyze and interpret test data for the above-defined topic. The reporting requirements included: proposal preparation and submitting within a week to receive an approval for the 'proceed to work'; and, a final report submitted for grading, prepared in accordance with the requirements of the 'Laboratory Report Preparation Guidelines'. [2]

3. Summaries and Assessment Of Student Performance

Team One

The premise of their test was based on the variation of volume of voids between aggregate particles with respect to shape and texture of the coarse aggregates. This property was stated to be increasing with aggregate angularity and roughness. The round/smooth aggregate data were compared with the angular/rough aggregate data to establish limiting boundaries. Testing procedures include use of the 'control volume' concept. Measurements were made for the volume of water required to fill the voids when the 'control volume' was filled with different aggregate types. An increase in the amount of water to fill the voids in the 'control volume' was expected to happen and indicate an increase in angularity and roughness. The data was compared with the results from the established database, which were previously obtained from aggregates with known particle shape and surface texture characteristics. A family of plots was generated to review and compare data graphically, and match with the curves known to represent a specified aggregate, which were used previously to establish a database.

The conclusions for this testing procedure were deemed inconclusive. The group determined that more 'control curves' were needed to establish a proper and conclusive correlation. The team members addressed in their report the 'critical thinking' steps and concluded that civil engineers should be able to measure and specify shape and texture of aggregates for a specific design to control the effects on abrasion, moisture content and void ratio.

Team Two

The students of this team researched the existing American Society for Testing Materials (ASTM) and American Association of State Highway and Transportation Officials (AASHTO) methods and standardized testing procedures used to investigate the angular and elongated particles. Students wanted to verify that there are no more than 15% by weight of elongated particles in the coarse aggregate sample, which will in turn regulate the water-cement ratio of concrete mixture.

By researching existing ASTM and AASHTO standards, they were able to design a new method and develop a flume to measure the surfacial characteristics of the aggregate. The non-elongated particles were removed from the test sample, leaving the elongated particles in the test chamber, by utilizing a mechanically operated rake. The amounts of elongated particles were calculated as a percentage of the initial sample mass. They have performed visual comparisons and correlated the test results to establish limiting guidelines in determining the acceptable samples by ensuring that there is less than 15% by weight elongated particles. The mechanical rake's effectiveness was assessed by visually comparing the test sample with the results of the test.

The team addressed the 'critical thinking' steps and concluded that more extensive testing with minor alterations to the mechanical rake was required to analyze the angularity of the aggregate particles, although the initial test results were encouraging.

Team Three

This team surmised that by measuring a reduction in flow rate of water through a given test sample shape and surface texture characteristics of aggregates could be determined. They have asserted that different shapes and sizes of aggregates will cause dissimilar friction loss and drag forces, which can be detected through the flow rate of the fluid stream. They have developed a flume and a testing procedure after researching and testing existing ASTM standard methods, ASTM D3398 and D4791. Measurements were taken of the flow of water through a flume with the aggregates placed in the channel of the flume. These readings were compared to a set of control readings that were obtained before testing the aggregate sample. The results were compared graphically to the readings of the control test data. By visually comparing the test sample and comparing the results of the test, the students were able to assess the effectiveness of the test procedure.

They determined the precision and bias factors to evaluate their decisions, and obtain accurate results with minimal percentage of error. They observed noticeable differences in the flow rates between rounded and angular aggregates and made an attempt to measure the flow rate more carefully. Unfortunately, elongated aggregates were undetectable using this method. They observed that angular particles allowed a faster flow rate than the rounded particles and attributed this to the presence of more void space, thus allowing fluid to flow more freely through the particles.

Throughout the experiment, they had problems with maintaining a constant flow rate. Recommendations were developed for improvement of the testing procedure and to develop a large control database. The team concluded that the determination of shape and texture of aggregates is very important for the civil engineering design and construction to control the effects on the performance of the paving mixtures.

Team Four

Students clearly defined their goals as follows: reduce amount of elongated and flat particles less than 15% by weight; measure the amount of rounded particles in comparison to the amount of angular particles in a given aggregate sample. Students developed a series of sieves that would be shaken only horizontally to separate the elongated particles. This would consider allowing the elongated/flat particles to rest on their side of greatest surface area and allow the smaller 'round' particles to pass through the sieves. A plow device was used to separate the round or angular particles from the elongated/flat particles.

To measure the amount of angular versus round aggregate a cylindrical water device was used. The amount of water needed to fill the voids in a 'control volume' was measured and then compared to data obtained from a control test.

The results of the 'Separation of Elongated Particles' and the 'Separation of Flat Particles by Plowing' tests were reported as a percentage of the sample mass. Test results for the determination of the amount of rounded and angular aggregates were reported as the volume of water required to fill the cylinder to the controlled line.

The test results were compared to the results obtained from a 'control test'. Students were able to determine if the test procedure was accurate and assess the percentage of error. This group tried to address the 'critical thinking' steps and omitted to conclude about the uses of their test in civil engineering.

4. Conclusions and Recommendations

When this special testing assignment was included in the syllabus of the course to satisfy the ABET Criteria, it was doubtful if the students were sufficiently instructed and ready to undertake this critical thinking involved self study and deliver a credible testing procedure and an assessment of their work satisfactorily.

Students, working in teams, demonstrated that the author's doubts were not warranted. Students emphasized the importance of a collaborative teamwork for the success of their special laboratory testing design project. They have proved that the ABET 2000 Criteria (specifically Criterion 3-(b)) for program outcomes and assessments are appropriate and deliverable. Students were able to design and conduct their own integrated laboratory experiments, develop new testing apparatus and methods, make necessary modifications and revisions as required, and critically analyze and correlate data with interpretation of test results.

Students were given an opportunity to bring out their creativity, and establish interest in research and investigation techniques throughout their education for their self-development in the future.

One of the goals of the ABET 2000 Criteria for program outcomes and assessments is to provide students an opportunity to become critical thinkers. Critical thinking is self-directed, self-disciplined, self-monitored, and self-corrective thinking. [4] It entails effective communication and problem solving abilities, and a commitment to overcome egocentrism and sociocentrism. [4] Critical thinking is the exercise of reasoning and application of elements of thought logically, clearly, accurately with relevance, precision, depth and breadth. It is recommended that instructors should provide guidance to the students prior to the assignments of the experiments in relation to the elements of critical thinking. It is suggested that instructors may consider providing the mini-book titled " The Miniature Guide to Critical Thinking Concepts and Tools" [4] as a supplement to the textbooks. This should help to improve students' learning in the content area. The ultimate goal is to move students from 'unreflective thinker stage' to 'challenged thinker stage'; so that, they are prepared to become comfortable as 'beginning and/or practicing thinkers' throughout their professional and personal life.

5. References

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[2] CE 340/341, 2003, "CE 340/CE 341, Engineering Properties of Construction Materials and Laboratory", College of Engineering, Civil Engineering Department, Course Syllabus, Spring Semester 2003, pp. 11-13.

[3] PCA 1994, "Design and Construction of Concrete Mixtures," Portland Cement Association (PCA), 13th Edition, 1994, pp. 36.

[4] Paul, R. and Elder, L., 2001, "The Miniature Guide Book to Critical Thinking Concepts and Tools," The Foundation for Critical Thinking, ISBN 0-944583-10-5, pp.21.

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