Using the Internet to Transfer Knowledge on Concrete Durability: Improving and Fostering Knowledge Exchange, eWork and eBusiness in Architecture, Engineering and Construction

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Using the Internet to transfer knowledge on concrete durability: improving and fostering knowledge exchange

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ABSTRACT: Today, in the Digital Age, the Internet is becoming the most effective medium to transfer knowledge, developed under government R&D programs, to the industry. Presenting research results on the Web allows scientists to use effective knowledge dissemination and research collaboration tools, and companies to have timely anywhere, anytime and on-demand access to valuable research information. This is especially important for AEC companies, typically small and medium size businesses, that don't have enough resources to conduct their own research or to search for information published in scientific journals and conference proceedings. Currently, in Canada, on average 9 out of 10 AEC companies are connected to the Internet. Web resources are increasingly becoming important sources of vital information for AEC companies and the proposed new knowledge dissemination model could provide excellent knowledge transfer channels for new strategic economic development directions.

1 BACKGROUND

All industrialized countries are in the process of a fundamental paradigm shift associated with the movement from the previously established Industrial Age economy of production and consumption to the new Digital Age economy based on information and communication technology, and, to a large extent, on the digitization of information (Edquist. & Riddell, 2000). In the modern information society we are coming to recognize knowledge as a valuable entity in itself. It is often called "the ultimate intangible" asset for companies, universities and research organizations (Schreiber, 2000).

The value of knowledge can be expressed in hard figures; for example, Quinn in the book Intelligent Enterprise (1992) states that in the manufacturing sector knowledge-based service capabilities are calculated to be responsible for 65-75% of the total added value of the products, and, in general, for the average company these numbers are close to 75-80%.

1.1 Information dissemination models

To better utilize the value of information, the new knowledge-based economy is rapidly moving towards electronic models of information dissemination. A research study conducted by the Dissemination Analysis Group (cited in Klein & Gwaltney, 1991) identified four types of information dissemination:

- spread, which is defined as "the one-way diffusion or distribution of information,"
- choice, a process that "actively helps users seek and acquire alternative sources of information and learn about their options,"
- exchange, which "involves interactions between people and the multidirectional flow of information," and
- implementation, which "includes technical assistance, training, or interpersonal activities designed to increase the use of knowledge or R&D or to change attitudes or behavior of organizations or individuals."

1.2 Current state of scientific information dissemination

The research and scientific community is currently in the process of moving away from the old "information spread" model, normally channeled through refereed academic journals and conference proceedings. A new model of information dissemination is emerging, one that utilizes the Internet as a medium for information exchange, and where there is a multidirectional flow of information.

Scientists themselves are becoming increasingly involved in publishing their articles in online refereed journals that provide free or low fee public access to scientific information. Currently there are several such projects to create new means for knowledge dissemination, including the Public Li-

brary of Science movement (Case, 2001), and the self-organizing repository for scientific information exchange SciX initiative coordinated by the University of Ljubljana (SciX Project, 2002). Also evident is a shift towards a new publishing paradigm that involves publishing technical and scientific articles using XML (extensible markup language) technology that preserves the structure of knowledge contained in the article (Rzepa & Murray-Rust, 2001).

However, scientists have not yet fully embraced the power of the Internet. The Web was invented so that researchers would have a network to collaborate, exchange documents, discuss them, coordinate research, and create new knowledge. Yet, the use of the Internet by scientists is still mostly at the stage of electronic publishing and not at the level of true collaborative work and communication.

There are some rare examples of collaborative Internet-based research environments for knowledge exchange, such as the Virtual Laboratory for Technology (2002) at the University of California in San Diego, and the Virtual Laboratory for Biokinetic and Dosimetric Research (2002), but the majority of scientific information is still posted, mostly in the "information spread" mode, as electronic publications, on Web Portals.

1.3 Internet Portals as information dissemination tools

The knowledge-based economy facilitated the development of new ways of "information dissemination" by creating Web portals. The construction of Web portals "integrated gateways onto the Web, personalized for specific aggregation of interests" (Bressler & Grantham, 2000) is the major technological driver that enables the creation of online communities of practice. It is believed that the key to a successful knowledge dissemination strategy is to channel the knowledge to the communities of practice (Wengler, 2000) and at the same time provide means for information exchange and peer-to-peer collaboration.

A good example of this strategy from the business world is the success of the Corrosion-source.com site (Corrosion Source, 2002) that was named one of the Forbes Best of the Web sites in 2001 (McHugh, 2001). Corrosion Source is a Web portal that serves a broad community of corrosion scientists, consulting companies, engineers and even homeowners that have corrosion problems in their house.

The site was set up in 1995 as a marketing tool for the InterCorr company headed by a corrosion scientist. Initially the company used the site to post online papers, and host a simple discussion forum. Due to the wide popularity of the online forum among corrosion professionals, the site has expanded and started offering corrosion information from the company's own sources and from a wide variety of Internet sources to the subscribers. Currently it is the most comprehensive source for corrosion knowledge on the Internet.

1.4 Need for sustainable concrete information resource

It is widely recognized that there is a need to have a similar source of knowledge on environmentally friendly concrete. All industrialized countries strive to reduce the construction industry's contribution to global warming and at the same time, utilize accumulated amounts of industrial by-products. Concrete, as the most widely used construction material deserves special attention in this regard.

In 1995, the global production of cement was about 1.4 billion tones. Considering that the production of every tone of Portland cement contributes about 1 tone of CO_2 into the atmosphere, this means that the annual cement manufacture contribution to the global warming is about 1.4 billion tones of CO_2. This accounts for about 10 % of the total CO_2 emissions from the construction industry (Malhotra, 1999).

The need to reduce the environmental impact of concrete was recognized in a recent Report of the US Strategic Development Council. According to this report, "…concrete technologists are faced with the challenge of leading future development in a way that protects environmental quality while projecting concrete as a construction material of choice" (Plenge, 2001). To achieve this goal, government research laboratories have a responsibility to effectively disseminate the results of scientific studies on durability of environmentally friendly concrete to the practitioners in North America and all over the world.

In this paper authors propose a new approach to scientific information dissemination that is based on the Virtual Laboratory model. The online information exchange environment of the proposed Virtual laboratory will provide free Web-based access to the repository of research results and to a discussion forum for scientists, practitioners and AEC companies. Existing concrete durability information systems, such as the US Army Corps of Engineers and CANMET durability databases described below, could form an essential part of the repository for this Virtual concrete laboratory.

2 DURABILITY KNOWLEDGE BASES

2.1 Durability research at Treat Island

The Treat Island natural weathering exposure site goes back to 1937 and is the most comprehensive long-term concrete exposure site in the world. Today, approximately 40 test programs are active at

Treat Island. Some of the variables investigated include lightweight aggregates made out of industrial by-products, supplementary cementing materials, and blended cements. Treat Island programs are administered by the United States Army Corps of Engineers, Waterways Experimental Station.

Sponsors of the programs include the U.S. Bureau of Reclamation, the US Army Corps of Engineers, the Canadian Center for Mineral and Energy Resources (CANMET), the Construction Productivity Advancement Research program (CPAR), and private industry, with about 40% of specimens from Canadian agencies (Farny, 1996).

2.2 Information dissemination mechanism

Until recently, the findings of various research programs at Treat Island were not easily accessible to the engineering community and industry practitioners. To present the findings of the various research programs at the site, a visitation was scheduled on even numbered years. A few scientists and engineers, invited by the Corps of Engineers, attended this event.

The dissemination of results of the studies completed in previous years was confined to a relatively limited number of technical papers that needed to be brought to the attention of practicing professionals and of the construction industry.

2.3 CANMET database

A first step in developing a new knowledge dissemination mechanism was taken in 1994 with the development of a multimedia database accommodating the results of more than two decades of research for CANMET's "green" concrete durability studies. To provide for better data visualization capabilities, UNB researchers presented research data as a multimedia computer database (Fig. 1).

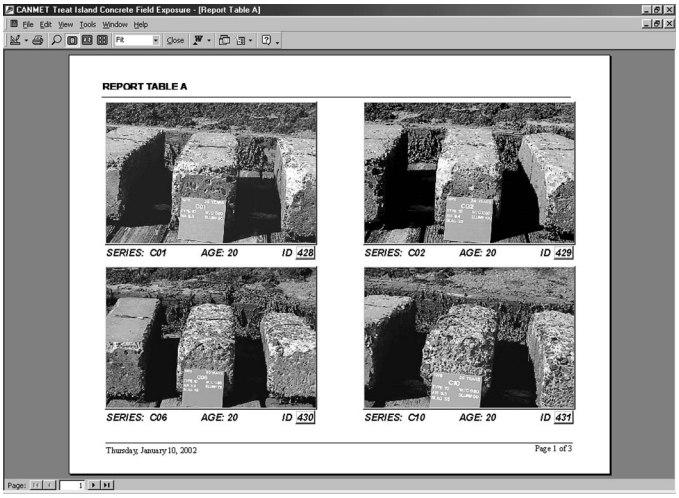
Multimedia data in the CANMET database comprises of static media, like text and historical photographs of specimens, and of dynamically linked Excel charts graphically representing annual results of non-destructive testing (NDT) and visual evaluation. The CANMET database was developed as a standalone CD-ROM database and is updated annually after the summer testing and inspection.

The database design allows side-by side comparison of historical photographs and testing results for concrete mixtures with different amounts of supplementary cementing materials and supports decision-making on the choice of environmentally friendly and durable concrete.

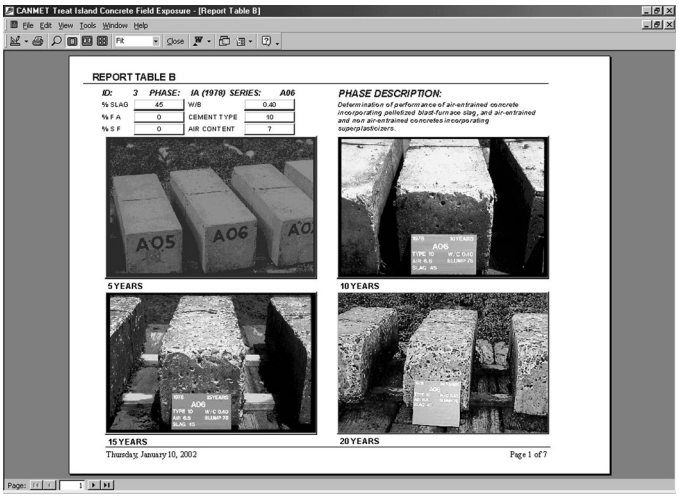
2.4 US Army Web information system

In 1999 the US Army Corps of Engineers were looking for better ways to disseminate the results of Treat Island research on concrete durability and wanted to exploit Information Technology as a knowledge dissemination tool.

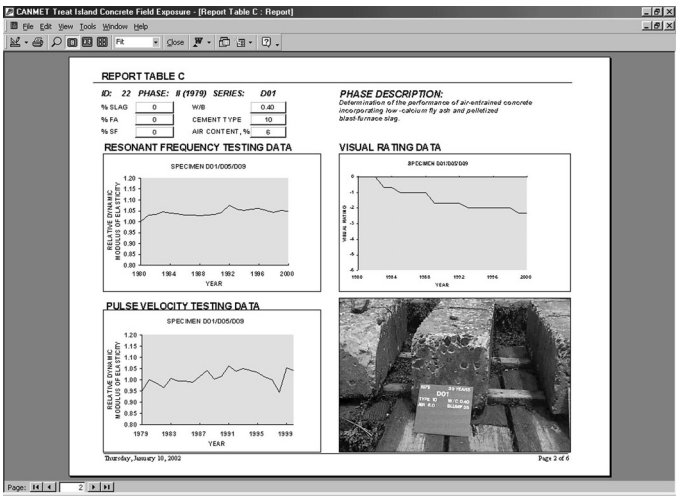
Owing largely to the international success of the CANMET database (Kondratova et al. 1998), the US Army Corps of Engineers invited UNB to submit a proposal for the development of a similar stand - alone multimedia computer database for all Treat Island site programs.



(a)



(b)



(c)

Figure 1. CANMET database: a) Specimens comparison Report; b) Historical Report; c) NDT and Visual Evaluation Report

However, in consultation with the US Army Corps of Engineers staff, it was decided that a Web-based information system should be created instead. The decision was based on the understanding that an online version would be easier to use and maintain, and, in addition, it would provide worldwide access to research findings at the Treat Island exposure site.

2.5 Site design and navigation

The architecture of the site (US Army Corps of Engineers, 2001) was chosen so as to allow users to get the information they need with as few clicks as possible. The Main page of the Natural Weathering Exposure Station Treat Island Web site allows easy information navigation through the links to the individual research programs. The user can also visually locate specific specimens using maps of the exposure rack and the beach, and find information using the keywords option.

Each research program at Treat Island is presented on the Web site with a page containing a general description of the program, a photograph, and a link to a data page (Fig. 2).

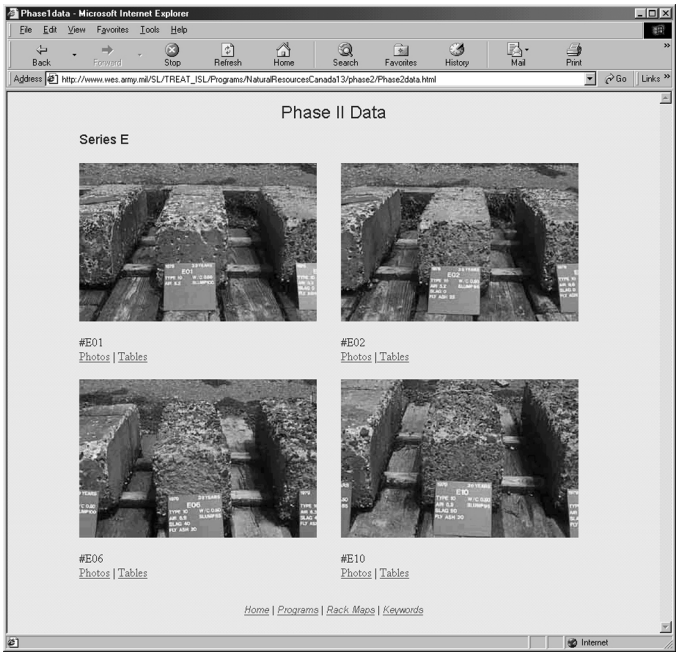


Figure 2. US Army Corps of Engineers Web-based information system

The data page includes thumbnail photographs of the specimens involved in the program and, in turn, leads to the third and forth design layers. These layers give detailed information on the concrete mixture design, NDT testing data, and present historical photographs of test specimens.

To account for the fact that reading from computer screens is about 25% slower than reading from paper sources (Nielsen, 2000), short descriptions of the programs were written so that the user would be able to see the entire program description on the computer screen without extra scrolling.

2.6 Current use of the US Army database

The Natural Weathering Exposure Station Treat Island Web-based information system was first presented to an audience of engineers and concrete scientists during the semi-annual inspection at Treat Island in August of 2000 and received excellent comments from the audience. They stated that the information system provided excellent visualization capabilities for research programs, and improved decision support potential.

However, currently only a few North American scientists and US Army researchers are using the data in the online database. Clearly, a new and more effective approach is needed in order to promote to the full extent the wealth of knowledge in the database and improve the flow of information dissemination and exchange for concrete durability research programs at Treat Island. This new approach will greatly benefit worldwide dissemination of research results on sustainable concrete.

3 NEW APPROACH TO KNOWLEDGE DISSEMINATION

3.1 "Knowledge exchange" environment

The authors believe that in order to facilitate the rapid development of expertise in strategic areas of research and, at the same time, channel knowledge and technology to the industry, government research laboratories should take a leading role in the creation of online virtual research environments.

These Web-based 'knowledge exchange" places would allow scientists and practitioners worldwide to discuss research results and technical issues, and would facilitate creation of the "virtual communities of researchers" where scientists will be able to work on joint projects regardless of their physical location. This model of an online research environment could also provide new opportunities for distance education of graduate students and young researchers (National Research Council, 2001).

The proposed knowledge exchange initiative would also provide a forum for private companies where they can ask questions, view "live" research results and get the most current information about scientific developments in a particular area.

3.2 Virtual Laboratory model

One of the possible models for this type of collaborative research environment would be the "Virtual Laboratory" model, where the Web site pro-

vides free access to the repository of scientific research results, search and retrieval tools, and a discussion forum for scientists, practitioners and private companies.

The participating research organizations, private companies, and industry practitioners will submit research artifacts (graphs, photographs, reports and preprint papers) in to the repository. A peer review process of submissions, by content experts from the user community, will be undertaken to assure the scientific value and quality of submissions. The technologies for creating the repository could vary, but, for the sake of interoperability and the ease of search and retrieval, XML technology seems to be the most appropriate.

Presentation of the data in XML format will also allow automated tools to extract the context of the data and to present it independently from the formatting in documents or databases. This will open research data to the "Semantic Web" world, a term that was first introduced by Tim Berners-Lee (Berners-Lee & Fischetti, 1999) to describe the World Wide Web that supports the exchange of knowledge online.

Search and retrieval tools for the repository should be based on both, content and metadata. In addition, to facilitate discussion of scientific results, it is very important to incorporate advanced search and retrieval capabilities into the discussion forum.

Over the years, the model of communications, using a data repository and discussion forum for information exchange, has become a popular choice for IT industry, including the open source software development community (World Wide Web Consortium, 2002) and technology consumer products Web sites (Digital Photography Review, 2002). We believe that it could also, potentially, bring significant benefits in the area of scientific information dissemination and exchange.

The Virtual Laboratory model will provide an environment of a "live" and dynamic scientific forum, where scientists will exchange information about new projects and research directions, get peer reviews of their research data and publications, and get valuable feedback from the industry. On the other hand, users from the industry would be able to follow the "cutting edge" research directions, and to receive answers to their questions from worldwide experts in the field. Currently a similar Virtual Laboratory for structural modeling of building structures is under development as a part of the ISTforCE project (Cervenka & Pukl, 2001).

3.3 Virtual concrete laboratory

According to a recent survey on the impact of information technology on the Canadian AEC industry (Rivard, 2000), the industry has quickly jumped on the Internet bandwagon. The survey found that that 86% of the architectural firms, 97% of the engineering firms, and 83% of the contractors surveyed are connected to the Internet. Thus, the Internet is rapidly becoming a natural communication medium for efficient technology transfer to the construction industry. The AEC industry is ready for using new electronic information exchange approaches.

As an example, applying a new approach to knowledge dissemination for the development of sustainable concrete, would involve the creation of the Concrete Virtual Laboratory Web site and information repository. The repository will include the US Army Corps of Engineers and CANMET databases on durability of concrete, as well as other research data. New submissions to the repository will be solicited from researchers all over the world, cement manufacturers, and the construction materials industry.

Engineers and construction companies would be able to use the repository of this Virtual Laboratory to search for durable and environmentally friendly materials, and to support the decision-making process on the choice of environmentally friendly concrete for the construction projects. They will also be able to post questions on the forum discussion board, and get answers from the experts. Researchers would be able to discuss their research results and conduct collaborative work, and new researchers could get valuable feedback from senior colleagues.

The proposed Virtual concrete laboratory will fill the knowledge gap in the area of "green" and durable concrete left by the existing popular concrete industry web sites, such as British Cement Association (2001), American Portland Cement Association (2002), National Research Council Canada Institute for Research in Construction (2002) and American Concrete Institute (2002). These sites also do not provide free access to a research knowledge base, and information exchange capabilities.

4 RECOMMENDATIONS

Results of research programs carried out by government laboratories, especially programs related to sustainable economic development and environment, should be available at no cost to all AEC companies via the Internet.

The important task of providing free and up-to date research information on environmental benefits and durability of concrete could be accomplished by establishing a Virtual Laboratory for environmentally friendly and sustainable concrete.

This Virtual Laboratory will facilitate collaborative information exchange between concrete researchers and construction companies, provide information on the current state-of-the-art research, and promote best practices. The existing concrete databases, including CANMET and the US Army

Corps of Engineers information systems, potentially could form an essential part of the research data repository for this future "green" concrete forum. Using XML technology for this repository will facilitate search and retrieval, reuse and creation of new information.

A discussion forum should become an essential part of the Virtual Laboratory and provide a place for scientific discussions, expert opinions and questions. The "peer review" option for all research materials posted on the site would support information credibility.

The proposed new model of the information dissemination and exchange is also applicable to other areas of knowledge in Engineering and Science and has a potential to improve scientific discovery, information dissemination, and technology transfer process for government R&D organizations and universities.

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