Civil engineering's internal skepticism on climate change

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The American Society of Civil Engineers (ASCE) describes civil engineering as "a profession that plans, designs, constructs, and operates society's economic and social engine – the built environment – while protecting and restoring the natural environment" (American Society of Civil Engineers 2017a). Canon 1 of ASCE's Code of Ethics, "Hold Safety Paramount," foregrounds the "safety, health and welfare of the public" as a professional obligation and priority (American Society of Civil Engineers 2017b) and civil engineers are taught to be conservatively protective of public welfare in assessments of risk. This conservatism appears in use of the precautionary principle, anticipating and designing for unusual events, and carefully considering and mitigating failure modes to improve safety. In US civil engineering, however, one potentially transformative source of hazard to the public and to the environment is notably absent from internal discourse within the profession: climate change. This forum piece describes American civil engineering's relationship with climate change, arguing that discourse about climate change internal to the profession—that is, in contexts where participation by non-civil engineers is unusual—is surprisingly skeptical that climate change is a real threat to be mitigated. This skepticism is illustrated most directly by the professional licensure process for United States civil engineers and is contrasted with public-facing statements by professional organizations, companies, and educational institutions.

Climate change is a threat to public welfare (US EPA 2009). Expected effects like rising temperatures, changing precipitation patterns, sea level rise, ocean acidification, and others (Intergovernmental Panel on Climate Change 2014) are likely to have major ramifications for civil engineering practice. For example, empirical relationships based on historical observations might not remain valid into the future. Changing precipitation patterns might render rainfall-runoff models and expected water distribution unreliable, and rising temperatures could introduce new concerns about water and air quality. Project cost structures might change in response to dynamic climate conditions, potentially leading to much higher capital or maintenance expenditures than would have otherwise been anticipated. For these and other practical reasons, civil engineers should expect the profession to be influenced by climate change. Furthermore, as greenhouse gases become more widely recognized as regulated pollutants (US EPA 2009), practicing civil engineers will need to adjust activities to reflect compliance targets and reporting requirements associated with climate change.

Many civil engineers and civil engineering organizations recognize the importance of climate change to future practice. In the United States, professional organizations, top-ranked civil engineering programs, and major employers of civil engineers refer explicitly to climate change or major expected effects of climate change prominently on their websites (AECOM 2017; American Society of Civil Engineers 2015; Bechtel 2017; Georgia Institute of Technology 2017; HDR, Inc. 2017; Massachusetts Institute of Technology 2017; The University of Texas at Austin 2017; University of California, Berkeley 2017; University of Illinois at Urbana-Champaign 2017; US Army Corps of Engineers 2014). Internal discourse, however, often reflects skepticism that anthropogenic climate change even exists. This short forum piece calls attention to a specific and meaningful proxy for the internal conversation about climate change for American civil engineering: namely, the professional licensure process.

Civil engineers in the United States frequently pursue professional licensure. To do so, nearly all engineers who eventually become licensed will sit for two major licensure exams: the Fundamentals of Engineering (FE) exam and the Principles and Practice of Engineering (PE) exam. In 2016, over 13,000 first-time test takers sat for the civil FE exam, and over 9,000 first-time test takers sat for the civil PE exam (NCEES 2016). In 2015, the most recent year for which these data are available, about 12,000 people received bachelor's degrees in civil engineering (National Center for Education Statistics 2017). These numbers suggest that most civil engineers will be exposed to the FE and PE exams. Further, given that many people take the FE exam close to graduation, the PE exam is one of the most significant standardized points of post-graduation professional engagement for civil engineers. As the PE exam is open-book, widely used reference texts become the basis for shared understanding of what civil engineers should know. Chief among these reference texts is the *Civil Engineering Reference Manual*, or CERM, which has been published since 1986 and is in its fifteenth edition as of this writing (Lindeburg 2015). CERM is not published directly by the administrators of the PE exam, but it has long been recommended as a reference (Everett and Mitroka 1993) and is one of the most common references available for the civil PE exam (as of December 2017, it is the fifth most popular civil engineering book sold on Amazon.com, after two pop-engineering books and two FE exam review books). As noted in the preface, the publisher "went far beyond industry standards in getting content checked and reviewed, edited, and proofread. ...this book goes beyond the subjects covered on the civil PE exam" (Lindeburg 2015). Given the high-stakes purpose for which CERM was written, and given its widespread use, it serves as a useful proxy for reflecting discourse by civil engineers for civil engineers, and specifically for reflecting priority topics even beyond what is discernible from examination standards.

With this context about CERM and professional licensure as reflections of internal discourse for civil engineers, it is particularly noteworthy that the rhetoric surrounding climate change, global environmental change, and sustainability in CERM is substantially different from the public facing rhetoric found in statements by professional organizations, universities, and major employers of civil engineers. In a book largely defined by its searchability for use during an open-book examination, "climate change" does not appear in the index, and "sustainability" appears only as "Sustainable development, ethics." The only discussion of sustainable development is to describe it as part of ASCE's first canon and defined it by reference (page 89-4) in a section on modern ethical issues. Despite the meaningful challenges climate change presents to the practice of civil engineering, climate change appears in CERM only in the form of a 600 word section on global warming (pages 32-8 and 32-9, Lindeburg 2015).

CERM's section on global warming is written using rhetorical devices commonly associated with climate change skepticism and departs from the largely factual tone used throughout the remainder of the 1648-page book. For example, reference to "the *global warming* theory" is accompanied by notes comparing the concentration of carbon dioxide (CO_2) to that of oxygen, anchoring readers on the idea that CO_2 concentrations are meaninglessly low, and by comparison of anthropogenic CO_2 emissions rates to natural CO_2 flux without mention of natural carbon removal from the atmosphere. CERM also explicitly claims that "Although global warming is generally accepted, its anthropogenic (human-made) causes are not" and makes note that both temperature and sea level rises are disputed. Further, in a seven-paragraph section on "global warming," three paragraphs are devoted to synthetic and carbon-based alternative fuels like coal-based syngas, noting that efficiency-minded engineers are uncomfortable with this practice—without also noting that the use of synfuels is uncommon and that non carbon-based fuels exist. The section concludes with an out-of-character "should" statement: "Thus, fossil fuels should be used primarily in their raw forms until cleaner sources of energy are available." In describing "global warming," only temperature and sea level rise effects are included as considerations. No mention of changing precipitation, extreme events, or other effects of climate change is made, no mention of regulatory action on greenhouse gases is made, and no comments on potential impacts on professional practice itself are made.

CERM's treatment of climate change (as "global warming") stands out particularly because of its rhetorical differences from the majority of the rest of the text. Even in comparison to other subsections in the same chapter, "Pollutants in the Environment," the "global warming" section is less technical, less focused on the manners in which pollutants are formed and influence the environment, and more focused on arguments suggesting that greenhouse gases are not actually pollutants. This edition of CERM was published in 2015, when federal regulations about greenhouse gases were actively being proposed (Environmental Protection Agency 2015), with potentially large impacts on civil engineering projects. No mention is made of the possibility of regulation or to international action, though the Montreal Protocol (regarding ozone-depleting substances), Clean Air Act, and other regulations are noted elsewhere. Comments about CO_2 concentrations being very low contrast strongly with the first sentence in the next section: "Lead, even in low concentrations, is toxic" (32-9, Lindeburg 2015). The presentation of "global warming" as a theory that is "disputed by some scientists and has not been proven to be an absolute truth" is also surprising in the context of a text that notes elsewhere that civil engineering often relies on assumptions and most-likely explanations. For example, chapter 19 on open channel flow notes that "Frequently, analyzing the flow from a river is a matter of making the most logical assumptions" (19-10, Lindeburg 2015).

Why is this important? Climate change is much less present in internal civil engineering discourse than would be expected based on public-facing statements about its serious threat to people and infrastructure. Climate change is not explicitly examined on either the Civil PE or the Civil or Environmental FE exams. Despite some evidence that interest in climate change can motivate people to become engineers (Klotz et al. 2014), according to one recent study, only about 47% of first-year civil engineering students either agree or strongly agree that climate change is caused by humans—the lowest proportion among engineering students in eight surveyed disciplines except for bioengineering (Shealy et al. 2017). Online spaces targeting the engineering community, like the Engineering News-Record (ENR) blogs and engineering.com, similarly reflect skepticism of anthropogenic climate change among civil engineers (Simpson 2014). The politicization of climate change in the United States is one potential explanation (Funk and Kennedy 2016). Civil engineers are more Republican than other engineers, at 55% of the civil engineering sample relative to 29% of the overall engineering sample, according to one analysis of campaign contributions by profession (Verdant Labs 2016).

One 2009 ENR blog post entitled “Global Climate Change is Real. Deal with It.” responds to this skepticism, writing:

> “You, Mr/Ms engineer, may take issue with claims about global climate change because you dislike the prospect of spending vast sums of money to solve a problem before it’s an undeniable crisis, but that’s different from insisting that it’s bunk...it is relevant because our country already is grappling with the effects of global climate change, and those effects, by and large, require engineering solutions. Your country needs your engineering knowledge. Don’t stand aside with arms folded until the crisis breaks like a wave over us. By the time that happens, nothing you can do will be much help” (Engineering News-Record 2009).

As the ENR blog post notes, climate change requires engineering solutions that are likely to fall within the purview of civil engineering. Civil engineering projects will need to account for the effects of climate change regardless, particularly in places where climate change pollution is regulated. Some of our most respected institutions publicly name climate change and its effects as major challenges and responsibilities for civil engineers. Climate change is explicitly a question of professional ethics for some members of the profession outside the United States, as with Engineers Canada’s statement that “Engineers, under their professional code of ethics, need to be involved in addressing the impacts of changing climate on infrastructure design and operations because it affects public safety and public interest” (Engineers Canada 2013). Some argue further that civil engineers should be ethically bound to actively play a role in the abatement of climate change, with the revocation of licensure as a penalty for contributing to climate pollution (Lawlor and Morley 2017). This forum article aims to draw attention to the fact that, far from debating sanctions against engineers for violating ethical codes via insufficient effort to abate climate change, American civil engineering is unusually skeptical that anthropogenic climate change even exists. This skepticism is reflected in our professional licensure process and other internal engineering spaces, despite outward proclamations that climate change is deeply important and a major challenge to the profession. Acknowledging this disconnect, and addressing both the reasons for skepticism and the ethical responsibility that civil engineers have to protect the public welfare, is a critical step toward improving civil engineering practice and adhering to principles of ethical engagement.

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