Construction Process Knowledge for Integration and Innovation

by C. B. Tatum, Stanford University

Vision of future construction processes

Design and construction markets currently face many drivers for increased project performance, including new materials of construction, new facility designs involving greater complexity and requiring increased quality, shorter schedules, and decreased investment. Increased integration and innovation, both fostered by more effective application of information technology, are important means to respond to these challenges. Effective integration of design and construction for improved project performance requires shared knowledge of design processes and products, construction processes, and the constraints faced by both. Construction process knowledge is also an essential foundation for innovation in construction, including adopting new materials and systems for use in future facilities and developing new construction processes.

The increased demands of future construction projects will drive a fragmentation of the design and construction industry into two main types of firms: those that are integrated and innovative and those that maintain traditional approaches. Design-build and performance-based engineering, strong current drivers in the industry, clearly indicate this trend. Increased understanding and application of construction process knowledge will provide an essential distinctive competence for the integrated and innovative firms.

The purpose of this paper is to highlight the importance of construction process knowledge in meeting future project challenges and identify key research needs to assist in responding to these challenges. It describes activities applying construction process knowledge, identifies the major categories of this knowledge, and asks research questions.

Activities applying construction process knowledge

Activities to technically support construction, often termed construction engineering, are strongly linked to success regarding each project objective: schedule (through design of methods, plans, temporary works), cost (thorough operations and productivity improvement), quality (through defining requirements, methods to achieve and verify, solutions), and safety (through temporary structures, safe designs and plans). Success in meeting increasingly demanding project objectives requires effective use of construction process knowledge in performing the following activities:

- plan and select construction methods by analyzing technical requirements from the design and site conditions, setting performance criteria, evaluating technical aspects of alternatives, and selecting feasible methods for economic analysis
- provide input to design by planning and selecting construction sequences and methods, jointly developing design approaches that support project-beneficial construction methods, and expressing preferences for materials of construction and design configuration

- design the construction facilities and plant, including application of engineering principles and construction design criteria to define the temporary works necessary to support construction operations
- provide technical information and materials tailored to the needs of the construction crafts building the work, including detailed drawings of components, composite drawings, sequence drawings, installation instructions, engineered materials and bulk materials
- provide technical support for field operations by interpreting the plans and specifications, identifying and evaluating alternate construction methods as required by site conditions, and solving field problems and non-conforming conditions
- analyze and record the results of construction operations, identify lessons learned, and disseminate this information in a form most useful for the design and construction of future projects.

Elements of construction process knowledge

Completing the activities listed above requires applying several types of knowledge, including engineering principles, materials, constructed facilities, construction-applied resources, temporary works, and construction processes. Increased understanding of these types of knowledge, including setting priorities for different types of construction, presents a major opportunity for using information technology to increase integration and innovation.

The fundamental engineering principles included in construction process knowledge are civil, structural, mechanical, electrical, and controls; other disciplines are also significant for certain types of facilities. The knowledge required is an understanding of the key engineering principles used in each discipline, how they are applied in analysis and design, and what are reasonable results.

Permanent equipment and materials of construction includes those used in the structural, architectural, mechanical, electrical, and other building systems. The knowledge required for construction processes includes chemical composition, physical properties, appropriate applications, limitations, special installation requirements, availability, and cost.

Functional elements and systems in constructed facilities include foundations, structural, architectural, mechanical, electrical, and other systems. The knowledge of these systems required for construction processes includes design intent and constraints, design process, basic method of operation, information and special requirements for installation, and acceptance criteria. Understanding the special characteristics of different types of constructed facilities is also vital. This requires asking, What is special about building a X? This knowledge includes process characteristics such as special information requirements, maintaining appropriate relationships in work progress, managing project transitions, and anticipating and avoiding frequent problems.

Construction-applied resources include crafts with required skills, construction tools and equipment, and consumables. Process knowledge concerning these resources includes needs, capabilities, limitations, most beneficial applications, availability, and cost. Temporary works for

construction and the construction plant generally consist of temporary yards and building, temporary structures, site utilities, and construction support services. Design criteria for temporary works include technical (functionality and safety) and practical (resources in the firm, fit with project objectives, fit with site and local conditions).

Construction process and operations include each of the major types of construction work: civil, steel, concrete, architectural, mechanical, electrical, and other special processes. Special construction processes and operations are identified by unusual complexity, skill, major safety concerns, or risk of not producing an acceptable outcome. Examples include concrete mix design, construction layout, blasting, welding, rigging, material handling, precise alignment, and testing. Required knowledge concerning construction processes includes needs, overall method, resources required, major activities, repeated operations, relationships, risks, duration, and cost.

These five preliminary categories illustrate the breadth of construction process knowledge required for effective planning and technical support of construction operations. The diversity of this background previously required many years of experience to acquire and effectively apply this experience. Construction professionals facing the challenges of tomorrow's will no longer have that luxury. Information technology can help but we need much better understanding of the content of knowledge bases for construction processes.

Examples of research questions regarding construction process knowledge

The following examples of research questions indicate the major effort required to increase understanding and beneficial use of construction process knowledge.

- What are the most important elements of construction engineering knowledge for each type of construction activity? How do different project conditions affect this?
- What is the most effective way to make sense of the immense amount of data and information available concerning technical support of construction processes and move toward knowledge and application?
- Is it possible to capture and represent specific types of construction engineering knowledge to provide advice and assist in decision making during each project phase?
- What types of construction process knowledge are needed for planning each type of construction operation and how can this knowledge best be applied?
- What types of construction engineering knowledge are needed for performance-based design of specific building systems?
- What are the most important elements of construction process knowledge and design process knowledge to share on different types of projects for increased integration and innovation?

Conclusions

Construction process knowledge is an urgent research topic with major potential benefits, especially because of information technology. The broad scope and combined basis of construction (fundamental and experiential) makes it an ideal example of the need to move from data to information to knowledge to application, as identified in the 1997 CII/NSF workshop.

In many respects, construction is an information business and information technology will bring major improvements, given increased understanding of construction process knowledge. Improved contracting and collaboration, combined with more positive attitude and motivation, can greatly improve the potential and process of integration and innovation on future projects; construction process knowledge is an essential catalyst for this to happen.

Focused on fundamentals, educational attention to construction process knowledge can provide two major advantages for entry level engineers: increased ability to add value soon ("work wise"), and basis for steep learning curves and innovation (change agents and future leaders).

Background

Work on military and power plant construction projects that required integration and innovation prompted my interest in these topics. Investigations of constructibility improvement and processes of innovation, along with teaching construction engineering courses, increased this interest. My current work in CIFE includes the construction process knowledge required for effective coordination of MEP systems in complex buildings and manufacturing plants.

References

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