Improving the Professional Engineering Licensure Process for Construction Engineers

David W. Johnston, P.E., F.ASCE[1]; Nancy Thomas Ahluwalia[2]; and Michael B. Gwyn, P.E., M.ASCE[3]

Abstract: Professional engineering licensure is important in the career development of engineers who undertake work critical to protecting public health, safety, and welfare. The knowledge and experience of construction engineers has not previously been well represented in professional engineering licensure evaluation. The ASCE-CI Construction Engineering Education Committee identified recognition of construction engineering in the professional engineering licensure process as one of its missions when it was organized in 1995. With the support of the states and the receptiveness of the National Council of Examiners for Engineering and Surveying (NCEES), improvements were gradually achieved in recognition of construction engineering experience by changes in NCEES *Model Rules*. In 2003, the NCEES Board decided to evaluate modification of the Civil Engineering PE exam to include a Construction Engineering module. The evaluation included a Professional Activities and Knowledge Study (PAKS) of the skills appropriate for construction engineers. Following approval of the NCEES Board in 2005, exam development has been underway with implementation planned for April 2008. An additional benefit of the PAKS is the improved understanding of knowledge needed by construction engineers in completing their work activities. These results should be valuable to construction engineering education and industry in identifying critical subject matter for inclusion in courses, curriculums, and continuing education.

DOI: 10.1061/(ASCE)0733-9364(2007)133:9(669)

CE Database subject headings: Construction; Engineering; Licensing; Engineering profession.

Background

After initial formation as a task committee in 1995, the ASCE Construction Engineering Education Committee (CEEC) was established in 1999 with the objectives to:

1. Foster the advancement of construction engineering education;
2. Serve as a forum for interchange among construction engineering programs, related engineering programs, and industry;
3. Interact with other professional and technical organizations on construction engineering education;
4. Assist in updating Accreditation Board for Engineering and Technology Inc. (ABET) criteria and guidelines for construction engineering degree accreditation; and
5. Encourage the recognition of construction engineering in the professional engineering licensure process.

A newly licensed engineer is defined as an individual who has (1) completed an ABET/EAC (Engineering Accreditation Commission) accredited engineering degree; (2) accumulated 4 years of practice; and (3) has passed the Professional Engineering Examination process for an engineering specialty area. Approximately 10,000 ABET/EAC civil engineering bachelor of science (B.S.) degrees are awarded each year. It is estimated that 25–35% of these graduates pursue careers in construction. In addition, the number of ABET/EAC accredited construction engineering degree programs is increasing with virtually all of those graduates entering the specialty field of construction.

The general format of the civil engineering exam and question distribution in recent years is illustrated in Fig. 1. The morning breadth questions are selected to represent levels of knowledge that should be expected of all civil engineers. Construction engineering knowledge was largely absent, although some construction engineers have historically elected to pursue the exam based on their secondary strength in another area of civil engineering.

In the past, professional engineering licensure for engineers specializing in construction has been hampered by both experience evaluation issues and the lack of an examination focusing on knowledge appropriate to design of the construction process. Involvement of qualified construction engineers in the construction process is critical to assuring safety, quality, and economy in construction of the built environment for the public benefit. Increasingly, specifications and standards (e.g., ACI 301, ACI 347, and the Masonry Wall Bracing Standard) and regulations (e.g., Occupational Health and Safety Administration and various local building regulations) require the involvement of a professional engineer in aspects of the construction process.

In 1999, the ASCE committee developed a white paper statement of concerns outlining needs for improvement in both evaluation of exam-required experience of construction engineers and in the content of the Principles and Practice of Engineering (PE)

[1]Professor and Associate Head for Graduate Programs, Dept. of Civil, Construction, and Environmental Engineering, North Carolina State Univ., Raleigh, NC 27695-7908. E-mail: johnston@eos.ncsu.edu

[2]Senior Test Developer, Prometric, 2000 Lenox Dr., Lawrenceville, NJ 08648. E-mail: nancy.thomas@prometric.com

[3]Consultant to Industry and President, Gwyn Consulting Services, Inc., Charlotte, NC 28210. E-mail: mbanksg@aol.com

Note. Discussion open until February 1, 2008. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on April 4, 2007; approved on May 2, 2007. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 133, No. 9, September 1, 2007. ©ASCE, ISSN 0733-9364/2007/9-669–677/$25.00.

Morning Breadth Exam 40 questions	Environmental 20% (8)	Geotechnical 20% (8)	Structures 20% (8)	Transportation 20% (8)	Water Resources 20% (8)
Break					
Afternoon Depth Exam 40 questions	Select the questions from any ONE of the following areas: Environmental Geotechnical Structures Transportation Water Resources				

Fig. 1. Current civil exam specification effective through October 2007

examination related to construction engineering. Based on the white paper, the president of the National Council of Examiners for Engineering and Surveying (NCEES) and the Executive Director of the North Carolina Board of Examiners for Engineers and Surveyors (NCBEES) were approached for guidance on how the objectives might be achieved. At that moment, NCEES was forming a task force to consider issues associated with experience evaluation and D. W. Johnston, as chair of the ASCE committee, was appointed a consulting member of the task force. The task force was receptive to the statement of concerns and proposed changes to the NCEES *Model Rules* on experience evaluation. The rules include statements of how various types of experience, such as experience gained during military service, are to be considered. The statement concerning construction, which had been phrased uniquely in the negative, was revised as follows:

- Previous statement—"Experience as a contractor in the execution of design by a professional engineer or in employment considered as that of supervising construction of such work may not be considered as creditable experience."
- New statement—"Experience in construction, to be creditable, must demonstrate the application of engineering principles." (NCEES 2002)

In addition, a new Appendix A of the *Model Rules*, Suggested Guidelines for Progressive Engineering Experience, was worded to reflect the varied duties of engineers, including the practical application of theory, management, communication skills, and social implications. This range of experience fits both engineers who design facilities as well as engineers who design the construction process. States are not required to adopt the model rules, but many do, or consider the model rules in their practices. To increase understanding of the licensure process and experience requirements, the ASCE committee published a guide for construction engineers (ASCE 2001).

In parallel, the North Carolina Board of Examiners for Engineers and Surveyors was approached and agreed to be the lead state board in requesting a PE exam for construction engineering. The NCBEES gained support of additional states in NCEES zone meetings and the ASCE CEEC also communicated with all state boards explaining the request and asking for support. In 2002, the NCEES Board decided to evaluate the possible modification of the Civil Engineering PE exam to include a construction engineering module. The evaluation included a Professional Activities and Knowledge Study (PAKS) of the professional activities and knowledge needed by construction engineers.

The decision by the NCEES Board was slightly different from the original request for a stand-alone exam; however, upon reflection of experience gained since, it was the better approach. A stand-alone exam for construction engineering would have been a Group II exam (NCEES 2006), which must be developed and maintained at significant expense by the requesting society. As part of a Group I exam, such as the civil engineering exam, the costs of development and maintenance are funded by NCEES from the exam revenues generated by the large number of Group I exam takers.

Professional Activities and Knowledge Study

This study is conducted for each PE exam about every 6–8 years (NCEES 2007). The purpose is to ensure that NCEES exams are relevant and valid for the discipline being examined. Key elements of the process are the development, conduct, and analysis of a survey to determine the knowledge content of the exam. The most recent civil exam PAKS was initiated in May 2004 with a job analysis meeting. A PAKS committee, which included four engineers from each of six civil engineering specialties, provided input to the psychometrician leading the PAKS. The specialties represented were:

- Construction engineering;
- Environmental engineering;
- Geotechnical engineering;
- Structural engineering;
- Transportation engineering; and
- Water resources engineering.

The study seeks to determine the tasks and knowledge important for the newly licensed engineer. In identifying tasks the question is—what does the newly licensed civil engineer do? In identifying knowledge, the question is—what does the newly licensed civil engineer need to know in order to perform these tasks? The activities of civil engineers in the various specialties were identified and described. Then a listing of the task, knowledge, and skills believed relevant to each specialty was developed as a basis for the survey. The activities and knowledge are those appropriate for an engineer in the specialty with four years of experience beyond the B.S. degree in engineering. In follow-up web conferences, the descriptions and listings for each specialty were refined by an expanded group of eight engineers in each specialty.

Professional licensing and certification programs generally use a content validation strategy as the basis for documenting the appropriateness of their examinations. In this context, content validity refers to the degree to which the items on the licensing examination are representative of the knowledge, skills, and abilities that are necessary to perform the job at the designated level. Unlike criterion-related validity, which is based on statistical inference, content validity relies on the integrity of the developmental process for assurances that an examination is measuring what it is supposed to measure, that trustworthy inferences may be drawn from the test results, and that the test will be fair to all applicants. Both professional standards and legal guidelines for testing stipulate that: (1) Job analysis results are to be used to formulate test specifications; (2) that this use serves as a critical step in the demonstration of content validity for licensure examinations (AERA/APA/NCME 1999).

Details of the survey instrument were developed by the psychometrician and then tested on groups of engineers not involved in the PAKS development. Following refinement, the survey was mailed to 1,600 professional engineers in each of the six civil specialties, a total of 9,600 surveys. The survey contained questions to determine that the respondents met the requirements of being in the specialty and being licensed professional engineers.

J. Constr. Eng. Manage., 2007, 133(9): 669-677

A minimum of 200 valid responses must be received for the specialty results to qualify. Responses were received from 2,314 licensed professional engineers. The responses by specialty area were:

- Construction engineers: 254;
- Environmental engineers: 327;
- Geotechnical engineers: 332;
- Structural engineers: 427;
- Transportation engineers: 512; and
- Water resources engineers: 427.

Among many questions, the survey respondents were asked to evaluate the importance of each task or knowledge for their respective fields by answering the following question:

How important is the performance of the task (or how important is the knowledge) for a newly licensed civil engineer to protect public health, safety, and welfare?

- 0: Of no importance;
- 1: Of little importance;
- 2: Moderately important;
- 3: Important; and
- 4: Very important.

Examination Specification Development

From the information derived during the job analysis meetings and from the survey, a set of examination specifications are developed by the psychometrician with the assistance of Test Specification Committees. These specifications become the blueprint for defining the content of the examination. Test items are then developed according to these specifications. This developmental process from job analysis to test specifications to test items, when done properly, should result in an examination that is fair to all candidates, content valid, and job related. Assembling examinations according to the same test specifications blueprint ensures that the important content is covered in each and every examination regardless of when that examination is administered. The test specifications resulting from the work of these committees are being used to assemble new forms of the Civil Engineering PE examination.

The Test Specifications Committees were composed of civil engineers with specialties in the disciplines required. For construction engineering, eight licensed construction engineers with varied experience and having good geographic distribution participated.

Each meeting began with a presentation providing an overview of the goals of the meeting and an explanation of the process. During this presentation, the committee was instructed in the use of the PAK study results and how those results were to be formed into test specifications. Then once these overall considerations were decided upon, the panel began discussing the specific PAK study results for their task, which had been sent to them prior to the meeting and were displayed using Web software.

Following the introduction, each committee reviewed tasks and knowledge statements from the PAK study. Each task and each knowledge statement was considered by the committee members as appropriate for the specific module. In the case of the task statements, the committee members were asked to confirm that the tasks provide appropriate support and context for the knowledge topics included on the exam module. Table 1 lists the Tasks available for linkage to the modules. In the case of knowledge statements, the Test Specification Committees approved their inclusion on the test specifications, made modifications to clarify the meaning of the included topic, or deleted them. The knowledge statements approved for the breadth examination were not discussed by the depth panels. However, all topics from the PAK study surveyed as breadth topics that were not approved for breadth were discussed by the depth panels in addition to the depth specific topics. The tasks are often in the context of the specialty. For example, task statement 14, *plan, design, and/or compute aspects of structural systems*, might be focused primarily at permanent structures for the structural engineer and at temporary structures for the construction engineer.

Following the discussions of the knowledge statements, each participant responded to a survey in which they provided independent values for each knowledge domain. The results of the survey were shared with the committee members. They were also told how the PAK study respondents had allocated the topics and the impact of the percentage weights would have on the number of actual test questions. Consensus was reached on the final weights.

The final activity for the committee members was the linkage of the approved knowledge topics to the Task Domains. The assignments were distributed to all of the invited committee members regardless of their participation in the Web conference. Several individual members completed their assignments. The final linkages based on collation of the individual assignments are provided in Table 2.

The PAKS concluded that the civil engineering examination including construction engineering should be revised to the specification illustrated in Fig. 2. Overlap between the environmental and water resources knowledge was found to be substantial and the PAKS concluded that they should be combined. Based on the results from the PAK study, the NCEES Board approved the decision to combine environmental and water resources that are currently separate depth modules into one. At the same time, they approved the introduction of the construction depth examination to the battery.

The specific knowledge areas determined to be important for the construction engineer are listed in Table 3. The weighting determined from the PAKS is also listed. These knowledge areas and weightings have been adopted for the construction knowledge areas of the new Civil Engineering PE exam.

The study results met the requirements and supported the validity of the exam module need for construction engineering, the knowledge topics that should be examined, and the weighting for each topic area. The NCEES Board of Directors approved the results of the PAKS for the civil engineering exam in 2005, and the exam development process began almost immediately.

Principles and Practice of Engineering Exam

Tables 4 and 5 provide the final specification for the civil engineering examination as related to the content that would be encountered by a construction engineer taking the required breadth exam in the morning and selecting construction as the depth exam in the afternoon.

As measured by the survey response, knowledge with mean importance scores of 2.5 and above were considered to be important for inclusion in the exam. Knowledge with mean scores from 2.4 to 2.49 were considered to be borderline and knowledge with mean scores of less than 2.4 were considered not to be important. The mean importance ratings of the knowledge areas for the construction engineering depth exam, based on survey respon-

J. Constr. Eng. Manage., 2007, 133(9): 669-677

Table 1. Applicability of Task Statements and Domains to Specialty Areas

	Task statements	Breadth	Environmental/ water resources depth	Geotechnical depth	Structural depth	Transportation depth	Construction depth
	Domain 1: Preliminary studies						
1	Identify and interpret client needs	Yes	Yes	Yes	Yes	Yes	Yes
2	Analyze survey reports, maps, engineering drawings (blueprints) and specifications	Yes	Yes	Yes	Yes	Yes	Yes
3	Analyze site conditions, aerial photography and other topographic or geologic data	Yes	Yes	Yes	Yes	Yes	Yes
4	Analyze existing infrastructure (e.g., structures, traffic, drainage systems, water systems) for adequacy (e.g., performance, safety, cost)	Yes	Yes	Yes	Yes	Yes	Yes
5	Serve on multidisciplinary teams	No	Yes	Yes	Yes, e.g., work with architects	Yes	Yes, e.g., work on teams that involve owners, contractors, and/other engineers; communicate information to others who do not have the same background
6	Determine engineering feasibility of project	Yes	Yes	Yes	Yes	Yes	Yes
7	Interpret and/or review presentations, written reports, designs, and/or graphics developed by others	Yes	Yes	Yes	Yes	Yes	Yes
8	Perform economic analysis (e.g., break-even, net-present value, life-cycle costing).	No	Yes	No	No	Yes	No
9	Review results of the analysis of geologic data	Yes	Yes	Yes	Yes	Yes	Yes
	Domain 2: Design						
10	Plan, design, and/or compute aspects of construction systems	Yes	Yes	Yes	Yes	Yes	Yes
11	Plan, design, and/or compute aspects of environmental systems	Yes	Yes	Yes, e.g., dewatering, infiltration, sediment control	No	Yes	Yes
12	Plan, design, and/or compute aspects of foundation systems	Yes	No	Yes	Yes	Yes	Yes
13	Plan, design, and/or compute aspects of hydraulic systems	Yes	Yes	Yes, e.g., dewatering, pipe design, retention systems	No	Yes	Yes
14	Plan, design, and/or compute aspects of structural systems	Yes	No	Yes, e.g., cofferdams; retaining walls	Yes	Yes	Yes
15	Plan, design, and/or compute aspects of transportation systems	Yes	No	Yes, e.g., embankment stability, pavement design	Yes	Yes	Yes
16	Evaluate the results of laboratory tests on soils and construction materials	Yes	Yes	Yes	Yes	Yes	Yes

J. Constr. Eng. Manage., 2007, 133(9): 669-677

Table 1. (*Continued.*)

	Task statements	Breadth	Environmental/ water resources depth	Geotechnical depth	Structural depth	Transportation depth	Construction depth
17	Interpret and apply pertinent codes and other regulatory information	Yes	Yes	Yes	Yes	Yes	Yes
18	Estimate quantities and cost of materials, equipment, and labor	Yes	Yes	Yes	Yes	Yes	Yes
19	Validate and interpret input to and output from computer software	Yes	Yes	Yes	Yes	Yes	Yes
20	Conduct studies of environmental contamination	No	No	No	No	No	No
21	Direct or participate in preliminary surveying and construction surveying	No	No	No	No	No	Yes, limited
	Domain 3: Preparation of documentation						
22	Prepare contract or construction documents (e.g., drawings, specifications, terms and conditions)	Yes	Yes	Yes	Yes	Yes	Yes
23	Prepare permit applications and ensure compliance with permits	Yes	Yes	Yes	Yes	Yes	Yes
24	Prepare environmental assessments, and/or impact statements	No	No	No	No	Yes, especially the environmental assessment; generally seek assistance for impact statements	No
25	Prepare presentations, written reports, and/or graphics	Yes	Yes	Yes	Yes	Yes	Yes
26	Prepare and/or direct preparation of property and right-of-way descriptions	No	No	No	No	No	No
27	Review shop drawings and submittals	Yes	Yes	Yes	Yes	Yes	Yes
	Domain 4: Construction						
28	Provide reference points, grades, and elevations	Yes	Yes	No	Yes	Yes	Yes
29	Implement, monitor, and/or control construction systems and activities (means and methods)	No	No	Yes	No	No	Yes
30	Prepare bid proposals	No	No	No	No	No	Yes
31	Perform and direct quality control of the constructed product	Yes	Yes	Yes	Yes	Yes	Yes
32	Perform site observations during construction	Yes	Yes	Yes	Yes	Yes	Yes
33	Perform value-engineering and/or constructability reviews	No	No	Yes	Yes	Yes	Yes

dents who identified their primary area of civil engineering expertise as construction, are listed in Table 5 for reference.

Table 6 lists some example knowledges that were among the many listed in the initial job analysis meeting. There were discussions of many possible knowledges that might be relevant. Some were discarded as either too specialized or not an appropriate expectation for the newly licensed engineer with four years of experience. When there was uncertainty, the knowledges were left in the survey with the expectation the survey would provide the broader assessment. The examples listed are among those that were eliminated as a result of the survey.

Understanding the categories and distribution of knowledge will be important to the exam takers. The distribution of knowledges is valuable to educators because it reflects what practicing construction engineers consider to be important for construction engineers to understand early in their careers. It is also valuable to industry and to ASCE as they develop and provide continuing education opportunities.

J. Constr. Eng. Manage., 2007, 133(9): 669-677

Table 2. Linkage of Construction Depth Topics to Task Domains

Construction depth topics	Task domain linkage
Earthwork construction and layout	
Excavation and embankment (cut and fill)	1 2 4
Borrow pit volumes	1 2 4
Site layout and control	4
Earthwork mass diagrams	2 3 4
Estimating quantities and costs	
Quantity take-off methods	1 2 3 4
Cost estimating	1 2 3 4
Engineering economics	
Value engineering and costing	1 2 3 4
Construction operations and methods	
Lifting and rigging	2 4
Crane selection, erection, and stability	2 4
Dewatering and pumping	2 4
Equipment production	2 4
Productivity analysis and improvement	2 4
Temporary erosion control	2 3 4
Scheduling	
Construction sequencing	2 4
CPM network analysis	2 4
Activity time analysis	2 4
Resource scheduling	2 4
Time-cost trade-off	1 2 4
Material quality control and production	
Material testing (e.g. concrete, soil, asphalt)	2 4
Welding and bolting testing	2 4
Quality control process (QA/QC)	2 4
Concrete mix design	2 3 4
Temporary structures	
Construction loads	2 4
Formwork	2 4
Falsework and scaffolding	2 4
Shoring and reshoring	2 4
Concrete maturity and early strength evaluation	2 4
Bracing	2 4
Anchorage	2 4
Cofferdams (systems for temporary excavation support)	2 4
Codes and standards [e.g., American Society of Civil Engineers (ASCE 37), American Concrete Institute (ACI 347), American Forest and Paper Association–NDS, Masonry Wall Bracing Standard]	2 4
Worker health, safety, and environment	
OSHA regulations	1 2 3 4
Safety management	2 3 4
Safety statistics (e.g., incident rate, EMR)	2 3 4
Ground water and well fields	
Groundwater control including drainage, construction dewatering	1 2 4
Subsurface exploration and sampling	
Drilling and sampling procedures	2 4
Earth retaining structures	
Mechanically stabilized earth wall	2 4
Soil and rock anchors	2 4
Deep foundations	
Pile load test	2 4
Pile installation	2 4
Loadings	
Wind loads	2 4
Snow loads	2
Load paths	2
Mechanics of materials	
Progressive collapse	2
Materials	
Concrete (prestressed, post-tension)	2 3 4
Timber	2 3 4
Traffic safety	
Work zone safety	1 2 3 4

Morning Breadth Exam 40 questions	Construction 20% (8)	Geotechnical 20% (8)	Structures 20% (8)	Transportation 20% (8)	Water Resources and Environmental 20% (8)
Break					
Afternoon Depth Exam 40 questions	Select the questions from any ONE of the following areas: Construction, Geotechnical, Structures, Transportation, Water Resources and Environmental				

Fig. 2. New civil exam specification effective April 2008

Table 3. Construction Knowledge Areas and Question Distribution

Portion	Knowledge area	Weight (%)	Questions
Morning breadth exam	Earthwork construction and layout	20.0	8
	Estimating quantities and costs		
	Scheduling		
	Material quality control and production		
	Temporary structures		
Break			
Afternoon depth exam	Earthwork construction and layout	10.0	4
	Estimating quantities and costs	17.5	7
	Construction operations and methods	15.0	6
	Scheduling	17.5	7
	Material quality control and production	10.0	4
	Temporary structures	12.5	5
	Worker health, safety, and environment	7.5	3
	Other topics	10.0	4

J. Constr. Eng. Manage., 2007, 133(9): 669-677

Table 4. Civil Engineering Breadth Exam Knowledge and Distribution Effective April 2008

Breadth knowledge area topics	Approximate percentage of examination
I. Construction	20
A. Earthwork construction and layout	
1. Excavation and embankment (cut and fill)	
2. Borrow pit volumes	
3. Site layout and control	
B. Estimating quantities and costs	
1. Quantity take-off methods	
2. Cost estimating	
C. Scheduling	
1. Construction sequencing	
2. Resource scheduling	
3. Time-cost trade off	
D. Material quality control and production	
1. Material testing (e.g., concrete, soil, asphalt)	
E. Temporary structures	
1. Construction loads	
II. Geotechnical	20
A. Subsurface exploration and sampling	
1. Soil classification	
2. Boring log interpretation (e.g., soil profile)	
B. Engineering properties of soils and materials	
1. Permeability	
2. Pavement design criteria	
C. Soil mechanics analysis	
1. Pressure distribution	
2. Lateral earth pressure	
3. Consolidation	
4. Compaction	
5. Effective and total stresses	
D. Earth structures	
1. Slope stability	
2. Slabs-on-grade	
E. Shallow foundations	
1. Bearing capacity	
2. Settlement	
F. Earth retaining structures	
1. Gravity walls	
2. Cantilever walls	
3. Stability analysis	
4. Braced and anchored excavations	
III. Structural	20
A. Loadings	
1. Dead loads	
2. Live loads	
3. Construction loads	
B. Analysis	
1. Determinate analysis	
C. Mechanics of materials	
1. Shear diagrams	
2. Moment diagrams	
3. Flexure	
4. Shear	
5. Tension	
6. Compression	
7. Combined stresses	
8. Deflection	

Table 4. (*Continued.*)

Breadth knowledge area topics	Approximate percentage of examination
D. Materials	
1. Concrete (plain, reinforced)	
2. Structural steel (structural, light gauge, reinforcing)	
E. Member design	
1. Beams	
2. Slabs	
3. Footings	
IV. Transportation	20
A. Geometric design	
1. Horizontal curves	
2. Vertical curves	
3. Sight distance	
4. Superelevation	
5. Vertical and/or horizontal clearances	
6. Acceleration and deceleration	
V. Water resources and environmental	20
A. Wastewater treatment	
1. Collection systems (e.g., lift stations, sewer network, infiltration, inflow)	
B. Water treatment	
1. Hydraulic loading	
2. Distribution systems	
C. Hydraulics—closed conduit	
1. Energy and/or continuity equation (e.g., Bernoulli)	
2. Pressure conduit, (e.g., single pipe, force mains)	
3. Closed pipe flow equations including Hazen Williams, Darcy equation	
4. Friction and/or minor losses	
5. Pipe network analysis (e.g., pipeline design, branch networks, loop networks)	
6. Pump application and analysis	
D. Hydraulics—open channel	
1. Open channel flow (e.g., Manning's equation)	
2. Culvert design	
3. Spillway capacity	
4. Energy dissipation (e.g., hydraulic jump, velocity control)	
5. Stormwater collection including stormwater inlets, gutter flow, street flow, storm sewer pipe	
6. Flood plain/floodway	
7. Flow measurement-open channel	
E. Hydrology	
1. Storm characterization including rainfall measurement and distribution	
2. Storm frequency	
3. Hydrographs application	
4. Rainfall intensity, duration, and frequency (IDF curves)	
5. Time of concentration	
6. Runoff analysis including rational and SCS methods	
7. Erosion	
8. Detention/retention ponds	

J. Constr. Eng. Manage., 2007, 133(9): 669-677

Table 5. Civil Engineering Construction Depth Exam Knowledge and Distribution Effective April 2008

Construction depth knowledge area topics	Mean importance response	Approximate percentage of examination
I. Earthwork construction and layout		10
A. Excavation and embankment (cut and fill)	3.04	
B. Borrow pit volumes	2.67	
C. Site layout and control	3.04	
D. Earthwork mass diagrams	2.65	
II. Estimating quantities and costs		17.5
A. Quantity take-off methods	3.00	
B. Cost estimating	2.96	
C. Engineering economics: Value engineering and costing	2.67	
III. Construction operations and methods		15
A. Lifting and rigging	2.48	
B. Crane selection, erection, and stability	2.45	
C. Dewatering and pumping	2.53	
D. Equipment production	2.60	
E. Productivity analysis and improvement	2.82	
F. Temporary erosion control	2.75	
IV. Scheduling		17.5
A. Construction sequencing	2.90	
B. CPM network analysis	2.52	
C. Activity time analysis	2.73	
D. Resource scheduling	2.86	
E. Time-cost trade-off	2.80	
V. Material quality control and production		10
A. Material testing (e.g., concrete, soil, asphalt)	3.04	
B. Welding and bolting testing	2.95	
C. Quality control process (QA/QC)	2.64	
D. Concrete mix design	2.52	
VI. Temporary structures		12.5
A. Construction loads	3.06	
B. Formwork	2.83	
C. Falsework and scaffolding	2.85	
D. Shoring and reshoring	2.92	
E. Concrete maturity and early strength evaluation	2.82	
F. Bracing	2.79	
G. Anchorage	2.73	
H. Cofferdams (systems for temporary excavation support)	2.67	
I. Codes and standards [e.g., American Society of Civil Engineers (ASCE 37), American Concrete Institute (ACI 347), American Forest and Paper Association-NDS, Masonry Wall Bracing Standard]	3.07	
VII. Worker health, safety, and environment		7.5
A. OSHA regulations	2.95	
B. Safety management	3.01	
C. Safety statistics (e.g., incident rate, EMR)	2.81	
VIII. Other topics		10
A. Groundwater and well fields		
1. Groundwater control including drainage, construction dewatering	2.59	
B. Subsurface exploration and sampling		
1. Drilling and sampling procedures	2.56	
C. Earth retaining structures		
1. Mechanically stabilized earth wall	2.70	
2. Soil and rock anchors	2.62	
D. Deep foundations		
1. Pile load test	2.63	
2. Pile installation	2.73	
E. Loadings		
1. Wind loads	3.21	
2. Snow loads	2.92	
3. Load paths	3.01	
F. Mechanics of materials		
1. Progressive collapse	2.83	
G. Materials		
1. Concrete (prestressed, posttensioned)	3.02	
2. Timber	2.70	
H. Traffic Safety		
1. Work zone safety	2.78	

Item Development Process

Questions for the exam are termed *items* by NCEES. Items may be developed by either external, individual contributors or by members of the NCEES Civil Exam Committee. All items must be developed by licensed professional engineers. The committee members receive training in the item writing process and specific formats required for the items used in the exam. Most of the construction engineering items to date (2007) have been developed by members of the NCEES Construction Engineering Subcommittee. The process involves:

- Identification of an item idea that fits the exam specification and writing the item in the format required by the exam;
- Detailed checks of the item by two construction-experienced PEs;
- Review of the item by the subcommittee chair;
- Item editing and layout by NCEES staff; and
- Review of item edits by subcommittee chair.

The items include the statement of the question and four multiple choice answers, one for the correct solution and three distracters which result from possible incorrect solutions.

Exam Development Process

The development of each exam requires about two years of advance work from selection of exam items to administration of the

Table 6. Examples of Deleted Construction Knowledge

Topic	Mean importance response
Plant production	2.45
Life-cycle modeling	2.40
Equipment selection	2.36
Equipment cost analysis	2.34
Equipment replacement	2.17
Blasting	2.12

J. Constr. Eng. Manage., 2007, 133(9): 669-677

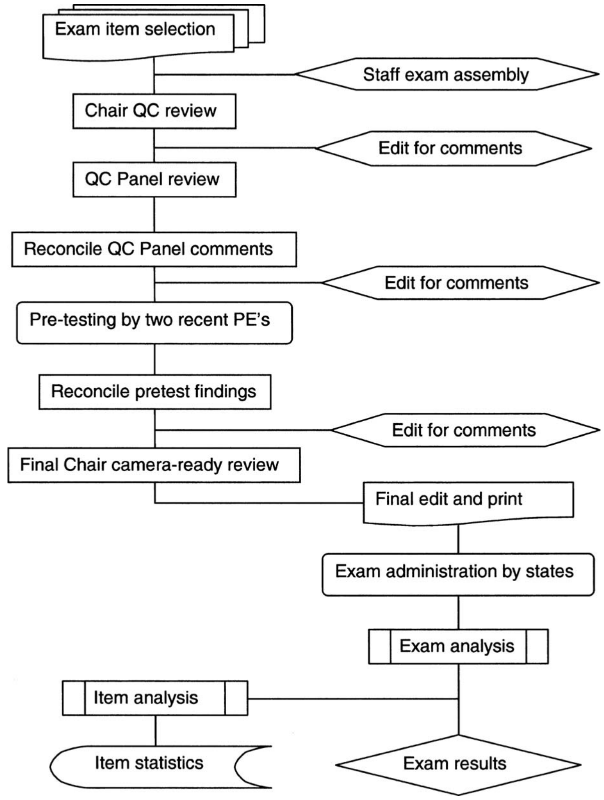

Fig. 3. Exam development process

exam as illustrated in Fig. 3. Items are selected to meet the distribution of content and time required by the exam specification. On average, the examinee has 6 min for each question, including time to read and understand the question, time to consult open-book references, and time to arrive at a solution. The exam development process must be rigorous and is subject to audit. During exam assembly, items and the exam go through a quality control panel review, pretesting by recently licensed professional engineers, and additional edits. Following the exam, the results are analyzed to determine if there are potential item errors and to develop item statistics. The item statistics help identify the good questions that have potential for future reuse and identify those that need revision prior to consideration for reuse.

About 25 construction engineer volunteers are participating in development of the items and exams. The volunteers are a diverse group in education, age, experience, geographic location, and gender. Exam development is a continuous process that must be maintained for as long as the exam is offered.

Conclusions

State boards and NCEES have been receptive to the inclusion of the construction engineering discipline in the Principles and Practice of Engineering (PE) examination.

1. Improvements have been made in the NCEES *Model Rules* for experience evaluation of construction engineers.
2. A Professional Activities and Knowledge Study has been conducted for civil engineering including construction engineering as a subdiscipline similar to geotechnical, structures, transportation, and water resources and environmental engineering. The study validated the appropriateness of including construction engineering in the civil engineering exam.
3. The examination following the new exam specification is currently under development with subject matter experts for construction engineering who are licensed professional engineers. The first examination under the new specification is scheduled for April 2008.
4. The detailed results of the PAKS and resulting exam specification should be valuable to construction engineering education in identifying critical subject matter for inclusion in courses and curriculums. Industry should also benefit as they implement continuing education and development programs for their employees.

Acknowledgments

The writers are most grateful to the ASCE-CI Construction Engineering Education Committee, the North Carolina Board of Examiners for Engineers and Surveyors, the National Council of Examiners for Engineering and Surveying, and the many construction engineers involved in exam development, for their supportive efforts toward the goal of improving the professional engineering licensure process for construction engineers.

References

American Educational Research Association/American Psychological Association/National Council on Measurement in Education (AERA/APA/NCME). (1999). *The standards for educational and psychological testing*, American Psychological Association, Washington, D.C.

ASCE Construction Engineering Education Committee. (2001). *Guide to professional engineering licensure for the construction engineer*, ASCE Construction Institute, Reston, Va.

National Council of Examiners for Engineering and Surveying (NCEES). (2002). *Model rules and regulations for licensing boards*, Clemson, S.C.

National Council of Examiners for Engineering and Surveying (NCEES). (2006). *Manual of policy and position statements*, Clemson, S.C.

National Council of Examiners for Engineering and Surveying (NCEES). (2007). *Exam development procedures manual*, Clemson, S.C.

J. Constr. Eng. Manage., 2007, 133(9): 669-677