Report for Working Group 1: Design Research in Civil and Environmental Engineering

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Report for Working Group 1: Design Research in Civil and Environmental Engineering

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Introduction

The first 2013 DCEE working group meeting focused on issues associated with design research in civil and environmental engineering. It addressed some of the motivation for establishing design as a research discipline in CEE and some of the challenges and outstanding questions about how to do so.

Sustainability as a Driver for Civil Design

One of the major themes of the working group discussion was the increasing need for a framework to support design activities associated with civil and environmental engineering. This is being driven, in part, by the demand for more sustainable buildings and infrastructure. Energy efficiency in buildings requires the close integration of form and function. This brings the realms of architecture and civil engineering much closer than they have traditionally been. One participant noted that the "aesthetic and seemingly arbitrary decisions often make by an architect on paper during the earliest stages of design can have a huge impact on the energy performance of a building." Thus, engineers now need to participate in the design process at a much earlier stage. In addition, architects and engineers now need to work more closely together. This requires them to understand and appreciate each other's disciplines and to find a way to bridge the disciplinary divide. The establishment of a common language will go a long way to achieving this goal. But perhaps simply acknowledging that both sides do 'design' – even if that activity is substantially different in the two domains – is a start. It may also be a justification for formalizing design research in civil and environmental engineering.

Interfacing with Architects

Although there seems to be an increasing need for civil engineers, especially in the building technology domain, to interface with architects, there are some challenges in doing so. One participant noted that designers and architects are often concerned that engineers will prematurely reject ideas due to feasibility and will thus hamper the creative process. Alternately, they are sometimes concerned that the engineers will take all of the fun out of the process. How to generate the initial problem and initial concept for a building and who will do so in the future remain open questions.

There are also clear benefits to closer contact with the architecture community. Architectural design has a long tradition of exploring ideas and many techniques for supporting that process. As a result, architects regularly use history to inform modern practice. A similar technique has been used at MIT to teach civil engineering history. Participants with experience in that program reported that this improves students' experiences by allowing them to explore who has created similar artifacts in the past and how those designs were defined. History in both civil engineering and architecture provides a reservoir of strategies that can help prevent the paralysis that stems from the blank page.

Interfacing with Stakeholders

There is an increasing awareness in both architecture and civil engineering that the built environment is culturally and contextually dependent. As a result, civil and building design are becoming more participatory. This brings with it an increased need for designers to interface with various stakeholders, including the civil engineers, the construction engineers, and the end users. This may present a great opportunity for everyone, including engineers, to learn more about the initial design phase and to explore how to participate in that process in a more active and effective way.

What Does Conceptual Design Mean in the Civil Domain?

The working group participants generally agreed that the role of civil engineers in the conceptual design process must be expanded, but there was some question as to what that meant. Conceptual design involves more uncertainty than later stages of design. As a result, detailed calculations are rarely needed.

Thus, it seems that conceptual civil design may only need abstract or simplified knowledge. Perhaps only a few simple principles are needed to guide the highest level efforts? One participant asked if design research at the conceptual design phase is less about developing new technical knowledge and more about supplying and using that knowledge in a way that makes more sense. Another noted that conceptual design methods will clearly depend on the type and scale of the artifact being designed. For example, the conceptual design of a system and of a structural member will be substantially different. For the member, detailed knowledge about the material behavior will be needed at the earliest stages of design.

How to Integrate Disciplinary Research Into Design?

If more detailed knowledge from the traditional technical disciplines is needed, how is that knowledge transferred to and integrated into the conceptual design process? There are many researchers who are working on developing new technologies, materials, and construction methods to improve civil structures and systems (nano and macro aggregates in asphalt, phase changing building materials, piezoelectric pavements, etc.). How do these researchers interface with those focusing on improving the process of designing and constructing civil artifacts?

What Does the Civil Design Process Look Like?

Conceptual design is one of the earliest stages of the design process. This discussion led the working group members to contemplate the overall civil design process. It was proposed that design in civil engineering could be very similar to design in mechanical engineering from a general perspective. Thus, the design processes from that domain could be a reasonable starting point for the development of formal models of the civil design process. But there certainly are differences between the two activities, particularly during detailed design. Some of those differences include:

- Customer expectations
- Production vs. construction
- Prototyping and proof of concept activities
- Design for use and maintenance
- Life span and design for end of life

Interfacing with Existing Design Theories and Traditions

One of the questions raised by the working group was how to interface with and leverage existing design theories and traditions. Axiomatic Design (AD) Theory is the most visible example in the DCEE community because the workshop was held back-to-back with the International Conference on Axiomatic Design (ICAD) in 2011 and 2013. Is AD just a collection of knowledge? Does it only address conceptual design? What about design software? Is there (or could there be new) design software that can support conceptual design from a civil engineering perspective? How can we best utilize the tools that are already available? Can we create better ones like the program proposed by Caitlin Mueller?

Routine vs. Creative Design

During the discussion, a question was raised about the role of novelty in conceptual design and a concern was voiced about the creation of novel artifacts for the sake of novelty. The group agreed that design activities should still be classified as ‘design’ even if the outcome is not novel. They also agreed that novelty for the sake of novelty is wasteful and not to be encouraged. In civil and environmental engineering, cost effectiveness and the responsibility to produce sustainable artifacts often applies a pressure which overcomes the incentive to do something new. Therefore, routine, robust design is – and should be – common and valued. This implies that design research should be divided into categories that look at creative and routine design. This divide exists in mechanical engineering, but there creative design receives much more emphasis (perhaps because it is fun). In contrast, routine design must receive more emphasis in civil and environmental engineering.

Defining the Design Artifact

The working group noted that it was important to clearly define the artifact to be designed. For example, a building can be designed, the process of designing the building can be designed, and the process of constructing the building can be designed. Each of these artifacts (building or process) will have different requirements, will occur at a different phase of the larger project, and will require different expertise. One participant noted that designers and design researchers often find themselves overwhelmed by a design project because they try to design too many different artifacts at once and try to incorporate all of the requirements of all of those projects into a single set. This is particularly important because the artifacts (tools, processes, equipment, infrastructure, etc.) that are designed by one group can be used freely by other groups to take on important projects. It is inefficient and often impossible to redesign everything from scratch for every project. At the same time, it is important to acknowledge that sometimes the artifact and the process to realize it must be designed together. The

goal is not necessarily to uncouple the processes or the design task but to clarify the design task to reduce the imaginary complexity.

Challenges in Civil Design

The working group participants noted that because most of the artifacts that are designed in the realm of civil and environmental engineering are unique, many of the tools and techniques from mechanical engineering and mass production do not apply. Every artifact is different and the way that each artifact is constructed is also different. Perhaps more importantly, the different suppliers and tradespeople involved in each project are different. This requires a totally different strategy for managing the design and construction process.

The working group participants noted that liability occurs on a different scale for civil and environmental engineering projects. The use of codes is necessary to protect the engineers and their firms from future lawsuits. Does this preclude truly creative design? Does it somehow change the design process? And does it introduce design research topics that are not currently addressed in the literature?

Finally, it was observed that many engineering decisions are made by non-engineering entities like the government for political, social, and economic reasons. For example, contractors who work on one large project are often forbidden from receiving the contract for a similar project in the same area to avoid corruption and encourage competition even though this is often less efficient and does not make good use of the original contractor's experience and expertise. This means that civil design is a techno-socio-economic undertaking but in a different way than mechanical design.

What Competencies Are Needed for Civil Design?

Finally, the working group briefly discussed the competencies required of a civil designer. The discussion focused on communication skills and teamwork. It was noted that the engineers need to make their knowledge and skills accessible to the designers and architectures. Graphical representation and building information modeling may be good vehicles through which to facilitate this communication.

Summary and Conclusions

Overall, the working group participants seemed very positive about the establishment of design as a sub-discipline within civil and environmental engineering. From the discussion, it seemed clear that this new domain will be informed both by mechanical engineering and by architectural traditions but that there are sufficient challenges and opportunities to justify (and require) a design perspective that is unique to CEE.