

Development of the First Architectural Engineering Professional Engineers' Examination

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Introduction

Historically graduates of Architectural Engineering (AE) programs have taken principles and practices examinations in engineering disciplines that only partially address the breadth of their undergraduate education. An AE principles and practice examination is currently being developed to cover the key areas of engineering education that an AE graduate receives. These areas include the analysis and design of structural, electrical, and mechanical systems for commercial, industrial, and institutional (CII) facilities as well as construction management. This paper will discuss the development and content of the AE examination along with lessons learned that may help other engineering disciplines considering developing a new examination for their discipline.

AE Examination Sponsors

The AE examination is being developed by the Architectural Engineering Institute (AEI) of the American Society of Civil Engineering (ASCE) under the guidance of the National Council of Examiners for Engineering and Surveying (NCEES). Currently, graduates of AE programs that are accredited by the Accreditation Board of Engineering and Technology, Inc. (ABET) must take the principles and practice examinations of other disciplines such as civil, electrical, and mechanical. These examinations are designed around the specific discipline and cover topics that are not part of the AE undergraduate program or used by the AE in professional practice. Members of the National Society of Architectural Engineers (NSAE) recognized the need for a discipline specific principles and practice examination and initiated the development of the AE examination in 1992. AEI was formed in 1998 as the result of a merger between the National Society of Architectural Engineers and the Architectural Engineering Division (AED) of ASCE. Both organizations recognized the need for an AE examination and the development of an AE examination became a strategic objective of the new organization.

Getting Started

NSAE began discussions with the NCEES in 1992 about developing the new AE examination. To begin a new examination, state board of professional registration that is a member of NCEES must request the examination. Pennsylvania, which has one of the largest and oldest AE undergraduate programs in the United States at Pennsylvania State University (Penn State), was the first state to request an AE examination.

Once the examination was requested, NCEES surveyed all of its state boards to determine interest in an AE examination. Forty-four of the 55 United States' jurisdiction boards for licensure in engineering indicated that they would offer the examination if it were available. An additional 6 boards indicated that they might offer they examination. The results of this survey demonstrated the possible demand for the examination as well as the number and distribution of AE graduates across the United States. At the time there were only thirteen ABET-accredited AE programs.

Based on the survey results, NCEES members voted to approve the development of an AE examination in 1995. NSAE was the lead organization charged with the development of the examination. Between 1995 and 1998, NSAE conducted a fund raising campaign to raise money to conduct the needed professional activities and knowledge (PAK) analysis survey.

PAK Analysis

The PAK analysis defines the subject matter of the principles and practice examination based on a survey of professionals in the field. It is the foundation for the development of the professional licensing examination. NSAE was unable to raise sufficient funds to perform the PAK analysis. As a result of the merger of NSAE and ASCE AED to form AEI in 1998, AEI through its parent organization ASCE became responsible for the AE examination. The new AEI had the funds necessary to start the PAK analysis.

The Buros Center for Testing and Outreach was contracted to assist AEI in the development of the PAK analysis. The first step in the examination development process was to convene a workshop comprised of a cross-section AE professionals to develop a survey. The purpose of this survey was to obtain input from the AE profession regarding the content of the AE examination. At least two members from practice and one member of higher education represented each of the four areas within the AE profession. These four areas included structural, electrical, and mechanical systems as well as construction management.

The survey was sent to 700 individuals that were selected by the Buros Center based on demographics from a database of 2900 individuals. The database of 2900 individuals were developed from AEI membership lists as well as AE alumni lists from Kansas State University (KSU), The University of Kansas (KU), and Penn State. The response rate was 34% which was considered acceptable.

A second workshop was convened in 1999 to review the survey results and to develop the test specifications based on these results. NCEES' psychometric consultants, The Chauncy Group, assisted AEI in performing this task. Workshop attendees again consisted of a cross-section of industry and academia that had has expertise in the field of architectural engineering. The detailed test specification is provided in Table 1.

TABLE 1: AE EXAMINATION SPECIFICATION		
SUBJECT AREA	SUBCATEGORY	NUMBER OF ITEMS
I. General Knowledge (13%)		
	1. Building Systems	4
	2. Construction and Building Materials	3
	3. Lateral Loads and Displacement Issues	1
	4. Codes, Regulations, and Statutes	2
II. Construction Management (15%)		
	1. Economic and Financial Issues	5
	2. Construction Processes	3
	3. Project Management	4
III. Electrical and Lighting Systems (23%)		
	1. Basic Electrical Knowledge (includes grounding, lighting, emergency systems, grounding)	7
	2. Theory (includes Power, circuits, loads)	11
IV. Mechanical Systems (23%)		
	1. Theory (includes fan and pump laws, loads, psychometrics)	6
	2. Basic Mechanical Knowledge (includes pumps, fire protection, pipe expansion, ducts, HVAC, Chillers)	12
V. Structural Systems (27%)		
	1. Load and Analysis (includes material behavior, serviceability, indeterminate structures)	9
	2. Design (includes major material types, fire, codes, connections, foundations)	13
TOTAL		80

Item Writing

NCEES provided the needed expertise to teach volunteers within AEI how to write questions for the examination. A question and answer combination is called an item by NCEES. For each examination, items are written to fit within the specifications developed by the PAK analysis as shown in Table 1. Each item is reviewed for time and content by at least two other writers to assure the quality of the question.

Once an item has been accepted, it is sent to NCEES to “bank” and may be used for future tests in the subject area and in some cases on principles and practice examinations in related disciplines. In fact, AEI used NCEES bank questions in the development of its examinations in both the mechanical and structural subject areas.

Benchmark Examinations

In 2000, when sufficient items were written to complete an entire examination, a panel of professional engineers (PE) that had passed the PE examination within the last 10 years was assembled to take the AE examination. The purpose of this panel was to ascertain the difficulty of the examination. None of the takers studied for the sample examination prior to taking it. Most of the test takers felt comfortable in their own area of practice but found the other areas of the AE examination difficult. It is anticipated that actual takers of the AE examination will study in their lesser areas of expertise prior to taking the examination.

Another panel of PE's was convened in 2001 to take a second sample AE examination. The purpose of the second AE examination was to determine if the AE examination could be completed in the time allotted time. The AE examination taken by the second panel is the examination that will be presented to NCEES in February 2002 for approval as the first examination to be offered to the state boards of registration. Assuming that approval is received, the first offering of the AE examination will be in the spring of 2003.

AE Examination Format

The desired format for the AE examination had always been a breadth and depth format. The nature of the AE curriculum is one of providing a broad background of knowledge related to the design and construction of engineered systems for buildings. AE undergraduate students take a broad spectrum of design courses that include structural, mechanical and electrical design courses as well as construction management. In practice, AE graduates typically practice in one of these specific areas.

NCEES offers a breadth and depth format for examinations with a history of numerous test takers such as in the civil and mechanical areas. The breadth and depth format includes general questions in the morning session that all test takers answer. In the afternoon session, test takers select a specific examination module that focuses on a primary subject area. For example, candidates taking the Civil Engineering principles and practice examination are required to answer all questions in the morning session. In the afternoon, candidates may select from any one of five modules that represent specific areas of practice in Civil Engineering. The five modules that make up the afternoon Civil Engineering examination are environmental, geotechnical, structural, transportation and water resources. As a result, the Civil Engineering examination becomes five independent examinations from a statistical standpoint which is why it is necessary to have a large pool of test takers in order to offer a breadth and depth examination.

A no-choice format is required by NCEES for examinations that have a smaller number of test takers. NCEES is requiring that the AE examination be a no-choice examination to assure that the sample size for the test is statistically viable. If the examination were broken into four modules, it would require that the sample size be four times larger to assure statistical integrity.

Many members of the AE community have expressed displeasure with the no-choice format of the AE examination. The reason for this is that most AE graduates practice in one of the four areas. In order to move to a breadth and depth format, the number of test takers must be consistently at a level to assure that each module will have a statistical integrity.

Lessons Learned

Development of the AE examination was a learning process for AEI. Groups considering the development of a PE examination for their specific discipline may want to consider the following five lessons during their planning process:

- Lesson #1: Developing An Examination Is Expensive
- Lesson #2: The PAK Analysis Is Highly Important
- Lesson #3: Multiple-Choice Items Are Difficult To Write
- Lesson #4: Volunteer Time Is Valuable
- Lesson #5: It Is A Never-Ending Process

The following paragraphs will discuss each of these lessons learned.

Lesson #1: Developing An Examination Is Expensive

Sufficient funds must be available to retain a consultant to perform the PAK analysis and to conduct the required workshops. Additional funding may also be required to pay for creating a database of written items. Also, there will probably need to be some travel funds that will need to be available to bring volunteers together to write new examination items. AEI found that the \$50,000 banked prior to starting the process was a bare minimum. Most of this was used for the PAK consultant, survey, and workshops. An additional \$10,000 per year has been required to cover travel costs of the item writing committee.

Lesson #2: The PAK Analysis Is Highly Important

The test specifications are entirely dependent on the outcome of the PAK analysis. This step should not be rushed. Careful selection of participants in the survey and specification workshops is necessary because these individuals determine the content of the examination. In addition to determining the subjects that the examination will test, these individuals will also determine the weighting of each of the various subject areas. It is imperative that you have a good panel covering the breadth of your specific discipline at each workshop.

Careful attention should be paid to the lists that you use to send the survey too. Try to have as many lists of practicing professionals as possible for the psychometricians to select their sample set from. Demographic information is often hard to obtain but it is necessary to assure that there is an appropriate gender, ethnic and regional distribution.

Lesson #3: Multiple-Choice Items Are Difficult To Write

It is easy to write a multiple-choice item with a right answer and several randomly selected wrong answers listed along with it. However, NCEES requires that all items have one right answer and at least three “distracters.” These distracters must be based on plausible errors in working the problem that an examination candidate might make. Distractors are often difficult to develop.

NCEES also suggests that questions be as short as possible without too much superfluous information. As such, the questions tend to be straightforward and test takers will either know how to work the problem or not. The result is that there is not a lot of room for developing complicated questions.

As an example, the following item was developed for the exam and will be used in the review manual:

In general, which of the following is the least efficient frame in limiting drift from lateral loads?

- a. Moment resisting Frame.*
- b. X-Braced Frame.*
- c. K-Braced Frame.*
- d. Shear Wall.*

The question is straightforward, all of the possibilities may be used in lateral loading situations, but moment resisting frames are the least efficient in limiting drift. The item measures a specific knowledge, skill or ability. A large portion of the questions on the exam do require computations, however they are written such that the solution does not solely prove that an individual can manipulate a calculator.

Lesson #4: Volunteer Time Is Valuable

It is hard to find people who have the time to dedicate to the examination. Any workshops developed for writing items must be designed to optimize item writing productivity and minimize time. AEI has found that outreach to other organizations such as the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) will increase the number of volunteers to write examination items. In the case of ASHRAE, items written support both the AE examination and the Mechanical Engineering examination.

Other organizations have found that holding item writing workshops at their professional conferences or other events where many participants are already present increases the likelihood of a good turnout of volunteers to write questions. With the time pressures of today’s society, AEI has found that it is very difficult to send people home to complete questions or tasks. The workshops help to focus time and energy on the task at hand.

Lesson #5: It Is A Never-Ending Process

It does not end. As soon as one test is done, it is time to develop the next one. NCEES allows some reuse of questions, but with an eighty-question test, the bank can be drained quickly.

Bibliographic Information

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Biographical Information

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