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Published in:

Proceedings of the 1st International Workshop on Design in Civil and Environmental Engineering

Publication date:

2011

Document Version

Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):

Thompson, M. K. (2011). Building a Civil Design Community: Lessons Learned from the 1st International Workshop on Design in Civil and Environmental Engineering. In *Proceedings of the 1st International Workshop on Design in Civil and Environmental Engineering*

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Building a Civil Design Community: Lessons Learned from the 1st International Workshop on Design in Civil and Environmental Engineering

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ABSTRACT

Design is an integral, yet commonly neglected, part of civil and environmental engineering. This paper briefly describes the results of 1st International Workshop on Design in Civil and Environmental Engineering and ongoing efforts to build a design community within civil and environmental engineering.

INTRODUCTION

Design is an integral, yet commonly neglected, part of civil and environmental engineering. Civil design experts are generally only found in the professional practice. Few members of the academic community pursue design research within civil and environmental engineering. And while design education is widely acknowledged to be important, most design courses are discipline-specific and involve more analysis than synthesis. This issue has been a regular topic of discussion at KKCNN. It was addressed in the technical sessions in 2007, during the 2008 Future Forum, and as a part of the 2009 and 2010 panel discussions on engineering education and sustainability. These discussions helped to identify the extent of the problem and show that the CEE community is increasingly open to the idea of design as a research discipline, especially in light of the increasing importance of energy efficiency and environmental sustainability. To help address these issues and provide a dedicated forum for their discussion, the 1st International Workshop on Design in Civil and Environmental Engineering was organized and held at KAIST during April 1st and 2nd, 2011. This paper briefly describes the results of that meeting and ongoing efforts to build a design community within civil and environmental engineering.

WORKSHOP OVERVIEW

The 1st International Workshop on Design in Civil and Environmental Engineering was attended by 30 scholars from civil, environmental, and geotechnical engineering, mechanical engineering, electrical engineering, architecture, and industrial design from Denmark, Italy, Korea, Taiwan, and the United States. The workshop featured an opening address about the need to discuss design as a discipline, 2 keynote presentations which addressed design as a scientific discipline and design thinking in engineering, as well as 3 technical sessions and 3 working group sessions.

The workshop was held in conjunction with two other international design conferences: the 21st CIRP Design Conference and the 6th International Conference on Axiomatic Design. Both of these meetings have their roots in manufacturing and production from mechanical engineering, although both have published work related to design in CEE in the past several years. The three meetings were held back-to-back in the hopes of bringing civil engineers together with design researchers from a number of different fields including to get advice on how to build a civil design community and what such an organization would look like. In many ways, this strategy was successful. Both of the keynote presentations and two of the technical papers came from the CIRP and ICAD communities. In addition, members of the CIRP and ICAD communities were enthusiastic contributors during working group discussions.

The theme of the first technical session was “Civil Design – The State of the Art” and featured 4 papers from KAIST related to design in structural engineering, design in geotechnical engineering, and the design of environmental infrastructure for urban sustainability. The second technical session, “Interdisciplinary Design: Civil Engineering at the Boundary”, featured papers which described design-related activities between civil engineering and other fields such as architecture and mechanical engineering. The third technical session focused on design education in civil engineering and was the largest technical session. Each technical session was followed by an open discussion.

The three working group sessions were organized to permit more focused discussion on themes related to the workshop. The first working group addressed issues associated with design as a discipline in civil and environmental engineering, including why design failed to develop into a discipline in CEE as it did in other fields. The second working group discussion focused on how to build a civil design community. The final working group considered issues associated with design education in civil and environmental engineering.

DESIGN WITHIN CIVIL ENGINEERING RESEARCH DISCIPLINES

The first technical session provided some insight into how design is treated within various research disciplines that are typically thought of as being analysis driven. Kim and Kim's (2011) paper on the role of physical modeling in the design of geotechnical systems highlighted the need for detailed analysis and experimental proof of concept during both the conceptual and detailed design phase of civil systems and the dangers of inadequate analysis and testing. In their paper about the design of a modular structural health monitoring inspection robot, Jeon et al. (2011) demonstrated that civil engineering researchers often take on the role of a designer in order to develop technology to address the needs of the larger civil engineering research community. Although the emphasis of these projects, and the publications about them, is usually on the research question and how the new artifact or system helps to answer it, there is nevertheless a great wealth of design knowledge both used and produced in the process. Shin et al. (2011) emphasized the need to identify good selection criteria in order to choose the best strategies and concepts to improve the environmental sustainability of urban infrastructure. Finally, through their discussion of the design of wired and wireless structural health monitoring systems, Cho and Yun (2011) demonstrated the usefulness of understanding and explaining what makes a design better or worse instead of simply acknowledging the difference. All of the papers from the first technical session showed that the design process in civil and environmental engineering shares the same basic elements as those from other fields. And they showed that design is an integral, if unspoken, part of civil engineering research activities at KAIST and beyond.

DRIVERS OF CIVIL DESIGN

The papers in both the first and second technical sessions revealed a number of different drivers for civil design projects. Bjerregaard Jensen and Almegaard's (2011a) paper on bridgescaping showed that civil design is increasingly being driven by the needs of the local community rather than by structural engineering concerns. They noted that policy makers are increasingly asking for "more than a bridge" and look at civil design projects as an opportunity for urban branding or renewal. Matt et al. (2011) showed that civil design and construction projects are also being viewed as economic engines. Their paper describes efforts in Italy to help small and medium sized enterprises in their area to work together in order to be more competitive with large international contractors. These trends require a more interdisciplinary approach from civil designers who are able to deal with large numbers of conflicting requirements from a variety of stakeholders. This will ultimately bring civil design closer to other more stakeholder-focused fields such as architecture, industrial design, and product design.

In contrast, Kim and Kim's (2011) paper highlighted the fact that many design challenges in civil and environmental engineering are handed down by teams or individuals from an earlier stage of the design process. For example, architects frequently envisage the basic concept of a bridge, and then hand off the project to a team of structural engineers who ensure that the bridge can support its own weight. The structural engineers then give the project to geotechnical engineers who must guarantee that the underlying soil can support the weight of the bridge. Finally, it is handed off to the construction engineers who must devise a way to build the specified structures and foundations. Engineers at each level are given requirements and expected to produce a satisfactory solution to fulfill them. Thus, the civil design process mirrors the mapping process between domains in Suh's (2001) Axiomatic Design Theory with different designers responsible for each of the different domains.

The work by Cho and Yun (2011) and by Jeon et al. (2011) showed that many civil design challenges require so much technical knowledge that they bypass the creative architectural phase and fall directly to the individuals who have the expertise to address them. In this case, policy makers act like clients who fund the engineers' design and research efforts to address the problem. Interestingly, this has caused another type of interdisciplinary shift in civil engineering. Structural health monitoring now requires its students and practitioners to have a working knowledge of sensors, electronics and robotics.

DISTINGUISHING CIVIL DESIGN FROM OTHER DISCIPLINES

Both of the keynote presentations and several of the technical papers provided insight into design-as-a-discipline in other fields such as mechanical engineering, architecture, and industrial design. For example, Chang (2011) presented an overview of design techniques and research areas in architecture while Boelskifte (2011) introduced a new curriculum for a bachelor's program in Design and Innovation. These papers and their authors played an important role in the workshop by providing examples of design research, education, methodologies, and philosophies from other design fields. However, there are two major risks associated with

having too much participation from individuals outside of civil and environmental engineering.

First, in the absence of an established identity for design as a discipline within civil and environmental engineering, there is a tendency for civil engineers to associate it with the prevailing design direction of their home institutions. For example, many of the workshop attendees from KAIST associated design-as-a-discipline in CEE with Axiomatic Design Theory because of strengths both within the department and in other departments at KAIST in this area. Similarly, many civil engineering faculty members at Stanford University think of design as a user-centered undertaking because of the philosophy of the Hasso Plattner Institute of Design (otherwise known as the Stanford D School). Unfortunately, these cultures of design were developed to address completely different types of design challenges. Thus, they may not be (entirely) applicable to civil design endeavors.

Second, since design is not an established discipline in its own right in civil and environmental engineering, there is a tendency for civil engineers to view design research as something that is, and should be, done in other fields. Thus, they may encourage design researchers and students who are interested in design to move to other departments or disciplines rather than to establish design as a discipline within CEE. In light of these considerations, it is important for civil engineers to work with design experts from other areas to establish and distinguish design in CEE as its own sub-discipline rather than allow it to be absorbed into the existing design communities.

PREPARING THE NEXT GENERATION OF CIVIL DESIGNERS

To a large extent, change in academia is generational. Thus, one of the best ways to help establish design as a discipline in CEE is to focus on increasing and improving design education in existing civil and environmental engineering departments. The more exposure that civil engineering students have to open-ended design problems and the more opportunity that they have to apply their coursework in creative and engaging ways, the more interest that the students as a whole will have in exploring design in a more rigorous manner and in pursuing design research within CEE. The 1st International Workshop on Design in Civil and Environmental Engineering featured five very strong papers on project-based civil design courses from Denmark, Taiwan, and the United States.

Kang et al. (2011), Ni et al. (2011) and Wu et al. (2011) gave a detailed overview of the reform in engineering design education that is ongoing in the Department of Civil Engineering at the National Taiwan University (NTU). Kang et al. (2011) described the need to move beyond “instructor-centered and knowledge-based” education and towards a “student-centered and application-focused” approach that allows students to be “active, imaginative, insightful, and adventurous” and increases students’ motivation to learn. They presented a six-part model for an Introduction to Civil Engineering course that included lectures, discussion, oral presentations, guest speakers, assignments, and a final project. Ni et al. (2011) presented a model for a complimentary first year design course in civil engineering that was based on a series of 6 short (5 to 6 week) build-and-test projects drawn from topics in structural, hydraulic, and geotechnical engineering. Wu et al. (2011) shared two different models of a senior capstone design course in civil engineering that provided the students with more and less expert guidance. All of the NTU initiatives had strong buy-in from the faculty and substantial input from the students, a working educational hypothesis, and detailed assessment of student satisfaction and learning.

Similarly, Lawson and Tate (2011) presented a redesigned capstone design course at Texas Tech that uses “an integrative approach to design in a real-world civil engineering context” and is influenced by design thinking and engineering design theory from other disciplines. Students in the course go through several iterations of analysis, synthesis, and evaluation as they act as engineering consultants to adapt an existing facility to a new location. However, the tasks of the design team are limited to reduce both student and faculty workload. Detailed assessment was also a key component of this endeavor.

Finally, Bjerregaard Jensen and Almegaard (2011b) described an interdisciplinary course that combined landscaping with structural design for large-scale infrastructure projects that create value in the surrounding areas. This course shows that the boundaries between civil engineering, architecture, and urban planning are becoming increasingly blurred and that designers from all fields will need to learn to work with those from the others to be successful in the future. Courses like this can help prepare students for such a future.

All of the papers in the civil design session showed that students are increasingly interested in and respond positively to cornerstone and capstone design courses. Civil and environmental engineering departments must rise to this challenge or risk a migration of their students to other disciplines where design is more heavily featured and where they can take a more active role in their educations.

LOOKING FORWARD

Although the 1st International Workshop on Design in Civil and Environmental Engineering was relatively small, the participants were very enthusiastic and all agreed on the need to continue the discussion on an annual basis. Since the majority of participants at the first meeting were from Asia or associated with the other design conferences, it was also decided that the location of the workshop should be held outside of Asia for the next few

years to encourage members of the US and European communities to attend future meetings. In response to this, the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology (MIT) has offered to host the second workshop in 2012. The Department of Civil Engineering at the Technical University of Denmark plans to host the third workshop in 2013. I sincerely hope that many members of the KKCNN community will be able to join us for the next meeting and would like to thank the entire KKCNN community for their advice and support in helping to bring the first workshop to life.

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