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IT PROVIDING A PATH FROM RESEARCH TO PRACTICE – PROMOTING USE OF ENVIRONMENTALLY FRIENDLY CEMENT AND CONCRETE IN CONSTRUCTION

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ABSTRACT
Developments in IT are rapidly changing the ways in which we communicate research results to provide timely technology transfer to the construction industry. This paper presents a computer database and a Web-based information system that were developed to disseminate the results of a long-term CANMET and U.S. Army Corps of Engineers studies on the durability of marine concrete incorporating supplementary cementations materials. These information systems provide tools to visualize the results of extensive field studies and support an informed decision-making on the choice of environmentally - friendly concrete for marine projects. The paper discusses some issues associated with the design and maintenance of concrete durability information systems and the need to develop a Web portal for Sustainable Development of Cement and Concrete that would provide collaborative environment for concrete researchers all over the world to share information on concrete durability, provide on-line training materials for construction companies, and offer professional services.

KEYWORDS
Information Technology, Web-Based Information Systems, Databases, Supplementary Cementing Materials, Concrete Durability

1. INTRODUCTION

The world needs environmentally friendly concrete. We strive to reduce the construction industry's contribution to global warming and at the same time, utilize accumulated amounts of industrial by-products. These by-products could be used as valuable additives or replacement for high energy content Portland cement, which represents 42% of the total concrete production energy cost (Malhotra et al, 1976).

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 (Malhotra, 1999). The 1997 Kyoto Protocol calls for countries to reduce their collective emissions of greenhouse gases (including CO_2) by 5.2 per cent below 1990 levels by 2012. For Canada specifically, the goal is to reduce emissions by 6 per cent below 1990 levels between by 2012, an annual emission target of 565 mega tones CO_2 equivalent (Wilkinson and Cairns, 2000). The

need to reduce the environmental impact of concrete was recognized in a recent Report of the Strategic Development Council published in Concrete International, March 2001. 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, concrete scientists have a responsibility to effectively disseminate the results of scientific studies on durability of environmentally friendly concrete to the concrete practitioners in North America and all over the world.

2. "GREEN CONCRETE" DURABILITY

2.1. US Army Durability Research Programs at Treat Island

Treat Island Natural Weathering Exposure Site goes back to 1937 and is the most comprehensive long-term concrete exposure site in the world. The site is located at Treat Island in Cobscook Bay near Eastport, Maine and is near the Canadian border at the entrance to the Bay of Fundy. 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 programs include the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, CANMET, the Construction Productivity Advancement Research program (CPAR), and private industry, with about 40% of specimens from Canadian agencies (Farny, 1996).

At the site, the test prisms are positioned on a rack at mid-tide level, so that they are exposed alternatively to a marine atmosphere, and immersion in seawater twice daily. The alternating cycles of immersion and exposure to air provide over 100 cycles of freezing and thawing per year. Experience, acquired at the site over the past six decades, has shown that concrete that successfully resist these exposure conditions will normally provide good long-term performance in marine facilities.

2.2. CANMET Research on Concrete with Supplementary Cementing Materials

The Canadian Center for Mineral Energy Technology (CANMET) has an ongoing program dealing with the long-term performance of supplementary cementing materials in concrete (Malhotra and Bremner, 1996). This program focuses on the use of fly ash, pelletized and granulated blast-furnace slag and silica fume, as a cement replacement. To make sure that supplementary cementing materials could be used in marine structures without adversely affecting the long-term durability of concrete, CANMET in 1978, began a comprehensive testing program that is still continuing. This entailed casting a series of concrete prisms, with various amounts of supplementary cementing materials, in order to identify to what extent these materials can be incorporated into concrete to produce durable marine facilities. To evaluate the concrete, specimens (prisms 305x305x915 mm) were placed at an outdoor marine exposure facility operated by the U.S.A. Army Corps of Engineers. Recently CANMET set up an International Center for Sustainable Development of Cement and Concrete (ICON) that currently is leading the program on the use of supplementary cementing materials in concrete.

All concrete specimens at Treat Island site are inspected each year. Inspection includes photographing, visual examination, visual rating and non-destructive testing (NDT) measurements for each specimen. NDT measurements include measuring the speed of sound through the concrete and determination of the transverse resonant frequency of the concrete prisms that give estimate of the change in the relative dynamic modulus of elasticity of concrete during the exposure. The voluminous data generated annually for the CANMET study on the use of supplementary cementing materials in concrete was normally handled manually. However, the large size of files and the need to examine the visual appearance of concrete from the photographs and consolidate that with the NDT measurement results became unwieldy, and, as a result, a multimedia computer database was developed in 1995 (Kondratova et al, 1998).

3. MULTIMEDIA DATABASE

3.1 Database Design

By 1995 the CANMET study generated over 10,000 units of data and more than 3000 color photographs. To ease the handling of this large amount of data, the Canadian Federal Department of Supply and Services awarded a

contract to the Materials Group at the Department of Civil Engineering, University of New Brunswick (UNB) for the development of a computer database for the CANMET specimens at Treat Island.

To provide for better data visualization capabilities, UNB researchers decided to present data as a multimedia computer database, as opposed to a text-only database. 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 NDT testing and visual evaluation. This data is updated automatically when a user starts the database. To keep the charts and the photographs current, the database design allows easy data updates after the annual inspections.

3.2 Database Management Software

In order to access and compare the accumulated research data easily and efficiently, a Microsoft® Access for Windows® 95 database management system was utilized to create a relational database with the potential to store all data records, hold photographic images and charts, and perform search and query operations. Microsoft® Access has a graphical design environment for creating and modifying tables, forms, reports, queries and macros and enables the user to place graphics in forms and reports. Thus a single record can contain a word-processing document, Excel chart and a photograph. In 1998 the database was updated to Microsoft® Access 97 version, and more recently to Microsoft® Access 2000. The additional advantage of using Microsoft database management software is that MS Access is a part of the Microsoft Office Professional, which is a standard software suite for the Canadian Federal government, is easy to use, relatively inexpensive and also readily available to industry practitioners.

3.3 User Interface Design

The database interface includes three menus. The Main menu allows the user to choose among three different formats of data presentation, and navigate to two other menus - Reports and Forms. In consultations with CANMET scientists, developers chose three data presentation formats.

3.3.1 Specimen comparison reports

This format allows the selection of specific specimens from a table, so that the photographs of several specimens can be displayed together on a computer screen. This enables different specimens of similar age to be compared visually. Data for all specimens is presented as a table with all the essential information about the concrete specimens, including a phase of the research project, year when specimens were placed at the exposure site, age of the specimen when the photographs were taken (5, 10, 15, 20 years etc.) and details of the mixture proportions, including type and the amount of supplementary cementing materials added. After the user chooses the specimens to review, the query is displayed in a report form (up to four specimens on one page) with an unlimited number of pages to be displayed. The report can be viewed on a computer screen and printed.

This data presentation format gives the concrete specialist a unique opportunity to view and compare, side-by-side, the visual history of different concrete mixtures, evaluate the performance of concrete specimens with supplementary cementing materials in severe marine exposure conditions, and make informed decisions about the choice of materials for a project.

3.3.2 Historical reports

The historical report format enables selection of a specific specimen from a table and displays photographs of it taken at 5, 10, 15, 20 and more years of exposure, along with details of the concrete mixture design. The user can choose specific specimens to review and generate a visual report on the performance of a particular type of concrete in a severe marine environment.

3.3.3 NDT and visual evaluation reports

This format enables selection of a specific specimen from a table, with a display of the visual rating, pulse velocity and resonant frequency testing data for all years, as a graph of performance vs. years of exposure, along with a detailed description of the specimen and its most recent photograph. NDT data presentation format allows the user to correlate the results of NDT testing expressed as a relative dynamic modulus of elasticity (durability measure)

with visual appearance for a particular concrete specimen, thus expanding the range of information available for decision support on the choice of durable marine concrete.

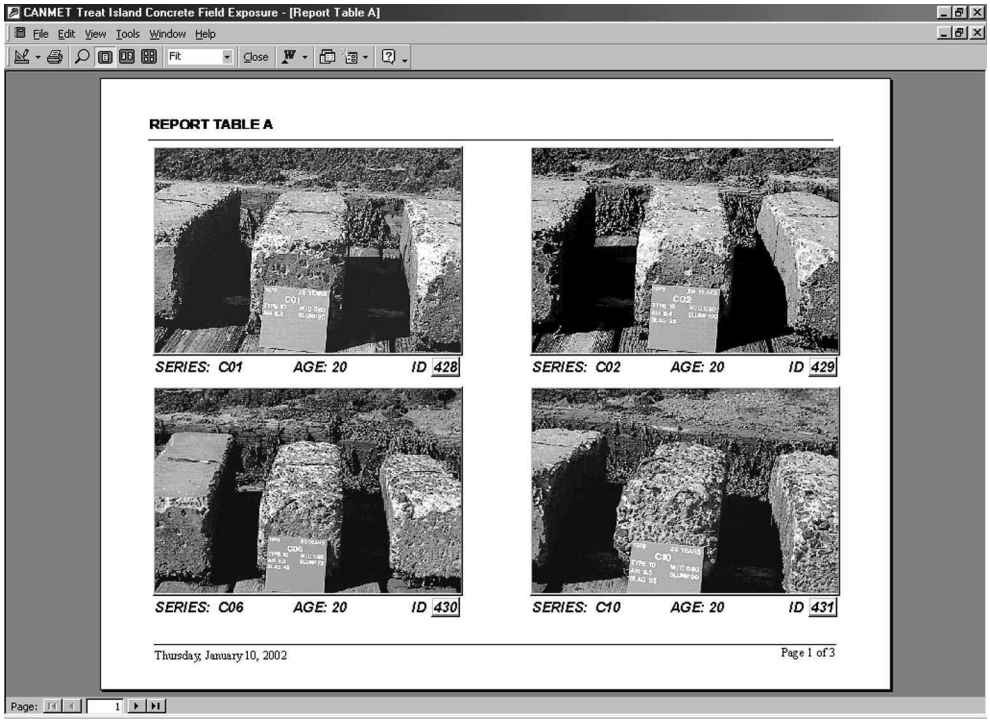

Figure 1: Specimens Comparison Report

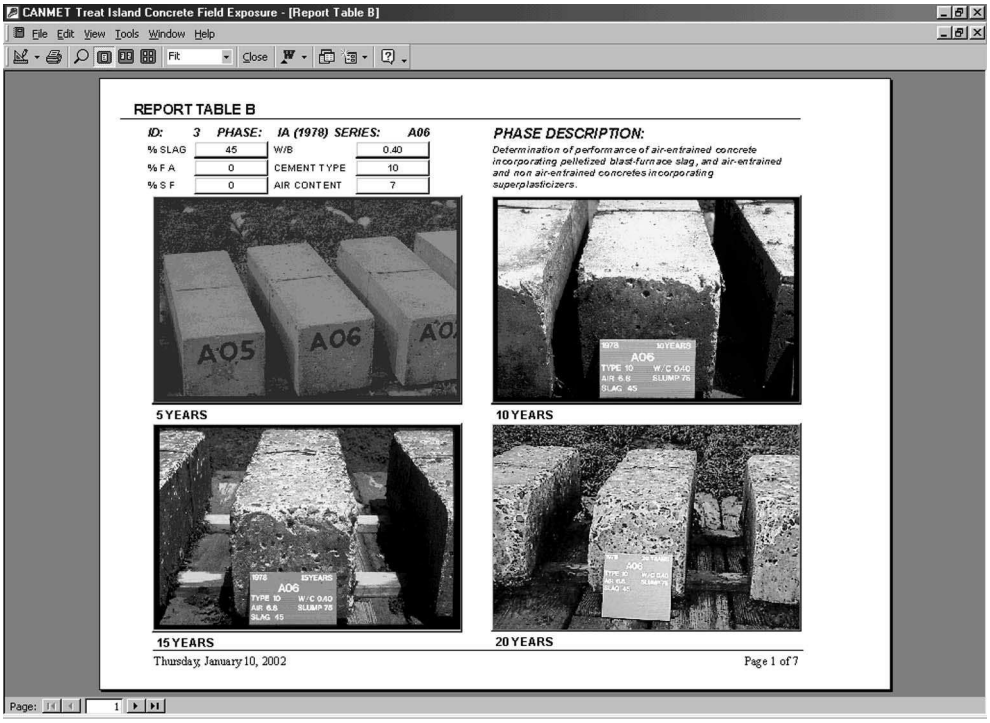

Figure 2: Historical Report for a Specimen at Treat Island

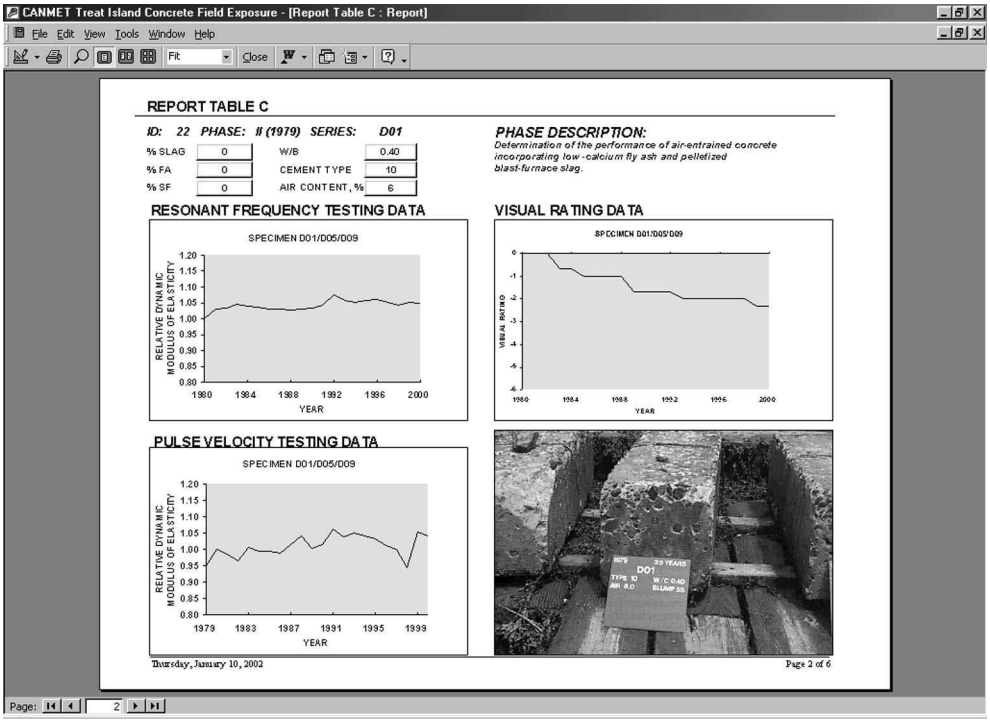

Figure 3: NDT and Visual Evaluation Report for a Specimen at Treat Island

3.4 Database Maintenance and Data Entry

Data entry into the database is handled through the forms that are used as index cards for every specimen with all the data entered in a convenient visual format. The photographs of specimens exposed at Treat Island site are taken annually. Up to 1996 photographs and slides of all of the individual specimens were taken with a 35-mm film camera and then stored for future reference. In order to enter these records into the database, slides of the individual specimens needed to be digitized. Starting with the summer of 1997, a digital camera is being used for taking photographs of the specimens at the exposure site. This enables convenient storage and easy incorporation of new photographs into the database.

To provide for the ability to closely examine the condition of concrete, all the images incorporated into the database are saved with resolution that permits the image to be enlarged by 200% without degrading the image quality, as well as to be incorporated into the printed report. The downside of this approach is that the size of the database is becoming rather large and should be kept below 650 MB to allow for CD-ROM distribution.

Pulse velocity and resonant frequency testing is being done every year on-site at Treat Island during the annual inspection of the specimens. Each year this data are entered into the Excel spreadsheets that are linked to the specimen record in the database, thus the database is automatically updated with the current NDT testing results.

4. WEB-BASED INFORMATION SYSTEM

Until last year, the findings of more than 40 various programs at Treat Island administered by the U.S. Army Corps of Engineers were not easily accessible to the engineering community and industry practitioners. Normally, to present the findings of the various research programs at the site, a visitation is scheduled on even numbered years and usually about thirty engineers, who are invited by the Corps of Engineers, attend 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. Also, most of the research programs at Treat Island rely to some extent on visual examination and the results are difficult to present in a technical publication.

4.1 System Design

U.S. Army Corps of Engineers were looking for better ways to disseminate the results of the Treat Island studies, and were interested in exploring how Information Technology can help them achieve this. Owing largely to the international success of the CANMET database that was presented at the First International Conference on New Information Technologies for Decision Making in Civil Engineering in 1998, the US Army Corps of Engineers invited UNB to submit a proposal for the development of a similar multimedia computer database that would visualize the results of all research programs at Treat Island and provide easy access to research findings for concrete practitioners and construction companies.

The initial plan was to develop a multimedia database using MS Access database management software, however, in consultation with US Army Corps of Engineers staff, it was decided to create a web-based information system instead, that would be easier to use and maintain, and that would provide worldwide access to the research findings at the Treat Island exposure site.

4.2 Site Architecture

Currently the Treat Island Web-based durability information system (U.S. Army Corps of Engineers, 2001) contains information on 37 long-term research projects, including studies on the use of supplementary cementing materials for marine concrete (CANMET); high strength and high performance concrete, supplementary cementing materials to lower cement consumption, and high-performance repair materials for concrete structures (US Army Corps of Engineers); concrete corrosion inhibitors and epoxy coatings (University of New Brunswick and Master Builders); and high performance semi-lightweight concrete (Exxon Mobil).

The architecture of the US Army Corps of Engineers site 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 the information using keywords option.

Each research program is presented using a general description and a photograph, with a link to a data page, which includes thumbnail photographs of the specimens involved in the program and, in turn, leads to the third and forth design layers, which give information on the concrete mixture design, non-destructive testing data, and photographic record of test specimens. To enhance the user experience and ease the navigation, the developer used standard page formats and kept pages consistent, so as, to allow the user to understand the common format and then use it efficiently.

5. DISCUSSION

Research shows that concrete as a construction material has the advantage of being an environmentally friendly material, due to its low maintenance, low energy consumption, and potential to act as a sink for liquid combustible hazardous and silica rich industrial wastes (Bremner, 2001). However, to transfer “green” concrete technology to the industry, the concrete research community should aggressively promote the environmental benefits of concrete.

Today in the Information Technology Age, the easiest and the most effective way to do this is to disseminate the research findings on the excellent durability of concrete incorporating industrial by-products using the Internet as a medium. The advantages of using a web-based format to present findings of scientific research are enormous.

On the Internet the information is available anytime, anywhere and the user does not require special training, just basic Internet skills, to access the information. Another advantage is that the information posted on the Web is available at no additional cost to all the construction companies that have Internet connection, and, according to a recent survey on the impact of information technology on the Canadian construction industry (Rivard, 2000), the industry has quickly jumped on the Internet bandwagon since it became popular in 1995. 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 Natural Weathering Exposure Station Treat Island Web-based Information System was first presented to the 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. However, more work needs to be done on promoting the US Corps of Engineers Treat Island Web site to the construction industry in Canada and U.S.A. and to concrete practitioners worldwide.

6. CONCLUSIONS

According to Mehta, "…the greatest challenge that the concrete industry faces during the 21st century is to achieve a sustainable pattern of growth" [10]. The task is tremendous, but we can accomplish this by making an industry-wide paradigm shift to the culture of conservation of energy and materials. Research on "green" concrete is being done in a large number of countries and the results are largely positive, but what seems to be lacking is the dissemination of this knowledge to a broader audience (Mehta, 2001). This could be accomplished by establishing an Internet Portal for Environmentally Friendly and Sustainable Cement and Concrete Industry that would facilitate collaborative information exchange between concrete researchers on the use of industrial by-products in concrete, and provide information on the current state-of-the-art of environmentally friendly concrete with respect to strength and durability. Both, CANMET and the US Army Corps of Engineers concrete durability information systems potentially could form an essential part of this distributed "green" concrete forum.

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8. REFERENCES

Bremner, T. W. (2001). "Environmental aspects of concrete: problems and solutions", *Proceedings of the First all Russian Conference on Concrete and Reinforced Concrete*, Editors: NIIZhB, Moscow, pp.232-246.

Farny, J. (1996). " Treat Island, Maine – the Army Corps' outdoor durability test facility", *Concrete Technology Today*, PCA, Vol. 17, No.3, pp.1-3.

Kondratova, I., Bremner, T., Goldfarb, I. and Malhotra, V. M. (1998). "Computer database for concrete specimens at a marine exposure site", *Proceedings of the First International Conference on New Information Technologies for Decision Making in Civil Engineering*, Editors: Edmond T. Miresco, Vol.2, pp. 803-811.

Malhotra, V.M. (1999). "Making concrete "greener" with fly ash", *Concrete International*, Vol.21, No.5, pp.61-66.

Malhotra, V.M. and Bremner, T.W.(1996). "Performance of concrete at Treat Island, U.S.A.; CANMET investigations", A*CI Special Publications, SP-163*, pp.1-52.

Malhotra, V.M., Berry, E.E., and Wheat, T.A. (1976). *Proceedings of the Seminar on Energy and Resource Conservation in the Cement and Concrete industry*, CANMET, Ottawa, Canada.

Wilkinson, C. and Cairns, S. (2000). "Negotiating the climate", David Suzuki Foundation, 33 pp.

Mehta, K. (2001). "Reducing the environmental impact of concrete", *Concrete International*, October 2001, Vol.23, No. 10, pp.61-66.

Plenge, W.H. (2001). "Introducing vision 2030: our industry's 30-year map to the future", *Concrete International,* March 2001, Vol. 23, No. 3, pp. 25-34.

Rivard, H. (2000). "A survey on the impact of information technology on the Canadian architecture, engineering and construction industry", *Electronic Journal of Information Technology in Construction*, Vol. 5, http://www.itcon.org/2000/3

U.S. Army Corps of Engineers. (2001). "Natural Weathering Exposure Station Treat Island, Engineer Research and Development Center Geotechnical and Structures Laboratory", http://www.wes.army.mil/SL/TREAT_ISL/index.html