CE Poster Session

Structural Analysis and Design in Tomorrow's Civil Engineering Curriculum

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Abstract
The paper examines coverage of various topics from typical required undergraduate courses such as Statics, Dynamics, Structural Analysis, and Structural Design. We also look into material typically covered in other structures related courses such as Strength of Materials, Finite Elements, Composite materials, Continuum Mechanics, Structural Dynamics, and Vibrations. Major topics covered in these courses are examined based on the following considerations.

1. Topic important/not important for passing the Fundamentals of Engineering Examination
2. Topic important/not important for passing the Professional Engineering Examination
3. Topic related/not related to their every day work
4. Topic learned/not learned through on job training
5. Topic learned/not learned through continuing education
6. Topic fundamental to learning related advanced topics

Input on these issues is sought from a selected group of practicing structural engineers and educators in Iowa. The paper summarizes results of this feedback.

Introduction
Engineering marketplace is vastly different today than it was few decades ago. Due to rapid advances in technology and globalization of engineering services there is high demand for engineers who have skills that go well beyond the technical knowledge gained through a typical engineering curriculum. As a result most engineering schools are under tremendous pressure to add courses into the curriculum that address the changing nature of the engineering marketplace. At the same time, because of economic factors and other issues that are well documented in debates related to the proposed ASCE policy 465, engineering schools must educate future practicing engineers generally through traditional four-year bachelors and perhaps one to two year masters degree programs. Obviously something must be taken out from the existing curriculum to make room for new courses that are designed in response to new challenges facing the engineering profession. This paper examines typical curriculum in structural engineering in an attempt to answer this question. We chose to focus on structural engineering because it is

our area of teaching and research focus. Also in traditional civil engineering curriculum there are several courses that deal with structures and there is constant pressure from other disciplines, even within civil engineering, to cut down on the number of required structures oriented courses.

The paper examines coverage of various topics from typical required undergraduate courses such as Statics, Dynamics, Structural Analysis, and Structural Design. We also look into material typically covered in other structures related courses such as Strength of Materials, Finite Elements, Composite materials, Continuum Mechanics, Structural Dynamics, and Vibrations. Major topics covered in these courses are examined based on the considerations such as the importance of the topic for passing the Fundamentals of Engineering Examination or the Professional Engineering Examination, its relationship to every day work, its importance for learning advanced topics, and whether it should be learned through on job training or through continuing education.

Input on these issues is sought from a selected group of practicing structural engineers and educators in Iowa. The paper summarizes results of this feedback.

Typical Undergraduate Structures Related Courses

Relevant questions for each topic

1. Is important for F.E. examination
2. Is important for P.E. examination
3. Is related to my everyday work
4. Best learned through on-the-job training
5. Best learned through continuing education
6. Is fundamental to learning advanced topics
7. Recommendation: 0: Keep as is, 1: Move to graduate level, 2: No need to teach

Responses: -1: Disagree Blank (0): Neutral 1: Agree

Basic Core Courses

	1	2	3	4	5	6	7
Statics							
Force vectors	0	0	0	-1	-1	0	1
Equilibrium of a particle	0	1	0	0	-1	1	0
Force system resultants	0	1	1	-1	-1	1	0
Equilibrium of rigid bodies	0	1	0	-1	-1	1	0
Forces in Trusses & Frames	0	1	1	-1	-1	1	0
Moment and shear diagrams	0	1	1	-1	-1	1	0
Friction	0	0	0	-1	-1	1	0
Center of gravity and Centroid	0	1	1	0	-1	1	0
Moment of inertia	0	1	1	-1	-1	1	0
Virtual work	0	0	-1	-1	-1	1	0
Dynamics							

Motion of a point	0	0	-1	-1	-1	1	0
Force, mass, and acceleration	0	0	0	-1	-1	1	0
Energy methods	0	0	-1	-1	-1	1	0
Momentum methods	0	0	-1	-1	-1	1	0
Planar kinematics of rigid bodies	0	0	-1	-1	-1	1	0
Planar dynamics of rigid bodies	0	0	-1	-1	-1	1	1
Energy and momentum	0	0	-1	-1	-1	1	0
Three dimensional kinematics	0	-1	-1	0	0	0	1

Structural Analysis and Mechanics Courses

	1	2	3	4	5	6	7
Structural analysis							
Statically determinate trusses	0	1	1	-1	-1	1	0
Shear and moment diagrams	0	1	1	-1	-1	1	0
Cables and arches	0	1	1	-1	-1	1	0
Influence lines	-1	1	-1	0	-1	1	1
Approximate analysis methods	0	1	1	-1	-1	1	0
Moment area method	0	-1	-1	-1	-1	1	1
Conjugate beam method	0	-1	-1	-1	-1	1	2
Castigliano's theorems	0	-1	-1	-1	-1	1	1
Force method	0	-1	-1	-1	-1	1	1
Slope-deflection equations	0	-1	-1	-1	-1	1	1
Moment distribution method	0	1	-1	-1	-1	1	1
Displacement method	0	-1	-1	-1	-1	1	1
Matrix methods	0	-1	-1	-1	-1	1	1
Mechanics of Materials							
Stress & Strain	0	1	1	-1	-1	0	0
Torsion	0	1	1	-1	-1	0	0
Stresses in Beams	0	1	1	-1	-1	0	0
Deflection of beams	0	1	1	-1	-1	0	0
Stresses due to combined loads	0	1	1	-1	-1	0	0
Composite beams	0	0	1	-1	-1	0	0
Columns	0	1	1	-1	-1	0	0
Inelastic action	0	1	1	-1	-1	0	0
Soil Mechanics							

Physical Properties of Soils.	0	-1	1	1	-1	1	0
Permeability of Soils.	0	-1	0	1	-1	1	0
Stresses in Soils.	0	-1	1	1	-1	1	0
Compressibility; Settlement.	0	-1	1	1	-1	1	0
Shear Strength of Soil.	0	-1	1	1	-1	1	0
Stability of Slopes.	0	-1	1	1	-1	1	0
Lateral Earth Pressure.	0	-1	1	1	-1	1	0
Bearing Capacity	0	-1	1	1	-1	1	0

Structural Design Courses

	1	2	3	4	5	6	7
Design of steel structures							
Allowable stress design (ASD)	0	1	1	-1	-1	1	0
Load & resistance factor design	0	-1	-1	-1	-1	-1	2
Loads on structures	0	1	1	-1	-1	1	0
Tension members	0	1	1	-1	-1	1	0
Compression members	0	1	1	-1	-1	1	0
Beams	0	1	1	-1	-1	1	0
Combined beam-columns	0	1	1	-1	-1	1	0
Bolted connections	0	1	1	-1	-1	1	0
Welded connections	0	1	1	-1	-1	1	0
Steel building frames	0	1	1	-1	-1	1	0
Composite beams	0	1	1	-1	-1	1	0
Plastic analysis & design	0	1	0	-1	-1	1	1
Design of concrete structures							
Singly reinforced beams and slabs	0	1	1	-1	-1	-1	0
Doubly reinforced beams	0	1	0	-1	-1	-1	0
Shear in beams	0	1	1	-1	-1	-1	0
Continuous beams	0	1	1	-1	-1	-1	0
Serviceability	0	1	1	-1	1	-1	0
Walls	0	1	1	-1	-1	-1	0
Columns	0	1	1	-1	-1	-1	0
Footings	0	1	1	-1	-1	-1	0
Formwork	0	1	1	-1	-1	-1	0
Detailing concrete structures	0	1	1	-1	-1	-1	0

Advanced Structures Related Courses

Relevant questions for each topic

1. Is important for P.E. examination
2. Is related to my everyday work
3. Best learned through on-the-job training
4. Best learned through continuing education
5. Is fundamental to learning advanced topics
6. Recommendation: 0: Teach at the graduate level, 1: Teach at the undergraduate level, 2: No need to teach

Responses: -1: Disagree   Blank (0): Neutral   1: Agree

Advanced analysis courses	1	2	3	4	5	6
Basic finite element analysis	-1	-1	-1	-1	1	1
Advanced finite element analysis	-1	-1	-1	-1	1	1
Structural dynamics and vibrations	-1	-1	-1	-1	1	1
Matrix analysis of structures	-1	-1	-1	-1	1	1
Advanced soil mechanics	-1	0	-1	-1	1	1
Advanced mechanics of materials	-1	-1	-1	-1	1	1
Continuum mechanics	-1	-1	-1	-1	1	1
Plates and shells	-1	-1	-1	-1	1	1
Energy methods	-1	-1	-1	-1	1	1
Structural stability	0	1	-1	1	1	0
Composite materials	0	1	-1	1	1	0
Fracture & fatigue mechanics	0	1	-1	1	1	0
Advanced design courses						
Design of high-rise building	-1	1	1	-1	-1	1
Design of bridges	1	-1	1	-1	-1	1
Design of timber structures	1	1	-1	-1	-1	0
Design of masonary structures	1	1	-1	-1	-1	0
Prestressed concrete design	1	1	-1	-1	-1	0
Shell structures	-1	-1	-1	-1	-1	1
Advanced concrete structures	1	1	-1	-1	-1	1
Advanced steel structures	-1	1	-1	-1	-1	1
Earthquake resistant design	1	1	-1	-1	-1	1
Design for wind loads	1	1	-1	-1	-1	0
Blast resistant design	-1	0	-1	-1	-1	1
Foundations and retaining walls	1	1	-1	-1	-1	0
Deep foundations	-1	1	-1	-1	-1	0
Advanced analysis & design courses						

Parking structures	0	1	-1	-1	-1	0
Structural optimization	0	0	-1	-1	-1	0
Boundary elements	0	-1	-1	-1	-1	1
Meshless finite elements	0	-1	-1	-1	-1	1
Blast & Fire resistant design	0	1	-1	-1	-1	0
Design practice and Marketing						
Project management	0	1	-1	-1	-1	1
Marketing services	0	1	-1	-1	-1	1
Business development	0	1	-1	-1	-1	1
Ethics	0	1	-1	-1	-1	0
Communications	0	1	-1	-1	-1	1
Quality control	0	1	-1	-1	-1	1
International marketplace	0	-1	-1	-1	-1	0
Sustainability	0	1	-1	-1	-1	0
Cost estimation	0	1	-1	-1	-1	1
Project financing	0	1	-1	-1	-1	0

Implications of Results

While the sample size on this survey was relatively small, it does provide some interesting feedback that should be considered when major curricular developments are being planned.

The results from the core course part of the survey can best be summarized as "maintain the status quo." Even the notion of teaching some of these topics by distance education was not well received. This raises an issue which cannot be addressed by the work in this study but nonetheless is relevant to the findings, namely to what extent are civil engineers an inherently conservative group that will be unlikely to embrace change regardless of the value of the change.

It is also somewhat disconcerting that the responses to the core section of the survey indicate that these core topics are important for the P.E. exam rather than for the F.E. exam, whereas a study of the two exams would suggest exactly the opposite. It may well be that responses to the survey are measuring respondents perceptions rather than any real evaluation on their part.

In the part of the survey examining Structural Analysis and Mechanics Courses, an interesting trend emerges. Most classical methods of structural analysis were rated as being not related to the respondent's everyday work. Specifically, influence lines, moment area method, conjugate beam method, Castigliano's theorems, force method, slope deflection equations, moment distribution method, displacement method and matrix methods were all rated in this way. However, of these methods, only the conjugate beam theory was suggested as a topic not needed to be taught. All of the other methods were suggested to be taught at the graduate level, which perhaps begs the question as to what should be taught at the undergraduate level, because not much is left!

In contrast, all the topics surveyed under the Mechanics of Materials section were rated as relevant to everyday work. This included stress & strain, torsion, stresses in beams, deflection of beams, stresses due to combined loads, composite beams, columns, and inelastic action. Perhaps respondents simply had a better experience in their mechanics of materials class than in their structural analysis class.

In the structural design segment of the survey, the topics were considered much more relevant to everyday work, with only one exception, that being Load & resistance factor design. This too was suggested as a topic that should not be taught (the only such topic in this segment) suggesting an antipathy to the method.

In the responses to the advanced topics segment of the survey, a number of internal contradictions become apparent. Several topics are suggested as needing to be taught at the undergraduate level, including finite element analysis (basic and advanced) vibrations, structural dynamics, advanced sol mechanics, continuum mechanics, plates and shells, energy methods, boundary elements, and meshless finite elements. It is not at all clear how you teach finite element analysis (for example) without teaching matrix methods (earlier suggested as a topic that should not be taught at the undergraduate level). An extensive range of additional design topics were suggested for inclusion at the undergraduate level also, including high rise buildings, bridges, shell structures, advanced concrete structures, advanced steel structures, earthquake resistant design, and blast resistant design.

In the area of practice and marketing, topics of project management, marketing services, business development, communications, quality control, and cost estimation were suggested as being needed at the undergraduate level.

There may be a number of themes that can be developed from the results, although in a broader sense the results simply appear to be all over the place. The first theme is that perhaps practicing engineers are not as familiar with the various examinations needed to obtain licensure as at least the authors of this paper presumed. The need for some sort of educational program in this regard should be examined.

Second, there does appear to be a sense that many topics once considered mainstays of structural analysis (e.g. conjugate beam theory) no longer merit such a role. Related to this is the need to bring newer techniques such as finite element methods, to an earlier point in the curriculum.

Third, there appears to be a strong desire for more design exposure at the undergraduate level, especially in what might be termed system design. It is not enough to be able to design a beam. Students must be able to design a building.

Conclusions

Practicing structural engineers were surveyed to determine which educational topics they thought were critical to the practice of structural engineering, and when those topics should be taught. The responses indicated three themes. Practitioners are uninformed about the content of examinations for licensure (especially the F.E.). Practitioners exhibit a sense that there is a need for an updating of topics in the area of structural analysis. Practitioners desire students to have more design experience. Further, that experience should focus on complete systems rather than on components.