Civil Engineering Program Criteria: A Snapshot of How Programs Meet the Criteria

Dr. Scott R. Hamilton, York College of Pennsylvania

Scott Hamilton is the Coordinator for the new Civil Engineering Program at York College of Pennsylvania. He is a registered Professional Engineer and has both a MS and PhD in civil engineering and a Masters in engineering management from Stanford University and a BS from the United States Military Academy, West Point. He is a retired US Army Corps of Engineers officer who has had assignments in the US, Germany, Korea, and Afghanistan. During his military career he spent over 10 years on the faculty at the US Military Academy at West Point teaching civil engineering. He also served as the Director, Graduate Professional Development at Northeastern University's College of Engineering.

Dr. David A. Saftner, University of Minnesota Duluth

David Saftner is an Associate Professor at the University of Minnesota Duluth. He received a BS in Civil Engineering from the United States Military Academy and MS and Ph.D. in Civil Engineering from the University of Michigan.

Dr. Camilla M. Saviz P.E., University of the Pacific

Camilla Saviz is Professor and Chair of Civil Engineering at the University of the Pacific. She received B.S. and M.S. degrees in Mechanical Engineering from Clarkson University, an M.B.A. from the New York Institute of Technology, and a Ph.D. in Civil and Environmental Engineering from the University of California, Davis. She joined Pacific in 1999 and is a registered Professional Engineer in California.

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Abstract

Programs seeking accreditation by the Engineering Accreditation Commission of ABET (EAC/ABET) must satisfy eight General Criteria plus any applicable Program Criteria that address curricular topics and faculty qualifications. Applicability of the Program Criteria generally is determined by the program name. As such, "Civil Engineering" and similarly named programs seeking accreditation by the EAC/ABET at the baccalaureate level must demonstrate that the program meets both the General Criteria for Baccalaureate Level Engineering Programs and the Civil Engineering Program Criteria (CEPC). A subset of curricular topics required by the CEPC includes the following [1], [2]:

- apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science; and
- analyze and solve problems in at least four technical areas appropriate to civil engineering.

This study was conducted to characterize current practices within EAC/ABET accredited civil engineering programs by examining:

- The minimum number of credit hours of mathematics and sciences, and engineering topics required;
- The minimum number of credit hours required for graduation;
- Required and designated elective courses and credit hours in mathematics and the sciences;
- Courses used to satisfy the additional area of basic science; and
- Technical areas of civil engineering required in the core curriculum.

Data were gathered for 131 of the 252 EAC/ABET accredited civil engineering programs as follows:

- Curricula of the 47 programs scheduled for a comprehensive review in the 2018-19 accreditation cycle were analyzed.
- A survey was sent directly to civil engineering department heads and chairs requesting the information also sought through review of materials posted online. Seventy unique responses were received and analyzed.
- In addition, data for 14 other programs were also analyzed. These additional programs were selected because their faculty are included among the membership of the American Society of Civil Engineers (ASCE) Committee on Education and the ASCE Department Heads Coordinating Council.

Among the curricula of civil engineering programs analyzed for this study, a great diversity of approaches appears to be used to satisfy requirements including the additional science requirement, number of engineering credits, number of required courses in civil engineering technical areas, and number of civil engineering technical areas covered. This analysis shows that ABET requirements are sufficiently broad, allowing programs to use a variety of creative and innovative approaches to customize their curriculum to fulfill the mission of their institution and to meet the needs of their program constituencies. Analysis of results presented in this paper can assist civil engineering programs in identifying different pathways to satisfying accreditation criteria and can

provide important information for the next review of the CEPC, scheduled to begin in October 2020.

Introduction

The purpose of this paper is to describe how civil engineering programs meet requirements of the Engineering Accreditation Commission (EAC) of ABET (EAC/ABET) General Criteria and the Civil Engineering Program Criteria (CEPC). Any engineering program with a program name that includes “civil” (or similar modifier) must satisfy the Civil Engineering Program Criteria [1]. The EAC/ABET General Criteria and the Civil Engineering Program Criteria define the <u>minimum</u> requirements for accreditation of civil engineering programs.

Criterion 5 of the EAC/ABET General Criteria requires that the curriculum include “one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences [1].” “One year” is defined as “the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation [1].” Beginning in the 2019-2020 accreditation cycle, the curriculum requirements specified in Criterion 5 will change to “a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program [2],” thus establishing a specific minimum without regard for the number of units required for graduation.

The CEPC provide additional specificity in the area of mathematics and sciences, namely, that the program must prepare graduates to apply a “knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science [1]”. One focus of this paper is to quantify how programs are meeting requirements in the mathematics and sciences.

The CEPC also require that students “analyze and solve problems in at least four technical areas appropriate to civil engineering [1].” This long-standing provision in the CEPC is intended to ensure that civil engineering graduates have sufficient breadth in the discipline [3]. The second focus of this study was to identify the number, distribution, and topics required by different civil engineering programs.

In this paper, the authors present a brief background on the CEPC currently in use, describe the study methods used, and present an analysis of how the 131 civil engineering programs examined meet requirements of the CEPC and ABET Criterion 5. This study is especially timely considering the upcoming publication of the American Society of Civil Engineers’ (ASCE) Body of Knowledge 3 (BOK3), completed by the BOK3 Task Committee in November 2018 [4]. Following the systematic 8-year review cycle adopted by ASCE for review and update of the BOK and the CEPC [5], [6], the Committee on Accreditation will soon appoint a Task Committee to review, and if needed, revise the CEPC. A summary of current practices will help inform the next generation of the CEPC, scheduled to begin development in October 2020.

Background

ABET is a federation of 36 member societies that represent the engineering, engineering technology, computing, applied science, and natural science disciplines that ABET accredits. The General Criteria for engineering programs, established by the EAC/ABET, are applicable to all engineering disciplines and must be approved by a majority of engineering societies that are members of the EAC/ABET (e.g., ASCE, ASME, IEEE, etc.). Program Criteria are applicable to a single engineering discipline and are developed by one or more ABET member societies designated as Lead Societies for the discipline, with assistance from Cooperating Societies, if appropriate. Program Criteria must be approved by a majority of the engineering societies that comprise the EAC/ABET. ASCE is the fourth largest member society comprising ABET [7], based on the number of programs that are evaluated under the six Program Criteria for which ASCE serves as the Lead Society, namely, Civil Engineering, Architectural Engineering, Construction Engineering, Civil Engineering Technology, Architectural Engineering Technology, and Construction Engineering Technology.

Civil Engineering Programs and Program Criteria

The CEPC currently in effect have been in use since the 2016-17 accreditation cycle [1]. Development of these criteria was well documented in two comprehensive papers by Estes et al. [5], [8]. Civil engineering program faculty review and revise the curricula to prepare graduates for success in their careers, to meet minimum requirements established in ABET criteria, to fulfill the mission of the institution, and to meet the needs of their program's constituencies. Program constituencies can include students, alumni, faculty, and employers, as defined by the program. In papers presented at recent American Society of Engineering Education (ASEE) annual conferences, authors have documented innovative ways to incorporate topic areas and assess students' understanding of sustainability [9] - [13], risk and uncertainty [14], and professional issues including business and public policy [15].

Fridley [16] reviewed curricular requirements for 90 civil and related engineering programs and characterized the total number of credit hours required in engineering topics, mathematics and basic sciences, general education, other areas, and total credit hours required for the degree. The author's analysis of results indicated that programs required, on average, 130 credit hours for the degree, 65 credit hours of engineering topics, 34 credit hours of math and science, and 25 credit hours of general education. In a related study [17], the total credit hours required in 33 civil, 45 mechanical, and 43 electrical engineering programs were compared and found to be very similar; on average 129-130 credit hours were required for each degree. The authors also found similarities in the distribution of credit hours within the degrees: 27% math/science; 51% engineering topics; and 22% general education and other required courses. These percentage distributions are consistent with the distributions observed in a foundational study of civil engineering curricula conducted in 2005 by Russell and Stouffer [18], although the total number of credit hours required has since decreased.

In a detailed analysis of civil engineering curricula, Swenty and Swenty [19] found that although the total number of credit hours in the engineering topics category had remained unchanged as compared to the study by Russell and Stouffer, the number of elective credit hours of engineering topics has increased. Specifically, the authors noted that fewer curricula require completion of standard, core engineering topics such as thermodynamics and electric circuits, and in many programs, this increased flexibility is used to increase specialization within the civil engineering topic areas, as evidenced by addition of discipline-specific courses required at the upper-division level.

ABET Accreditation

ABET accreditation serves several purposes. First, a degree from an EAC/ABET accredited program demonstrates to constituencies and outside entities, including students, alumni, parents, employers, and state licensure boards, that the program meets minimum standards established by the engineering profession. Many programs require students to fulfill graduation requirements that far exceed the minimum requirements established by ABET. Second, a degree from an EAC/ABET accredited undergraduate program is required – or reviewed favorably - by many engineering graduate programs. This requirement provides graduate programs with the knowledge that their incoming graduates have the requisite knowledge, skills, and abilities to successfully complete graduate-level work. Finally, in most licensing jurisdictions, an EAC/ABET accredited degree satisfies educational requirements for licensure. In some states, applicants who have not earned an EAC/ABET accredited degree may be eligible for consideration for licensure, but must satisfy additional requirements of qualifying experience.

Within the civil engineering profession, there is obviously recognized value in seeking ABET accreditation. There are currently 252 ABET accredited civil engineering programs in the United States [20]. Faculty and staff within these programs have put forth the extensive effort required to seek and attain ABET accreditation. Although many programs have a long history of continuous accreditation, apprehension regarding the criteria and past experience with, or urban legends about, “rogue Program Evaluators” seem to persist. Despite these concerns, very few programs receive a “Show Cause” or “Not to Accredit” action. Among all programs evaluated for accreditation in all disciplines (i.e., not just civil engineering) during in the 2016-17 cycle, only three programs received these actions, none of which were civil engineering programs [21]. As shown in Table 1, over 75% of programs evaluated for accreditation between 2012 and 2017 satisfied the EAC/ABET accreditation criteria and will be evaluated during the Next General Review scheduled for the program. Many faculty are not aware of these statistics, and as such, may perceive the EAC/ABET or CEPC accreditation criteria as being very rigid or prohibiting faculty from tailoring the curriculum to meet the needs of their program constituencies.

Table 1. EAC/ABET Action for General Reviews 2012-2017 [21]

Year	Next General Review	Interim Report	Interim Visit	Show Cause	Not to Accredit
2012	76%	21%	2%	0%	0%
2013	79%	16%	3%	0%	0%
2014	89%	10%	3%	<1%	0%
2015	90%	9%	<1%	0%	0%
2016	85%	13%	<1%	1%	<1%
2017	90%	9%	<1%	0%	0%

An analysis of how programs meet the CEPC at this time will provide useful information to other programs and to the upcoming CEPC Task Committee about common practices, areas where challenges may exist, and will reveal how programs are using flexibility and creativity to meet the needs of their program constituencies while also satisfying ABET criteria.

Study Methods

For the purposes of this study, the authors collected data on how civil engineering programs currently meet the CEPC requirements using two primary methods: a review of curriculum information and catalogs posted online and a survey distributed directly to department heads and chairs of civil engineering programs, as described in the following sections. Institutions included in this study are listed in Appendix A.

Online Sources

Curricula of the 47 programs scheduled for a comprehensive review in the 2018-19 accreditation cycle were analyzed together with data for 14 other programs. Programs under review in the 2018-19 accreditation cycle were considered to be more likely than others to have up-to-date information available on websites and to have made any curricular changes in response to the CEPC in anticipation of their upcoming accreditation visit. Each program's curriculum was found in the university's academic catalog posted online or on curriculum or program sheets posted on the department's website.

Many catalog sites or curriculum sheets included the course number and name (e.g., Math 51 – Calculus 1, Math 53 – Calculus 2, CIVL 133 – Water Resources Engineering). On a few sites, only the course prefix and number were listed (e.g., Math 51) without the corresponding course names. In such cases, and in cases where there was any doubt about the course content, the corresponding course name and/or description were further examined in the university's academic catalog.

Survey of Department Heads

Additional information was gathered using a survey that was sent to the department heads and chairs of civil engineering programs in the United States. Invitations to participate were distributed via the ASCE Department Heads' Collaborate site and by a direct email solicitation. Respondents were asked general questions including the accreditation cycle under which the program was reviewed, whether the university is public or private, and the Carnegie Classification. Respondents were also asked to either provide "Table 5.1" (Curriculum details) from their most recent ABET self-study report, a revised version edited to reflect the current curriculum, or to respond to a series of questions designed to elicit the information contained in Table 5.1 of the Self-Study Report.

Seventy nine complete survey responses were received including nine from programs undergoing review in the 2018-19 accreditation cycle. In the case of duplicate records, data obtained from both sources were compared to confirm that the methods used to identify curricular elements in this study were consistent with those used by the programs.

Data Analysis Methods

The curricula of 131 unique programs were examined. As shown in Appendix A, a wide range of programs was represented in this study, including programs at public, private, research-intensive, and primarily undergraduate institutions. For each program, required and elective courses in mathematics, physics, chemistry, and other areas of basic science were recorded. Civil engineering courses required for graduation were counted and grouped according to seven technical areas, as shown in Table 2. These areas were selected to coincide with those discussed in the CEPC Commentary [3]. Analysis of data revealed that several programs require students to take courses in technical areas unique to their geographic area, faculty expertise, or other program interests (e.g., Coastal Engineering, Sustainable Infrastructure). For the purposes of this study, these were categorized as "other" and are discussed in a later section of this paper. For analysis purposes, the minimum requirements for graduation were noted. For example, if students were given a choice of taking a 3 or 4 credit hour restricted elective course, the minimum requirement was considered to be 3 credit hours.

Many programs require students to take elective courses beyond the minimum required core. In some cases, students are required to complete additional restricted electives. For the purposes of this study, only required and designated courses were considered. Restricted electives were not included, as students could choose from among several areas within the discipline, from other engineering disciplines, or even from the sciences.

When different course names were used for a similar area (e.g., Geotechnical Engineering vs. Soil Mechanics), the course description and the placement within the curriculum were examined to determine whether the content was similar. Some curricula included a required course (e.g., Structural Engineering), but students were also required to take an additional restricted elective within the same technical area (e.g., "choose one from Steel Design and Reinforced Concrete Design"). In such cases, the curriculum was considered to require two courses in the Structural Engineering area.

Some programs require students to take courses in both Fluid Mechanics and Hydraulics. In such cases, Hydraulics was counted under the "Water Resources Engineering" technical area because information provided in the course description indicated that the course covered topics beyond fundamental fluid mechanics. Fluid Mechanics was not counted in the "Water Resources" technical area, nor was it considered to be a separate technical area, as the course is typically a pre-requisite for courses in hydraulics or water resources engineering, just as Mechanics of Materials is typically a pre-requisite for structural engineering courses. If the curriculum included only a hydraulics course (i.e., Fluid Mechanics was not required), then the course was counted either as Fluid Mechanics or "Water Resources", depending on the content described in the course description. Hydrology courses were included under the Water Resources Engineering area.

For the purpose of this study, "Construction Materials" courses were included in the Construction Engineering area if the courses included materials science plus materials selection, cost estimating, or other aspects that require engineering decision-making. Courses that were only focused on analysis of material properties, and whose descriptions appeared very similar to courses in "Materials Science", "Engineering Materials," or "Civil Engineering Materials" were not included in this category. Consequently, the study results may underestimate the number of courses required in the areas of civil engineering.

Table 2. Courses included within each technical area

Technical Area	**Required courses included under this technical area**	**Courses most commonly required**
Structural Engineering	Structural Engineering/Analysis Structural Steel Design Reinforced Concrete Design Seismic Design/Analysis	Structural Engineering/Analysis Structural Steel Design Reinforced Concrete Design
Geotechnical Engineering	Geotechnical Engineering / Soil Mechanics Foundation Design	Geotechnical Engineering / Soil Mechanics Foundation Design
Environmental Engineering	Environmental Engineering Water/Wastewater Treatment	Environmental Engineering Water/Wastewater Treatment
Transportation Engineering	Transportation Engineering Highway Design Traffic Design Transportation Planning and Management	Transportation Engineering and/or Planning Highway Design Traffic Design
Water Resources Engineering	Water Resources Engineering Hydraulics Hydrology	Water Resources Engineering Hydraulics and/or Hydrology
Construction Engineering	Construction Engineering and/or Planning Construction Materials	Construction Engineering
Surveying/ Measurements	Geomatics Surveying	Surveying

Results

Curricular data were analyzed to characterize the total number of credit hours required for graduation; courses and units required in mathematics and the sciences; courses used to cover the "additional area of basic science", as required by the CEPC; and number, type, and distribution of courses required to provide breadth in civil engineering, i.e., technical areas required. Results are described in the following sections.

<u>Total Credit Hours and Credit Hours of Engineering Topics Required for Graduation</u>

Among the 131 civil engineering programs examined, six programs do not use traditional credit hours or total credit hours as a graduation requirement. Eight of the schools in the survey are on a quarter system and their credits hours were adjusted using the 2/3 rule to convert quarter hours to semester hours. Credit hours required for graduation were examined for the 125 programs that use them. As shown in Figure 1a, the greatest number of credit hours required for graduation was 146, with an average of 128.2 credit hours and a median of 128 (25% of the programs required 128 credit hours for graduation). Although a recent national trend indicates that the number of credit hours required for graduation is decreasing, it is clear that the majority of the civil engineering programs examined (89%) require more than 120 credit hours, as shown in Figure 1b.

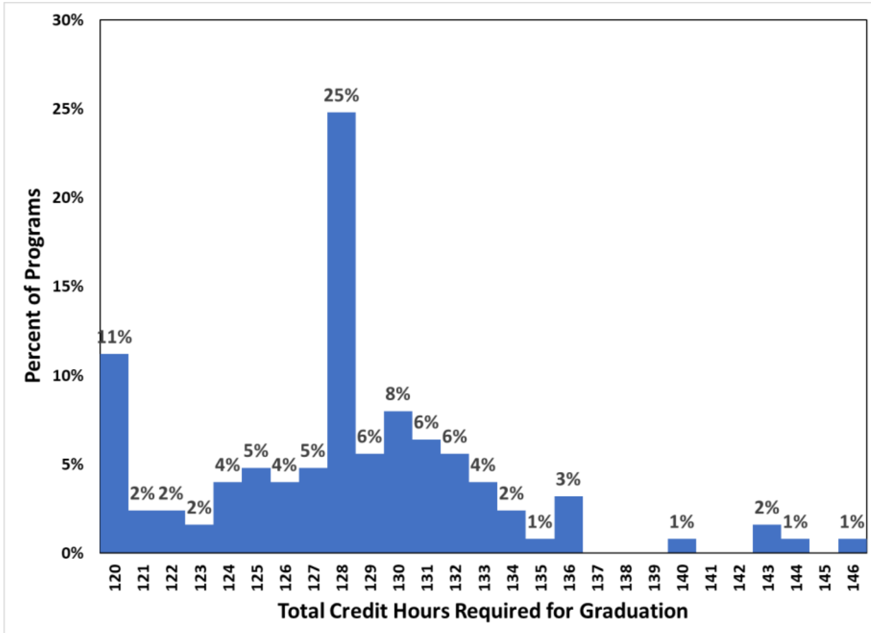
Criterion 5 of the EAC/ABET General Criteria currently requires that the curriculum include a minimum of “one and one-half years of engineering topics [1]”. That requirement is changed to a minimum of 45 credit hours starting in the 2019-2020 accreditation cycle [2]. As shown in Figure 2a and 2b, 95% of the programs analyzed required more than 50 credit hours of engineering topics. The average number of credit hours required was found to be 63.3, the median was 64, and the maximum was 76. Study results indicate that most programs currently exceed the minimum number of credit hours of engineering topics specified in ABET Criterion 5. This analysis was done based on 73 of the programs. Data on credit hours of engineering topics was not always readily available or discernible from catalog entries. This calculation is also complicated by virtue of the fact that programs have a degree of latitude as to how to characterize a course and can split credits assigned to a given course, as several do. As discussed in later sections, most programs also exceed the minimum requirements in mathematics, the sciences, and the technical areas of civil engineering covered.

Math and Science Requirements

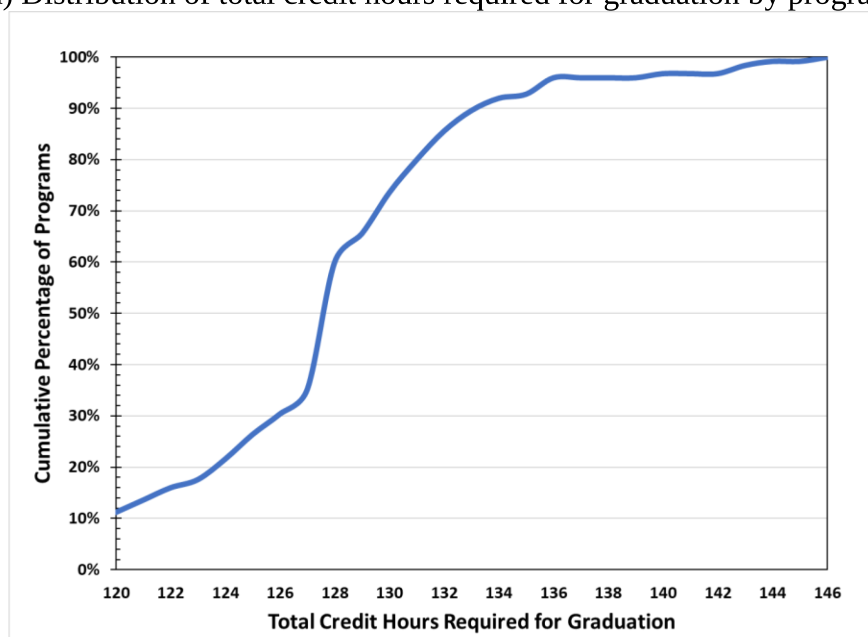
Significant variation was observed among mathematics and science courses required by civil engineering programs. The data included curricula of two new programs that will be reviewed for the first time under the 2019-20 and 2020-2021 EAC/ABET criteria. Additionally, 15 programs already either adopted the new minimum requirements in mathematics and sciences (30 semester credit hours minimum vs. 32 or 25% of the credits required, whichever was lower) or required only 30 credit hours, based on the credit hours required for graduation.

As shown in Figure 3, the programs examined required completion of an average of 34.8 credit hours of math and sciences, with a median of 34 credit hours. Approximately two thirds of programs appear to exceed the minimum requirements at present. The remaining one third of programs satisfy the EAC/ABET General Criteria and the CEPC while requiring students to complete 32 or fewer credit hours of mathematics and sciences. As shown in Figure 3a, approximately 42% of the programs examined required students to complete 33 to 35 credit hours of math and science courses. As shown in Figure 3b, 29% of programs require students to complete 36 to 43 credit hours of mathematics and sciences, far exceeding the minimum requirements established by the EAC/ABET General Criteria.

A summary of course requirements in mathematics is shown in Figure 4. Ninety two percent of the 131 curricula examined require an additional course in mathematics beyond calculus and differential equations, or mathematics are included specifically as part of other courses, as reported in Table 5-1 of self-study reports. Seventy three percent of programs require a course in probability and statistics. Although the CEPC do not specifically require that the curriculum include a separate course on this topic, different programs may be influenced by the CEPC requirement to “prepare graduates to apply probability and statistics to address uncertainty [1], [2],” and may be using a course in probability and statistics to meet the requirement and to fulfill credit hour requirements of Criterion 5. The remaining 28% of programs likely cover probability and statistics in other courses. Twenty three percent of programs require students to take a course in linear algebra.

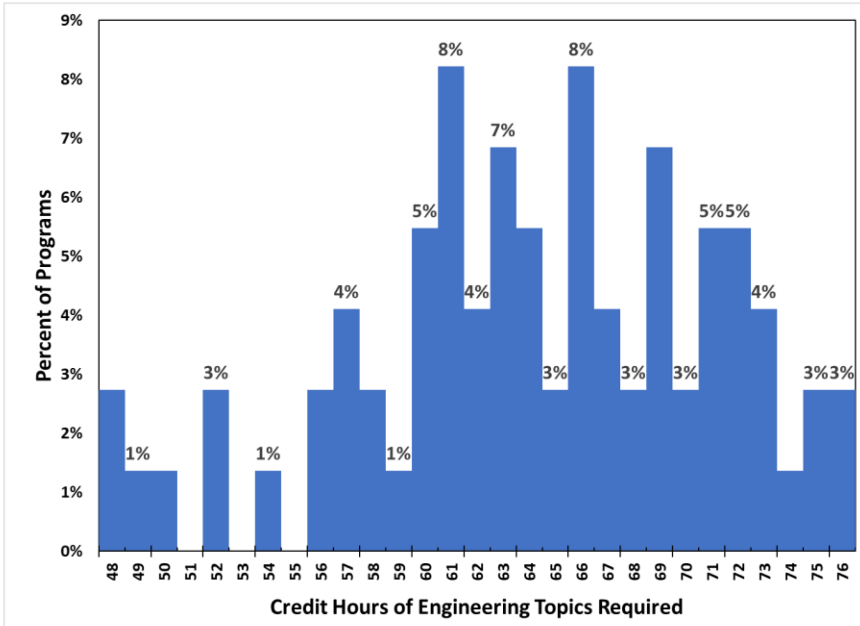


(a) Distribution of total credit hours required for graduation by programs

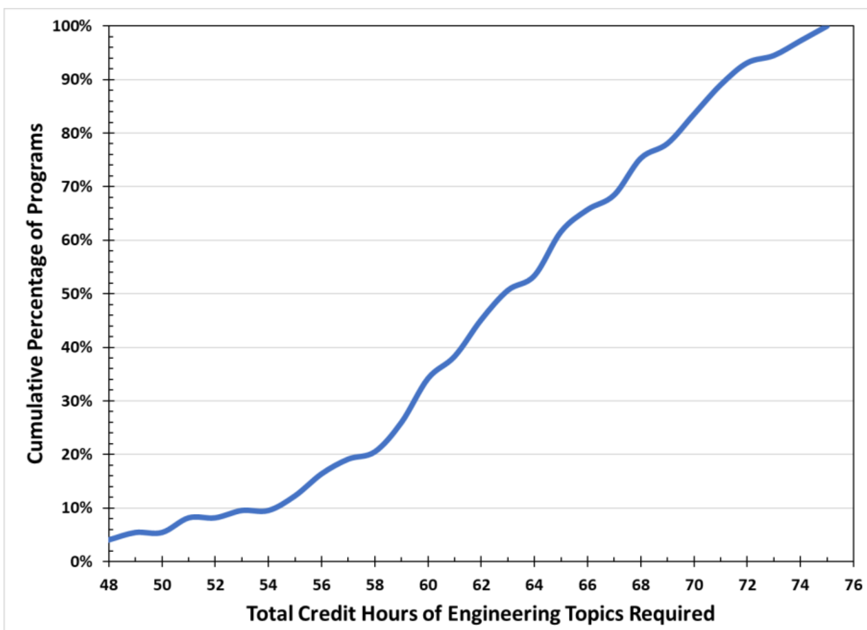


(b) Cumulative percent of total credit hours required for graduation

Figure 1. Summary of total credit hours required for graduation



(a) Distribution of credit hours of engineering topics required for graduation



(b) Cumulative percent of credit hours of engineering topics required

Figure 2. Summary of credit hours of engineering topics required in civil engineering programs

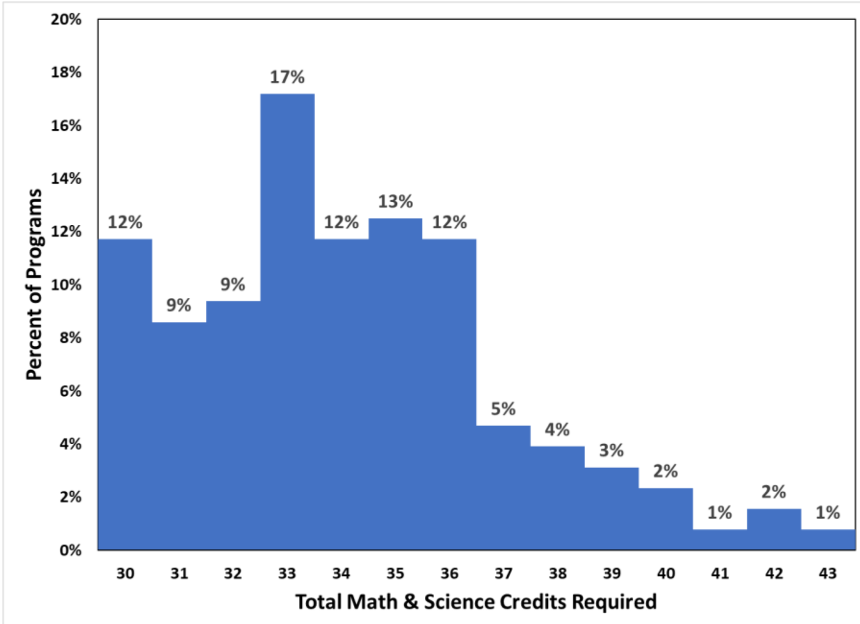
Almost 100% of programs require students to take courses in Calculus 1 and 2, but only 86% of programs require a Calculus 3 course. Five percent of the curricula examined do not include a stand-alone Differential Equations course. The CEPC require “calculus through differential equations,” so as with probability and statistics, those programs that do not explicitly include a course in differential equations are likely covering the material as part of other courses in the curriculum. In these programs, minimum credit hour requirements in the mathematics and sciences are fulfilled through other areas of relevance to the program and its constituencies.

A few programs require that students take courses in numerical analysis (Computational Methods, Modeling) or boundary value problems. Four programs allowed a restricted elective in the math or math and science areas. Six programs require a fourth course in calculus (Calculus IV), and in five of those six programs, this course was required in addition to Differential Equations. Some programs incorporated mathematics in unique ways, for example, through a course in statistics with experiment design, coverage of statistics as part of other courses, supplemental courses in calculus at the lower levels (presumably to strengthen students' skills), a course in systems analysis, or a multi-year integrated math and engineering course.

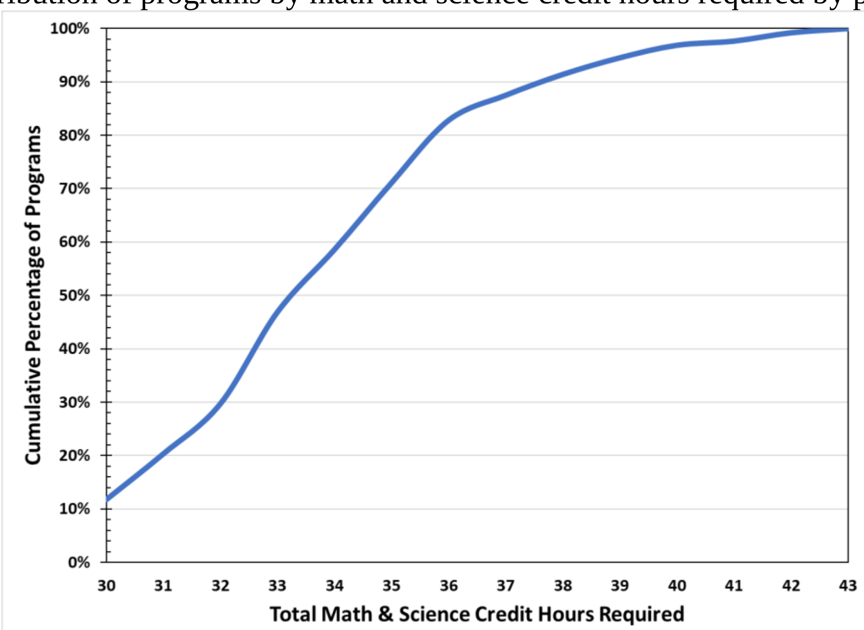
A summary of course requirements in the sciences is shown in Figure 5. Ninety eight percent of programs examined require at least one physics course and 100 percent require at least one course in chemistry. Seventy seven and 40 percent of programs require a second course in physics and chemistry, respectively. All but one of the curricula examined include at least one course in an additional area of basic science, as required by the CEPC. Twenty two percent of programs require that the course be in biological, ecological, environmental, or natural sciences, while 31% require a course in geology, engineering geology, or similar area. Additionally, 12% of programs restrict the science elective to a biology or geology (or related) course. Among the remaining programs, some require courses in biology, geology or other areas, or some combination thereof. As determined from curricular information given in Table 5-1, some programs cover more than one area in some courses, e.g. mathematics and engineering, or science and engineering. Courses used to satisfy the additional area of science were predominantly 3 or 4 credit hours. Twenty one percent of programs require students to take two or more courses in the sciences beyond physics and chemistry, or one additional science plus a restricted elective in the mathematics and sciences.

Many programs allow students to take advantage of offerings in other areas of science available at the institution, either as required courses or restricted electives. These courses include:

- People and the Environment
- Energy and Environment
- Natural Disasters and Natural Resources
- Geographic Information Systems (GIS) and Spatial Analysis
- Planetary Science, Astronomy
- Atmospheric Science, Climate Science
- Soil Science
- Meteorology
- Oceanography, Marine Science
- Chemistry Applications in Biological Systems



(a) Distribution of programs by math and science credit hours required by programs



(b) Cumulative percent of programs requiring various math and science credit hours

Figure 3. Summary of math and science credit hours required

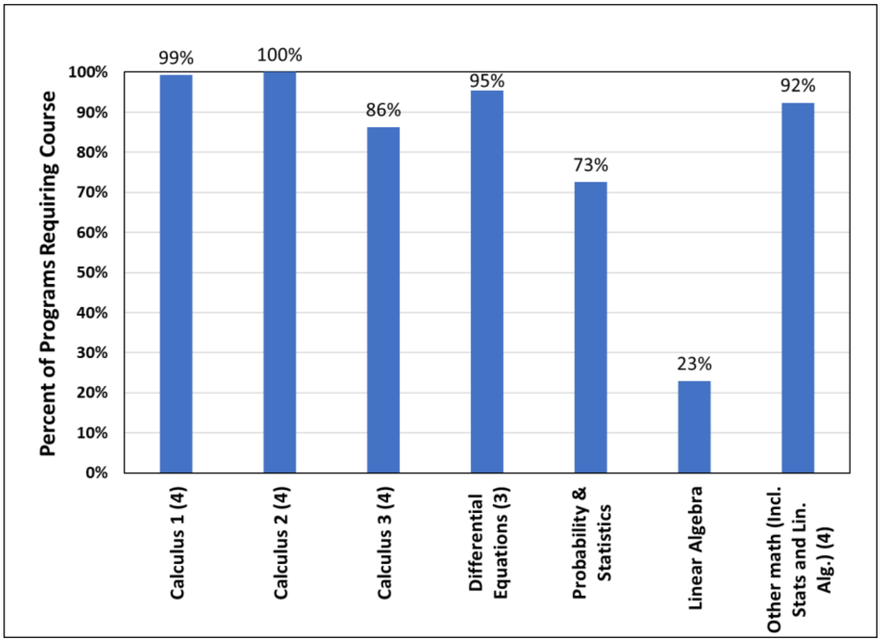


Figure 4. Math courses required (average number of course credit hours in parentheses)

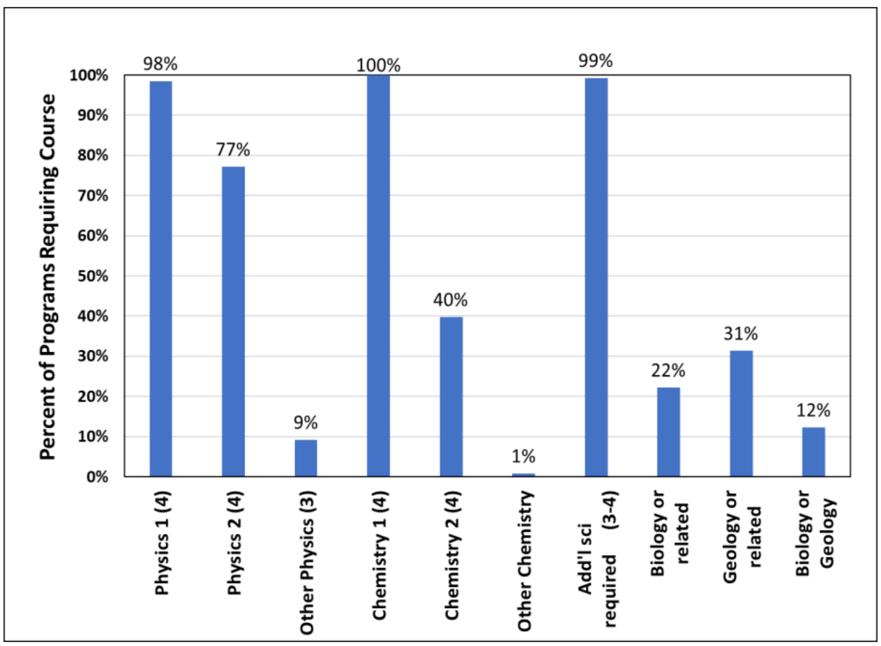


Figure 5. Science courses required (average number of course credit hours in parentheses)

Civil engineering program faculty choose required and elective courses in the areas of mathematics and the sciences considering the needs of their program constituencies. Analysis of the curricula indicates that some programs perceive sufficient flexibility within EAC/ABET General Criteria and the CEPC to cover the topics and meet the minimum requirements established for accreditation, while also tailoring the curriculum to meet the needs of their program constituencies. A significant number of programs far exceed credit hour and course or topic requirements specified in the EAC/ABET General Criteria and the CEPC. Programs may require students to take courses beyond the minimum requirements for a variety of reasons, including, preparing graduates to satisfy their Program Educational Objectives (EAC/ABET Criterion 2 [1], [2]), to meet the needs or interests of their program constituencies, or for historical reasons.

There appears to be no "one size fits all" model of coverage in mathematics and the sciences. Most civil engineering programs appear to have common elements, i.e., two or three courses in calculus, one course in differential equations, one course in physics and one course in chemistry. However, there is also significant diversity among program requirements at different institutions. Some programs require additional depth in physics and chemistry, while others encourage breadth through a range of electives in the mathematics and sciences. Faculty from civil engineering programs concerned about perceived constraints established by EAC/ABET General Criteria or whose programs are mandated to reduce the total number of credit hours can look to examples provided by many other programs who use entrepreneurial means to fulfill the minimum number of credit hours required for accreditation while also meeting the interests of their program's constituencies.

Civil Engineering Course Requirements

To provide breadth in the civil engineering discipline, the CEPC require that students "analyze and solve problems in at least four technical areas appropriate to civil engineering [1]." Curricula of 131 civil engineering programs were examined to characterize coverage within seven technical areas plus an eighth area defined as "other civil engineering topics". The seven technical areas examined were [3]: structural, environmental, geotechnical, transportation, water resources, construction, and surveying/measurements.

As shown in Figure 6, 96% of curricula examined include required courses in at least four technical areas of civil engineering while 78% of programs require students to take courses in five or more areas. Within the programs that require courses in fewer than four of the technical areas listed above, relevant topics may be covered in a different core course unique to the program (e.g., Civil Engineering Infrastructure) or multiple areas may be covered in a single course. In 59% of the programs, students are required to complete courses in at least six technical areas, exceeding the minimum requirement established in the CEPC.

The number of required courses in each of the civil engineering technical areas is shown in Figure 7. Over 95% of the curricula analyzed for this study required students to take courses in structural and geotechnical engineering. In 70% of programs examined, two or more courses were required in the Structural Engineering area. Approximately one third of programs required more than two courses in this area. These requirements typically included an introductory course in structural engineering and one course each in Steel and Reinforced Concrete, as presented in Table 2. Only 3% of programs required more than two courses in a technical area other than Structural Engineering. Surveying and Construction Engineering were the least likely to be included among the technical areas with required courses. In 87% of programs, no courses were required in areas beyond the seven areas described previously.

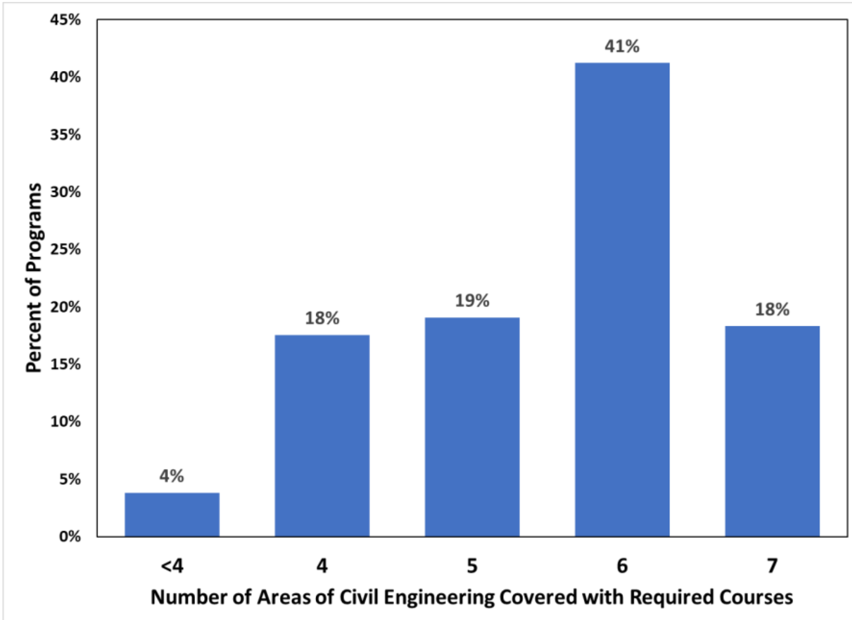


Figure 6. Number of technical areas appropriate to civil engineering, as required in programs

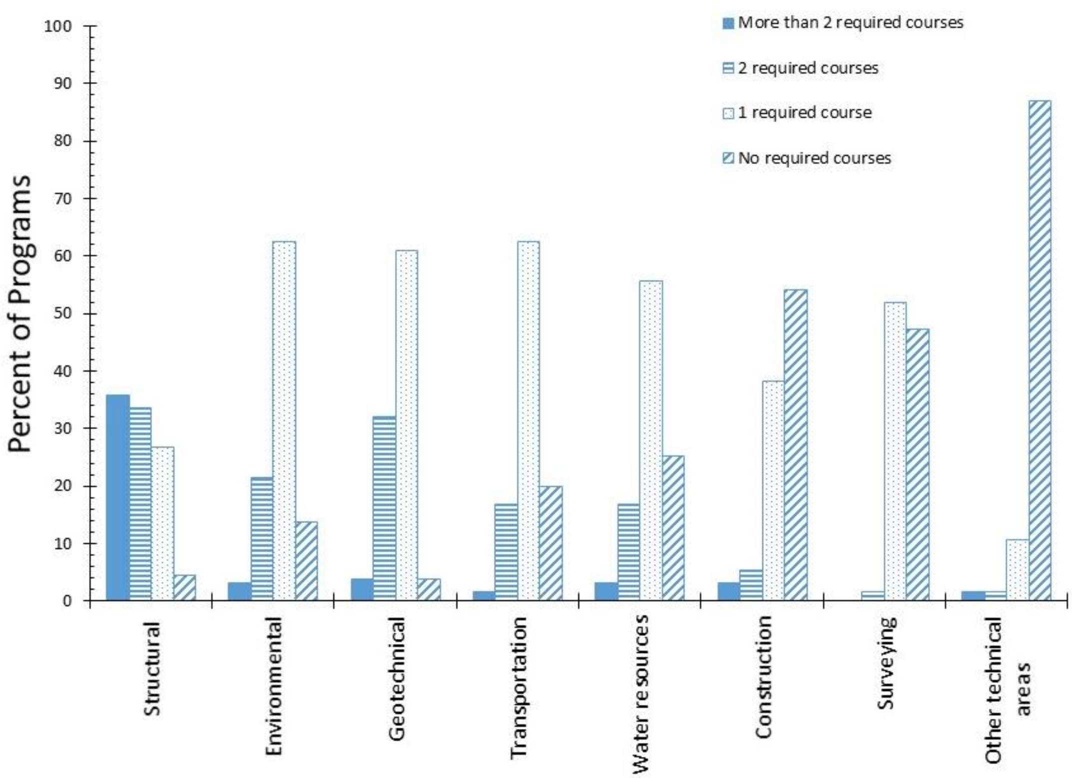


Figure 7. Distribution of courses required in different technical areas appropriate to civil engineering

The number of credit hours in each technical area is shown in Table 3. The greatest number of credit hours are required in the Structural Engineering area. On average, programs required more than 4 credit hours of coursework related to structural, environmental, and geotechnical engineering while the fewest number of credit hours are required in surveying, construction engineering, and "other" civil engineering areas. Civil engineering programs required students to take, on average, 7.4 courses total in the technical areas of civil engineering. Required courses were predominantly in structural, environmental, and geotechnical engineering. Fewer programs required courses in surveying, construction engineering, or other areas.

The CEPC require students to "analyze and solve problems in at least four technical areas appropriate to civil engineering [1]." There is no requirement that this work be completed in the context of individual courses in each area, nor is there a requirement that students take multiple courses in an area. As observed with courses and units in the mathematics and the sciences, many, if not most, civil engineering curricula far exceed the minimum requirements established for accreditation, possibly due to the program's interest in meeting the needs of their constituencies.

Table 3. Credit hours required in the technical areas appropriate to civil engineering.

	Structural Engineering	**Environmental Engineering**	**Geotechnical Engineering**	**Transportation Engineering**	**Water Resources Engineering**	**Construction Engineering**	**Surveying**	**Other technical areas**
Average number of credits	6.8	4.3	4.8	3.8	3.9	3.4	3.1	3.3
Maximum number of credits	16	12	12	8	10	9	6	6

Summary

Analysis of curricula of 131 civil engineering programs at a wide range of institutions indicates that a great diversity of approaches is used to satisfy, and in many cases exceed, the minimum requirements for accreditation by the EAC/ABET. Curricular elements examined in this study included requirements in mathematics, sciences, the additional area of basic science, number of credit hours of engineering topics, and breadth and depth requirements in technical areas appropriate to civil engineering.

Programs appear to be customizing the curriculum to fulfill the mission of the institution and the program and to meet the needs of their program constituencies (e.g., students, faculty, alumni, and employers). Local industry needs, faculty expertise, employment opportunities for graduates, and program history are likely among the factors that influence decisions of a program's faculty to include certain core and discipline-specific requirements in the curriculum. Program Educational Objectives (PEOs) and Mission statements shown on websites of different civil engineering programs indicate that many programs are preparing graduates for licensure, to pursue advanced studies, and/or for a breadth of practice in the civil engineering profession. Consequently, and appropriately, civil engineering curricula appear to be designed to support the program's mission and PEOs, while also satisfying EAC/ABET accreditation requirements.

Results of this study show that civil engineering programs are able to meet EAC/ABET requirements using a variety of approaches, while also including elements that reflect a program's mission, unique opportunities afforded by the institution, and aspirations for their graduates, as defined by the PEOs. Many programs are using flexibility within the curriculum to include courses in mathematics and the sciences beyond the minimum requirements established in EAC/ABET General Criteria. A significant number of programs provide depth and breadth in technical areas appropriate to civil engineering far exceeding the minimum of four areas required by the CEPC. In many cases, it appears that programs are allowing for specialization in civil engineering areas by requiring fewer fundamental engineering courses such as Thermodynamics or Electric Circuits that were traditionally included in many civil engineering programs. Programs appear to be meeting EAC/ABET accreditation criteria while using entrepreneurial and creative approaches to construct and modify their civil engineering programs to meet the needs of their constituencies and their program mission.

Analysis of results presented in this paper can assist civil engineering program faculty in identifying different pathways to satisfying accreditation criteria and can provide important information for the next review of the CEPC, scheduled to begin in October 2020.

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APPENDIX A: List of Civil Engineering Programs that participated in the present study.

No.	University Name	Date of Next ABET Comprehensive Review*	Data source**
1	Alabama A&M University	2018-2019	A
2	Angelo State University	NEW 2019	B
3	Arizona State University	2021-2022	B
4	Arkansas State University	2018-2019	A
5	Auburn University	2022-2023	B
6	Boise State University	2022-2023	B
7	Brigham Young University	2020-2021	B
8	Brigham Young University - Idaho	2018-2019	A
9	Bucknell University	2020-2021	B
10	California Polytechnic State University, San Luis Obispo	2020-2021	B
11	California State University Chico	2021-2022	B
12	California State University, Fresno	2018-2019	A
13	California State University, Long Beach	2018-2019	A
14	California State University, Los Angeles	2018-2019	A
15	California State University, Sacramento	2021-2022	A
16	Carnegie Mellon University	2018-2019	A
17	Carroll College	2018-2019	A
18	Case Western Reserve University	2018-2019	A
19	Clemson University	2023-2024	B
20	Colorado School of Mines	2018-2019	A
21	Columbia University	2018-2019	A
22	Cooper Union	2018-2019	A
23	Drexel University	2019-2020	A
24	Duke University	2020-2021	B
25	Embry-Riddle Aeronautical University	2019-2020	B
26	Florida A&M University-Florida State University	2021-2022	B
27	Florida Gulf Coast University	2021-2022	B
28	George Mason University	2018-2019	A
29	Georgia Institute of Technology	2020-2021	B
30	Gonzaga University	2020-2021	B
31	Howard University	2018-2019	A
32	Idaho State University	2023-2024	B
33	Illinois Institute of Technology	2020-2021	B
34	Iowa State University	2018-2019	A
35	Jackson State University	2018-2019	A
36	Kansas State University	2023-2024	B
37	Kennesaw State University	2018-2019	A
38	Lafayette College	2020-2021	B
39	Lamar University	2018-2019	A
40	Louisiana State University	2021-2022	B
41	Louisiana Tech University	2020-2021	B

No.	University Name	Date of Next ABET Comprehensive Review*	Data source**
42	Loyola Marymount University	2018-2019	A
43	Manhattan College	2020-2021	B
44	Marquette University	2018-2019	A, B
45	Michigan State University	2022-2023	B
46	Michigan Technological University	2023-2024	A
47	Minnesota State University, Mankato	2023-2024	B
48	Mississippi State University	2023-2024	B
49	Missouri University of Science and Technology	2020-2021	B
50	Montana State University	2021-2022	B
51	New Jersey Institute of Technology	2019-2020	B
52	New Mexico Institute of Mining and Technology	2022-2023	B
53	New Mexico State University	2018-2019	A
54	North Carolina A&T University	2019-2020	B
55	North Carolina State University	2022-2023	B
56	North Dakota State University	2018-2019	A
57	Northeastern University	2019-2020	A
58	Oklahoma State University	2021-2022	B
56	Oregon State University	2020-2021	A
60	Pennsylvania State University, Harrisburg, The Capital College	2018-2019	A
61	Portland State University	2023-2024	B
62	Prairie View A&M	2022-2023	A
63	Princeton University	2019-2020	B
64	Purdue University	2019-2020	A
65	Rose-Hulman Institute of Technology	2018-2019	A, B
66	Rowan University	2018-2019	A
67	Rutgers, The State University of New Jersey	2018-2019	A
68	Saint Louis University	2018-2019	A
69	South Dakota School of Mines and Technology	2022-2023	B
70	Southern Methodist University	2020-2021	A
71	Stanford University	2018-2019	A, B
72	Tennessee State University	2021-2022	B
73	Tennessee Technological University	2020-2021	B
74	Texas A & M University	2022-2023	A
75	The College of New Jersey	2018-2019	A
76	Trine University	2020-2021	B
77	United States Air Force Academy	2020-2021	B
78	United States Coast Guard Academy	2019-2020	B
79	United States Military Academy	2022-2023	B
80	University at Buffalo	2020-2021	B
81	University of Alabama at Birmingham	2018-2019	A
82	University of Arkansas	2020-2021	B
83	University of California, Berkeley	2018-2019	A
84	University of California, Davis	2018-2019	A

No.	University Name	Date of Next ABET Comprehensive Review*	Data source**
85	University of California, Los Angeles	2018-2019	A
86	University of Colorado Denver	2023-2024	B
87	University of Florida	2018-2019	A
88	University of Hartford	2021-2022	B
89	University of Hawaii	2021-2022	B
90	University of Illinois at Chicago	2020-2021	B
91	University of Illinois at Urbana - Champaign	2019-2020	A
92	University of Kansas	2018-2019	A, B
93	University of Kentucky	2022-2023	B
94	University of Louisville	2018-2019	A, B
95	University of Maine	2018-2019	A, B
96	University of Maryland	2023-2024	B
97	University of Massachusetts - Amherst	2019-2020	B
98	University of Massachusetts Lowell	2018-2019	A
99	University of Michigan	2023-2024	B
100	University of Minnesota Duluth	2021-2022	B
101	University of Minnesota Twin Cities	2019-2020	B
102	University of Mississippi	2022-2023	B
103	University of Missouri-Kansas City	2019-2020	B
104	University of Missouri – St. Louis	2018-2019	A
105	University of Nebraska – Lincoln	2023-2024	A
106	University of New Haven	2023-2024	B
107	University of New Orleans	2018-2019	A, B
108	University of North Carolina – Charlotte	2022-2023	B
109	University of Oklahoma	2023-2024	B
110	University of Rhode Island	2018-2019	A
111	University of South Alabama	2023-2024	B
112	University of South Carolina	2023-2024	B
113	University of Southern California	2021-2022	A
114	University of Tennessee at Knoxville	2023-2024	B
115	University of Texas at Arlington	2018-2019	A
116	University of Texas at Austin	2022-2023	B
117	University of the District of Columbia	2020-2021	B
118	University of the Pacific	2018-2019	A
119	University of Toledo	2023-2024	B
120	University of Vermont	2021-2022	B
121	University of Virginia	2022-2023	B
122	University of Washington	2019-2020	B
123	University of Wisconsin - Madison	2018-2019	A, B
124	University of Wisconsin - Platteville	2018-2019	A, B
125	University of Wyoming	2021-2022	B

No.	University Name	Date of Next ABET Comprehensive Review*	Data source**
126	Villanova University	2020-2021	B
127	Virginia Military Institute	2018-2019	A
128	Virginia Polytechnic Institute and State University	2019-2020	A
129	Wayne State University	2018-2019	A
130	West Virginia University Institute of Technology	2020-2021	B
131	York College of Pennsylvania	NEW 2020	B

* from www.abet.org, accessed 1/21/19 and 4/7/19

**Data sources:

A = Online university catalog or curriculum sheet

B = Completed survey or submitted ABET Self-study Table 5-1 (Curriculum)