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EXPANSION OF SUSTAINABILITY IN THE ACI 318 BUILDING CODE

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Abstract.
The American Concrete Institute (ACI) has long recognized the growing importance of accounting for environmental sustainability in the design of concrete structures. As the next version of the ACI 318 Building Code is being developed (ACI 318-25), a new sustainability subcommittee, Subcommittee N, has been formed and tasked with expanding the provisions related to sustainability in the code. This paper reviews the current provisions in the ACI 318 Code that are related to sustainability and explores the possible future expansion of code and commentary language to provide better guidance on sustainable design. Areas of focus for expansion of code language, including definitions of sustainability metrics, as well as the defined baseline for comparison, are discussed. While sustainable design is increasingly being specified in concrete projects, the sustainable properties of concrete are often interrelated with other aspects of design, including resiliency and intended lifespan. Approaches to acknowledging the impacts of life cycle considerations on the sustainability of concrete construction are also explored. Finally, the anticipated timeline for the development of ACI 318 sustainability provisions is described, as well as potential interactions with other code writing organizing that are currently developing sustainability provisions.

Keywords: ACI 318, code, sustainability.

1. Introduction

Historically, concrete building codes have focused mainly on provisions related to strength, serviceability, stability, and durability of the structure. However, as the priorities of policy makers, owners, and designers have increasingly included environmental sustainability, the question of the role of the concrete building code in setting standards related to sustainability has arisen. This paper includes a summary of how the current ACI 318 building code addresses sustainability, an exploration of the current practices in the design and specification of sustainable concrete, and finally a description of the areas of expansion that are currently being worked on by the new ACI 318-N Sustainability Subcommittee.

2. Concrete sustainability at ACI and in the ACI building code

As the focus on environmental sustainability of building materials has increased in recent years, the American Concrete Institute (ACI) has expanded the committees, standards, and publications related to concrete sustainability. In particular, ACI Technical Committee 130 Sustainability of Concrete, has been actively producing technical publications on approaches to the design, specification, and performance of sustainable concrete. There are also numerous committees studying concrete topics related to sustainable concrete including supplementary cementitious materials, alternative cements, and recycled aggregate. As the practice of incorporating sustainability into buildings has become more common, the need to incorporate provisions related to sustainability within the concrete building code has increased. Provisions directly referencing sustainability were first incorporated in Section 4.9 of the 2014 version of the American Concrete Institute building code, ACI 318-14 [1]. These provisions, which remain essentially unchanged in the newly released ACI 318-19, acknowledge that design professionals are permitted to specify sustainability requirements, but do not define how sustainability of concrete could be specified or considered in the design of a concrete structure [2].

While the code language with direct references to sustainability remained unchanged in the ACI 318-19 code, there were several additions and expansions within that code edition that are associated with materials that are increasingly being used in projects targeting sustainability goals. These include new provisions regarding the use of alternative cements and recycled aggregates.

The current code cycle for ACI 318 is working toward further expanding the concrete sustainability provisions with the establishment of a new Sustainability Subcommittee, ACI 318-N. This subcommittee is now working toward developing new provisions related to sustainability within the building code.

3. How sustainability is being considered in design

Before addressing how the approach to defining sustainability can be incorporated into a concrete building code, it is important to understand how the current market is regulating environmental sustainability in concrete.

3.1. Environmental sustainability in relation to cement content

Since the cement in concrete contributes the majority of the emissions in the production of concrete, the majority of environmental sustainable efforts have been associated with cement reduction. Until recently, most design professionals and owners utilized either maximum amounts of cement or minimum amounts of cement replacement with supplementary cementitious materials to define sustainability. However, as information related to the environmental impacts of materials has become more readily available, the ways that the sustainability of concrete is being defined are changing.

3.2. A new focus on embodied carbon and environmental product declaration

Much of the historical focus on the sustainability of buildings has been on the reduction of the carbon utilized for the operations of buildings. Thus, energy codes have increasingly required better insulated structures and more efficient mechanical systems. However, as these systems have improved and the operational carbon footprint of structures has reduced, the focus is now increasingly shifting to reductions of embodied carbon in buildings. Embodied carbon is the global warming potential (GWP) associated with the manufacture of a product.

In order to quantify the GWP of a building, design professionals are increasingly utilizing environmental product declarations (EPDs) to calculate the impacts of elements of a building. EPDs are reports, typically abiding by the requirements of the International Organization for Standardization (ISO) 21930 for construction products [3], that quantify various environmental impacts of the production of a product. The declaration of environmental indicators includes environmental impacts, resource use, energy use, and waste flows. As shown in Figure 1; GWP, ozone depletion, and freshwater use are amongst the impact categories that are typically included in the summary of impacts for a product. Many industries have created industry-wide EPDs that reflect the average impacts of a product across an industry, but individual manufacturers are increasingly creating EPDs for their specific products.

It should be noted that EPDs typically do not account for the full life cycle impacts of the use of a product, as their scope usually only includes the "cradle to gate" portion of the cycle, where the "gate" is

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Declared Product:
Mix 3DAZ75Z2 • South San Francisco (wet) Plant
3 IN LN .30 W/C 1" EF70 5 - 7 SL CO2
Compressive strength: 7000 psi at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	291
Ozone Depletion Potential (kg CFC-11-eq)	1.2E-5
Acidification Potential (kg SO_2-eq)	2.79
Eutrophication Potential (kg N-eq)	0.38
Photochemical Ozone Creation Potential (kg O_3-eq)	62.2
Abiotic Depletion, non-fossil (kg Sb-eq)	6.0E-6
Abiotic Depletion, fossil (MJ)	1,242
Total Waste Disposed (kg)	1.59
Consumption of Freshwater (m^3)	0.55

Product Components: natural aggregate (ASTM C33), slag cement (ASTM C989), Portland cement (ASTM C150), fly ash (ASTM C618), admixture (ASTM C494), batch water (ASTM C1602)

Figure 1. Example of the summary of environmental impacts from an EPD for a concrete mixture [4].

the gate of the manufacturing facility. So while EPDs can help quantify the impacts of the production of a product, the impacts from transportation to site, construction, use, deconstruction, and end-of-life are not included.

This increased availability of information regarding the environmental impacts of concrete is starting to change the way that design professionals, building owners, and building officials are requiring and specifying the sustainability of concrete.

3.3. Collection of EPDs into searchable databases

As the number of EPDs has grown, numerous databases have been developed to aggregate the information in one place to better compare products. One of these online directories, the Embodied Carbon in Construction Calculator (EC3) has an extensive and growing collection of EPDs that it utilizes to calculate the GWP of building projects. As can be seen in Figure 2, concrete represents by far the largest number of EPDs collected [5], likely due to the fact that each concrete mixture at a plant has a separate EPD and because the concrete industry has rapidly adopted the use of EPDs.

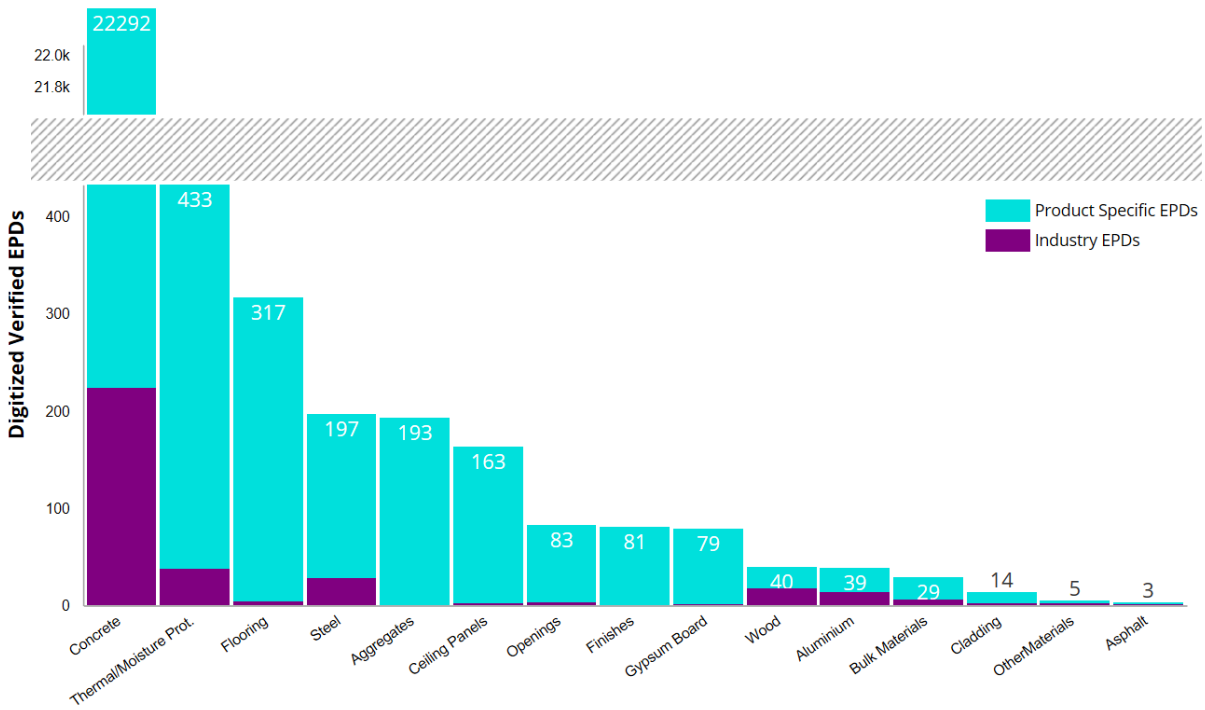

Figure 2. Graph showing number of EPDs for materials in EC3 carbon calculator software [5].

3.4. Life cycle assessment and resiliency

In addition to the trend of examining the relative environmental impacts amongst a group of products within a certain industry, designers are increasingly examining the overall impacts of building construction and use over the entire life of the building. This process, called life cycle assessment (LCA), is used to calculate the environmental impacts associated with all the life states of a product. Often when LCA is undertaken, the performance of a structure is compared to a baseline structure to calculate the degree to which the building has reduced its impacts. Many sustainable certification systems for building construction require that an LCA for a structure be performed, sometimes with a requirement for reductions of impacts or performance below a set threshold.

While LCA studies do assign a lifespan to certain products and adjust the overall impact of those products based on the selected lifespan of the structure, the resiliency of the structure is not necessarily accounted for with LCA. With concrete structures, one of the benefits often cited is the resiliency of the structure in the event of natural disasters, extreme exposures, an extended lifespan, or other conditions. The question of how those qualities are to be accounted for is one that should be addressed when examining the life cycle impacts.

3.5. Mandating of sustainability in local building codes

With the increased focus on embodied carbon in building structures, local jurisdictions are beginning to mandate or consider mandating some characteristics of concrete related to sustainability. These ordinances and legislation vary in their scope and requirements, but many set limits on GWP and/or cement content. The advent of these laws lends an importance to ensuring that the concrete building code, ACI 318, adequately addresses the items that must be considered when accounting for the sustainability of concrete structures.

4. ACI 318-N Sustainability Subcommittee

To address the increasing trend of defining limits on the environmental impacts of concrete in the design of buildings, the ACI 318 Building Code has established a new sustainability subcommittee. This new subcommittee, ACI 318 Subcommittee N, is tasked with expanding the provisions related to sustainability in the concrete building code. The members on this subcommittee include practicing engineers, researchers, and concrete producers. Many have extensive experience specifying and producing concrete to meet sustainability goals.

4.1. Timeline for code development

The ACI 318-N subcommittee had its first official meeting at the October 2019 ACI Fall Convention in Cincinnati, Ohio. The last published edition of the ACI 318 Building Code was ACI 318-19. It is anticipated that the next version released will be ACI 318-25 and any provisions developed by the 318-N subcommittee that are approved by the main ACI 318 committee will be included in the next edition.

4.2. Possible areas of sustainability expansion in ACI 318

While the manner and details surrounding the incorporation of sustainable concrete have not yet been established, the subcommittee is currently considering creating an appendix with sustainability provisions and commentary that will be part of the code. Since the inception of the ACI 318-N subcommittee, a number of task groups have been established to begin the process of writing code provisions related to sustainability. These task groups include the following:

- Scope Section Task Group - This group is addressing both the existing sustainability section of the code and its reference to the proposed sustainability appendix.
- Sustainable Design of Structural Concrete Task Groups - There are two separate task groups associated with this topic:
  - Sustainable Design - This task group is focused on how the design of structures should account for concrete when sustainability is an objective. In particular this group will be looking at approaches such as life cycle assessment and how aspects of concrete should be accounted for.
  - Resiliency - This task group is examining how resiliency of concrete structures relates to the consideration of the sustainability of a structure and how it should be considered. This group is also examining resiliency in general and how it is accounted for in the code.
- Concrete Mixture Design Information Task Group - This group is working to develop provisions that outline how concrete mixtures can be specified to require sustainability metrics. The group is currently examining several approaches and is debating what methods to include. The interface between this section and the sustainable design section is still under consideration.
- Recycled Aggregate Task Group - This group is looking at the new provisions in ACI 318-19 related to the use of crushed hydraulic-cement concrete and recycled aggregate. In particular, the new provisions require testing and quality control programs for these types of aggregate [2] and the task group is examining whether additional guidance could be provided in the commentary of this section regarding those programs. This code section falls within the overview of a separate ACI 318 subcommittee, thus any changes to this section will require coordination across subcommittees.
- Cements and Alternative Cements Task Group - Chapter 26 of ACI 318-19 contains a list of acceptable ASTM specified cementitious materials along with a new section regarding alternative cements [2]. This task group is examining whether additional cementitious materials with ASTM specifications should be added and whether any additional clarifications are needed for the alternative cement section. As with the recycled aggregate topic above, any changes to the provisions related to cement will need to be coordinated across ACI 318 subcommittees.

Since the ACI 318 code has both code language and commentary, these groups will be writing proposed sections for both. The commentary will likely include discussions of what approaches could be taken to achieve the code standards. As this subcommittee's work progresses, the relationships between the work of the different task groups will emerge and there will be more clarity regarding the form and content of the proposed provisions.

4.3. Interactions with other sustainable concrete code writing organizations

As the ACI 318-N subcommittee is beginning its work to expand the code language related to sustainability in the ACI 318 building code, the subcommittee is reviewing the work of other concrete code writing bodies and their approach to the incorporation of sustainability into their codes. In particular, ACI 318-N has studied the sustainability sections of the fib Model Code 2010 and sought insight into the active developments in fib Commission 7: Sustainability (COM7). In order to further foster coordinating and information sharing, ACI 318-N will have a joint meeting with COM7 at the fib International Conference on Concrete Sustainability that will occur in Prague in September 2020.

5. Conclusion

This paper has addressed how the current ACI 318 building code addresses sustainability, the changing landscape of sustainable design and specification, and the possible areas of expansion within ACI 318. The efforts related to this expansion are in their infancy, but with the wide use of ACI 318 the possible impacts are great. The implementation of sustainable regulations on concrete are growing and will continue to grow regardless of the incorporation of sustainability in this building code. However, if efforts are made to make new provisions pertinent and easily implementable, the potential to make specifying sustainable concrete more consistent and logical are significant.

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