



# EMERGING CONSTRUCTION TECHNOLOGIES AND THE ADVANCED CONSTRUCTION TECHNOLOGY SYSTEM

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# **Emerging Construction Technologies and the Advanced Construction Technology System**

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## Executive Summary

In 1987, the Construction Industry Institute formed the Technology Survey Task Force. The purpose of the task force was to examine the R&D work that could impact productivity in a positive way, and to make such R&D efforts more broadly known. This publication is a report on the task force efforts.

The task force established three objectives for their scope of work: (1) identify innovations and emerging technologies, concentrating on aspects of construction that could contribute to the improvement of productivity; (2) develop computer software to store information on construction technologies and provide methods for searching electronic databases for such technologies; and (3) promote the establishment of a capability for the continued identification of emerging technologies and the maintenance of the data and software system.

Improved knowledge in the technology area can contribute to productivity improvements. To a large degree, however, current R&D in the technology area stresses materials and design criteria research. Relatively few developing technologies were identified by the task force that focus on the construction process. The improvements made are considered either proprietary or not innovative and thus, are often not available. For these reasons, the industry needs to develop a strategy that encourages a focused effort on technology research and information distribution that relates to construction processes.

Over 300 technologies have been identified by the task force. These technologies are housed in the Advanced Construction Technology Systems (ACTS), a computer software database developed by the task force. The ACTS database has been designed for classifying, documenting, and retrieving information about emerging construction technologies. Specifically, ACTS can help the industry improve its productivity through dissemination of information.

The long-range plan for ACTS is that it be an ongoing information service to the construction industry. The task force strongly recommends that individual companies utilize ACTS as a method of collecting their own innovations and disseminating them within their organization and jobsites. The availability of the information contained in the system should quicken the pace of technology utilization in the industry and contribute toward cost effectiveness, productivity, and overall competitiveness.



## Introduction

The U.S. construction industry is facing major changes, challenges and competition as the Twentieth Century draws to a close. Productivity within the industry has been declining dramatically over the past 25 years<sup>1</sup>, and the industry is far less progressive than many other major industries in developing and adopting emerging technologies<sup>2</sup>.

The lack of a coordinated effort to disseminate new technologies is causing the industry to fail to benefit from information and techniques that can increase productivity and reduce costs. The Business Roundtable Construction Industry Cost Effectiveness (CICE) Project, a five-year study of the industry, concluded in 1983 that there is an industry-wide need to gather, manage, and provide emerging construction technology information<sup>2</sup>. The CICE study<sup>3</sup> identified three priority areas having high payoff potential: steel and concrete construction, electrical and instrumentation construction, and mechanical and piping construction. The CICE reports suggest that economic improvements could be achieved if these areas of construction were significantly improved.

The CII Technology Survey Task Force was formed to examine emerging technologies and make them more widely known to industry. The task force objectives were: (1) identify innovations and emerging technologies, particularly in fields of construction that could provide a high payoff; (2) develop computer software to store information on construction technologies and provide methods for searching electronic databases for such technologies; and (3) promote the establishment of a capability for the continued identification of emerging technologies and the maintenance of the data and software system. Information on technology identification and the software system developed by the task force (ACTS) is presented in the following chapters.

The development of a formalized mechanism to identify new technologies was initiated by conducting an extensive literature search. This search was necessary to establish a knowledge base associated with construction areas and the nature of research and development taking place. Establishing a formalized mechanism is necessary to facilitate a repeatable ongoing survey and identification of innovative technologies.

One of the goals of the search was to locate information sources that are actively involved in new technologies. These identified sources could then be utilized to suggest additional sources, provide technological information, predict trends and establish patterns, or simply answer specific questions. Such informational sources would include published literature in addition to trade groups, code writing organizations, governmental agencies, research facilities, manufacturing companies, contractors, and design firms. Once these sources were identified, they provided a body of knowledge from which research information could be obtained.

With these sources identified, an organized approach to obtaining information was established. The nature of these sources varies considerably as do the methods of obtaining information. These methods included literature reviews, personal interviews, site visits, and telephone and mail surveys. The methodology described in the source documents provides a model for the ongoing searches for technologies.

Perception of what is a new technology may vary with different individuals and companies depending upon whether it has been encountered previously. Thus, ACTS also includes some product stage technologies that particular companies may already have in active use.

## Emerging Construction Technologies

Besides research efforts in developing ACTS, the Technology Survey Task Force also investigated emerging construction technologies that have the potential to improve construction efficiency and effectiveness. The CICE Project<sup>3</sup> identified three areas of construction where emerging technologies have the highest payoff potential: steel and concrete structural construction, electrical and instrumentation construction, and piping and mechanical construction. Researchers from North Carolina State University<sup>5</sup>, Purdue University<sup>6</sup>, and the University of Michigan<sup>7</sup> examined these three areas. General Motors also contributed to the research by examining building mechanical construction.

All of the technologies identified and documented by the task force have been entered into the ACTS database. Although somewhat limited at this time, the documentation of these technologies will improve.

Perception of what is an emerging technology may vary with different individuals and companies depending upon whether it has been encountered previously. Thus, ACTS also includes some product stage technologies that companies may already have in active use. This section summarizes the general thrusts identified in the priority areas.

Research funded by government agencies in these areas, while significant, tends to focus on concerns of the owner related to acceptability of the finished product. Similarly, materials producers tend to focus research on their products. Thus, there is much activity in terms of performance testing which will improve design understanding and quality control and much for development of improved materials which will be more durable. Very little research is funded to improve the construction process since the owner has traditionally been less concerned with how the contractor achieved the requirements. Most of the construction process R&D has been privately funded by vendors to the industry in the form of proprietary product development. Little government or cooperative construction industry funded technology research for the construction process is conducted.

Materials and design are significantly influenced by the importance of the building code process. The critical nature of safety and durability of the facility combined with the non-repetitive production process mandates accumulation of thorough engineering knowledge of new technologies before they are adopted. Thus, new materials and design criteria need extensive study before general use. New construction process technologies, however, are often not subject to the same lead time and approvals before wider use unless they affect the outcome of the constructed product. Thus, some process, equipment, and tool improvements can be adopted by industry rather quickly.

## **Concrete and Steel Structural Construction**

### **Background**

The concrete construction industry is highly fragmented, being composed of many players supplying many constituent products, accessories, and subcontracted services. The concrete construction process involves many components. The concrete mixture itself can be designed to project-specific needs and has the opportunity for being impacted by cement, admixture, and testing advances. Formwork can be 50 percent of the total concrete structure cost, thus developments in this area have major implications. Placement of reinforcing steel is labor intensive. Delivery, handling, placing, finishing, and curing of concrete have substantial impact upon the quality of the finished product. Although some concrete is more economically produced as plant precast, constant developments for field production continues to make cast-in-place construction viable.

The steel construction process involves comparatively fewer components. While many steel materials and grades are available, they are highly standardized. Production by its nature requires substantial mill investment. Fabrication plants are fairly numerous and prefabrication and shop painting of the largest elements possible in the plants is important to overall economics. Nevertheless, significant field operations remain, such as erection, field connections, field painting, and so forth, with opportunities for technology improvement.

Some technologies have applications related to both steel and concrete construction. Many technologies that have been in existence for years are not always well understood or known by

the entire industry. Development of technology is alive and well in some structural areas, such as materials and testing methods. R&D that is focused on the construction process is more limited and not as readily shared when developed in-house due to competitive reasons.

### Concrete Technology—Current and Future Trends

Before looking forward, it is helpful to look at recent history. Numerous developments in concrete construction have occurred over the last two decades. However, three stand out in terms of impact, one each in materials, delivery, and forming. The introduction of superplasticizer admixtures has significantly improved the placement process resulting in a better product when used properly. Concrete pumping equipment and understanding of mix designs for pumping has revolutionized concrete placement. Flying forms and gang forms have made many forming operations in repetitive structures less expensive. When these three technologies were combined, the result was a shift in the economical system for many building structures to the resurgence of the Flat Plate floor system, which simultaneously simplified reinforcement details and placement.

Much current research is focused on improving materials for concrete. High Performance Concrete encompasses many objectives for the concrete itself. One objective might be high full-cure strength; indeed, some building columns are being constructed with concretes over 15,000 psi strength. Another objective might be high early strength, 2,000 psi in 4 hours or 5,000 psi in 24 hours in field applications, so that the structure can be used more quickly or so the forms can be stripped earlier for reuse. Silica fume and other cement replacements and additives continue to expand in development and use. New technologies are available for monitoring field strength based on the “Maturity” concept as well as physical tests which safely allow optimum removal/reuse of forms. Other objectives involve improved durability for longer lasting infrastructure needs.

Reinforcing materials are also being studied for improved corrosion resistance and to facilitate placement. Epoxy-coated rebar introduced in the mid-1970s and epoxy coated prestressing strand introduced in the mid-1980s are available technologies and cathodic protection continues to evolve. Other coatings for steel rebar, such as silicon, are under development. Non-metallic

base materials are also under development and trial use as replacements for steel in severe environments. Examples are carbon fiber and glass fiber elements for rebar, for prestressing strand, and for two- and three-dimensional mesh grids. While all of these materials have possible benefits, each also has its own set of problems and limitations.

The variety of couplers and dowel bar replacement alternatives for splicing rebar continues to increase. Prestressing strand in a higher 300 ksi ultimate strength is in limited production. Automation and robotic research has been demonstrated through development of prototypes for some tasks such as slab finishing. New technologies are constantly being developed for special concrete operations such as hydrodemolition, diamond wire cutting, and vacuum blasting for concrete removal during rehabilitation.

### Steel Technology—Current and Future Trends

In steel construction, new technologies emphasize fundamental design approach changes, improvements in weldability of steels, and equipment and processes for welding and other connection developments.

The introduction of Load and Resistance Factor Design (LRFD) for steel structures is expected to gradually replace Allowable Stress Design, resulting in more economical and uniformly safe structures. Heavy use of CAD in detailing offers the possibility of more accurately designed connections which can be made more economical if design is specified to be predicated upon actual factored loads rather than maximum or factored member strength.

Improvements in welding for structural applications are occurring through a combination of materials, equipment and process developments. The development of High Strength Low Alloy steels and In-line Direct Quench or Quenched and Self-Tempered production methods have promise in producing heavy and high strength structural shapes which can be welded without or with less preheating. Improved methods have also resulted in the re-emergence of electro-slag welding for heavy structurals. Inverter power supplies have reduced the size of welding equipment, particularly for field use. Plasma arc cutting, a computer controlled articulated arc welding robot with high speed rotating arc, weldable paints, and automated inspection techniques are among the technologies that are improving the fabrication process.