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Integrating Concrete Testing Certifications into a University Course Curriculum

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Construction materials courses at a university commonly cover sampling and testing concrete. The knowledge and skills developed in both the classroom and laboratory sessions can be further capitalized by incorporating a concrete certification into this course curriculum, which will further validate their knowledge gained and enhance the resume of the students. However, this integration of the entire certification process can be challenging for an instructor. This paper discusses common delivery methods for the instructional training and an overview of the American Concrete Institute (ACI) certification process. This work provides insights of 445 students over a 13 year period for the pass/fail rates of both the written and performance exams for the ACI Concrete Field Testing Technician–Grade I certification. These findings provide valuable ideas for developing a certification curriculum and even improving a current certification curriculum.

Keywords: Concrete testing, certifications, ACI field testing technician grade I, training; engineering education; student certifications

Introduction

Only to be surpassed by water, concrete is the second most consumable material on planet Earth (Gagg 2014). Concrete is the foundation of the US infrastructure. Concrete materials testing plays a critical role in ensuring the concrete structures meet the standards for the project (Taylor, et al. 2019; Lammond and Pielert, 2006; Snell, 2010). Quality control and assurance testing of fresh concrete provide information about the concrete mixture being placed and this information with the specifications from the engineer is commonly used to accept or reject a truckload of concrete (Wilson and Tennis, 2021). Therefore, it is important to conduct the testing in a proficient and timely manner. Both the ASTM C94 "The Standard Specification for Ready-Mixed Concrete" and ACI 301 "Specification for Structural Concrete" require testing freshly mixed concrete before it is incorporated into any infrastructure project (Snell, 2005). Both provide similar language where these standards require concrete testing for compliance with project specifications to be conducted by a certified ACI Concrete Testing Technician, or equivalent. This distinction of "ACI Concrete Testing Technician, or equivalent" is important because while the ACI organization offers this certification worldwide through prequalified sponsor groups (Nehasil 2023), this ACI certification may not be sufficient in countries using different standards such as EN standards. To resolve this issue, ACI has been collaborating with groups such as the Institute of Concrete Technology (ICT) in the UK to develop and offer an ACI certification based on EN standards (Lewis and Trout 2020).

ACI Concrete Field Testing Technician–Grade I

Starting in 1983, the first and most popular ACI certification has been ACI Concrete Field Testing Technician–Grade I certification exam, which is sometimes referred to-as Field Grade I (Snell 2005). Currently, ACI offers more than 30 certifications focusing on a wide range of concrete industry wide testing procedures and practices on a worldwide platform (Morrison 2023). These certifications are offered based on collaboration between the ACI certifications program and ACI approved local sponsoring groups. To become certified as ACI Concrete Field Testing Technician–Grade I, American Concrete Institute (ACI) requires an individual to demonstrate the knowledge and skills related to the seven standardized tests as shown in Table 1. Both the written exam and the performance exam have been developed by ACI. This consists of both a written exam and a performance examination with a strong emphasis on ASTM standards. The written exam is closed book and consists of 55 questions. The performance exam requires the individual to perform these seven procedures, with the optional exception of sampling which can be alternatively evaluated verbally. ACI will grant certification only to those applicants who pass the ACI written examination and successfully complete the ACI performance examination. This certification is valid for a period of five years from the date of successfully completing all requirements and then recertification requires successfully completing both the written and performance examinations again (ACI Certifications Committee, 2022; Snell, 2005)

Table 1. Concrete Sampling and Testing Procedures for ACI Field Grade

Procedure	ASTM	Description
Sampling	C172	Collecting a specimen of fresh concrete
Making & Curing Strength Samples	C31	Making strength samples of fresh concrete
Slump	C143	Evaluating the consistency of fresh concrete
Temperature	C1064	Measuring the temperature of fresh concrete
Unit Weight	C138	Determining the density of fresh concrete
Air Pressure Method	C231	Measuring the air concrete of fresh concrete
Air Volumetric Method	C173	Measuring the air content of fresh concrete

Classroom and Laboratory Instruction of Certification

To emphasize this certification, some engineering schools have even gone as far as requiring students to become certified through the American Concrete Institute (ACI) with the ACI Concrete Field Testing Technician–Grade I certification exam. This certification is usually offered within the construction materials course of Civil and Construction Engineering or other related bachelor's degrees. The ACI Field Grade I certification has been incorporated in different ways into the student's grade for the course such as part of the laboratory grade, percentage of the overall grade, final examination, or even the criteria of passing the course. The delivery of this course type is traditionally composed of a.) lecture component and b.) laboratory component. While the lecture component introduces the concrete engineering concepts and fundamentals behind testing, the laboratory component creates an avenue for the hands-on application of knowledge (Snell, 2008). Figure 1 shows students performing the procedures of Sampling in Figure 1(a), Slump Test in Figure 1(b), and making a 4 in. x 8 in. concrete strength cylinder in Figure 1(c).

The lecture part of the course is typically located in a classroom (Morrison, 2024). The content of the lectures focuses on fundamental concepts of concrete materials, mixture design, quality testing, and general concrete construction practices (Snell, 2008). Teaching these engineering concepts behind concrete materials testing are commonly delivered using multiple methods as outlined in Table 2 (Morrison, 2024; Snell, 2008). The lectures are typically presented verbally using slideshow presentations or even writing notes on a marker board. Other supporting materials such as handouts, lecture notes, videos, books, standards, etc. are used to help further aid the lectures. Case studies from the experiences of the instructor emphasize engineering concepts by transforming the conception into real-world scenarios. This can all lead to in-class question and answer (Q &A) discussions, where this discussion helps highlight areas of confusion. Sometimes an informative search for the answer within the literature, usually a standard, can also help provide insight. Many times, assignments using a study guide, workbook, homework, quizzes, etc. are used to provide a deep understanding of the topic and highlight the key items to know for the certification. Unfortunately, too much theory and not enough application can also provide a learning disconnect.

(a) (b) (c)

Figure 1. (a) sample of fresh concrete being taken, (b) the Slump Test being conducted, (c) and strength cylinder being molded by Oklahoma State University students.

Table 2. Summary of Common Conceptual Teaching Techniques

Teaching Method	**Description**
Lecture	Conceptual delivery of topics
Case Studies	Discussing possible real-life scenarios
Review of Standard	Reading part or all the standard
Video	Watching a video on the topic
In-Class Q & A Discussion	Exchange of questions and answers among the group
Information Search	Having participants search for information in the literature
Assignments	Coursework of homework, quizzes, etc.

The laboratory component of the course provides hands-on learning applications to reinforce basic engineering concepts. Unlike the lecture component, there is less structure with the laboratory component. Various strategies within this laboratory component have been incorporated depending on the laboratory facilities, equipment, and number of students. This is especially true for minimal laboratory space, limited equipment, and large student size can provide challenges for effective teaching (Snell 2008). Traditionally, the laboratory sessions occur in a physical laboratory room with the testing equipment, but some have offered laboratory sessions in a parking lot or vacant field, possibly next to the building where the lecture room is located. The equipment for the specific laboratory sessions may be set up before the students arrive, or the students will be given instruction to set up the equipment themselves. This equipment may only be enough for a limited number of students to conduct the testing at a time. In addition, a laboratory manual is usually developed to provide a curriculum through different laboratory lessons, but the curriculum can fluctuate greatly depending on the facilities, equipment, and number of students.

During each laboratory session, the instructor and/or teaching assistant (TA) provides guidance and training. The term "training" refers to the process of learning how to physically perform a test method. Within this training, many tools can be incorporated to help the attendees learn. Table 3 provides a list of training methods with descriptions. Laboratory exercises should be designed to offer the student an adequate opportunity to perform the concrete testing procedure. At the beginning of the laboratory session or the start of a new testing procedure, showing a video can be a great refresher for students to recall the information presented during the lecture component of the course. Live demonstrations can help assist complicated test procedures or highlight difficult aspects of possibly using the testing apparatus. Breaking the students into small groups can be an effective means of assisting one another to complete the testing. Sometimes students prefer the self-practice method where the individual student spends time after the laboratory session period practicing by oneself.

Table 3. Summary of Common Performance Training Methods

Teaching Method	**Description**
Laboratory Exercises	Developing skills during the laboratory time
Live Demonstration	Developing skills through live performance
Video Demonstration	Developing skills through video
Group Participation	Developing skills through group involvement
Self-Practice	Developing skills by oneself

Challenges with Passing this Certification

Becoming certified as ACI Concrete Field Testing Technician–Grade I is an achievement that enhances credentials on a resume and provides real value to a potential employer (Snell, 2008). Yet, students struggle to pass this certification and other related certifications (Morrison, 2024). The ACI certifications committee has even gone as far as developing a workbook to assist people studying for the certification (ACI Certifications Committee, 2022). Still, the challenges of becoming certified can be associated with many factors including: 1.) curriculum developed by the instructor, 2.) learning process of the student, 3.) laboratory facilities and equipment, and 4.) number of students. Unfortunately, some of these other factors are out of the control of the instructor. Facilities can be expensive to build. Therefore, laboratory space for education purposes can be competing against laboratory space for a research project. Student enrollment can fluctuate, and overcrowded laboratory space or limited laboratory equipment can impede the teaching and learning process.

While some of these factors cannot be easily controlled, the instructor can control the curriculum. The instructor must have both the conceptual knowledge to communicate how these standards are performed, and these instructors must have enough experience to train students in how to perform these procedures based on the standards. Developing the material for the classroom component of the course can be straightforward with good literature (Wilson and Tennis, 2021; Lammond and Pielert, 2006) and the ACI workbook (ACI Certifications Committee, 2022). Most of the challenges can be found in the laboratory component of the course. Laboratory exercises should be designed to offer the student adequate opportunity to perform the concrete testing procedure. The amount of time required to sufficiently train a person can vary depending on the student's physical abilities. However, no known studies are comparing the time needed to properly train a person for this type of certification.

Scope of Work

The aim of this work is to provide insights into how construction programs at a university level can offer ACI Concrete Field Testing Technician–Grade I certification exam. This will be based on historical written and performance data of this ACI certification from the students and the experiences of faculty in the construction program. These findings can be used to establish and improve both a training program and the certification process for a construction related program at a university level.

Methodology

With any certification process, the goal should be to evaluate a person's knowledge of a subject, minimal competency, and/or skill to complete procedure. The certifications committee of ACI has set forth minimum criteria by which an individual's proficiency is to be judged for the ACI Concrete Field Testing Technician–Grade I certification. This certification process involves both performance and written examinations based on sampling fresh concrete (ASTM C 172), Slump (ASTM C143), Temperature (ASTM C1064), Unit Weight (ASTM C138), make and cure specimens for strength cylinders (ASTM C31), and both Type B pressure air meter (ASTM C231) and Volumetric (roll-a-meter) air meter (ASTM C173). While the training curriculum of the ACI certification was developed and delivered by 4 faculty at Oklahoma State University, both the written exam and the performance exam were created by the ACI certifications committee. The written and performance examinations for ACI Concrete Field Testing Technician–Grade I certification results of 445 students in the concrete program have been collected from 2009 through 2022. Each session represents one semester with between 10 to 62 students with an average of 30 students depending on the enrollment of the semester. The demographic data of the students were not collected. ACI will grade the written examinations and grant certifications only to those applicants who pass both examinations.

Curriculum of ACI Field Grade I Certification

Since the late 1980s, this construction program has offered students the opportunity to become ACI Concrete Field Testing Technician–Grade I certification through collaboration with local state chapter of the National Ready-Mixed Concrete Association (NRMCA). At first the certification was optional and offered on a weekend either at the university or the NRMCA certification location. Overtime the majority of the students in the program began seeing the value in this ACI certification. Now, this has been a requirement in a concrete materials course as part of the construction degree since 2008. This 3-credit hour, sophomore level course is composed of two 50 minute lectures and a two hour laboratory session each week. The ACI Field Grade I certification has been incorporated different ways into the student's grade in this class. Some semesters the certification was worth a portion of their grade such as 0%, 10%, 20%, 30% and other semesters the students would receive an “F” as the final grade if they didn't pass the performance portion of the certification.

Lecture Delivery

For the lecture component of the concrete materials testing, the educational curriculum incorporated multiple teaching methods. Each semester a different sequence of these methods was introduced or taken away in the curriculum. The topics within these lectures incorporated one or more of the following: slide shows of lecture notes, handouts, a review of standards, and the ACI workbook. Below is a description of the different delivery methods of the ACI Curriculum.

- **Scenario 1** *(Chalk & talk):* verbally delivering lecture notes with a visual aid of a marker board.
- **Scenario 2** *(Slide show)***:** presenting the lecture notes in a slide show for classroom instruction.
- **Scenario 3** *(Handouts)***:** providing a summary 8.5 in. x 11 in. piece of paper and then discussing the handout as the classroom instruction.
- **Scenario 4** *(Slide show with handout)*: incorporating both the slide show and handouts into the classroom instruction.
- **Scenario 5** *(Review Standards)*: reading the testing standard and highlighting the key details within the standard.
- **Scenario 6** *(Workbook as an informative search)*: allowing the class as a group to find the answer to the test procedure questions.
- **Scenario 7** *(Workbook as an assignment)*: assigning a test procedure as a homework assignment.

Laboratory Delivery

Within five concrete testing laboratory sessions of this course, students learn to properly make, sample, and test fresh concrete. Slump, temperature, and making and curing strength cylinders were conducted in all 5 laboratory sessions. Unit weight and Type B air meter were conducted between 3 and 5 laboratory sessions depending on the semester. The Volumetric meter was only conducted during one lab session. During each session both the instructor and teaching assistants (TA) were present to help students learn to conduct the test procedures and answer any questions. If a student was struggling to properly perform any of these procedures, the student would been given the opportunity to stay after the lab session and work with the professor and/or TA. Sometimes, within the week leading up to the ACI performance exam, the laboratory and testing equipment would be available for students who need additional practice time.

Lab #1 3-2-1 Method for Proportioning Concrete: A traditional approach to designing and batching concrete has been using some version of 3:2:1, where three portions of coarse aggregate, two portions of fine aggregate, and one portion of cement is mixed together to make concrete. This is a quick and simple design method to make concrete. However, this amount of cement may be excessive, and it can be more economically feasible to use a design method requiring less cement. Furthermore, the 3:2:1 approach fails to consider the amount of water added and water-to-cementitious material ratio (w/cm) to meet the strength and durability requirements. Often the construction manager is tempted or pressured to consider adding additional water to the mixture at the jobsite. In some instances, this is unavoidable. In other instances, the results of adding water at the jobsite may be catastrophic. To help simulate the effects of water addition on a concrete mixture, this laboratory exercise will use a series of water additions. Slump and temperature will be measured for the fresh property and cylinders will be made for compressive strength.

Lab #2 Water Reducer: Fresh concrete being placed and finished must be workable. The strength, durability, and sustainability efforts become secondary because a concrete mixture must first meet the workable requirements for an application. This laboratory exercise begins by using a stiff concrete mixture and measuring the slump, temperature, and unit weight. Then a large dosage of a high range water reducer is added the concrete and same tests were conducted again. Also, cylinders for compressive strength are made before and after water reducer was added to the concrete.

Lab #3 ACI 211 Mixture Design (Absolute Volume): One of the most used concrete mixture design methods has been the absolute volume method, which is also known as the ACI 211 mixture design method. The purpose of this lab is to give the student exposure to 1.) design a concrete mixture using the ACI 211 absolute volume method and 2.) trial batch this mixture design to better understand the translation from design to actual performance. Then each group will design a 1 cyd mixture based off the project specifications provided and applicable tables from ACI 211. After designing the mixture, the concrete will be trial batched for 2 cubic feet and tested for slump, temperature, unit weight, air content with Type B pressure meter, and compressive strength.

Lab #4 Using SCM replacement: Secondary cementitious materials (SCMs) are commonly incorporated into concrete mixtures due to sustainability, durability, and economic cost. This is a partial replacement of Portland cement. For this laboratory exercise, each group will modify the previously designed concrete mixture based on ACI 211 to have 20% fly ash and 80% Portland cement. The concrete will be trial batched for 2 cubic feet and tested for slump, temperature, unit weight, air content with Type B air meter, and compressive strength.

Lab #5 Air-Entrained Concrete: Among the most desirable properties of air-entrained concrete is an improved resistance to freeze-thaw deterioration. Air-entrained concrete can be produced by adding an air-entraining admixture into the concrete. This lab exercise requires the use of an air-entraining admixture to achieve a target air content of 6%. Each group will modify the previous concrete mixture design based on ACI 211 to have 6% air volume. The concrete will be trial batched for 2 cubic feet and tested for slump, temperature, unit weight, air content with volumetric air meter, and compressive strength.

Assessment of Performance and Written Exam

Based on ACI certification requirements, the assessment process for ACI Concrete Field Grade I Testing Technician is broken into a performance examination and a written examination. This 60-minute written examination is a closed-book and consists of 55 multiple-choice questions. To pass the written examination, the student must have a minimum score of 70% overall and at least 60% correct for each section. For the performance exam, ACI has a step-by-step checklist of key performance elements for each procedure where a qualified supplementary examiner evaluates the student based on this performance document and circle "pass" or "fail" as the examinee conducts the procedure. A proctor evaluates the examinee as they are performing the test in-person with the optional exception of sampling concrete where ACI allows for this to be either performance or verbal. For these assessments, sampling concrete was only evaluated verbally because it is not practical and too costly to pay for a concrete revolving drum truck to deliver a small quantity of material for a laboratory session. The performance exam is graded on a "pass or fail" basis. If a student fails the performance exam on the first trial, they are offered one additional trial proctored by a different performance examiner. Results of the performance exams are unofficially known when the student completes the performance exam. The official results of the performance exams are graded by the ACI certification program.

Results & Discussion

The written and performance examinations for ACI Concrete Field Testing Technician–Grade I certification results of students in the concrete program have been collected from 2009 through 2022. Various training techniques with 4 different instructors were introduced into the curriculum during this time. Within these 13 years, there were 445 students who took both the written and performance exams. Figure 1 shows the pass rate of both performance and written exams. Each session represents one semester. The demographic data of the students were not collected.

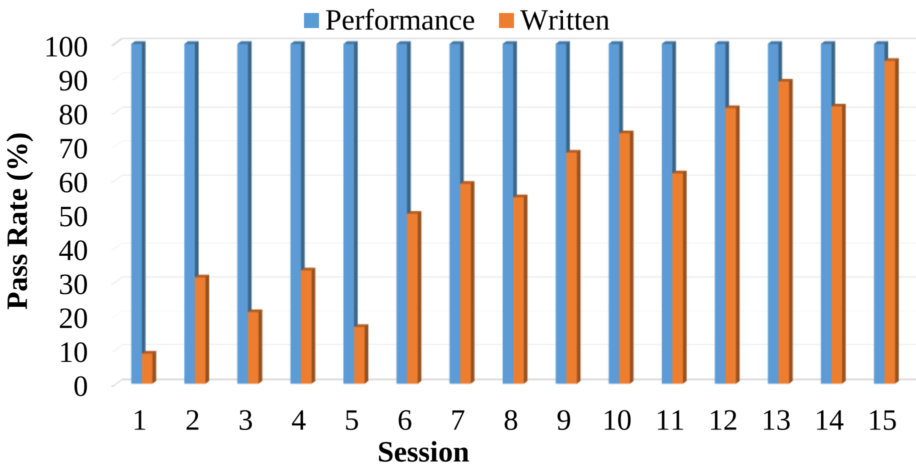

Figure 2. Comparison of the pass rate of both performance and written exam.

Performance Examination

The performance examination is typically completed during the allotted laboratory session time of 2 hours, but it may take additional time depending on the number of students being certified and proctors on hand per semester. The pass rate on the performance exam is shown in Figure. The examinees on the performance exam attained a 100% pass rate each semester. This high passing rate is largely due to the amount of practice time provided within the curriculum of the lab sessions. Each student spends a minimum of 10 hours practicing these procedures during their allotted lab sessions. Also, the professor and teaching assistant (TA) work with each student to help them develop the basic skill sets required within these procedures. If a student was struggling to properly perform any of these procedures, the student would been given the opportunity to stay after the lab session and work with the professor and/or TA. Sometimes, within the week leading up to the ACI performance exam, the laboratory and testing equipment would be available for students who need additional practice time. It is important to point out 2 attempts are allowed for each performance test. So, if a student fails a test procedure, they are allowed to repeat it again.

Written Examination

While typically the examinees pass the performance examination each semester, the written exam has been more challenging for them to pass. It is speculated that the difficulty may lie in the fact that the exam is closed book, and the students must memorize facts and figures related to the specific ASTMs. Figure 2 shows the average, high and low grade on the written exam. The average student score was commonly higher in both Slump and Temperature. The scores for unit weight, Type B Pressure Meter, and Volumetric Meter are typically the lowest. Recalling the unit weight, yield, relative yield, and air content equations from memory can be challenging within the unit weight procedure. Additionally, there are calculations that students have to run using the equations for unit weight, yield, and air content.

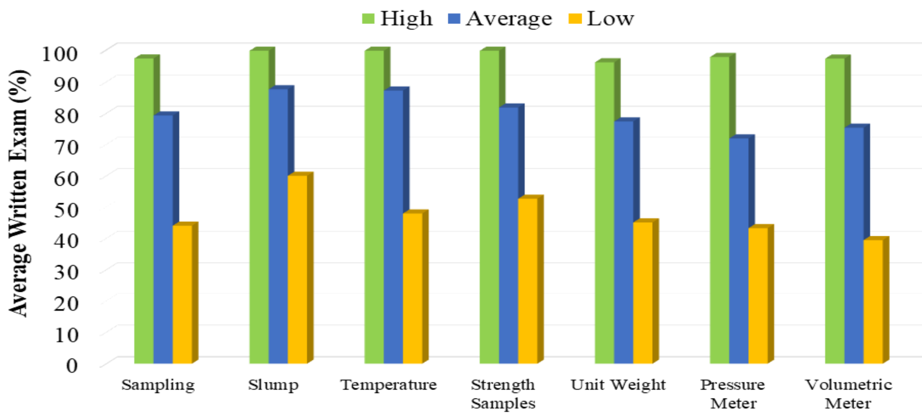

Figure 3. Comparison of the average, high and low grade on the written exam.

Lessons Learned

Preparing students for ACI Field Grade I certifications can be a time consuming but rewarding process. Working with the local concrete promotional group such as the local ACI chapter or NRCMA can be of great benefit for all. These local concrete promotional groups usually offer ACI Field Grade I certifications already. They have an approved ACI examiner, pool of qualified supplementary evaluators, and even testing equipment. This promotional group can also collect the student certification fees, handling orders for the exam, scheduling of performance evaluators, and may even help proctor the written exam. Adding a student focused certification session may seem almost effortless for this promotional group.

Benefits of Student Certifications

While students graduating with a construction related degree may not necessarily testing concrete every day, there are many benefits for construction and civil engineering majors to experience the process of attempting and hopefully obtaining the ACI Field Grade I certification. For students to graduate, the construction program requires two 400-hour internships (evaluative to 10 weeks at 40 hours). During especially the first internship between the sophomore and junior year, the student intern is commonly a more entry, hands-on field experience on jobsites where it is common to be involved with placing and testing concrete. This is where this ACI Field Grade I certification has been extremely beneficial for both students and the companies they are interning. Below are some other student benefits of the certification.

- Added recruitment value for future employment after graduation.
- Increased advantage and even possible financial compensation for internships.
- Provides hands-on activities with classroom theory.
- Gaining concrete testing knowledge and a practical skillset.
- Enhancement of credentials on resume.
- Personal achievement of obtaining certification.

Conclusions

The written and performance examinations for ACI Concrete Field Testing Technician–Grade I certification results of 445 students in the construction program at Oklahoma State University from 2009 through 2022 were analyzed. The results provide helpful insights into how various training techniques affect the pass rate of the ACI certification. While this study was limited to one university, the following insights were found:

- For these certifications, students excelled at the performance exam.
- The written exam was the obstacle for students not passing the certification.
- Examinees on the written exam frequently struggled with unit weight, Type B Pressure Meter, and Volumetric Meter.
- Students performing the volumetric meter were not always able to successfully perform this test on the first attempt.

Future research work will incorporate other universities, current workforce, and non-traditional teaching approaches including virtual reality (VR).

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