Commentary on the ABET Program Criteria for Civil and Similarly Named Programs

Effective for 2024-2025 Accreditation Cycle

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By the ASCE Civil Engineering Program Criteria Task Committee

Subsequent revisions

By the ASCE Committee on Accreditation Operations

Contents

Purpose of the Commentary

This commentary was prepared by the Civil Engineering Program Criteria Task Committee as charged by the ASCE Committee on Accreditation. It guides civil engineering program evaluators (hereafter "PEVs") and civil engineering program faculty by expounding on the Civil Engineering Program Criteria (hereafter "Program Criteria") to be utilized in association with the Criteria for Accrediting Engineering Programs of the Engineering Accreditation Commission of ABET (EAC/ABET). This commentary does not add to, detract from, or modify the EAC/ABET General Criteria for Baccalaureate Level Programs, the General Criteria for Master's Level Programs (hereafter "General Criteria," or the "Program Criteria"). In the spirit of the General Criteria, this commentary does not attempt to prescribe a single approach for compliance; rather, it emphasizes the institution's freedom to innovate within the framework of the Program Criteria.

Program evaluation is an inherently subjective process. This commentary aims to help PEVs make subjective judgments consistent with EAC/ABET procedures. It is not a set of rigid rules without flexibility. Ultimately, recommendations about compliance with the criteria are based on the PEV's judgment with input from and concurrence of the evaluation visit team.

This commentary should assist program faculty in gaining a better understanding of what must be included in the curriculum relative to the Program Criteria. In addition, discipline-specific qualifications required of the faculty are included. This document may be used by stakeholders other than faculty, (e.g., industry advisory boards, administration, donors, employers, and constituencies). Herein, the term "faculty" represents faculty members and others providing input into curriculum development.

ABET policies do not require measuring and assessing learning achievements for the Program Criteria. Rather, the curricular components of the Program Criteria are satisfied solely through topical coverage in the curriculum. There is no requirement for a separate course or courses to satisfy the individual provisions of the Program Criteria; however, the program must demonstrate that each provision of the Program Criteria is addressed within the curriculum to the intended level of curricular coverage described therein. Course syllabi, assignments, and student work are often used as artifacts to document material coverage in the curriculum. Some examples of compliance in Section D of this document may cite examples of student activities. However, there is no requirement or expectation that the program assess any student work to demonstrate compliance with any provision of the Program Criteria.

Commentary Development and Updates

This Commentary was authored by the ASCE Civil Engineering Program Criteria Task Committee with input from numerous stakeholders and the ASCE Committee on Accreditation Operations (COAO). The information presented herein reflects its authors' and reviewers' best collective judgment. The Commentary is periodically reviewed and revised by the COAO to reflect input from constituencies and lessons learned from accreditation practice.

Evolution of the Civil Engineering Program Criteria

For more than two decades, ASCE has been involved in an ambitious effort to better prepare civil engineering professionals to meet the technological, environmental, economic, social, and political challenges of the future. This initiative produced policy statements that defined the knowledge, skills, and attributes necessary to enter professional practice. The most recent policy statement (PS568, July 2022) states in part:

> The American Society of Civil Engineers (ASCE) supports the attainment of the Civil Engineering Body of Knowledge (CEBOK) as a requirement for exercising responsible charge in the practice of civil engineering. . . .

In conjunction with this effort, the first Civil Engineering Body of Knowledge (*Civil Engineering Body of Knowledge for the 21st Century*) was published in 2004. The first and subsequent CEBOK reports emphasize that the preparation of the civil engineer and the fulfillment of CEBOK must include both formal education and mentored experience. Thus, CEBOK is not directed solely at formal civil engineering education.

ASCE has established an eight-year cycle for review of the CE Body of Knowledge. Once a new CEBOK is published, a comprehensive review of the Civil Engineering Program Criteria is made by a task committee, using stakeholder input, to ensure that Program Criteria are appropriately aligned with the current CEBOK outcomes. The educational component of this alignment may be addressed through either the EAC General Criteria or the Program Criteria. In conjunction with the development of CEBOK and related Program Criteria, ASCE identified the need to establish the expected level of achievement associated with each CEBOK outcome. This distinction is particularly important to ASCE because the BOK differentiates the knowledge, skills, and attitudes gained through education from those gained through experience and self-development. Given that both education and experience contribute to the attainment of most outcomes, it is critical to define the levels of achievement expected from each activity. CEBOK uses Bloom's Taxonomy to define levels of achievement, and Bloom's Taxonomy uses action verbs to specify levels of achievement, as summarized in Appendix I. However, action verbs imply the attainment of outcomes, and according to ABET, policy program criteria cannot specify student outcomes. Thus, in the 2024 Civil Engineering Program Criteria, the action verbs of Bloom's Taxonomy used in CEBOK3 have been converted to nouns. These nouns are still indexed to Bloom's Taxonomy; however, in the context of the Program Criteria, they specify the level of curricular coverage, rather than the level of student outcome achievement. The framework describing the levels of attainment from various CEBOK pathways is depicted by the "outcome rubric" extracted from Appendix F of CEBOK3 and included in Appendix II herein.

It is important to note that the Civil Engineering Program Criteria are complete as written, fully independent of CEBOK3. Whereas CEBOK3 was an important resource in reviewing and updating the Program Criteria, the ASCE Civil Engineering Program Criteria Task Committee relied on additional resources, stakeholder inputs, and the collective professional judgment and experience of the group in revising the CE Program Criteria.

ABET Engineering Accreditation Criteria

The ABET criteria for accrediting engineering programs, updated periodically according to a specified schedule, are divided into three sections: General Criteria for Baccalaureate Level Programs, General Criteria for Master's Level Programs, and Program Criteria. This commentary deals solely with the Program Criteria, reproduced here for reader convenience.

Program Criteria for Civil and Similarly Named Engineering Programs

These program criteria apply to engineering programs that include "civil" or similar modifiers in their titles.

1. **Curriculum**

The curriculum must include:

(a) Application of

(i) Mathematics through differential equations, probability and statistics, calculus-based physics, chemistry, and either computer science, data science or an additional area of basic science

(ii) Engineering mechanics, materials science, and numerical methods relevant to civil engineering

(iii) Principles of sustainability, risk, resilience, diversity, equity, and inclusion to civil engineering problems

(iv) The engineering design process in at least two civil engineering contexts

(v) An engineering code of ethics to ethical dilemmas

(b) Solution of complex engineering problems in at least four specialty areas appropriate to civil engineering

(c) Conduct of experiments in at least two civil engineering contexts and reporting of results

(d) Explanation of

(i) Concepts and principles in project management and engineering economics

(ii) Professional attitudes and responsibilities of a civil engineer, including licensure and safety

2. **Faculty**

The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure or by education and design experience.

Understanding the CE Program Criteria

The task of demonstrating compliance with the criteria belongs to the program, not the PEV. Many methods are available to demonstrate compliance with facets of the General and Program Criteria. The PEV judges whether the submitted material adequately demonstrates what is claimed, and in collaboration with the ABET review team, whether it demonstrates compliance.

With this consideration, the following sections aim to assist both faculty and PEVs in understanding the Program Criteria. In addition, for each part of the Program Criteria, a brief background on each provision is provided to provide background about *what* is intended and *why* the provision is included.

Program Criteria include only curricular and faculty requirements; programs *are not required* to assess or evaluate student achievements related to the various provisions of the Program Criteria. The program, however, must demonstrate that each curricular item in the Program Criteria is included within the curriculum and that the faculty experience and composition meet the faculty Program Criteria requirement.

1.a.i. The curriculum must include application of mathematics through differential equations, probability and statistics, calculus-based physics, chemistry, and either computer science, data science or an additional area of basic science.

Understanding the Criterion

The program must demonstrate that every student's program includes applications in the following subject areas:

- Mathematics through differential equations
- Probability and statistics
- Calculus-based physics
- Chemistry
- Either computer science or data science or one additional area of basic science

The program should present sufficient information to document that application of the listed mathematics and science subject areas is addressed in the curriculum and to all students. This provision does not require separate courses in each subject listed, nor does it require that all of the program's students receive instruction in the same additional science (computer science, data science, or basic science).

Examples of Compliance

Compliance concerning the first four subjects in this provision may be satisfied if applications can be explicitly demonstrated in courses of mathematics through differential equations, probability and statistics, calculus-based physics, and chemistry courses as part of the 30 semester credit hours (or equivalent) of college-level mathematics and basic sciences required by Criterion 5.a of the EAC/ABET General Criteria. Inclusion of a course with applications of an additional basic science would complete compliance with this provision of the Program Criteria and could also contribute to satisfaction of Criterion 5.a. This would also complete compliance with this provision of the Program Criteria.

CAUTION: programs should recognize that computer science courses do not meet the EAC/ABET Criterion 5 requirements for 30 semester credit hours of college-level mathematics and basic sciences.

Alternatively, programs might also opt to incorporate one or more of these subjects by alternative means, such as in combination with other parts of the curriculum. For example, probability and statistics, or data science, might be addressed as evaluative techniques in support of other science or engineering science classes. Similarly, applications of other mathematics or science subjects may also be incorporated elsewhere in the curriculum rather than in a basic math and science sequence. However, programs should demonstrate that such an approach provides instruction of sufficient depth in each subject area.

Note also that application of these mathematics and science subjects to civil engineering topics is not required by this element of the program criteria – application may occur in any context, such as economics or social science, for example.

Basic Science

Basic Science is defined in ABET's Criteria for Accrediting Engineering Programs as "disciplines focused on knowledge or understanding of the fundamental aspects of natural phenomena. Basic sciences consist of chemistry and physics and other natural sciences including life, earth, and space sciences" (https://www.abet.org, 2022). Examples include but are not limited to:

- Biology
- Ecology
- Geology
- Meteorology
- Astronomy

Courses such as geophysics or seismology that are not part of a standard physics or chemistry sequence would also be appropriate.

In general, an advanced physics or chemistry course would not fulfill this requirement's intent because such a course would provide additional depth rather than additional breadth of scientific knowledge. Likewise, engineering science, materials science, and thermodynamics courses would not typically fulfill this requirement's intent.

Computer Science or Data Science

Curricular content and applications in either of these sciences could be selected from a wide variety of theoretical and applied fundamentals related to computation, computers, automation, and information management systems. These might include, but are not limited to, topics such as machine learning, artificial intelligence, network science, queueing theory, and natural language processing. Curricular content and applications emphasizing algorithms, data structures, data analytics, or data visualization is also appropriate, especially if it supports other components of a program's curriculum. Such content might be addressed in one or more separate courses. Alternatively, a program might incorporate theoretical and applied computer science or data science fundamentals, such as those mentioned, in combination with other parts of the curriculum. Regardless of the approach, each program should demonstrate that instruction in, and application of, computer science fundamentals or data science fundamentals are included. **CAUTION**: a course or curricular content primarily devoted to learning a computer language would not demonstrate sufficient depth in either computer science or data science fundamentals.

Definitions and References

Definition: Computer Science is the study of computers and computational systems. Computer scientists deal mostly with software and software systems; this includes their theory, design, development, and application. (www.britannica.com/science/computer-science)

Definition: "Data science is an interdisciplinary field that uses algorithms, procedures, and processes to examine large amounts of data to uncover hidden patterns, generate insights, and direct decision making". (www.coursera.org/articles/what-is-data-science)

1.a.ii. The curriculum must include application of engineering mechanics relevant to civil engineering.

Understanding the Criterion

Engineering mechanics is the study of the behavior of systems under the action of forces. Concepts of engineering mechanics are often applied in solving complex problems in civil engineering and in the design process. A technical core of knowledge and breadth of coverage in engineering mechanics and the ability to apply it to solve civil engineering problems are essential for civil engineers. Knowledge of engineering mechanics concepts may also be used to develop experimental and computational tools as a bridge between theory and application.

Examples of Compliance

This provision of the Program Criteria requires that concepts and principles of engineering mechanics and their application in civil engineering are addressed in the curriculum. Typical civil engineering courses that comply with this provision of the Program Criteria include but are not limited to statics, dynamics, mechanics of solids, and fluid mechanics. There is no requirement that mechanics concepts be offered only by courses in the civil engineering program or that all students in a program undertake the same areas of engineering mechanics. Many engineering schools/colleges offer common courses in engineering mechanics such as statics, dynamics, mechanics of materials/solids, fluid mechanics, and others taken by students in multiple programs. Topics covered in these interdepartmental courses will meet this requirement.

For compliance, it is important that the curriculum include instruction on the application of engineering mechanics to the solution of problems relevant to civil engineering. While programs can define the scope of engineering mechanics appropriate for their curriculum, a minimal sequence of engineering mechanics topics for most civil engineering programs would include courses that deal with the application of statics, mechanics of solids, and mechanics of fluids.

This provision of the Program Criteria requires only the inclusion of engineering mechanics topics in the curriculum at the application level. A program is not required to assess a student's ability to apply engineering mechanics concepts.

Definition

Definition: Engineering mechanics is the study of the response of bodies to the action of forces. The forces may cause deformations, motions, vibrations, accelerations, and other actions. Engineering mechanics encompasses statics, dynamics, mechanics of solids/materials, and fluid mechanics.

1.a.ii. The curriculum must include application of materials science relevant to civil engineering.

Understanding the Criterion

Materials science is the scientific study of the properties of solid materials and how a material's composition and structure determine those properties. From a civil engineering perspective, materials science provides a foundation for understanding the engineering properties and behavior of materials employed in civil engineering projects (e.g., metals, rock, clay, cements and concretes, polymers, timber, glass, fiber-reinforced polymer). Civil engineers are responsible for selecting and specifying materials to be used in a broad spectrum of projects and for quality control of those materials. Thus, knowledge of the composition and structure of materials used in civil engineering applications is essential to understanding their suitability for particular applications. A wide range of materials are relevant to civil engineering, including materials traditionally used in construction but also many other materials relevant to other civil engineering specialty areas. Each program has the flexibility to provide its students with exposure to materials science concepts in a manner most relevant to the program's chosen specialty areas.

Examples of Compliance

Separate courses such as materials science, engineering materials, or materials selection are not required to satisfy this provision of the Program Criteria. Programs may incorporate concepts and principles of material science in one or more courses with different foci (e.g., construction materials, soil mechanics, steel design, reinforced concrete design, water treatment, etc.). Materials science can be broadly interpreted in different contexts, and programs may decide which concepts and principles of materials science to address in their curriculum.

Some examples of application topics relevant to civil engineering in which aspects of material science can be incorporated include:

- Metal corrosion and prevention measures with coatings and relationship to the composition and properties of the metals and coatings involved.
- Plastic liners in water or liquid waste containment impoundments and composition and properties of the polymers used for the liner materials.
- Behavior of asphalt binders under varying loading and environmental conditions and relationship to the composition and properties of the binder materials.
- Curing of concrete and the relationship to the crystallization of the cementitious material.
- Performance of fire-resistive spray coatings and relationship to the composition and properties of the coating material.
- Fatigue in wind turbine blades and relationship to the properties of the carbon- or glass-reinforced polymer material of the blade.
- Performance of a multi-media filter in water treatment and relationship to the composition and properties of the media materials employed.
- Permeability of a clay liner in a landfill and relationship to the composition and properties of the clay mineral employed.

Courses that include materials science concepts need not be civil engineering courses. For example, programs may expose their students to materials science concepts via a materials science course offered by another department. Regardless of the means selected to expose students to materials science concepts in the curriculum, the application of materials science relevant to civil engineering must be demonstrated.

The criterion requires only the inclusion of materials science in the curriculum; there is no requirement for a separate course, no requirement for a specific amount of coverage, and no requirement for assessing student understanding of materials science concepts.

1.a.ii. The curriculum must include application of numerical methods relevant to civil engineering.

Understanding the Criterion

Civil engineers often encounter problems that analytical methods cannot solve. Civil engineers commonly use analysis and design software that is based on numerical methods to solve complex problems. However, a working knowledge of numerical methods is necessary to model the problem and analyze the results properly. Therefore, civil engineers should understand the use of algorithmic formulations and procedures to arrive at approximate solutions with reasonable accuracy.

While these techniques are generally taught in a mathematics course, those courses may not offer the application of numerical methods to civil engineering problems. Therefore, the curriculum must include topics on numerical methods relevant to civil engineering.

Although this provision of the Program Criteria does not require the inclusion of a specific number of topics in numerical methods, the included topic(s) should explain the process of defining the problem with constraints, applying a mathematical model, formulating the mathematical model with the appropriate numerical model, and evaluating the results. The topics could also include using tools for creating numerical solutions, such as programming languages, spreadsheets, and high-level scripting programs (MathCAD, MATLAB, Mathematica, etc.).

Examples of Compliance

A separate course on numerical methods or their application related to civil engineering is not required. Various topics in numerical methods can be incorporated into civil engineering courses, and the program can choose the topics and their extent of coverage. Examples of applications of numerical methods include but are not limited to the following:

- Curve fitting of data obtained in civil engineering laboratory experiments (least squares)
- Statistical computations on data (average, mean, standard deviation, bias, distribution plots)
- Application of stiffness and flexibility methods in the response of statically indeterminate beams or frames
- Pipe network analysis in a water distribution system (network analysis)
- Solutions to ordinary and partial differential equations by finite difference, finite element, or boundary element methods (continuum approaches to solid mechanics and fluid flow)
- Hydrological analysis, river mechanics, flood routing (HEC RAS)

- Risk assessment (statistical simulations)
- Traffic flow models for optimized traffic movement
- Transient analysis using discrete difference or integration methods (particle dynamics to non-steady state fluid analysis)

Definition and Reference

Definition: Numerical analysis is a branch of mathematics that solves continuous problems using numeric approximation. It involves methods that often give approximate but accurate numeric solutions, which is useful in cases where the closed-form analytical solution is impossible or prohibitively expensive to calculate.

The link following references a commercial software package. This description is robust and inclusive. These topics might be addressed in many ways with a variety of software. MATLAB is one of several options. https://www.mathworks.com/discovery/numerical-analysis.html

1.a.iii. The curriculum must include application of principles of sustainability, risk, and resilience to civil engineering problems.

Understanding the Criterion

ABET, under the definition of engineering design, recognizes the importance of risk and sustainability. Civil engineering systems and projects must consider sustainability, risk, and resilience in design and operation (ASCE BOK3, Bocchini et al. 2014). These attributes intersect.

Sustainability for civil engineers is defined as "a set of economic, environmental, and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of environmental, social, and economic resources." (ASCE 2023a).

Resiliency is the ability of a system to withstand an extreme event and recover efficiently. Extreme events have a probability of occurrence during the lifespan of the civil engineering system. The recovery from these extreme events has economic, environmental, and social costs that can be calculated. Sustainability requires planning for the impact natural and man-made disasters and changing conditions can have on economic, environmental, and social resources.

The definition and importance of risk in civil engineering are outlined in ASCE Policy 437: "Risk assessment is the characterization of the potential adverse effects that hazards can inflict on people, property, or the environment, often with both stochastic and deterministic inputs." (ASCE 2022). Resiliency links sustainability to risk because understanding the risks of extreme events is essential to building resilient infrastructure. Further, climate change increases risk due to certain extreme events.

The criterion does not require a program to include sustainability, risk, and resilience in all student experiences or include them in multiple contexts. It does not require that all factors influencing risk, resilience, and sustainability be included in the curriculum, but only that students be exposed to the concepts and their application to civil engineering.

Examples of Compliance

There are several ways in which a curriculum may include risk, resilience, and sustainability within courses or capstone design. Examples are given as follows (in a non-exhaustive list):

Sustainability

- In selecting construction materials, a discussion of resource requirements for several alternative materials (including recycled materials) can be included.
- The impact of a project on land, water, and air resources can be included. For example, excess runoff due to an increase in impervious areas for residential development can be reused for the irrigation of lawns.
- In a transportation course, the impacts of different alternatives (multimodal transport, electric vehicles, etc.) could be used to illustrate principles.
- The use of various "scorecards" (e.g., LEED, Green Globes, ENVISION) could be used to analyze the sustainability of an overall design.
- Apply principles of ASCE 73-23 (ASCE 2023b) to an infrastructure problem.

Risk

- Risks associated with potential and highly variable natural hazards.
- The impact of variability or uncertainty of material properties on performance poses a risk that could be incorporated into courses on construction materials, structural design, soil mechanics, or foundation design.
- Risk associated with variability in precipitation or streamflow and impacts could be included in hydrology.
- Risk associated with variability in demand could be included in courses on traffic design or hydraulics.
- Risk associated with variability and uncertainty in project execution could be included in courses on engineering economics or project/construction management and construction-risk assessment.
- Risk associated with variability in demand or environmental conditions could be used to incorporate safety factors in structures.
- Risks associated with the inability to characterize the entirety of a setting, whether a soil, a water body, or an existing infrastructure condition could be included in various courses.

Resilience

- The use of redundant elements to achieve a more resilient design could be included in structural or water network design courses.
- The impact of road outages and recovery times as examples of resilience could be included in transportation courses.
- Design approaches to achieve Class I reliability in water and wastewater infrastructure could be included in courses on water/wastewater treatment and water supply.

- Combined consideration of multiple stressors for a holistic resilience assessment of water infrastructure, building design, or road networks in areas prone to natural hazards (e.g., earthquakes, hurricanes, tornadoes) could be incorporated in related courses.
- Case studies of failures and recovery from various infrastructure disasters could be used as illustrative of resilience concepts.

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1.a.iii. The curriculum must include application of principles of diversity, equity, and inclusion to civil engineering problems.

Understanding the Criterion

Civil engineers are responsible for designing, building, and maintaining systems and infrastructure to solve problems and improve the quality of life for society. For these solutions to serve the intended communities well, they must incorporate perspectives that represent the diversity of those communities and ensure equitable engagement of stakeholders from various backgrounds and identities (Pearson and Simmons 2018).

In short, the application of DEI principles is integral to current civil engineering practice. For example, planning and designing public infrastructure for community-wide access, safety, and resilience requires understanding and accommodating disparate community or regional needs. Recognizing a community's diverse members, considering the differing needs of those members, and seeking design solutions to meet those needs equitably are all crucial to the success of public infrastructure. Failure to understand these responsibilities can result in a failed civil engineering solution.

Over the last several years, ASCE has increased its intentionality toward and prioritization of diversity, equity, and inclusion (DEI) in its policies and practices (see more detail in Appendix III). Definitions of DEI are included in ASCE Policy Statement 417 (ASCE 2021a). Notably, the ASCE Code of Ethics includes diversity, equity, and inclusion explicitly and implicitly in each of the four fundamental principles (e.g., "treat all persons with respect, dignity, and fairness in a manner that fosters equitable participation without regard to personal identity") and in practices related to all five stakeholders. For example (ASCE 2021b),

- Society: acknowledge the community's diverse historical, social, and cultural needs and incorporate these considerations in their work.
- Peers: promote and exhibit inclusive, equitable, and ethical behavior in all engagements with colleagues.

It is important to note the clear difference between the DEI provisions of the EAC Pilot General Criteria and the DEI provisions of the Civil Engineering Program Criteria. These provisions are *not* redundant. The Pilot General Criterion 5 provision only requires "[curricular] content that ensures awareness" of DEI. ASCE's position is that DEI should not be taught solely in isolation but rather integrated into civil engineering contexts. Consistent with this position, the DEI provision of the Civil Engineering Program Criteria is focused on the importance of DEI in civil engineering problem-solving. In addressing this criterion, there is no expectation that faculty or students will change their personal beliefs.

Appropriate contexts for DEI-related curricular content include but are not limited to research, design, community engagement, leadership, and team-based problem solving. It is not expected that every course will include principles of DEI, nor is it expected that standalone courses will be created to address this criterion. Addressing DEI in civil engineering problem-solving may involve collaboration with experts outside of civil engineering (e.g., social science, behavioral science, policy, social work), but it is not required to do so. There is no singular set of "principles of diversity, equity, and inclusion," as the principles and priorities vary depending on context and are often defined in a context-specific manner. Thus, programs are given wide latitude to include DEI principles of their choice, as long as they are relevant to civil engineering problem-solving. Example principles include but are not limited to the fundamental principles in ASCE's Code of Ethics (ASCE 2020), the principles of universal design (Center for Universal Design 1997), and others that are aligned with ABET's definitions of diversity, equity, and inclusion (ABET 2021), which have been adopted by ASCE (ASCE 2021).

Examples of Compliance

- Using rating systems such as Greenroads, ENVISION®, and/or LEED to introduce students to metrics related to societal well-being.
- Using case studies to address past civil engineering projects that adversely affected or failed to address the needs of an underserved community (e.g., the 2014 Flint, Michigan, water supply crisis and the pre-Katrina New Orleans flood control system); such case studies could be used to inform instruction in the engineering design process.
- Using case studies to address past civil engineering projects that successfully met the needs of one or more underserved communities.
- Evaluating zoning laws, planning codes, and/or accessibility regulations applicable to an example public or private project to determine whether they promote or advance equity; alternatively, a capstone project team could do a similar analysis of their engineering design project.
- Addressing targets within the United Nations Sustainable Development Goals (SDGs) that focus on equity for historically marginalized populations, for example, SDG 11 (Sustainable Cities and Communities), Target 11.2 (United Nations 2015) – "By 2030, provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons."

- Apply the DEI-related principles of ASCE 73-23 (ASCE 2023), especially Chapters 2 and 3, to an infrastructure problem.
- Teaching principles of user-centered design and assigning problems that require the inclusion of diverse stakeholder perspectives in each stage of problem solving (Pearson 2019a, b).
- Teaching principles of universal design and universal design for learning not only to address utility and accessibility for a wide range of stakeholders/end users but also equitable and inclusive communications with stakeholders (Pearson 2019a).
- Evaluating current equity issues in a community or project location using tools such as the Council on Environmental Quality Climate and Economic Justice Screening Tool or Environmental Justice Screening and Mapping Tool.
- Additional details and examples are included in Appendix III.

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1.a.iv. The curriculum must include application of the engineering design process in at least two civil engineering contexts.

Understanding the Criterion

Engineering design is defined in the EAC/ABET General Criteria (ABET 2021) and design-related requirements are imposed by Criterion 3.2 and Criterion 5. The Program Criteria adds a requirement that each civil engineering program expose all its students to applications of the engineering design process, as defined by EAC/ABET, in at least two civil engineering contexts. These civil engineering contexts should be significantly different from one another, such as two different technical specialties, as discussed below and in Section D9 of this commentary. Furthermore, the program's students need not all be exposed to design applications in the same civil engineering contexts.

Examples of Compliance

One unambiguous way to satisfy the criterion for at least two civil engineering contexts is for the program to require all its students to experience design in more than one specialty area of civil engineering. For example, a program that requires students to design a steel or reinforced concrete structure (a structural context) and a deep foundation (a geotechnical engineering context) likely complies with this requirement. Conversely, a program that requires students to design a reinforced concrete structure and a steel structure may not comply because the design context for both structures is similar.

Engineering design experiences in two different areas of the following list would demonstrate compliance with the intent of this criterion. This list does not include all possible design contexts or specialty areas; evolving areas of civil engineering beyond these traditional contexts are also appropriate.

Construction Engineering

Topics related to the design of shoring, falsework, and temporary structures that carry construction loads; excavation shoring, cofferdam design, and dewatering.

Geotechnical

Topics related to the design of foundations of different types (wall footing, isolated footings, mat foundations, and deep foundations).

Design of earth retaining structures (retaining walls) and application of slope stability.

Structural

Topics related to the design of structural elements for buildings, bridges, and nonbuilding type structures from different types of civil engineering materials such as reinforced concrete, prestressed concrete, steel, timber, or reinforced masonry.

Transportation

Topics related to the design of roadways include vertical and horizontal alignments with consideration of concepts such as sight stop distance; intersection design including signal selection and timing; mass diagram for linear projects, and its use to optimize earthwork movement.

Water Resources/Land Development

Topics related to the drainage design of a site for land development (open channels, storm sewers, or other surface drainage facilities), design of sanitary sewer lines, or design of a water treatment and/or distribution system.

Environmental Engineering

Topics related to wastewater treatment plant design, air quality monitoring and control, landfill design, and site remediation.

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ABET. 2021. "EAC of ABET 2022-2023 criteria." Accessed March 1, 2022. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/.

1.a.v. The curriculum must include application of an engineering code of ethics to ethical dilemmas.

Understanding the Criterion

The primary objective of this criterion is to expose students to reading, understanding, and applying a code of ethics to specific professional situations. The most common code of ethics encountered by civil engineers in the United States is the ASCE Code of Ethics, or alternatively, the National Society of Professional Engineers Code of Ethics. However, programs may use other codes as appropriate. *Civil Engineering Body of Knowledge*, Third Edition (CEBOK3) provides a detailed rationale and discussion concerning using codes and the ethical responsibilities of a civil engineer.

The NSPE Code of Ethics (NSPE 2019) fundamental canons are that engineers shall do the following in the fulfillment of their professional duties:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully to enhance the profession's honor, reputation, and usefulness.

The ASCE Code of Ethics (ASCE 2020) divides the ethical responsibilities of the civil engineer into the following categories:

1. Society
2. Natural and Built Environment
3. Profession
4. Clients and Employers
5. Peers

Ethical dilemmas can occur when practice-related responsibilities associated with the above categories conflict.

Examples of Compliance

The application of an engineering code of ethics to ethical dilemmas may be fulfilled through a combination of undergraduate coursework, exposure to practicing professionals, and/or mentoring experience.

Compliance with the criterion may be achieved through *one or more* of the following:

- Requiring a course in engineering ethics, which includes the application of the ASCE Code of Ethics or other code of ethics to a specific design or professional situation.
- Covering ethical dilemmas within a course such as a capstone senior design course, referencing a specific design or professional situation (e.g., applying codes to evaluate a project design within the natural and built environment).

- Applying a code within an undergraduate course to evaluate a potential conflict of interest or another ethical situation that civil engineers may encounter.
- Applying ENVISION© in the classroom as an evaluation tool to engage students in a discussion of ethics, as well as the design and decision-making process to address various levels of achievement for all ENVISION categories.
- Providing seminar presentations from practicing professionals on real-world ethical dilemmas and possible solutions based on applying a code of ethics.

References

ASCE. 2019. *Civil engineering body of knowledge: Preparing the future engineers.* 3rd Edition. Reston, VA: ASCE Civil Engineering Body of Knowledge 3 Task Committee.

ASCE. 2020. "Code of ethics," Reston, VA: ASCE.

ISI (Institute for Sustainable Infrastructure). 2018. *ENVISION: Sustainable Infrastructure Framework Guidance Manual*. Washington, DC: ISI.

NSPE (National Society of Professional Engineers). 2019. "Code of Ethics for Engineers." Alexandria, VA: NSPE.

1.b. The curriculum must include solution of complex engineering problems in at least four specialty areas appropriate to civil engineering.

Understanding the Criterion

The first student outcome in Criterion 3 of the EAC General Criteria. ABET (2021) requires students to have an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. This outcome stems from the Graduate Attributes and Professional Competencies (GAPC) created by the International Engineering Alliance (IEA) (2021). The distinction between engineers and engineering technologists, as described in the engineering knowledge profile and engineering technologist knowledge profile of the GAPC, is that engineers must be able to apply mathematics, science, engineering fundamentals, and discipline-specific knowledge to develop solutions to complex engineering problems. In contrast, engineering technologists apply mathematics, science, engineering fundamentals, and discipline-specific knowledge to defined and applied engineering procedures, processes, systems, or methodologies.

This provision of the Program Criteria requires the civil engineering curriculum to provide opportunities for students to solve complex engineering problems in at least four specialty areas relevant to civil engineering. There is no requirement in the Program Criteria that the program demonstrate a student's ability to solve complex engineering problems. The only requirement is that the program demonstrates that the curricular content of the program presents complex engineering problems for solution.

Complex engineering problems are defined in the EAC Criteria for Accrediting Engineering Programs. The EAC definition contains seven distinct attributes, and satisfying one or more of those attributes constitutes a complex problem.

Specialty Areas

The field of civil engineering involves many traditional areas of specialization. Generally recognized civil engineering specialty areas include but are not limited to:

- Construction engineering
- Environmental/sanitary engineering
- Geotechnical engineering
- Water Resources/Land Development
- Structural engineering
- Surveying/measurements
- Transportation engineering

New specialty areas will emerge as civil engineering evolves. Therefore, enforcement of this provision must not constrain curricular innovation or a program's ability to respond to future opportunities or needs. The program (not the PEV) must demonstrate that the specialty area or areas are *appropriate to civil engineering* in sufficient detail to make a well-reasoned judgment. This judgment must consider the balance of the desirability of curricular innovation against the need for relevant technical breadth.

Civil engineering programs may need to develop nonstandard specialty areas in response to emerging societal needs. These breadth areas should be supported by constituent and stakeholder feedback and connected to the program's educational objectives. Possible justifications for nonstandard specialty areas might include the following:

- ASCE has an institute or technical division, publishes a journal, or sponsors specialty conferences in the technical area.
- A national or international civil engineering-related professional society has an institute or technical division, publishes a journal, or sponsors specialty conferences in the technical area.
- Civil engineering consulting or contracting firms specialize in the technical area.
- A technical area has a civil engineering connection with an applicable grand challenge from the National Academy of Engineering (NAE) or other initiatives by national or international engineering organizations.
- There is an applicable and established program in a technical area within a government agency to identify emerging areas of societal need. Examples could include programs with the Department of Commerce, Department of Energy, Department of Transportation, Department of Energy, Department of Homeland Security, Department of Defense, Environmental Protection Agency, National Science Foundation, or National Institutes of Health.

The list above is not inclusive, as many other legitimate, well-reasoned justifications are possible.

Note: Whereas all students must be exposed to the solution of complex engineering problems in four specialty areas, there is no requirement for a minimum number of credit hours or courses in each of the four technical areas, and there is no requirement that all graduates of a given program satisfy the requirement in the same four areas.

Examples of Compliance

Some examples of problems that would satisfy the definition of complex engineering problems are open-ended problems that do not have a predetermined correct answer, those that require interpretation of field or laboratory data to infer design parameters, those that involve stakeholder input, those with multiple parts, those that involve more than one subdiscipline of civil engineering or other disciplines, or those that consider the economic or cultural impact of solutions. These would meet the criteria of a complex problem. While it is not possible in this brief commentary to provide exhaustive examples for compliance, a few examples of what could satisfy this provision of the Program Criteria are provided.

Geotechnical

A problem is given where the student is required to interpret a series of soil boring logs to develop the necessary soil properties needed to design a shallow foundation for strength and serviceability, given a set of live, dead, and environmental loading conditions. Possible complex problem attributes include: no obvious solution, multiple sub-problems, and potentially multi-disciplinary. However, a problem for which a student is given a specific loading condition and necessary soil properties to analyze a foundation with a specified geometry to determine a safety factor against a bearing capacity failure would not satisfy the definition.

Structural

The student is given the dimensions of a two-story, multibay rigid frame structure and its intended use. The student must determine the appropriate loads for the intended use and the critical loading condition for the structure. To satisfy strength and serviceability criteria, the student must further design a specified beam or column in steel, concrete, or both. It could also include an economic analysis of potential design choices. Possible complex problem attributes include: no obvious solution, and multiple sub-problems. However, a problem where the student is given a beam of specified dimensions and loading conditions and is required to determine the maximum moment, shear, and deflection would not satisfy the definition.

Transportation

Given detailed two-way traffic data for a suburban intersection, determine the appropriate interchange configuration to maximize its capacity. Possible complex problem attributes include: no obvious solution, diverse groups of stakeholders, and multiple sub-problems. However, a problem where the student must determine the maximum degree of curvature or minimum radius of curvature for a horizontal curve, given a roadway type and design speed, would not satisfy the definition.

Water Resources/Land Development

Given topographic, land use, and annual rainfall information, determine the impact on existing downstream facilities of converting a 100-acre parcel of mixed timber-pasture and tillable farmland to a shopping center. If required, recommend mitigating structures or processes. Possible complex problem attributes include: no obvious solution, diverse groups of stakeholders, multiple sub-problems, and potentially multidisciplinary. However, a problem where the student is given a channel configuration, max flow, and slope to determine the appropriate corrugated steel circular culvert size to carry the flow would not satisfy the definition.

Capstone

The solution of complex engineering problems provision of the Program Criteria may be satisfied in several ways. One way is by including solutions to complex engineering problems within individual courses covering one or more specialty areas appropriate to civil engineering. Another way could be within the culminating “Capstone” design experience.

If the capstone design experience is used to satisfy this curriculum requirement, the capstone requirement must include the solution of complex engineering problems within at least four of the specialty areas individually.

A capstone experience could involve the design of a building on a site, which would require the solution of complex structural issues (perhaps including choice of materials of construction), evaluation of soil conditions from data, design of a foundation, design of elements of water management and runoff control, and design of adjacent road and traffic patterns to minimize the impact on adjacent parcels. In addition, each element of the capstone project must satisfy one or more attributes of the complex problem definition.

However, a capstone experience relying solely on the application of extant codes or regulations, without the need for judgment and incorporating stakeholders' consideration, would not satisfy the complex solution requirement. For example, a capstone experience in which the design was only for a surface parking lot would not satisfy the requirement.

Note: If the Capstone project is the sole curricular component used to satisfy this provision of the Program Criteria, all Capstone projects must include at least four civil engineering specialty areas and the necessary attributes contained in the complex problem definition.

Definition and References

Definition: Complex engineering problems include one or more of the following characteristics: involving wide-ranging or conflicting technical issues, having no obvious solution, addressing problems not encompassed by current standards and codes, involving diverse groups of stakeholders, including many component parts or sub-problems, involving multiple disciplines, or having significant consequences in a range of contexts (ABET 2021).

ABET. 2021. “EAC of ABET 2022-2023 criteria.” Accessed March 1, 2022. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/.

International Engineering Alliance. 2021. “Graduate attributes and professional competencies, version 2021.1.” Accessed March 1, 2022. https://www.ieagreements.org/assets/Uploads/IEA-Graduate-Attributes-and-Professional-Competencies-2021.1-Sept-2021.pdf

1.c. The curriculum must include conduct of experiments in at least two civil engineering contexts and reporting of results.

Understanding the Criterion

The General Criterion 3(6) requires “an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.” The related provision of the Program Criteria differs from this General Criterion; it emphasizes conducting laboratory experiments or tests in at least two civil engineering contexts and reporting the results. Compliance may be established by demonstrating that the curriculum includes the required exposure to laboratory experiments and that all students obtain that level of exposure.

To comply with the Program Criteria provision, experimental experiences typically include but are not limited to opportunities for students to practice the following:

- Understand the objectives and procedures associated with an experiment.
- Conduct an experiment, including setup, measurement, and data collection.
- Observe and document errors and uncertainties in data collection procedures.
- Accurately report experimental results.

Examples of Compliance

Compliance is demonstrated with physical laboratory courses in which students gain hands-on experience conducting civil engineering experiments incorporating appropriate standards (ASTM, AASHTO, etc.). Examples of appropriate laboratory experiences would include surveying, fluid dynamics, water quality testing, soil property testing, and construction materials testing, among other topics. Physical laboratory courses should maintain sufficient equipment for all students to engage with experiments individually or in a team (not simply a demonstration).

Laboratories that use software to solve civil engineering problems (i.e., AutoCAD, finite element analysis, and similar) do not satisfy this criterion. Videos/demonstrations of experiments do not satisfy this criterion, even if coupled with opportunities for students to work with experimental data. However, while physical, hands-on laboratory experiences are preferred, using “virtual laboratories” (e.g., computer simulations to mimic the hands-on experiences of physical experiments, or virtual reality technology employed for lab experiences) may be appropriate. The PEV should consider the effectiveness of such curricular innovations with openness. An evaluation of a virtual laboratory experience should consider the following factors:

- Extent to which the subject matter lends itself to accurate simulation
- Extent to which the simulation replicates the actual physical experiences of setup, measurement, errors, and data collection
- Nature of student interaction with the simulation

1.d.i. The curriculum must include explanation of concepts and principles in project management and engineering economics.

Understanding the Criterion

Fundamental knowledge of project management is necessary for successful projects regardless of the project type, team size, or project budget. Whereas entry-level civil engineers typically do not serve as project managers, a basic understanding of the concepts and principles of project management enables them to better serve in their assigned roles and contribute to the success of their projects and professional development. Broadly, project management involves coordinating resources (financial, human, materials, equipment, etc.) through the life of a project to achieve the project’s objectives within the allotted time frame and budget with acceptable quality. Typical phases of project life include initiation, planning, execution, monitoring and controlling, and closing. Some projects also involve operations, maintenance, and decommissioning.

A proper appreciation of economic impacts plays a role in developing successful and sustainable civil engineering projects in all practice areas, including consulting, design, construction, operations, maintenance, and research. Engineering projects are frequently approached from the perspective of developing alternatives and evaluating them against established criteria, for example, environmental, health, and safety or diversity, equity, inclusion, and accessibility.

Economic viability is practically always one of the considerations in selecting the optimum alternative. Engineering economics incorporates business, finance, and classical economics concepts. It involves formulating, estimating, and evaluating project financing and economic performance, as well as alternative economic strategies to accomplish a defined purpose.

The criterion states that the curriculum must include an explanation of concepts and principles in project management and engineering economics. The curriculum must explain some, but not necessarily all, of the key concepts and principles. As with all curricular topics included in the Program Criteria, there is no obligation to assess students' ability to explain the key concepts and principles.

Examples of Compliance

Examples of basic concepts in project management include but are not limited to:

- Manager responsibilities
- Client requirements definition and fulfillment
- Risk assessment and management
- Stakeholder identification and involvement
- Contract negotiation
- Project work plans, scope, and deliverables
- Budget and schedule preparation and monitoring
- Interaction among engineering and other disciplines
- Quality assurance and quality control
- Dispute resolution processes.

Concepts and principles of engineering economics include but are not limited to:

- Time value of money and interest rates
- Categorization of costs, including incremental, average, and sunk costs
- Estimation of cash flows, including inflows and outflows such as initial capital, annual operation, maintenance, repair, salvage value, and replacement costs
- Economic analyses, including present and/or annual worth, return on investment, and cost-benefit
- Depreciation and taxes
- Type and breakdowns of costs, including fixed, variable, direct and indirect, and labor
- Accounting, including financial statements and overhead cost allocations
- Capital budgeting
- Financial risk identification
- Profit and loss, supply and demand, as well as basic economic life-cycle analysis.

Providing standalone courses in project management and/or engineering economics is one way to comply with the criterion, but it is not a requirement. In addition, the criterion does not require that students be exposed to all concepts and principles.

Outside of a standalone class, other means of exposing students to the concepts and principles of project management and engineering economics include but are not limited to:

- Incorporating into the major design experience
- Incorporating concepts of project management through teamwork exercises in laboratory or design courses
- Including lecture topics in engineering courses devoted to business or professional issues
- Including business or economic courses in the general education component of the curriculum
- Introducing at a basic level through a first-year "Introduction to Engineering" or other survey courses
- Documenting exposure within the context of specific co-curricular experiences (concrete canoe, steel bridge teams, or Engineers Without Borders) or cooperative employment placements. Documentation should be sufficient to allow the PEV to understand how and in what context students were exposed to the concepts through these experiences.

1.d.ii. The curriculum must include explanation of professional attitudes and responsibilities of a civil engineer, including licensure and safety.

Understanding the Criterion

The curricular topics on "professional attitudes and responsibilities" need not be extensive, as long as students can generally explain their definition and importance and give examples of how to incorporate them in the workplace. Therefore, developing a separate course in the curriculum is unnecessary, and these topics can be integrated into any required course.

Professional responsibilities encompass a range of elements, including safety, legal issues, integrity, licensure, credentialing, and innovation. Although not specifically listed in CEBOK3 (ASCE 2019) outcome statements, other important professional responsibilities include knowledge and appreciation of the history and heritage of the profession, cultural perspectives, public policy, and global perspectives.

The primary responsibility of a civil engineer is to ensure public safety and to keep this goal at the forefront during engineering design and other engineering activities.

A civil engineer must be aware of the wide variety of legal and regulatory responsibilities that pertain to the practice of civil engineering, including regulations, standards, codes, contracts, and guidelines relevant to the applicable authorities, which can span federal, state, and local requirements.

Civil engineers must appreciate and understand the importance of professional licensure, when licensure is required, the process of becoming a licensed professional engineer (P.E.), and the responsibilities associated with licensed practice, including lifelong learning to stay current with advances in civil engineering practice.

Civil engineers must understand the importance of safety in all their activities. Safety aspects of design, construction, operation, and infrastructure management are critical to civil engineering. As indicated in ASCE

Policy Statement 350, civil engineers are responsible for considering the safety of those affected by their designs and for recognizing that site safety and constructability are important considerations when preparing construction plans and specifications. Civil engineers will also benefit from an understanding of occupational safety because it affects their workplaces, and it is a factor in the design of various facilities.

Examples of Compliance

Professional attitudes could be explored in an "Introduction to Engineering" course. One lecture could cover the required topics. These topics could also be covered in upper-level courses, including the senior design course. The course syllabus can include "professional attitudes and responsibilities." Examples of activities and lecture topics supporting compliance include but are not limited to the following:

- Use of ACI, AASHTO, AISC, ASCE, etc., codes and standards to implement safety factors in design.
- Evaluation of a specific design, with respect to how it included consideration of the safety of those who construct, use, operate, and maintain the design.
- The incorporation of typical codes, standards, regulations, and statutes in engineering practice.
- The need to become a licensed professional engineer and the associated responsibilities.
- The meaning of safety culture within an organization and the need for a personal commitment to promoting safe practices.
- The necessity for and value of ABET accreditation.
- Concepts of hazard identification and mitigation.

Activities outside of coursework supporting compliance may include, but are not limited to:

- Actively promoting the process of the program's students sitting for the fundamentals of engineering (FE) exam.
- Supporting the establishment and sustainability of professional society students' chapters and related activities.

References

Al-Bayati, A. J., Albert, A. and Ford, G. (2019). "Construction Safety Culture and Climate: Satisfying the Necessity for an Industry Framework." Practice Periodical on Structural Design and Construction, American Society of Civil Engineers. 24 (4), DOI:10.1061/(ASCE)SC.1943-5576.0000452

ASCE (American Society of Civil Engineers). 2019. *Civil engineering body of knowledge: Preparing the future engineers.* 3rd Edition. Reston, VA: ASCE Civil Engineering Body of Knowledge 3 Task Committee.

Proceedings from the National Academy of Construction's safety symposia series on "Introducing and Embedding Safety Culture Concepts in Undergraduate Education" are now available online. (https://www.naocon.org/research/) The series aimed to advance the goal of teaching safety and safety culture to students to make them better hires and to empower them to lead and immediately contribute to the industry and their employer.

2. The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience.

Understanding the Criterion

The phrase "courses that are primarily design in content" is intended to apply to the differentiation between engineering science, engineering analysis, and engineering design courses. Courses in the design category would be those in the third and fourth years, where design is the majority of the course. Typically, these courses are identified in the Curriculum Table in the self-study and are often used to satisfy the EAC General Criteria 5d design outcome and the civil engineering design provision of the Program Criteria. As an aid to the PEV in differentiating classes and faculty covered by this criterion, the program may elect to include a listing of all courses primarily addressing design content or a tabulation indicating the design component of each class, and the faculty members who teach the respective courses.

The next phrase, "qualified to teach the subject matter by professional licensure, or by education and design experience," describes the minimal qualifications necessary to teach the design courses. Professional licensure, usually as a Professional Engineer (P.E.), is considered satisfactory evidence of necessary qualifications to teach design. The second half of the requirement, "or by education and design experience," provides an alternative to the demonstration by licensure that a faculty member is qualified to teach design in a specific area. The program must demonstrate to the reasonable satisfaction of the PEV that faculty members who teach design courses meet at least one or the other of these qualifications.

Examples of Compliance

Documentation of licensure as a professional engineer (P.E.) in a US state or territory is sufficient to demonstrate that a faculty member teaching design meets the criterion. Outside of the United States, a government agency's professional engineering licensure (registration, certification, or equivalent) is also sufficient to demonstrate compliance. Certification by a nongovernmental agency is also sufficient if it is recognized by the government as a qualification to practice engineering.

The demonstration by the program that relevant faculty members are qualified by professional licensure can be as simple as a table with the appropriate information. Information in the table could include the jurisdiction(s) of licensure, discipline (if appropriate), date of initial licensure, and the license's expiration date.

For individuals who do not meet the provisions of the previous paragraph, individual credentials are evaluated on a case-by-case basis to determine if their education and design experience are adequate for compliance with the criterion. Aspects of the individual's resume that support qualification include but are not limited to:

- Licensure in a discipline closely related to the field in which the faculty member is teaching design. For example, licensure as a professional geologist and appropriate design experience can indicate qualification by virtue of education and design experience to teach foundation design or other courses with geotechnical design components.
- Certification in a relevant discipline or specialty. These are not professional licensures and cannot be used to satisfy the criterion fully. However, certification can indicate proficiency/expertise in a particular field. Thus, certification may help demonstrate experience in a specific discipline or specialty.

- Educational history. Faculty without a civil engineering undergraduate or graduate degree should be educated in a field closely related to that in which they are teaching design. For instance, the related field may be chemical or mechanical engineering for teaching environmental design.
- Employment history. If the individual teaching design has an ABET-accredited degree and enough experience to be eligible to be licensed, that may also support that they are qualified. Design experience can come in many forms and from many types of employment, the most common being private sector work doing engineering design. Relevant design experience for a state or federal agency responsible for infrastructure, such as transportation, environmental protection, or public works, would also support qualification by design experience. Design experience may come in a sustained period of employment or incrementally over several years.

For claiming qualification by virtue of education and design experience, the Faculty Qualifications table and curriculum vitae in the self-study provide the educational history. The program should concisely document the specifics of the claimed experience in design, and more detail than that provided with the ABET faculty curriculum vita template may be needed. The specific method for documenting the claimed design experience is left to the program, and the PEV should request more details if needed.

The PEV may also wish to review the class materials to determine if the subject matter aligns with the instructor's education and experience.

Appendix I: Bloom's Taxonomy

The third edition of [*Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer* (CEBOK3)] explicitly included the use of Bloom's Taxonomy for the Cognitive Domain to define the level of achievement for each of 21 outcomes. CEBOK3 also considered achievement in the affective domain for the six professional outcomes and sustainability. Appendix E of CEBOK3 provides a detailed overview of Bloom's Taxonomy in the cognitive domain and an additional taxonomy in the affective domain developed by Bloom's colleagues. For reader convenience, the six Bloom's levels in the cognitive domain are summarized in Table I-1.

Bloom's Taxonomy uses action verbs to specify levels of achievement; however, action verbs imply the attainment of outcomes, and according to ABET policy program criteria cannot specify student outcomes. Thus, CEPC has adapted Bloom's Taxonomy by converting the action verbs (used in CEBOK3) to nouns in CEPC. These nouns are still indexed to Bloom's Taxonomy; however, in the context of CEPC, they indicate the level of curricular coverage rather than the level of student outcome achievement. For example, the verb "apply" has been converted to "application of" in CEPC but still refers to Level 3. The verb "explain" has been converted to "explanation of" in CEPC but still refers to Level 2.

While all levels of the taxonomy are defined, only levels two and three are required in the current Civil Engineering Program Criteria. The level of curricular coverage in the affective domain is not considered.

Table I-1. Defining the Levels of Bloom's Taxonomy for the Cognitive Domain (from CEBOK3)

Bloom's Level	**Examples and Keywords**
1. Remember: Recall or retrieve previously learned information.	Example: Recite safety rules. List the steps in the engineering design process. Keywords: define, describe, identify, label, list, match, recall, recite, recognize, reproduce.
2. Comprehend: Restating a problem in one's own words, or interpreting content or instructions. *Note*: Anderson called this category *Understanding*.	Example: Explain how to conduct an experiment. Translate an equation into a spreadsheet. Keywords: convert, distinguish, explain, extend, paraphrase, rewrite, summarize.
3. Apply: Apply what was learned to solve a problem or use a concept in a new situation.	Example: Calculate stress in a in a beam. Construct a free body diagram. Keywords: Calculate, compute, construct, determine, predict, produce, solve, use.
4. Analyze: Break concepts or problems into their component parts so that their structure can be understood.	Example: Select the appropriate technique(s) to interpret data. Identify the largest bending moment in structure. Keywords: Breakdown, compare, contrast, differentiate, identify, illustrate, infer, relate, select, separate.
5. Synthesize: Combining disparate knowledge to create a new whole. Build a pattern or matrix from diverse elements.	Example: Design a structure to carry specified loads. Create construction specifications for a project. Keywords: Categorize, compile, create, design, devise, plan, revise, summarize.
6. Evaluate: Making judgments about the value of ideas, work products or processes.	Example: Critique a proposed design. Justify a novel design or construction technique. Keywords: Assess, conclude critique, judge, justify, validate.

Appendix II: BOK Outcomes Rubric (Third Edition)

One of the key sections of [*Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer* (CEBOK3)] is the full outcomes rubric, which includes outcome statements for all six levels of achievement for each and every outcome. Included in the rubric are the typical pathways for attaining the outcomes. The following excerpt from *Civil Engineering Body of Knowledge* describes the pathways:

- Undergraduate Education (UG): undergraduate education leading to a bachelor's degree in civil engineering or a closely related engineering discipline, in general, from a four-year program accredited by the Engineering Accreditation Commission of ABET (EAC/ABET).
- Postgraduate Education (PG): postgraduate education equivalent to or leading to a master's degree in civil engineering or a closely related engineering discipline, in general, equivalent to one year of full-time study.
- Mentored Experience (ME): early career experience under the mentorship of a civil engineer practicing at the professional level, progressing in complexity and level of responsibility.
- Self-Developed (SD): individual self-development through formal or informal activities and personal observation and reflection.

Civil Engineering Body of Knowledge includes rubrics for both Bloom's Taxonomy cognitive and affective domains, but only the former is addressed by the Civil Engineering Program Criteria. Further information regarding the affective domain is in Appendixes E and F of *Civil Engineering Body of Knowledge*.

The cognitive domain rubrics describe target undergraduate levels of achievement and can aid in understanding the level of coverage required for each of the curricular topics in the Civil Engineering Program Criteria. However, note that the Program Criteria curricular topics are not outcomes, and do not map directly with the CEBOK3 outcomes. Nevertheless, the interested reader may find the CEBOK3 rubrics (Table II-1 below) helpful in understanding the background of the Program Criteria.

Table II-1. Cognitive Domain Outcome Rubrics (from CEBOK3)

	Cognitive Domain Level of Achievement *The cognitive domain describes the development of intellectual skills, ranging from the simple recollection of specific facts to the integration and evaluation of complex ideas and concepts.*					
Outcome	**Level 1** **Remember** *The ability to remember previously learned material.*	**Level 2** **Comprehend** *The ability to grasp the meaning of learned material.*	**Level 3** **Apply** *The ability to use learned material in new and concrete situations.*	**Level 4** **Analyze** *The ability to break down learned material into its component parts so that its organizational structure may be understood.*	**Level 5** **Synthesize** *The ability to put learned material together to form a new whole.*	**Level 6** **Evaluate** *The ability to judge the significance and importance of learned material for a given purpose.*
Foundational Outcomes						
Mathematics	**Identify** concepts and principles of mathematics, including differential equations and numerical methods. (UG)	**Explain** concepts and principles of mathematics, including differential equations and numerical methods. (UG)	**Apply** concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems. (UG)	**Select** appropriate concepts and principles of mathematics to solve civil engineering problems.	**Develop** mathematical models to solve civil engineering problems.	**Assess** mathematical models used to solve civil engineering problems.
Natural Sciences	**Identify** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences. (UG)	**Explain** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences. (UG)	**Apply** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences, to solve civil engineering problems. (UG)	**Select** appropriate concepts and principles of natural sciences to solve civil engineering problems.	**Integrate** appropriate concepts and principles of natural sciences to solve civil engineering problems.	**Evaluate** solutions to civil engineering problems involving concepts and principles of natural sciences.

Table II-1 (Continued)

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Social Sciences	**Identify** concepts and principles of social sciences. (UG)	**Explain** concepts and principles of social sciences. (UG)	**Apply** concepts and principles of social sciences relevant to civil engineering. (UG)	**Select** appropriate concepts and principles of social sciences to solve civil engineering problems.	**Integrate** appropriate concepts and principles of social sciences to solve civil engineering problems.	**Evaluate** solutions to civil engineering problems involving concepts and principles of social sciences.
Humanities	**Recognize** relationships between the humanities and the practice of civil engineering. (UG)	**Explain** relationships between the humanities and the practice of civil engineering. (UG)	**Apply** aspects of the humanities to the solution of civil engineering problems. (UG)	**Illustrate** aspects of the humanities in the solution of civil engineering problems.	**Integrate** aspects of the humanities into the solution of civil engineering problems.	**Assess** the integration of the humanities into the solution of civil engineering problems.
Engineering Fundamentals Outcomes						
Materials Science	**Identify** concepts and principles of materials science. (UG)	**Explain** concepts and principles of materials science. (UG)	**Apply** concepts and principles of materials science to solve civil engineering problems. (UG)	**Select** appropriate concepts and principles of materials science to solve civil engineering problems.	**Develop** new applications in materials science to solve civil engineering problems.	**Evaluate** solutions to civil engineering problems involving new applications in materials science.
Engineering Mechanics	**Identify** concepts and principles of solid and fluid mechanics. (UG)	**Explain** concepts and principles of solid and fluid mechanics. (UG)	**Apply** concepts and principles of solid and fluid mechanics to solve civil engineering problems. (UG)	**Select** appropriate concepts and principles of solid and/ or fluid mechanics to solve civil engineering problems.	**Develop** new methods in solid and/ or fluid mechanics to solve civil engineering problems.	**Evaluate** solutions to civil engineering problems involving new methods in solid and/or fluid mechanics.
Experimental Methods and Data Analysis	**Identify** the procedures and equipment necessary to conduct experiments in at least two specialty areas of civil engineering. (UG)	**Explain** the purpose, procedures, equipment, and practical applications of experiments in at least two specialty areas of civil engineering. (UG)	**Conduct** experiments in at least two specialty areas of civil engineering, and **report** the results. (UG)	**Select** appropriate experiments, and **analyze** the results in the solution of civil engineering problems. (PG)	**Develop** new experimental methods and/or **integrate** the results of multiple experiments for the solution of civil engineering problems.	**Assess** new experimental methods and/or the results of multiple experiments for the solution of civil engineering problems.
Critical Thinking and Problem Solving	**Identify** and **define** a complex problem, question, or issue relevant to civil engineering. (UG)	**Explain** the scope and context of a complex problem, question, or issue relevant to civil engineering. (UG)	**Formulate** a possible solution to a complex problem, question, or issue relevant to civil engineering. (UG)	**Analyze** a possible solution to a complex problem, question, or issue relevant to civil engineering. (ME)	**Develop** a set of appropriate solutions to a complex problem, question, or issue relevant to civil engineering. (ME)	**Assess** a set of solutions to determine the most appropriate solution to a complex problem, question, or issue relevant to civil engineering.
Technical Outcomes						
Project Management	**Identify** concepts and principles of project management. (UG)	**Explain** concepts and principles of project management. (UG)	**Apply** concepts and principles of project management in the practice of civil engineering. (ME)	**Analyze** components of a project management plan for a complex civil engineering project.	**Integrate** components into a complete project management plan for a complex civil engineering project.	**Evaluate** a complete project management plan for a complex civil engineering project.
Engineering Economics	**Identify** concepts and principles of engineering economics. (UG)	**Explain** concepts and principles of engineering economics. (UG)	**Apply** concepts and principles of engineering economics in the practice of civil engineering. (ME)	**Select** appropriate concepts and principles of engineering economics for the practice of civil engineering.	**Integrate** engineering economics analyses in the practice of civil engineering.	**Assess** the effectiveness of engineering economic analyses in the practice of civil engineering.
Risk and Uncertainty	**Identify** concepts and principles of probability, statistics, and risk relevant to civil engineering. (UG)	**Explain** concepts and principles of probability, statistics, and risk relevant to civil engineering. (UG)	**Apply** concepts and principles of probability and statistics to determine risk relevant to civil engineering. (UG)	**Select** appropriate concepts and principles of probability and statistics and **analyze** risk in a complex civil engineering problem. (ME)	**Integrate** risk analyses into the solutions to complex civil engineering problems.	**Assess** the acceptability of the risks associated with solutions to complex civil engineering problems.
Breadth in Civil Engineering Areas	**Identify** concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering. (UG)	**Explain** concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering. (UG)	**Apply** concepts and principles to solve complex problems in at least four specialty areas appropriate to the practice of civil engineering. (UG)	**Analyze** complex problems that cross multiple specialty areas appropriate to the practice of civil engineering. (ME)	**Integrate** solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.	**Evaluate** solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.
Design	**Define** engineering design and the engineering design process. (UG)	**Explain** engineering design and the engineering design process. (UG)	**Apply** the engineering design process to a given set of requirements and constraints to solve a complex civil engineering problem. (UG)	**Analyze** a complex civil engineering project to determine design requirements and constraints. (ME)	**Develop** an appropriate design alternative for a complex civil engineering project that considers realistic requirements and constraints. (ME)	**Evaluate** design alternatives for a complex civil engineering project for compliance with customary standards of practice, user and project needs, and relevant constraints.

Table II-1. (Continued)

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Depth in a Civil Engineering Area	**Define** advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering. (UG)	**Explain** advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering. (UG)	**Apply** advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering. (PG)	**Select** appropriate advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering. (PG)	**Integrate** advanced concepts and principles into the solutions of complex problems in a specialty area appropriate to the practice of civil engineering. (ME)	**Assess** advanced concepts and principles in the solutions of complex problems in a specialty area appropriate to the practice of civil engineering.
Sustainability	**Identify** concepts and principles of sustainability. (UG)	**Explain** concepts and principles of sustainability. (UG)	**Apply** concepts and principles of sustainability to the solution of complex civil engineering problems. (UG)	**Analyze** the sustainable performance of complex civil engineering projects from a systems perspective. (ME)	**Develop** practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.	**Assess** practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.
Professional Outcomes						
Communication	**Identify** concepts and principles of effective and persuasive communication to technical and nontechnical audiences. (UG)	**Explain** concepts and principles of effective and persuasive communication to technical and nontechnical audiences. (UG)	**Formulate** effective and persuasive communication to technical and nontechnical audiences. (UG)	**Analyze** effective and persuasive communication to technical and nontechnical audiences. (ME)	**Integrate** different forms of effective and persuasive communication to technical and nontechnical audiences. (ME)	**Assess** the effectiveness and persuasiveness of communication to technical and nontechnical audiences.
Teamwork and Leadership	**Identify** concepts and principles of teamwork and leadership, including diversity and inclusion. (UG)	**Explain** concepts and principles of teamwork and leadership, including diversity and inclusion. (UG)	**Apply** concepts and principles of teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems. (UG)	**Select** concepts and principles of effective teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems. (ME)	**Integrate** concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems. (ME)	**Evaluate** the effectiveness of leaders and teams in the solution of civil engineering problems.
Lifelong Learning	**Identify** the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning. (UG)	**Explain** the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning. (UG)	**Acquire** new knowledge, skills, and attitudes relevant to civil engineering through self-directed learning. (UG)	**Analyze** new knowledge, skills, and attitudes relevant to civil engineering acquired through self-directed learning. (ME)	**Integrate** new knowledge, skills, and attitudes acquired through self-directed learning into the practice of civil engineering. (ME)	**Evaluate** the effectiveness of additional knowledge, skills, and attitudes acquired through self-directed learning.
Professional Attitudes	**Identify** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	**Explain** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	**Apply** knowledge of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	**Illustrate** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	**Integrate** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	**Assess** the effectiveness of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.
Professional Responsibilities	**Identify** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (UG)	**Explain** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (UG)	**Apply** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	**Illustrate** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	**Integrate** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	**Assess** the integration of professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.
Ethical Responsibilities	**Identify** the ethical responsibilities of a civil engineer. (UG)	**Explain** the ethical responsibilities of a civil engineer. (UG)	**Apply** appropriate reasoning to an ethical dilemma. (ME)	**Analyze** ethical dilemmas to determine possible courses of action. (ME)	**Develop** courses of action to ethical dilemmas in complex situations. (ME)	**Assess** courses of resolution to ethical dilemmas in complex situations.

Note: Shaded outcome statements in the table above are levels of achievement beyond what is necessary for entry into the practice of civil engineering at the professional level per CEBOK3.

Appendix III: Additional Information on 1.a.iii.: DEI in CE Problem Solving

1.a.iii. "Application of principles of diversity, equity, and inclusion to civil engineering problems"

Background

Over the last several years, ASCE has increased its intentionality toward and prioritization of diversity, equity, and inclusion (DEI) in its policies and practices. The following summarizes some key efforts.

In 2017, when ASCE had its historical canon-based code of ethics, the ASCE Board of Direction unanimously approved Canon 8, which stipulated that engineers must "treat all persons fairly and encourage equitable participation without regard to [identity]." In addition to establishing the expectation that civil engineers treat everyone with dignity, respect and fairness and not engage in discriminatory or harassing behaviors, Canon 8 required civil engineers to consider community diversity and to endeavor to include diverse perspectives in their work (ASCE 2017).

In 2019, ASCE published the third edition of *Civil Engineering Body of Knowledge* (CEBOK3) (ASCE 2019). Principles of diversity and inclusion are woven throughout the Teamwork and Leadership Outcome in both the cognitive and affective domains.

Also in 2019, ASCE held a Civil Engineering Education Summit, which convened academicians, practitioners, and other stakeholders to discuss the future of civil engineering education. One of the four objectives that emerged from the group's efforts was "Develop a diverse, inclusive, equitable, and engaging culture within the civil engineering profession" (Hall et al. 2020). The Education Summit Working Group developed an action plan for achieving this objective along with the other three.

In 2020, ASCE reconstructed its code of ethics to be stakeholder-based rather than canon-based. Building on what was previously Canon 8, the newly revised code includes diversity, equity, and inclusion explicitly and implicitly in each of the four fundamental principles (e.g., "treat all persons with respect, dignity, and fairness in a manner that fosters equitable participation without regard to personal identity; consider the current and anticipated needs of society") and in practices related to all five stakeholders on which the code is now based. For example (ASCE 2021a),

- Society: acknowledge the diverse historical, social, and cultural needs of the community, and incorporate these considerations in their work;
- Natural and Built Environment: consider and balance societal, environmental, and economic impacts, along with opportunities for improvement, in their work;
- Profession: promote mentorship and knowledge-sharing equitably with current and future engineers;
- Clients and Employers: present clearly and promptly the consequences to clients and employers if their engineering judgment is overruled where health, safety, and welfare of the public may be endangered; and
- Peers: promote and exhibit inclusive, equitable, and ethical behavior in all engagements with colleagues.

Also in 2020, ASCE revised Policy Statement 417, Justice, Equity, Diversity, and Inclusion (formerly Diversity and Inclusion) to emphasize the global implications of this policy and to expand it beyond representational diversity to emphasize civil engineers' responsibility to justice, equity, and inclusion, as well as diversity. In 2021, definitions of justice, equity, diversity, and inclusion were adopted by ASCE and added to the policy (ASCE 2021b).

ASCE, through a grant from the United Engineering Fund, produced a video in 2021 highlighting best practices in diversity, equity, and inclusion as related to sustainability, universal design, and the K-12 STEM pipeline. https://www.asce.org/publications-and-news/civil-engineering-source/article/2022/04/13/dei-best-practices-expanding-the-k12-pipeline?utm_medium=email&utm_source=rasa_io

Additional Examples of integrating DEI issues into civil engineering education

- Using ENVISION® as a teaching tool to engage students in design and decision making that address various levels of achievement for the Quality of Life and Leadership categories, at a minimum. For example, the Quality of Life category includes credits for projects that "advance equity and social justice," "improve accessibility and wayfinding," and "preserve historical and cultural resources," among others (ISI 2018). Students could be asked to include in their designs elements that would enable them to attain various levels of achievement if they were to be assessed using ENVISION® criteria. Using ENVISION® verified projects as case studies to promote ideation around the application of principles of DEI to civil engineering problems, particularly those achieving "superior" or above levels for the Quality of Life and Leadership categories, then asking students to apply what they learn to their designs (Ghose Hajra et al.2018, Burian and Reynolds 2014).

- Having students research and consider historical policies and practices that have produced inequitable outcomes for various communities and incorporate that information into their problem solving. For example, students might review zoning laws, planning codes, and/or accessibility regulations applicable to an assigned problem or project to determine whether they promote or advance equity. For those that fall short, they could share ideas for changes that might be needed to bolster equitable outcomes. Then, they could apply what they learn intending to advance equity through their solutions. If information is available, students could also research who was "at the table" when the codes, policies, or standards were developed and/or when decisions were made using them and perform a critical analysis of equitable engagement in those processes.

- Assigning case studies of water crises in cities such as Jackson, Mississippi, and Flint, Michigan; and highway projects in states such as Texas, South Carolina, Illinois, and New York.

- Engaging students in exercises to explore and solve problems related to the civil engineer's role in less obvious United Nations Sustainable Development Goals (SDGs) (United Nations 2015, Pearson Weatherton and Hasselbalch 2017). For example,

    SDG1: No Poverty (access to basic services and resources, including but not limited to transportation to/from school or work).

    SDG2: Zero Hunger (water availability for crops, resilience to climate change and extreme weather conditions).

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Appendix IV: Civil Engineering Program Criteria Task Committee Membership

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