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Expectations for the Masters-Level Structural Engineering Graduate Preparedness using the Delphi Method

Dr. Zsuzsa Balogh, Metropolitan State University of Denver
Dr. Marvin E. Criswell P.E., Colorado State University

Dr. Marvin Criswell is professor emeritus of the Department of Civil and Environmental Engineering at Colorado State University in Fort Collins, Col.

Dr. Michael A De Miranda, Colorado State University

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Introduction

Structural engineering educational programs in the U.S. are facing great challenges in correlating their programs and goals with the needs of their graduates and the structural engineering profession in today's constantly changing global environment. The ASCE Raise the Bar initiative within civil engineering, its call for education beyond the undergraduate level for future entry into civil engineering practice, and ongoing and upcoming changes in professional registration emphasizes the need for structural engineering at the graduate level to be carefully planned. The educational content and requirements of especially the Masters-Level programs should be examined, along with the needs and expectations of structural engineering practice, with input from both academics and the profession. The reported study was designed to obtain significant critical information on the expected preparation of the young engineer in structural engineering practice using a survey based modified Delphi method.

This paper discusses a methodology for determining the expectations of the structural engineering profession for the preparation of the young engineer achieved through graduate work and early-career experience, along with the results of this study. For structural engineering the question of expected competencies may be examined for at least three times in the student's preparation: after their undergraduate work, immediately after a graduate level program, or after Masters-Level graduation and the first few years of experience. This study addresses in some detail how well the Masters-Level structural engineering education, supplemented with the knowledge increase expected from the initial professional experience, meets the expectations of the structural engineering profession in the United States.

The outcomes of this research project include an assessment of the competency level (using Bloom's taxonomy [1]) expected to be achieved by the conclusion of the Masters-Level program and after the initial five years of professional practice following the graduate program in each of the 44 (50 including the added subtopics recommended by expert panel participants in Round 1 of the study) areas within the following five (plus one) general categories: A-Basic Mechanics and Engineering Tools, B-General Structural Engineering Tools, C-Technology and Communication Tools, D-Structural Engineering Topics and Tools, E-Management and Professional Tools, F-Additional Topics. This paper describes the overall study and emphasizes the competencies expected upon completion of the Masters-Level programs. Results specifically addressing the post-graduate and early experience period are presented in a companion paper. The results of the research provides very useful information to both the academic and practicing structural engineering communities by defining a framework of knowledge (FOK) expected by the profession for the young structural engineer.

Purpose of the Study

The overall objective of this study [2] was to define the needed content of the Masters-Level graduate programs in structural engineering as perceived by the profession and to thereby

provide critical input and a basis for defining an improved framework for the Masters-Level graduate programs in structural engineering which will better prepare its graduates for professional practice. As the initial professional experience and various continuing education programs have an important role, these are also addressed.

The future implementation of this framework recognizing the needs of the profession will depend upon resource limitations and current practices of both the academic and the practice environments, along with the availability and use of additional academic electives, the individual's initial professional employment, continuing education, and other lifelong learning resources. This study provides the key information and recommendations in support of the development of what will be called a Framework of Knowledge (FOK) for structural engineering Masters-Level education, and which is consistent with the more-generally stated ASCE Body of Knowledge [3] but is more directed to focus on structural engineering, with emphasis on the Masters-Level education and the graduate's initial period in practice. This study is expected to have a positive and significant impact, both short term and long term, on the preparedness of the new Masters graduates in structural engineering.

Background

The actions of ASCE in leading the call for additional preparation of young engineers and its further definition of this need through its "Raise the Bar" initiative and activities, including the Body of Knowledge (BOK) report by its Body of Knowledge Committee of the CAP3 [3] are very notable and a major motivation for this study. The ASCE BOK addresses the breath of the civil engineering profession rather than the specialties of civil engineering. Although it includes the importance of early professional experience, it addresses more the basic educational programs for the young civil engineer. In many ways, this study extends the findings of the BOK Report to the large specialty area of structural engineering. As increased emphasis is being given to the Masters-Level or equivalent preparation as an future expectation of licensure and the overall profession, there appears to be an increasing need for information on a number of civil engineering specialties to be generated in a format similar to that used in this study.

The major steps in the formulation and implementation of a Body of Knowledge for a profession, such as the ASCE Body of Knowledge [3], are well summarized by Ressler in his paper entitled "Sociology of Professions: Application to the Civil Engineering "Raise the Bar" Initiative" [4]. Because the current study addresses elements of the ASCE Body of Knowledge (BOK) as applied to structural engineering, it is relevant to examine the steps involved in defining and implementing this BOK and how the current study fits within these steps. The paper by Ressler is a basic reference paper describing requirements for professions in general and the adaptation of these requirements to the profession of civil engineering. He describes the progression of first formulating the Body of Knowledge then next defining the knowledge and skill sets needed by the young professional civil engineer a step described as preparing the "Topic Specific Framework of Knowledge" or "The specialty-specific BOK". This process and the subsequent delivery of this Framework of Knowledge are very much influenced by the resources, philosophy, expertise, and judgment of the educational institution and academic unit.

The ASCE BOK certainly applies to the civil engineering specialty area of structural engineering as well as to the overall civil engineering area, even though the 2008 ASCE BOK report emphasizes the undergraduate program. The current study addresses a specialty-specific BOK and thus it will be described as a study to define the Framework of Knowledge (FOK) for the steps in preparing the young engineer for practice in a specialty area of civil engineering,

namely the structural engineering profession. It is a step directed towards assisting the structural engineering profession and the associated educational communities in their planning of the programs needed to deliver the overall BOK within one of the many practice areas of the civil engineer. Like the ASCE BOK report, this study has given considerable attention to the importance of the early period in the profession, a time which has many attributes of an apprenticeship, in the preparation of the young professional, as the overall preparation structural engineer is very much a collaborative effort of the educational programs, the structural engineering design and construction community, and the overall structural engineering profession.

Design of the Study

Delphi method

The methodology chosen for the reported study was a modification of the Delphi method. This is a method for structuring a group communication process to facilitate group problem solving and to structure models [5]. The method can also be used as a judgment, decision-aiding or forecasting tool [6], and it can also be applied to program planning and administration [7]. In cases when there is partial knowledge about a problem or phenomena [8], the Delphi method can be applied to problems that do not lend themselves to precise analytical techniques but rather could benefit from the subjective judgments of individuals on a collective basis and to focus their collective human intelligence on the problem at hand [8]. Also, the Delphi method can be used to investigate and predict what does not yet exist [9], [10], and [11]. In this study, a basic Delphi method is adapted to the formation of a group consensus.

The use of the Delphi method in graduate research has been most extensive in the medical field. However, it has been employed in several engineering-related areas such as industrial engineering [12]. The goal of this research was to create a Masters-Level structural engineering curriculum framework recommendation with the input of experts in the structural engineering professional field in the United States. The characteristics of the Delphi method as described in the literature are a good fit to the needs of this study.

Limitations of the study were:

- Size of the participant group. The methodology used included a modified Delphi study with 33 (Round 1), 32 (Round 2), and 25 (Round 3) participants. This study size is considered to be large enough to provide a broad representation of the profession and yet limit to a practical magnitude the resources needed to compile and analyze the data in a realistic and timely manner for the purpose of this research. A larger sample size could strengthen the findings.
- Selection of the participants representative of the population group. The sampling criteria for the identification of potential volunteers who are practicing structural engineers, educators, and professional organization members in the structural/civil engineering area are a possible limitation of the study. The participants in the Delphi study were volunteers from an invitation list of representative individuals determined to be knowledgeable and interested in the educational preparation of the structural engineer rather than being from a random selection of the entire structural engineering population.

- A key feature of the Delphi method is the use of repeated rounds of participant inquiry with the participants given information of the group response in previous rounds and a request to review and reconsider their response; a process expected to produce some convergence toward a common group outcome. Another methodology-related limitation thus comes from the number of rounds planned for the modified Delphi method, a method which inherently has no set upper limit on the number of rounds. The number of rounds can be limited to the number needed to give a well considered and useful individual and group information.

Selection of Expert Participant Panel

In the Delphi-study the researcher selects a representative expert panel with expertise in the specific focus area of the research topic. In this research, the structural engineering profession was the overall group of interest. Expert structural engineers were selected from three major sub-groups: academia, professional firms with service profiles including structural engineering, and professional societies associated with the structural engineering profession, with the largest number from the professional firms segment.

- Within the industry, the focus was on individuals in structural engineering firms or civil engineering firms providing structural engineering services and who were registered engineers with authority and experience in hiring and training young engineers.
- Participants in the academic institution representative group were required to be faculty members and/or administrators of institutions of higher education in the United States that offers graduate degrees in structural engineering.
- Participants from the professional societies related to structural engineering were chosen from the officers, engineering staff, and major activity leaders of American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI), National Council of Structural Engineers Associations (NCSEA), Structural Engineering Certification Board (SECB), or the individual state's Structural Engineers Associations (SEAs).

Based on the expert panel qualifications in Round 2, the survey participants were 93.8% PE's, 37.5% SE's and/or SECB members (all PE's), and 71.9% hiring authorities. Out of the structural engineering firm representatives 96% were hiring authorities. The modified Delphi study used included three rounds of participant response and was conducted using e-mail. A basic characteristic of an e-mail survey is that only some of those invited will respond, individually, even with follow-up contact, and a few participants will drop out in each round. The participant distribution by affiliation and structural engineering firm size are presented in Figure 1 and Figure 2. The Initial Target Panel was considered with 98, Panel Returning R1 with 40, Panel Returning R2 with 39, and Panel Returning R3 with 32 total participants in the three categories (with some overlaps, several participants being members of more than one affiliation group).

Based on the number of employees, six company categories are defined by the American Council of Engineering Companies (ACEC) as shown on Figure 2:

Small (1-30 employees)
Medium (31-75 employees)
Medium Large (76-150 employees)
Large (151-499 employees)
Extra Large (500-999 employees)
Extremely Large (1000+ employees)

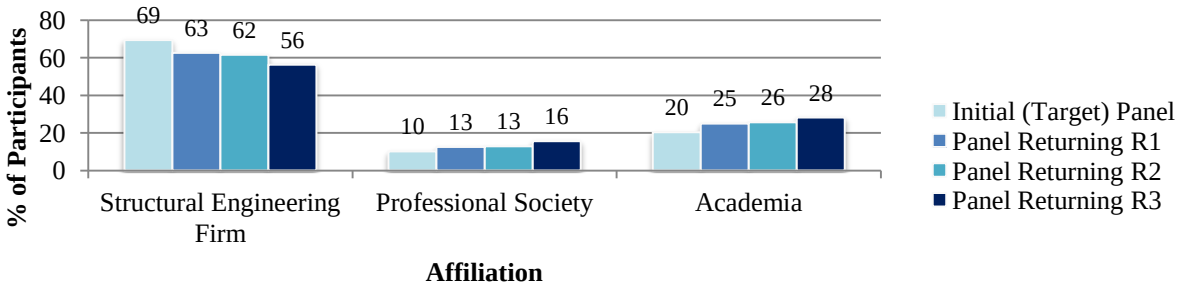

Figure 1: Participants distribution by affiliation

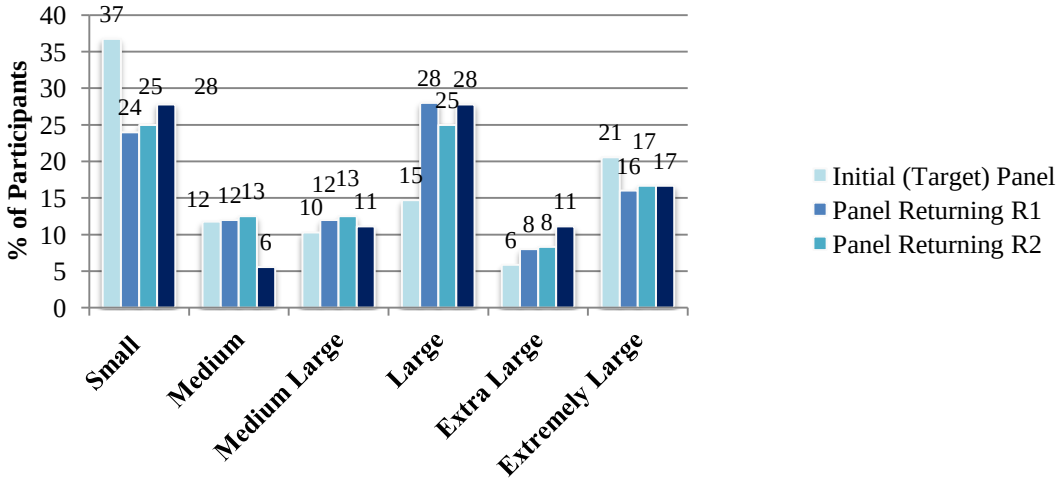

Figure 2: Distribution of Panel Participants by Firm Size

The distribution by regions of the participants nationwide including invited participants from structural firms, professional societies, and academic institutions, is summarized in Table **1**.

Table 1: Expert Panel Distribution by Regions in the United States

ASCE Region	1	2	3	4	5	6	7	8	9	Washington D.C.
% of total (87) representation	11.5	5.7	13.8	10.4	10.4	4.6	29.9	10.3	2.3	1.1
Round 2 (32 total) representation (nr)	2	2	2	2	4	0	17	1	1	1
Round 2 representations (%)	6.1	6.1	6.1	6.1	12.1	0	51.5	3	3	3

ASCE Region 7 had the highest representation. The initial expert panel with 29.9% representation from Region 7 is largely due to the inclusion of the expert group members (all from Colorado) in the initial expert panel.

Conduct of the Survey

The Delphi study survey for this research was conducted in two phases, using three rounds, hereafter identified as Round 1, Round 2, and Round 3. For all three rounds, the survey participants were instructed to assume the default or typical path of the young structural engineer, namely, undergraduate engineering followed by a Masters-Level program emphasizing structural engineering, and then initial employment in structural engineering practice. An initial professional practice phase of five years was chosen as the typical minimum requirement for professional licensure.

The initial assessment by the Delphi-study participants included 44 sub-topics organized into five major Topic Groups. The questionnaire for the Delphi study was formulated by input, including review and critique of a draft document, obtained through personal interviews and follow-up comments from Denver and Front Range Colorado engineers in structural engineering practice and /or education. The purpose of Round 2 was to provide the respondees of Round 1 with an opportunity to view a summary of the group's evaluations and to give them the option to revise, considering this feedback on group response and additional time for reflection, their own individual evaluations. This is consistent with the basic principles of the Delphi Method.

The Round 2 questionnaire included the same topics as did Round 1, with the addition of a group of six questions recommended for inclusion in the participant's Round 1 responses. The requested participant input was to assign the achievement levels using Key Set #1 as follows: Level 1-Knowledge; Level 2-Comprehension; Level 3-Application; Level 4-Analysis; Level 5-Synthesis, and Level 6-Evaluation. The numbers ranging from 1 to 6 were assigned to the rank-ordered categories for the achievement levels using Bloom's taxonomy, and were considered to be ordinal variables. Although Key Set #1 assigns higher numbers to the higher achievement levels, the achievement intervals between these achievement levels are not uniform and thus such usual statistical tools as the mean and standard deviation are approximate and their use can be considered inappropriate.

It was expected that a potential third round configured to repeat Round 2 would not result in significant changes and could negatively affect the response rate. If the results of Round 2 were found to be little different than those of Round 1, plans were to use Round 3 to explore the importance of several sources of additional competency available in the early professional years. As discussed below, the results of Round 2 were very similar to those of Round 1, and thus the results of Round 2 are used to define the participant group's evaluation. Before the planned Round 3 (described in more detail in a companion paper) was conducted, a statistical study was carried out to determine how similar the responses to the questionnaire in Round 1 and 2 were. The Kendall's tau-b method was used as the strength of relationship test to quantify the similarity of the Round 1 and Round 2 results. This non-parametric statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 20.0 for Windows [13].

Since the differences between the two sets of results were sufficiently small, the conclusion was reached that an additional similar round, one which essentially repeats Round 2, would give minor change. Since the values obtained in the second round were the improved and more informed values, but are little different than the first round values, only the Round 2 values were utilized in the rest of the study.

Study Results

For each of the three educational levels considered (upon Masters-Level graduation, with 5 Years of Experience, available through electives), the percentage of responses for each task assigned to the top two of the six Bloom's achievement levels (≥ 5) and to the top four levels (≥ 3) were determined, along with the preparation of stacked bar-charts showing the distribution of all responses. This paper emphasizes the results of Topic Groups A and E. Group A includes subtopics which can be considered to be mostly the responsibility of the educational programs, while Group E subtopics are most dependent upon practices of the professional-practice community.

Table 2 lists results for these two Topic Groups. The Topic Groups not included in Table 2 are shown in Table 3.

Table 2: Expected Competency Summary for Round 2, Topic Groups A and E

Question	At Graduation		After 5 Years	
	≥ 5 Level	≥ 3 Level	≥ 5 Level	≥ 3 Level
A. Basic Mechanics and Engineering Tools				
A1. Advanced Mechanics of Materials	9	75	31	97
A2. Structural Analysis – Framed Structures	28	97	84	100
A3. Finite Element Analysis/Modeling	6	75	50	100
A4. Elastic Stability	3	66	38	100
A5. Structural Dynamics	3	75	41	97
A6. Analysis of Plates and Shells	3	31	16	78
A7. Properties & Behavior of CE Materials	6	66	47	97
A8. Numerical Methods	3	44	13	56
E. Management and Professional Tools				
E1. Design Office Organization/Management/Office Ethics	0	19	34	94
E2. Business Development and Practices	0	10	22	81
E3. Design/Build & Other Project Methods	0	13	23	87
E4. Leadership Skills/Adaptation to Changes	0	32	25	91
E5. Working with Architects, Contractors, etc.	0	27	34	100
E6. LEED, Green Buildings, Energy Use	0	23	19	84
E7. International Design and Construction Practices	0	7	3	48

Only 7 of the 50 subtasks in Group A through F were assigned a Bloom's Level of 5 or 6 by more than 10% of the experts at the time of graduation, while the percentage of Level 5 or 6 responses for the time after 5 Years of Experience are somewhat uniformly distributed between about 10% and 85%. The "≥ 3" measure for the 44 evaluations (Group A through F) at the time of Masters-Level graduation was between 7% and 25% for 8 subtasks, between 26% and 50% for 15 subtasks, between 51% and 75% for 14 subtasks, and between 76% and 97% for 7 subtasks, a wide distribution which was found very useful in identifying individual subtasks usually assigned the higher and lower expected achievement levels.

Table 3: Topic Groups and Subtopics besides Topic Group A and Topic Group E

B. General Structural Engineering Tools
B1. Behavior of Structural Systems. Load-Path.
B2. Building Codes & General Requirements
B3. Architectural/Aesthetics Considerations
B4. Conceptual & Preliminary Planning
B5. Design Loads, Including Evaluation
B6. Foundations & Geotechnical Topics
C. Technology and Communication Tools
C1. Project Plans & Specifications
C2. Communication Software & Tools
C3. Computer Graphics
C4. Structural Engineering Design Software
C5. Building Information Management (BIM) Systems
C6. Programming Skills
D. Structural Engineering Topics and Tools
D1. Structural Steel Design – Basics
D2. Structural Steel – More Advanced Topics
D3. Reinforced Concrete Design Basics
D4. Prestressed Concrete Design
D5. Reinforced Concrete – Advanced Topics
D6. Masonry Design
D7. Timber Design
D8. Design with Structural Aluminum
D9. Bridge Design – Short/Mid Span
D10. Bridge Design – Long Span Systems
D11. Earthquake Engineering – Basics
D12. Earthquake – High Risk Areas
D13. Design to Resist Unusual Loads/Blast
D14. Special Concerns for High Rise Systems
D15. Condition of Structures/Repair, Renovation, Reuse
D16. Special Requirements – Residential
D17. Special Requirement – Light Commercial
F. Additional Topics
F1. Communication Skills (Oral, Written, Graphical)
F2. Effective Speaking
F3. Financial Assessment
F4. Working as a Team
F5. Total Building Design Project
F6. Bridge Design Codes (as an addition to B2)

A sample of the graphical representation of the participant expected frequencies by achievement level in Round 2 are shown in Figure 3 for Topic Group A at the graduation level of preparation and Figure 4 for Topic Group E at the graduation level of preparation. On these stacked bar charts, the largest bar segment identifies the achievement level most often assigned.

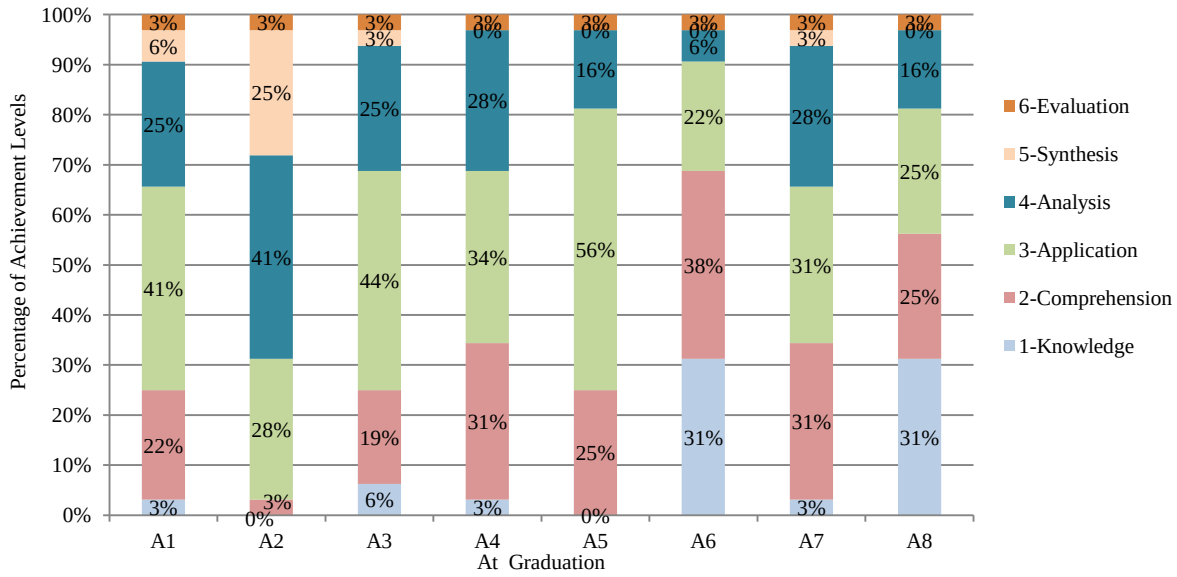

Figure 3: Frequencies of Achievement Levels for Topic Group A at Graduation

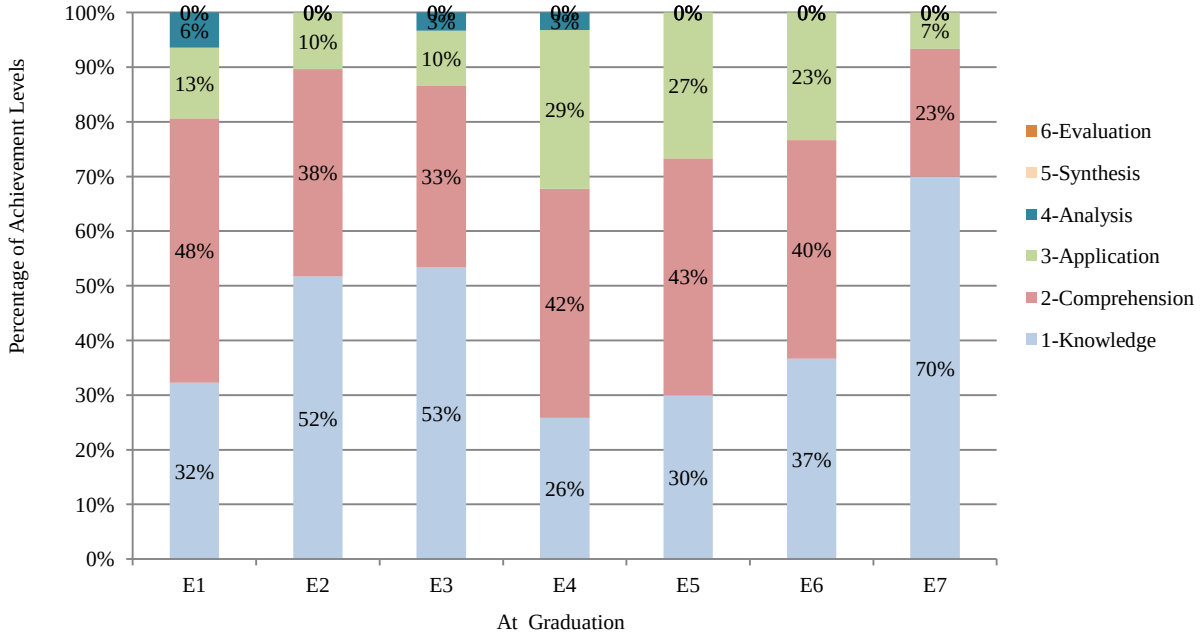

Figure 4: Frequencies of Achievement Levels for Topic Group E at Graduation

For the Basic Mechanics and Engineering Tools (A) topic, an achievement Level of ≥ 3-Application was usually expected at the time of graduation, with the ≥ Level 3 expected by 60% or more of the participants for 6 of the 8 subtasks. The lowest achievement level expectation by the expert participants at graduation was for Analysis of Plates and Shells (A6) with 31% ≥ Level 3, with 44% at that level for A8, Numerical Methods. After 5 Years of Experience, the Numerical Methods (A8) sub-topic was assigned the lowest expected achievement level with 13% ≥ Level 5-Synthesis, not much below the 16% value for A6, Plates and Shells. The highest

expectations of achievement level was Structural Analysis-Framed Structures (A2) both at graduation (97% ≥ Level 3) and after 5 Years of Experience (84% ≥ Level 5). In addition to the subtask A2 just mentioned, fairly high expectations at the after 5 year level using the "≥ Level 5" measures also were assigned to subtasks A3, Finite Element Analysis/Modeling (50% at ≥ Level 5), A7, Properties and Behavior of Civil Engineering materials (47% at ≥ Level 5) and A5, Structural Dynamics (41% at ≥ Level 5).

Topic Groups E, Management and Professional Tools, and F, Additional Topics, include many topics that are very important and integral to professional practice and which are not often emphasized in the academic programs. The results reflected this trend. Many of the highest increases in expected achievement levels between graduation and after five years experience are for the subtasks of these two areas.

The highest achievement levels expected at graduation were E4, Leadership Skills and Adaptation to Changes (32% at ≥ Level 3) for Group E, and F1, Communication Skills (96% ≥ Level 3) for Group F. The lowest expected achievement levels among Group E and F topics at the time of Masters-Level graduation were assigned to E7, International Design and Construction Practices (7% at ≥Level 3 at graduation) and F3, Financial Assessment (8% at ≥ Level 3 at graduation). Subtask F1, Communication Skills, was the only subtask in Group F expected by any of the participants to reach the ≥ Level 5 proficiency by any individuals at the time of Masters-Level graduation.

Use of the Survey Results by the Academic Community and other Stakeholders

The results of this research can contribute to the structural engineering profession on several levels and in several different ways for the various stakeholder groups in the structural engineering areas. These many stakeholder groups include academic institutions, providers of structural engineering services, the taxpayers, and a wide variety of general interest groups. Six stakeholder communities most directly involved in structural engineering, and thus potentially most directly able to utilize the results of this research, are next identified and potential uses by the first group, the three groups most directly involved in the graduate programs are described in some detail.

- Academic Institutions offering Masters-Level Structural Engineering Programs

A primary set of information which should be of interest to the educational institutions is the identity of the subject areas (i.e. subtasks) for which the graduates are expected to have the higher levels of abilities. It is suggested that the structural/civil engineering programs examine the ways in which their graduate program can best build upon the undergraduate engineering program to most effectively deliver these desired competencies.

Among the subject areas for which the profession has the highest expectations are: Group A, Basic Mechanics and Engineering Tools: Advanced Mechanics of Materials, Structural Analysis-Framed Structures, Finite Element Analysis/Modeling, and Structural Dynamics. Group B, General Structural Engineering Tools: Behavior of Structural Systems – Load Path; and Design Loads, including Evaluation. Group C, Technology and Communication Tools: Communication Software and Tools, and Structural Engineering Design Software. Group D, Structural Engineering Topics and Tools: Structural Steel Design Basics, Reinforced Concrete Design Basics, Earthquake Engineering – Basics, Prestressed Concrete Design, with Masonry Design, Timber Design, with more advanced topics in both steel and reinforced concrete also assigned quite high expectations. Group E, Management and Professional Tools:

The two subtopics with the highest expectations are Leadership Skills/Adaptation to Change, and Working with Architects, Contractors, etc., although both of these were assigned lower expectations than for about two-thirds of the topics in Group D, including those mentioned above. Group F, Additional Topics: Communication Skills (Oral, Written, Graphical), and Total Building Project Design.

Academic programs have several options for packaging academic content, the default mode being a well-defined course dedicated to a single topic. Other modes include a single class addressing in sequence two or more topics, a class addressing two or more topics together, and a class with the inclusion of a secondary topics within a primary topic. Logical candidates for a dedicated course at the graduate level are most of the topics listed above for Areas A, B and D. Some of the topics assigned the highest expectations are topics usually supported by one or more undergraduate classes – topics such as structural analysis of frames, basic structural steel design, and basic reinforced concrete design. Given the limitation of the number of courses or credits in the typical Masters-Level programs, some of the topics may need to be combined into a single class. Some possible pairs include (a) timber and masonry design, (b) structural dynamics and earthquake engineering fundamentals, (c) elastic stability and advanced steel design topics, and (d) structural loads, security/safety considerations and risk analysis, and design principles to resist disproportionate damage/collapse. An efficient approach may be to place three or more topics in a survey course providing breadth instead of depth, with one possible group of topics being green buildings and LEED, building inspection and monitoring, and building repair, renovation and reuse. A well-organized survey course, perhaps taught by a local structural engineer with extensive experience in project and office management, addressing many of the management and professional topics could be very effective in building on the undergraduates limited abilities in these areas to reach the expected proficiency levels. Structural engineering design software may be best taught as an integral tool in a building design project class emphasizing one or more structural materials. Ethics, a critical topic not specifically addressed in the questionnaire, leadership skills, management topics, and construction/architectural concerns may be best addressed by these topics being infused into other classes as secondary but important considerations often noted in the conduct of the class.

- Employers Hiring Masters-Level Graduates in Structural Engineering.
- Young Structural Engineers Planning their Professional Growth

The description of the expectations of the structural engineering profession for identified subject areas can be effectively used at several points along the individual's formal education and early career years. The Framework of Knowledge can communicate to the young engineer useful information on what a structural engineer does and what are the expected competencies. Any electives in Masters-Level program can be chosen with one major consideration being how well the elective courses address the expectations of the profession and the topics included in the professional (P.E. and S.E.) licensure exams. Involvement in activities outside of the formal classes, including self-study, can be planned considering the available information on the expectations of the structural engineering profession.

- Institution/Firms/Organizations Involved in Post Masters Degrees Education.
- Licensing Boards and Professional Exam Providers.
- ASCE and Other Professional Societies Addressing Structural Engineering

The American Society of Civil Engineers (ASCE), its Structural Engineering Institute (SEI), along with a large number of other professional organizations such as the American Concrete Institute (ACI), the American Institute for Steel Construction (AISC), and the

American Institute of Timber Construction (AITC) are important sources of seminars, short course and other professional development programs.

Notable activities of most of these groups not directly addressed in this study include meetings ranging from national and international conferences to local chapter meetings, publications containing a combination of professional and research information, and technical committees which provide a combination of professional service and significant professional development for the committee members. Participation in appropriate professional activities is an important additional source of professional development not directly addressed in this study, but one that all young structural engineers should choose.

Thus, encouragement is offered to ASCE to include in their current plans and activities studies such as the reported project to give an increased description and assessment of professional expectations in other sub-disciplines/specialties of civil engineering. The present study should be able to serve as one model or starting point for these types of studies. Through the ASCE organization, such studies can be conducted with the intense level of planning and the high level of participation by members of the profession not possible in this initial study. The profession would greatly benefit by having this type of description of needs and expectations, including structural engineering, with the depth and credibility that can be provided best by ASCE.

Recommendations

The primary recommendations from the parts of this study presented in this paper relate to use of the study results and suggested additional efforts.

The survey results can and should be used by the educational programs as one input to consider in their critique and planning of their graduate academic programs in structural engineering, along with faculty, graduates, employers, and advisory committee input, course recommendations for NCSEA, and content of the relevant NCEES exams.

The strength of the Framework of Knowledge findings from this study, which can be considered a limited-scope pilot study, would be improved by expanding this study to a much larger participant group, perhaps facilitated by ASCE or a similar professional group.

It is proposed that a similar set of studies addressing the topic areas and appropriate level of achievement in each could and should be carried out in the other practice areas (geotechnical, transportation, environmental, etc.) within civil engineering.

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