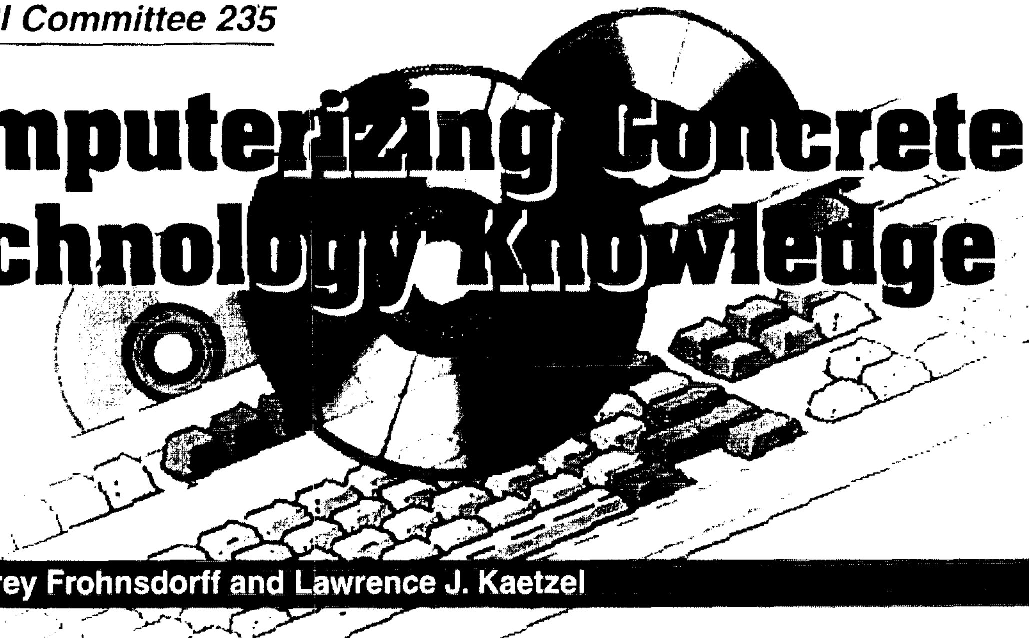
Computerizing Concrete Technology Knowledge



by Geoffrey Frohnsdorff and Lawrence J. Kaetzel

The ability to organize, store, process, and exchange knowledge of concrete using computers is growing rapidly. Without fully knowing what will be possible in the future, it is apparent that computers will bring great changes to the way knowledge of concrete technology is used. It seems inevitable that computers will become the major source of knowledge for concrete technologists.

In recognition of the potential of knowledge-based systems to help advance the knowledge of concrete technology, ACI Committee 235, Knowledge-Based Systems and Mathematical Modeling of Materials, was organized in 1994. Its goals are to study, develop and report on: knowledge-based systems for concrete; mathematical modeling for prediction of material properties of concrete; guidance on protocols; and promotion of concrete knowledge-based management and understanding.

Since 1994, the computerization of concrete technology knowledge has progressed remarkably and the need for a committee such as 235 is even more imperative. Some examples of knowledge-based computer applications are:

- The expert system for Highway Concrete (HWYCON)
- The electronic monograph on computational materials science of concrete[2]
- The three-dimensional model of cement hydration[3]

One may now begin to see a possible way that a practical structure for the knowledge of concrete technology can be developed. While there are many possibilities, the authors would propose that, for the present purpose, the knowledge should be divided into the following categories:

- Processing
- Characterization
- Constructibility
- Simulation of microstructure and property development
- Structural performance
- Predicting fire performance
- Economics (life cycle cost)
- Environmental effects (life cycle analysis)
- Predicting maintenance and durability

While these categories may not be the final choice, they serve to illustrate how many of the present ACI Committees could provide input to a Computer Integrated Knowledge System (CIKS) Network.[4,5] For example, the following committees could provide input to the CIKS under the "processing" heading:

211 Proportioning Concrete Mixtures
212 Chemical Admixtures
214 Evaluation of Results of Tests Used to Determine the Strength of Concrete
221 Aggregates
225 Hydraulic Cements
231 Properties of Concrete at Early Ages
232 Fly Ash and Natural Pozzolans in Concrete
233 Ground Slag in Concrete
234 Silica Fume in Concrete
301 Specifications for Concrete
304 Measuring, Mixing, Transporting, and Placing Concrete
308 Curing Concrete
309 Consolidation of Concrete

Concrete knowledge-base interoperability

Nearly every research organization and business has been affected by computers and information technology. Improved business practice leading to productivity gains and reduced costs can result through the use of technologies such as the Internet. The exchange and transfer of research results can be improved however, thus benefitting research organizations and concrete technologists.

Currently, the concrete industry is far from taking full advantage of computerized methods. A barrier to rapid exploitation of computer use by the industry is the number of small businesses within it and the lack of concrete-related protocols and standards for representing and exchanging concrete knowledge. Often, short-term business priorities and lack of available resources limit the rate of the computerization of knowledge. Generally-accepted guidance on knowledge representation and exchange methods, and improved tools for applying the methods would speed the application of computers in the

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concrete industry and increase competitiveness of concrete against other construction materials.

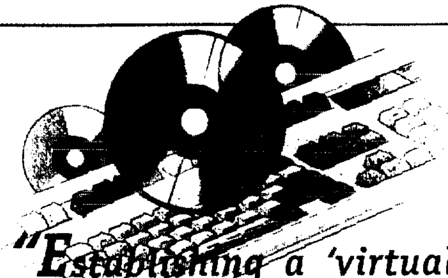
This situation creates an opportunity for ACI to move expeditiously to address the information technology needs of the concrete industry by developing guidance and protocols for knowledge representation and exchange. The first and foremost issue to address is interoperability among concrete knowledge-based systems. Interoperability can be defined as: a process that allows for the exchange of knowledge between computers and humans in a seamless manner. Interoperability for concrete knowledge would require several critical elements to be put in place:

- Accepted practices for the design, production, selection, maintenance and repair of concrete;
- Standard terminology represented in knowledge bases;
- Standard data, information, and knowledge formats;
- Process and activity models;
- Criteria for data quality, and knowledge exchange;
- Common user interface(s); and
- Information technology protocols and standards.

At this stage, several of the terms used here may not be familiar to many concrete technologists. They will become more familiar however as the computer age progresses. ACI Committee 235 has a part to play in promoting familiarity with these concepts and to develop guidance for concrete knowledge-base creation and distribution. In an effort to investigate issues and benefits for interoperability, the newly established ACI 235-A Subcommittee on Knowledge Interoperability will be evaluating exchange protocols and barriers to the seamless exchange of computerized knowledge-based systems.

An example of interoperability for several concrete activities representing topics being addressed by the subcommittee is shown in Fig. 1.

The interoperable framework is adaptable to ACI's technical committee goals and output. For example, the "concrete knowledge" element represents all ACI committees that produce documents and guidance on concrete design, production, and maintenance, such as that represented in the ACI Manual of Concrete Practice and the 318 Building Code. Also, within ACI, several technical committees have established goals dealing with knowledge representation and exchange. These are: 116, Terminology and Notation; 118, Use of Computers; 126, Database Formats for Concrete Materials Properties; and 235, Knowledge-Based Systems and Mathematical Models for Materials.



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Developing an interoperable framework does not necessarily have to involve new activities and goals of ACI committees. For example, the Committee 116 Concrete and Concrete Terminology report, and the Committee 126 report, "Guide to a Recommended Format for the Identification of Concrete in a Materials Property Database," represent efforts to standardize and provide guidance for terms and database formats. Using these tools as a basis for knowledge representation, additional efforts are necessary to address areas such as process and activity models, criteria for data quality, and a common user interface. Process and activity models are systematic procedures that define inputs/outputs (data, information, and knowledge) and the appropriate steps for conducting concrete-related activities such as diagnosing structural distress and selecting concrete materials and repair methods. Potential benefits of these activities are significant. Benefits include improved practice and reduced time to develop and implement computerized knowledge-based systems. The goals of ACI Committee 235 recognize that efforts should begin addressing the need for establishing guidance on protocols — process, activity, and data models, and develop criteria for data quality and exchange.

A common user interface to concrete knowledge can draw upon current information technologies, such as the Internet's World-Wide Web (WWW) capabilities to deliver data, information, and knowledge virtually anywhere. The current state of WWW is somewhat chaotic however, because relevant information is difficult to

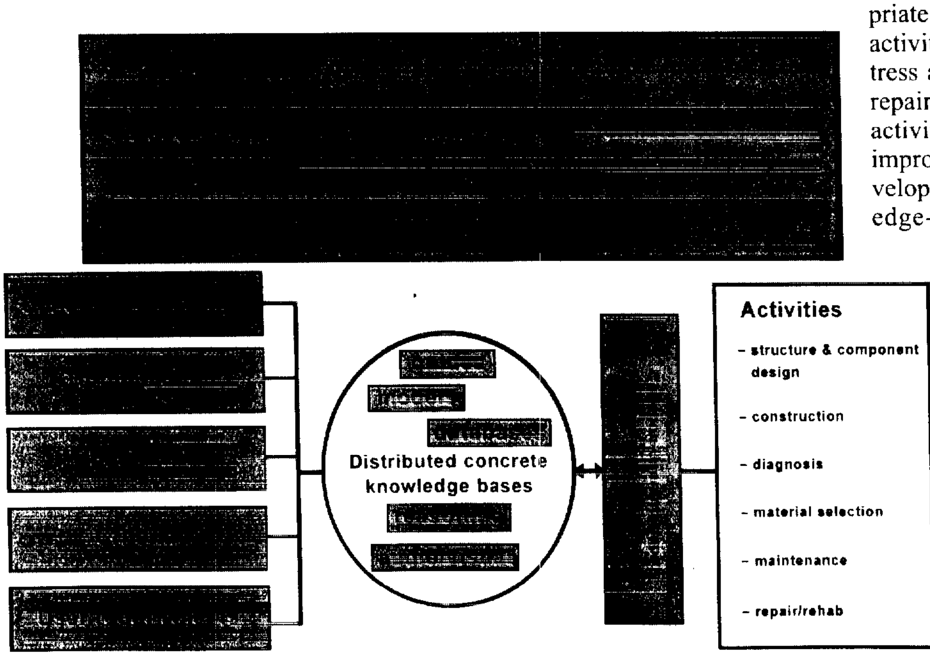

Fig. 1 — Diagram of concrete knowledge-base interoperability.

Table 1 — CIKS Concrete Working Group projects

Project	Concrete knowledge domain	Sponsoring organization
HYPERCON	Design, processing, repair of high-performance concrete	National Institute of Standards and Technology (NIST)
Forensic Systems	Life cycle of highway structures	University of Texas at Austin
Decision Support System (DSS)	Repair and rehabilitation of structures and advanced learning systems	Structural Preservation Systems, Inc.
HWYCON	Highway structure diagnostics, materials selection, and repair	American Association of State Highway and Transportation Officials (AASHTO)
Concrete Processing	Design, placement, and quality control of concrete	Shilstone Companies, Inc.
HIPERPAVE	High-Performance Concrete Paving	Federal Highway Administration (FHWA)
HYDROCON	Diagnosis and repair of concrete hydraulic structures	U.S. Army Corps of Engineers, Waterways Experiment Station

find and data quality is often unknown. Establishing a "virtual community" for the concrete industry is essential to improving the use of computers and concrete knowledge. ACI Committee 118 has previously been alone in addressing this topic, and synergy is needed with other ACI computer-related committees to demonstrate the importance and potential of this "virtual community" for the concrete industry.

Developing an interoperable framework for concrete knowledge must start with a prototype to demonstrate the concept and benefits to the concrete industry. Efforts to develop the CIKS Network by the National Institute of Standards and Technology can serve as the basis for identifying issues, goals, and organizations to participate in a demonstration prototype. During a 1997 CIKS Workshop, members from industry and government organizations met to discuss the needs involving concrete knowledge-based systems. The CIKS Concrete Working Group, led by David W. Fowler, University of Texas at Austin, identified several projects and priorities that could benefit from an interoperable framework. Table 1 shows the projects and organizations that were discussed during the workshop.

Similarities among the information needs and goals of these projects suggest an opportunity to develop an interoperable framework prototype, while satisfying short-term project goals. In subsequent meetings, the CIKS Concrete Working Group has demonstrated a willingness to collaborate on important issues related to concrete knowledge representation and exchange. One possibility for continuing this work is the alignment of the CIKS Concrete Working Group and goals with the ACI Committee 235 agenda. This scenario and its merits will be addressed by ACI Committee 235, and those interested in these issues are cordially invited to attend the Committee meetings at ACI conventions.

Summary

In the future, new concrete materials, products, systems, and procedures will be developed for use within the concrete industry and by its customers. As more data, information, and knowledge are produced, the task of representing, exchanging, interpreting, and managing the vast data quantities will become even more daunting. Information technology has provided an opportunity to improve ways to transfer and store knowledge, yet a generally accepted framework involving more automated exchanges has not been developed. There appears to be an immediate opportunity for the concrete industry to establish a "virtual concrete community" that addresses the specific needs of the industry and its customers, so that greater advances in understanding knowledge and improving concrete practice can result. ACI, its technical committees, and its member organizations are encouraged to begin addressing the need for interoperability and improvement in the way the concrete industry uses computers as soon as possible.

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Selected for reader interest by the editors.

ACI member **Geoffrey Frohnsdorff** is chairman of ACI Committee 235, Knowledge-Based Systems and Mathematical Modeling for Materials, and is vice chairman of the Concrete Research Council. At the National Institute of Standards and Technology, he is chief of the Building Materials Division in the Building and Fire Research Laboratory and leader of the Partnership for High-Performance Concrete Technology.

ACI member **Lawrence J. Kaetzel** is principal of K-Systems, a knowledge engineering services company. He is a member of ACI Committees 116, Terminology and Notation; 118, Use of Computers; 126, Database Formats for Concrete Materials Properties; 235, Knowledge-Based Systems and Mathematical Modeling for Materials; and the Publications Committee.