Bringing Constructibility Issues to Design Courses

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Abstract

This paper describes a teaching tool being developed to fill gaps in the typical student's knowledge of the construction process. A CD-ROM and/or web site is being created to document construction practices in transportation, bridge, utility and building projects. It will also provide case studies of ways designs can be modified leading to more efficient construction. The information obtained from construction site visits, surveys, and interviews with construction site personnel is being organized in a way that makes the product interactive. Users will be able to focus on areas of construction of most interest. The tool provides a forum for contractors to detail the points they wished engineers knew about construction. The product will also contain miscellaneous information such as a glossary of construction terms and an overview of careers for engineers in construction.

Background and Purpose of the Work

The design content in Civil Engineering curricula across the country is being increased to address accreditation concerns through the introduction of capstone courses and design projects within other courses. Most students are now graduating with some relevant instruction and experience in design[1, 2]. However contractors note that the designs they are asked to build include features that are difficult or even non-buildable. Often significant field revision occurs to correct oversights, inconsistencies, or omissions in the plans at significant cost to the owner or contractor. Sometimes field revision is required to improve the economy of the work. Lack of experience or knowledge of construction practices on the part of the designer is often cited for these problems. One survey notes that employers are least satisfied with the proficiency of entry-level civil engineers and building science graduates in the areas of management, communications, surveying, and construction[3].

There is limited room in the undergraduate curriculum to include construction practices along with the required engineering science and design. Construction practices can be acknowledged in a limited frame during design courses and further covered through student club field trips and guest speakers. Information related to construction can be found in trade publications and journals devoted to the industry however students probably do not have direct access or the motivation to find these publications unless they are studying construction engineering. A structural engineering student is less likely to see these publications.

With the support of the Construction Industry Advancement Program of New Jersey and the General Building Contractors Association of New Jersey, the author is working with a team of undergraduate students to create a tool for the dissemination of construction practices and contractor concerns. The project team is visiting contractors and construction sites and preparing a survey to 1) Capture the common practices in building, utility, and highway construction, 2) document "poor" designs and the alternatives that could have been employed, and 3) discuss engineering and construction with contractors. The team is collecting the contractors' input and concerns related to the design and construction process, from the start of bidding to completion of the project. The essential question being asked is "What do you wish designers knew about construction?" The information and images captured will be compiled into a CD-ROM or web site for distribution to students in design courses. While this type of tool cannot create construction experts, it is hoped the effort will increase students' awareness of construction issues.

Development of the Project

The project team is directed by the author and consists of five undergraduate students. The students involved had varying levels of previous experience with construction ranging from extremes of a student who works in his family's home construction business to a student who had never stepped onto a construction site. The range of experience of the project team had some influence on the order of work on the project. All of the students are studying civil engineering rather than construction engineering.

Data for the project is being collected in three ways; through literature searches, site visits and meetings with construction personnel, and through a contractor survey. Initially the project team performed literature searches for information related to the interrelations between design and construction. This was done to give the team some familiarity with construction and the historic relationship between design and construction. This literature review gave the student team some insight into issues contractors face before the students entered the job sites. The literature review made the students better prepared for the subsequent discussions with the contractors.

The two project sponsors worked with their membership to identify contractors and job sites the student team can visit to further explore construction. The goal was to visit sites in all stages from initial earthwork to final punch listing. When possible the team visited the same site at several stages of progress. The types of sites visited include rail, bridge, and utility projects and steel and concrete framed buildings. There was some limitation on the site visits caused by travel distances and liability issues. Safety was emphasized. The students were covered by a liability policy and received on site safety training specific to each job site. Additional site visits will continue throughout the project.

The typical site visit begins with a trailer meeting between the project team and representatives from the contractor. At this meeting the team is given an overview of the construction project and a safety briefing. Often at this meeting plans and details are brought out to show some items that gave the contractor problems during construction. The team then moves onto the job site to film and photograph on site activities and look more closely at details the contractor particularly wants to bring to the team's attention. Often the team then returns to the trailer for further

discussions with the contractor. Most sites have provided the opportunity for return visits and phone calls to follow-up on construction at the site or additional questions the team has.

Early site visits were not as productive as those taken later. Initially the team had to become comfortable with being on site, with the terminology used, and with asking questions. Without exception, the contractors have made the students feel welcome on site and have been enthusiastic in sharing their knowledge.

The third method of collecting information is a survey. The survey was intended to gather information from a greater cross section of contractors because there are time constraints on the number of sites that can be visited. The survey contains specific questions related to all stages of construction and the relationship between design and construction. It provides another forum for contractors to provide their input to "What contractors want you to know." The survey was not conducted at the start of the project because it was important to have an overview of the issues contractors are concerned about in order to better formulate the questions. Surveys were distributed in January of 2002 and tabulated through the spring. The survey contained the following questions.

1. Do you employ engineers at the work site? If so, what is their role?
2. Are there areas of construction practice that you think engineers should be more aware of? If so, please identify some of these areas and explain why you cite them.
3. Identify concerns you have with design documents engineers provide.
4. What can engineers do during the design phase that will improve the construction process?
5. What can engineers do during the construction phase that will improve the construction process?

Complete development of the CD-ROM and web site is expected to take approximately 18 months from the project start in September of 2001. A review copy of the material is anticipated in the early summer of 2002 with the remainder of the project used to refine the product based on reviewers' comments. Although a CD is presented in this paper as the end product of this work, the team believes the web-based format is the better alternative because of the increased capability of that format to create a dynamic and easily updated environment instead of the more static environment of a disc. In either form the product will be available at no cost to interested users.

Preliminary Findings

Contractors repeatedly cite three general areas where designers can improve their impact in the construction process. First, designers are often reluctant to consider alternative construction methodology or materials. Contractors would prefer more flexibility in specifications to allow these alternative methods and materials when they can significantly improve construction efficiency or alternatively, more input during the design stage to suggest these alternate methods. Second, engineers need to recognize that labor is often the single greatest cost on the job and is certainly a cost that design can greatly influence. The use of repetitive details and minimization of labor-intensive tasks such as field welding can greatly influence the cost of a job. Finally,

communication is the single item most often cited by contractors. Engineers need to be willing to work with contractors at the start and throughout the design process. The contractor can provide advice on detailing and other constructibility issues that are most easily addressed early in design. Indeed, several contractors noted that the most important time to have good communications between the contractor and designer is before construction starts. Clearing up questions or conflicts or consideration of alternatives is best done before the labor pool and leased equipment are on site.

Few surveys were returned although the information obtained has been useful. One area of concern cited was the engineers' consideration of staging and site access. The often-mentioned issue is that engineers do not recognize the space required for equipment, material stockpiles, and other staging. Traffic control and maintenance of traffic were also suggested, as items engineers do not give enough thought to in design. Finally, several contractors described delays in construction caused by the use of specifications that were outdated or not job specific, concrete construction that did not consider available forms and methods, and close-mindedness in reviewing contractor initiated changes.

One contractor suggested that the best way engineers could improve the construction process was to be more involved with regular job meetings after construction has started. Many constructibility related issues are discussed at these meetings. The more active the engineer is during construction, the more experience they will gain. This experience will then improve the constructibility of their future designs.

Other Information Available

The CD-ROM and web site developed provides an organized presentation of the construction information collected including still and video images of construction processes, examples of detailing concerns, and comments from contractors. Links are provided to additional information on the construction industry for those who desire to explore further. This includes links to major construction organizations or trade groups, a list of common construction terms and equipment, construction cost information and descriptions of typical contracting forms. There is additional information about careers for engineers in construction.

There is a body of information currently available to introduce constructibility and economic issues into a typical structural design course, particularly in the area of steel design. Much of this is written for practitioners but is presented in ways that most undergraduate students will be able to follow. Examples include a discussion of the economics of constructing a steel building and practical advice on how contract documents and design details can influence the cost[4] and similar advice on reducing steel fabrication costs[5] and joist costs[6]. Advice on creating effective contract and shop drawings is also available[7, 8]. Concrete constructibility is addressed in print[9] and on video[10].

Summary

A product is being developed to fill gaps in the typical student's knowledge of the construction process. It is believed that giving students an increased awareness of construction and the

constraints faced by contractors will improve the end product of their design efforts. Designs will improve when students have a better understanding of how their creations will be built. A CD-ROM and/or web site are being created that documents construction practices. The product will contain information on the construction practices common to transportation, bridge, utility and building construction. It will also provide case studies of ways designs could have been modified to lead to more efficient construction. The product is being developed by organizing information obtained from construction site visits, surveys, and interviews with construction site personnel. This provides a forum for contractors to detail what they wished engineers knew about construction. The product will also contain miscellaneous information such as a glossary of construction terms and an overview of careers for engineers in construction.

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