Teaching a Civil Engineering Materials Class

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Abstract

The objective of this study is to present the experience of teaching a Civil Engineering Materials Class. This course is designed for junior and senior undergraduate students. This class covers different materials such as steel, aluminum, various alloys, aggregate, portland cement, portland cement concrete, asphalt, asphalt mixtures, and wood. In the class lectures, the basic concept of asphalt specification, mechanical properties and test methods are discussed. The sustainability concept of the materials is also integrated in lectures. Homework is assigned to students so that they have the chance to bridge the concepts and practical problems. The most important parts of the class are the hands-on experiments in laboratory, and the sustainable material concepts in lectures. The relationship between students' homework, exams, labs, and total grade are compared. Three semesters' results are analyzed to improve the curriculum.

Introduction

The Civil Engineering Materials class (CE 3101) is designed for junior and senior undergraduate students. This class covers different materials such as steel, aluminum, various alloys, aggregate, portland cement, portland cement concrete, asphalt, asphalt mixture, and wood. These materials are used in civil engineering structures. The objectives of this course are: 1) to develop fundamental knowledge of materials, including material science concepts (mechanical and nonmechanical properties, material variability, and laboratory measuring devices) and the nature of materials (bonding, metallic materials, inorganic solids, and organic solids); 2) to understand aggregate production, properties, and utilization in civil engineering structures; 3) to learn how portland cement is produced, its composition, and the nature of hydration products, and how microstructures influence the behavior of the material when combined with aggregates to make portland cement concrete; 4) to understand how asphalt cement and hot-mix asphalt concrete is produced, tested, and constructed; 5) to develop a basic knowledge of steel production, treatments, and alloys, and how this influences the behavior of structural steel used in civil engineering structures, and; 6) to develop a basic knowledge of wood and wood products, how they are produced, tested, and utilized in civil engineering structures.

In this course, students are offered lectures which cover a basic knowledge of measurements, steel, aluminum, aggregate, portland cement, portland cement concrete, asphalt, asphalt mixture, and wood. These materials are used in civil engineering structures. A basic understanding of material behavior can significantly increase innovation and cost savings. Homework is assigned to students to allow them to practice class concepts. The most important parts of the class are the lab experiments (and field trips when possible) and the sustainable material concepts. Exams are given to assess the outcome of the lecture and homework. The entire course plan is illustrated in Figure 1.

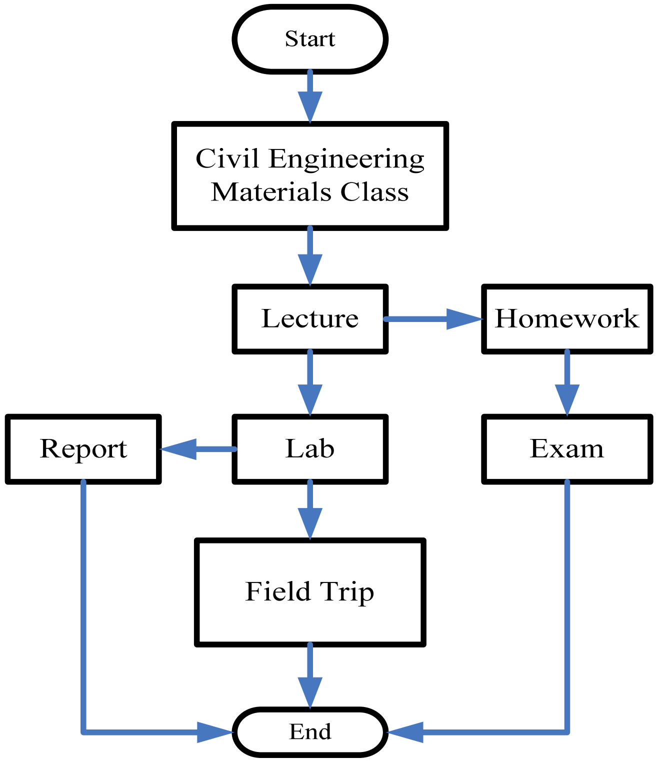

Figure 1: Course plan illustration

Objectives

The first objective of this paper is to present the experience of teaching the Civil Engineering Material class, which deals with fundamental knowledge of materials and the nature of materials. A basic understanding of materials science is required for civil engineers to work effectively. The materials (e.g., metals, aggregates, cement, cement concrete, asphalt, asphalt concrete and wood) are used in civil engineering structures and the understanding of material behavior will greatly reduce the misuse of these materials. The second objective of this paper is to show a relationship between labs, homework, exams and the total grade of three semesters of this class. This relationship could help to improve the lectures and laboratory classes.

Lectures on the course materials

The introduction to civil engineering materials includes information on the basic mechanical properties of materials and environmental impacts, engineering application, design and construction. In this course, sustainability of civil engineering materials such as reuse of polymer and rubber in asphalt pavements and warm mix asphalt technology are introduced. The following topics were included in lecture classes (Mamlouk and Zaniewski (2005)):

- civil engineering materials introduction and simple mechanical behavior
- advanced mechanical behaviors and the nature of materials
- introductions to steel and aluminum

- introductions to aggregate
- aggregate gradations
- portland cement
- portland cement concrete
- advanced portland cement concrete
- introductions to asphalt binder, asphalt binder- superpave
- mixture design
- introductions of recycled asphalt and aggregate in mixture design
- asphalt concrete testing
- composites, wood, and recycled materials

Experimental Design of Class

The laboratory tests are discussed in this paper as a part of the Civil Engineering Materials course. In order for the students to get the most benefit from the laboratory sessions, tests have been coordinated with the topics covered in the lectures. The laboratory summarizes the main component of each test method corresponding with the American Society for Testing and Materials (ASTM) or American Association of State Highway Transportation Officials (AASTHO) methods (Mamlouk and Zaniewski, 2005).

The lab is basically focused on promoting improvement in the sustainability of design, construction and maintenance of the built and natural environment. The students have received lab works in the concepts of sustainability. The entire laboratory plan is illustrated in Figure 2. Laboratory is basically focused in measurements, metals, aggregates, cement and concrete, asphalt and asphalt concrete and wood parts. The details of each part are described below.

A. Measurement

The first laboratory assignment 'Measurement' is focused on the importance of making precise and accurate measurements in the laboratory. Accuracy is described as the difference between the measured value and the actual value. Precision is the ability to reproduce accurate measurements. The proper use of measuring devices is essential in the laboratory in order to collect meaningful data.

B. Metals

During the second laboratory assignment, there were three experiments performed. Each of these three tests demonstrated a certain aspect of materials. The tests that were performed were: 1) Tension Tests; 2) Dynamic Loading Tests, and; 3) Compression Tests.

The first test, Tension Test, was performed to discover the stress-strain relationship properties and strength characteristics of three materials. Steel, aluminum, and brass were the materials tested. Each specimen was fixed to a machine with a crank and loaded. By measuring the lengths, diameters, and load applied the students were able to calculate modulus of elasticity, toughness and the percent of elongation. These calculations tell the strengths and what kind of stress-strain relationships each of the materials possess.

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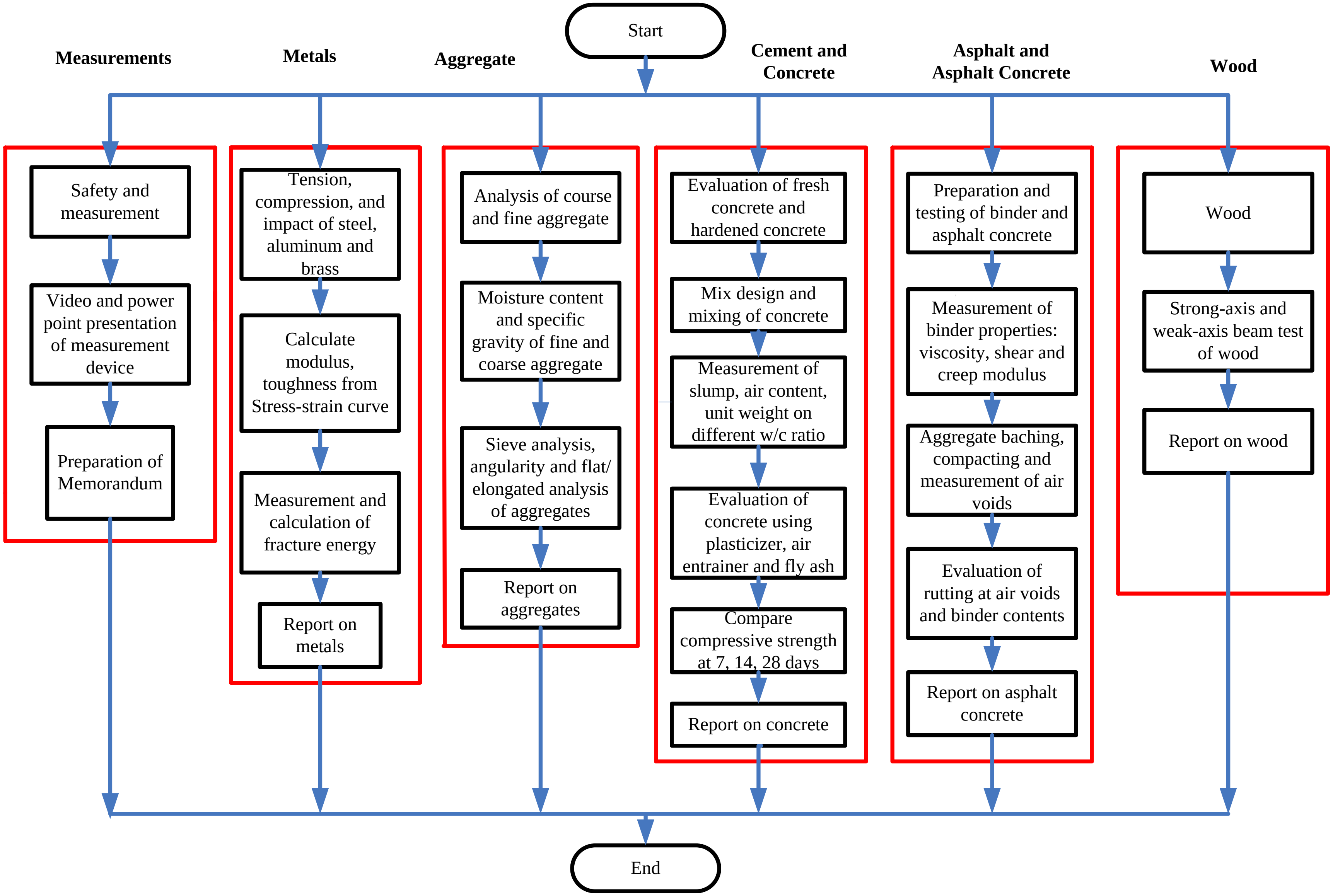

Figure 2: Laboratory plan illustration

For the Dynamic Loading Test, three materials (i.e., steel, aluminum, and brass) were tested. This second test determined how each material's properties can be affected by strain and the amount of energy required to fracture a specimen under specific loading. The specimen was loaded onto a pendulum and released to be fractured. The energy required was read from the scale.

The last test, Compression Test, demonstrated the compressive strength and stiffness properties of the three materials. Measurements of the original length and diameter were taken before the specimen was compressed, and the results observed. Depending on whether the material was brittle or ductile determined the deformation and how strong the material was.

C. Aggregate

The properties of aggregates were studied in this lab. Aggregates need to be monitored to ensure the quality of Portland cement concrete and asphalt concrete. A good characterization of the physical properties of aggregates is an important part of the mix design process. The specific gravity and absorption of fine and course aggregate, moisture content of aggregates, sieve analysis of fine and coarse aggregates, loss by wash, coarse aggregate angularity, and fine aggregate angularity were tested.

Properties of aggregates, such as specific gravity and percent of absorption as well as moisture content, play key roles in the design and mixing of Portland cement concrete and asphalt concrete. These properties affect everything from the plasticity of cement concrete to the ultimate strength of the material. Minor deficiencies in these properties can have drastic effects on the function of the materials in which the aggregates are used. Sieve analysis is a useful tool for finding if the aggregate that is being used will hold up the structure and not collapse. It is designed in such a way that small aggregate fills the gaps between large aggregate pieces so that there are less air voids in the structure. The angularity of the aggregate is an important property due to the fact that it helps the aggregate stability. The bad part of angularity is that it also makes it harder to fill the same volume because of the difficulty of sliding the aggregates across each other. For Portland cement concrete, a more rounded aggregate is preferred to improve the workability of fresh concrete. In asphalt concrete a more angular aggregate is preferred in order to increase the stability and to reduce rutting. The flat and elongated aggregates are also undesirable for asphalt concrete due to the fact that they are difficult to compact and easy to break.

D. Concrete

Concrete is formed through a series of chemical reactions between cement, water, aggregate, and admixtures. Each of these materials directly affects the ultimate strength of the concrete. In this lab, the effects of various water cement ratios, admixtures, entrained air in hardened concrete were discussed. Properties such as slump, air content, unit weight and compressive strength were determined for different water cement ratios. Similarly properties of cement concrete were determined using three different admixtures such as super plasticizer, air entertainer and fly ash. Entrained air of hardened concrete was determined by image analysis as well as optical microscope. Entrained air is important to provide adequate freeze-thaw durability.

Digital analysis of concrete images were done to measure air void content. This test was able to quickly and accurately determine the amount of air voids in hardened concrete. This not only allows for a true determination of freeze-thaw durability but it can be used to verify new entrained air tests for fresh concrete (PCA, 2002).

E. Asphalt Concrete

Asphalt is one of the most important construction materials. It accounts for over 94% of roads within the U.S. Therefore accurate predictions of performance and behavior are desired. The experiments that were conducted in the Bituminous Materials Lab dealt with the mixing process and the testing process of asphalt concrete. It is important to understand how to properly choose an asphalt binder depending upon the location of where the asphalt concrete is placed. The tests were conducted in order to have a better understanding of the asphalt pavement materials. The asphalt binder properties such as viscosity, shear modulus, and creep stiffness were determined during the test. Rotational viscometer was used to determine viscosity. The dynamic shear rheometer was used to determine the shear stiffness of the binder. This test can evaluate both rutting potential and fatigue potential for asphalt. The bending beam rheometer was used to determine creep stiffness of the asphalt (Asphalt Institute, 2003).

The asphalt concrete mix was prepared by properly batching the aggregate. The hot mix asphalt was formed by mixing asphalt binder and aggregates. The asphalt mixture was compacted by a gyratory compactor to get the desired air voids (e.g., 4%). The proper mixing and compaction of hot mix asphalt is important because it allows for accurate testing of the performance properties of asphalt concrete. The theoretical maximum specific gravity and bulk specific gravity were determined. Then the Voids in the Mineral Aggregates (VMA), the Voids in Total Mix (VTM, or air void), and the Void Filled with Asphalt (VFA) are computed according to the volumetric relationship. These steps will help in choosing the optimum binder content for a specific application. The specimens were tested in the Asphalt Pavement Analyzer (APA) so that the samples could experience the effects of repeated loading force (in order to simulate the traffic condition) (Asphalt Institute, 2001) .

F. Wood

Residential and small commercial buildings are commonly constructed of wood. This lab focused on strong-axis and weak-axis bending of wood construction members and compared the strong-axis bending to a similar beam made of steel.

Comparison of the Grades

The final grade of the Civil Engineering Materials course was based on the homework grades, exam grades and lab grades. Students were required to submit homework on each lecture topic. Two exams were taken during the course. The exams contained topics taught during the lectures, students' reading and understanding of the subject outside the classroom and the laboratory exercises. The exam depended upon the home work and lab performance. Those who performed creditably in the homework and lab exercises were naturally the top scorers in the exams. The lab grade was based on lab reports, quizzes and attendance. The total (final) grade was a combination of 45% exam, 25% homework, and 30% lab. Figure 3 shows the comparison between the total (final) grades, exam grades, homework grades, and lab grades of Spring 2006, Fall 2006 and Spring 2007 (all taught by the first tutor). Fall 2006 has a lower average total grade and Spring 2007 has a higher average total grade. The standard deviations are shown in the figure. Figures 4, 5 and 6 shows the comparison between the total (final) grades and lab grades of Spring 2006, Fall 2006, and Spring 2007. Figure 4 shows the comparison between the total (final) grade and homework grade. Figure 5 shows the comparison between the total (final) grade and exam grade. Figure 6 shows the comparison between the total (final) grade and lab grade. From the data showing in the three figures, it appears that the total grade is highly correlated to the homework grade, where the R-square ranges 0.6034 to 0.7607. The exam grade has a very high correlation with the total grade, where the R-square ranges 0.7463 to 0.8414. The lab grade has lower R-square. The reason is due to the relative good grade for al the students. The correlation of total grade with homework grade, exam grade and lab grade help to improve teaching methods and curriculum.

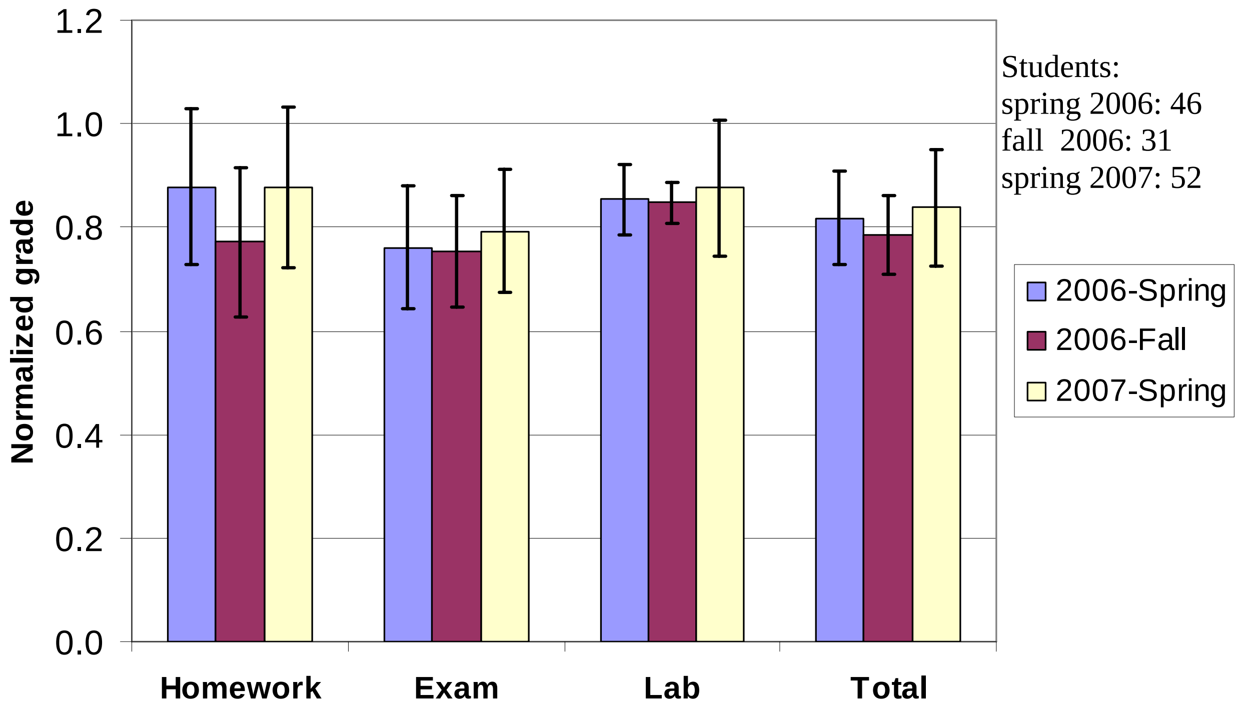

Figure 3: The comparison between the total (final) grade, exam grade, homework grade, and lab grade of spring 2006, fall 2006 and spring 2007

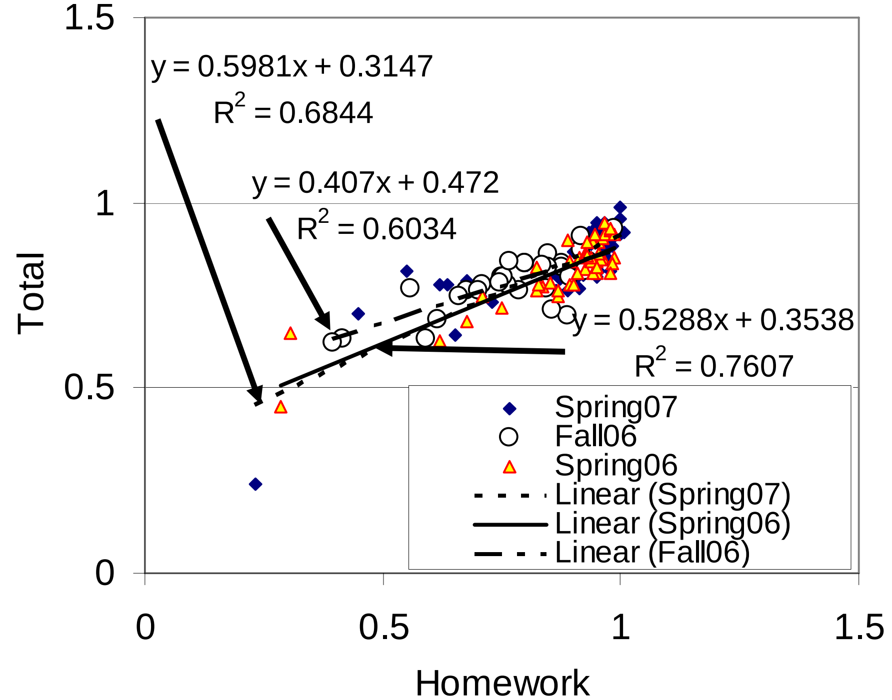

Figure 4: The comparison between the total (final) grade and homework grade of 2006 spring, 2006 fall and 2007 spring

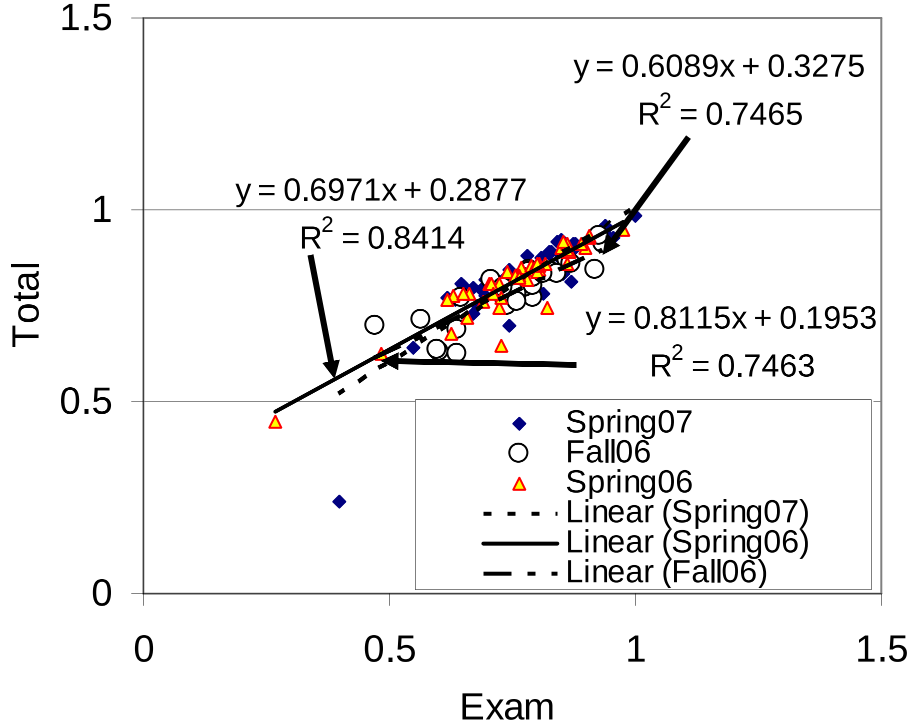

Figure 5: The comparison between the total (final) grade and exam grade of 2006 spring, 2006 fall and 2007 spring

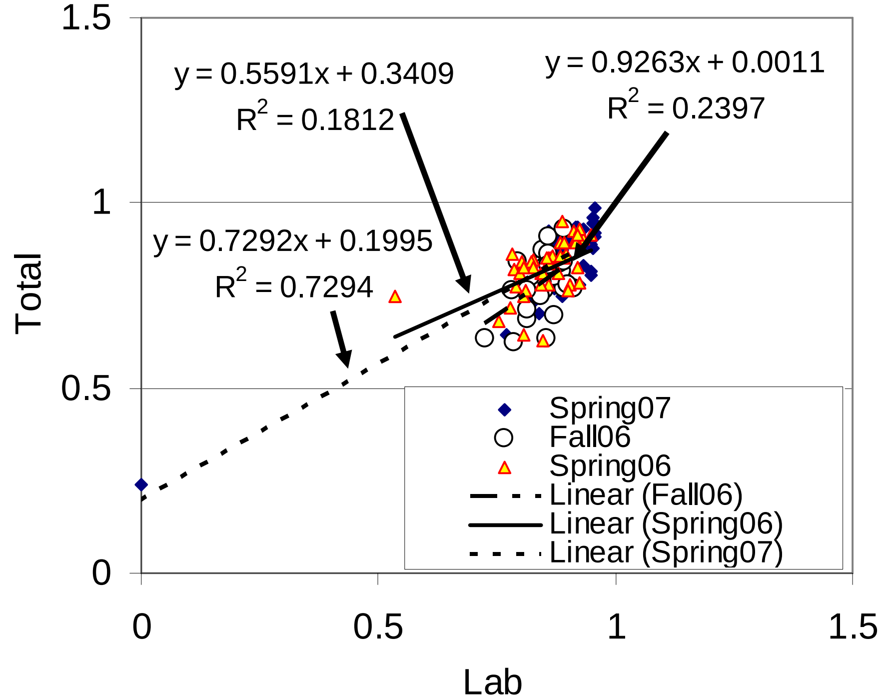

Figure 6: The comparison between the total (final) grade and lab grade of 2006 spring, 2006 fall and 2007 spring

Summary and Conclusion

The main objectives of this paper are to present the experiences of teaching the Civil Engineering Materials class to undergraduate students. This class covers different materials such as steel, aluminum, various alloys, aggregate, portland cement, portland cement concrete, asphalt, asphalt mixtures, and wood. In the lectures, the basic concept of the mechanical properties, test methods, and engineering applications are discussed. Homework and exams were assigned to students. The most important parts of the class are the hands-on experiments in laboratory and the sustainable material concept in lectures. The relationship between students' homework, exams, labs, and total grade are compared as the second objective.

References

Asphalt Institute (2003), *Performance Graded Asphalt Binder Specification and Testing*, 3rd Edition, Asphalt Institute, Lexington, Kentucky.

Asphalt Institute (2001), *Superpave Mix Design*, Asphalt Institute, 3rd Edition, Lexington, Kentucky.

Mamlouk, M. S., and Zaniewski, J. P. (2005). *Materials for Civil and Construction Engineers*, Addison Wesley Longman, Inc

PCA (2002), *Design and Control of Concrete Mixtures*, Portland Cement Association, Skokie, Illinois.

Biographies

ZHANPING YOU received his Ph.D. from University of Illinois at Urbana-Champaign in Civil Engineering. Dr. You is the honored Donald and Rose Ann Tomasini Assistant Professor of Transportation Engineering of the Department of Civil and Environmental Engineering at the Michigan Technological University, and serves as the Associate Director of the Transportation Materials Research Center. Dr. You taught graduate and undergraduate courses in construction materials, pavement engineering, numerical modeling, transportation engineering, and bituminous materials and mix design at Texas A&M University -Kingsville. He teaches Civil Engineering Materials and Advanced Bituminous Materials at Michigan Tech. Dr. You's research interests include asphalt materials characterization and mix design, performance evaluation and rehabilitation, with an emphasis on micromechanical modeling of asphalt mixture and numerical analysis of pavement structures. Dr. You's research work has been funded by the NSF, FHWA, EPA, TxDOT, and MDOT.

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