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Publisher's version / Version de l'éditeur:

CANMET/ACI International Conference on Durability of Concrete,, 2003

National Research Council Canada
Institute for Information Technology

Conseil national de recherches Canada
Institut de technologie de l'information

NRC · CNRC

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June 2003

* published in Proceedings of the Symposium on High Performance Lightweight Concrete Honoring the Extraordinary Contributions of Professor Theodore Bremner. CANMET/ACI International Conference on Durability of Concrete, June 1-7, 2003, Thessaloniki, Greece. NRC 45796.

Canada

How Information Technology Can Help Sustainability and Aid in Combating Global Warming

by I. L. Kondratova and I. Goldfarb

Synopsis: This paper discusses the evolution of different methods of disseminating the results of research programs on durability of concrete at the US Army Corps of Engineers Treat Island marine exposure site; beginning with paper reports, and evolving into deployment of modern information technology tools such as a multimedia computer database and a Web based information system. Theses information systems allow side-by side comparison of historical photographs and testing results for different concrete mixtures and support decision-making on the choice of environmentally friendly and durable concrete. With the help of these tools, an easy comparison of the performance of lightweight and normal weight concrete from long-term testing programs at the Treat Island site becomes possible. The results clearly show that structural lightweight and semi-lightweight concrete provides long-term durability in a marine environment. The authors also discuss the advantages of using modern IT tools for research, education and technology transfer for the industry.

Keywords: database; durability; information technology; Internet; structural lightweight concrete; nondestructive testing.

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INTRODUCTION

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 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 (1).

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" (2). To achieve this goal, government research laboratories and construction industry professional associations have a responsibility to effectively disseminate the results of scientific studies on durability of environmentally friendly and sustainable concrete, including lightweight concrete, to concrete practitioners.

Research on sustainable 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 (3). Fortunately, the Canadian federal government, and, in particular, Natural Resources Canada (NRCan) is starting to realize the value of knowledge and information on sustainable development and is committed to providing Canadians with the required knowledge: "Given the importance of natural resources in our everyday decisions, NRCan must be able to create, share and communicate the knowledge and information Canadians require" (4). Slowly, but steadily, it becomes widely recognized, within the Civil Engineering community, that there is a growing need for an easily accessible and credible source of knowledge on environmentally friendly concrete.

INTERNET AS A NEW KNOWLEDGE DISSEMINATION CHANNEL

New Paradigm of Information Dissemination

According to the author's experience, information technology can be used very effectively to communicate accumulated knowledge on sustainable development (5). All industrialized countries are currently in the process of a fundamental paradigm shift associated with the movement from the Industrial Age economy of production and consumption to the new Digital Age economy. This new economy is based largely on information and communication technology, and on the digitization of information (6). To better utilize the value of this information, the knowledge-based economy is moving towards more efficient electronic models of information dissemination. A new model of information dissemination is emerging, one that utilizes the Internet as a medium for knowledge exchange, sharing and technology transfer.

The research and scientific community is also in the process of moving away from the old "information spread" model for dissemination of scientific information (7), where knowledge is normally channelled through refereed academic journals and conference proceedings following the traditional Garvey-Griffith model of a scientific communication system (8). Researchers are becoming increasingly involved in publishing their articles in online-refereed journals that provide free or low fee access to scientific information (9).

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 in the strategic research areas such as nuclear and fusion energy research (10,11) but the majority of scientific information is still posted, mostly in the "information spread" mode, as in the case of online publications.

Lightweight Concrete Online

To evaluate the state of information dissemination in the area of lightweight concrete, the authors of this paper thoroughly researched online resources on lightweight concrete and found only few available. The most comprehensive source of information on lightweight concrete and, particularly, on structural lightweight concrete found was a web site of the Expanded Shale, Clay & Slate Institute - ESCSI (12). The ESCSI site provides detailed information on structural lightweight concrete; lightweight concrete aggregates, national and international companies-members, and has links to some comprehensive state-of-the-art reports and publications on the long-term performance of lightweight concrete. (13,14).

The Solite Corporation web site (15) also provides information on structural lightweight concrete, but does not cover the durability aspect, which is quite important to ensure wide spread acceptance and use of lightweight concrete. Concrete Network (16) claims to be the number one source of information on residential concrete, but does not provide any substantial information on lightweight concrete usage and production. The ACI web site (17) provides paid access to the comprehensive database of research reports, standards and ACI publications on lightweight concrete, but is set up more like a large library catalogue than a site of a professional organization that has a mandate to promote concrete knowledge. The American Portland Cement Association (18) maintains a comprehensive Web site related to cement materials and concrete, but our search for "lightweight concrete" and "lightweight aggregate" on this site did not retrieve any results. Lightconcrete.com (19) by Plan City / National Concrete Services LLC in Tuolumne, California promotes the usage of high-strength lightweight cellular concrete, and gives detailed information on its use. However, the site does not provide names and credentials of professionals involved, thus, in our opinion, lacks scientific credibility.

US Army Corps of Engineers Engineering Research and Development Centre (20) offers free online access to an excellent Digital Archive of full text ERDC publications and reports. This is a valuable source of information for civil engineering materials and concrete. The US Army Corps of Engineers Web site maintains another valuable resource on concrete, and in particular, on lightweight concrete - a complete Web based information system on the concrete durability research at Treat Island (21).

We found that even the most comprehensive of the above-mentioned online resources on lightweight concrete lack the depth and breadth of coverage of the topic. For a person seeking information on lightweight concrete, be it a homeowner, a concrete researchers, or a representative from the industry, it would be beneficial to have a "one stop" complete information source on production, properties, use, and environmental advantages of lightweight concrete – a Lightweight Concrete Portal. This Lightweight Concrete Portal should contain repository of scientific reports, research papers as well as raw testing data for lightweight and normal weight concrete. To demonstrate the advantages of using raw digital experimental data for research and decision-making, the success story of a computer database and an online resource for the long-term concrete testing at Treat Island, Maine will be discussed.

CONCRETE DURABILITY RESEARCH AT TREAT ISLAND

The Treat Island natural weathering exposure site dates 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 clay, shale and 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 at Treat Island include the U.S. Bureau of Reclamation, the US Army Corps of Engineers, the Canadian Centre for Mineral and Energy Resources (CANMET), the Construction Productivity Advancement Research program (CPAR), and private industry, with about 40% of specimens from Canadian agencies (22, 23).

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.

All concrete specimens at the Treat Island site are inspected yearly. Inspection is carried out by the Materials Group, Department of Civil Engineering, University of New Brunswick (UNB) in Canada. Inspection includes photographing, visual examination, visual rating and non-destructive testing (NDT) measurements for each concrete specimen. NDT measurements include measuring the speed of sound through the concrete and determination of the transverse resonant frequency of the concrete prisms - a process that estimates the change in the relative dynamic modulus of elasticity of concrete during exposure, thus giving a measure of concrete deterioration.

Evolution of Information Dissemination Mechanisms

Until 1995, the findings of various research programs at Treat Island were not easily accessible to the engineering community and industry practitioners. To present these findings, visitations were 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 annual research reports and a relatively limited number of technical papers that needed to be brought to the attention of practicing professionals and of the construction industry.

CANMET Database

The 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 concrete durability studies (24). The researchers of the Materials Group, UNB, developed the database. To provide for better data visualization capabilities, research data were presented as a multimedia computer 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 non-destructive testing (NDT) and visual evaluations. The CANMET database was developed as a stand-alone CD-ROM database and is updated annually following the summer testing and inspection.

The database design allows side-by side comparison of historical photographs and testing results for different concrete mixtures and supports decision-making on the choice of environmentally friendly and durable concrete. Unfortunately, the database is not accessible via the Internet, which makes this valuable resource virtually inaccessible for concrete practitioners and the construction industry.

US Army Web Based 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 the US Army Corps of Engineers invited UNB's Materials Group to submit a work proposal for the development of a similar multimedia computer database for all Treat

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

Currently the Treat Island Web-based durability information system (25) contains information on 37 long-term research projects, including studies on the use of supplementary cementing materials and lightweight aggregates 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 design of the US Army Corps of Engineers site allows easy information navigation through links to the individual research programs. The user can find information using a keywords option; also experienced users can visually locate specific specimens using maps of the exposure rack and the beach area.

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 individual specimens involved in the program, which, in turn, leads to the third and forth design layers, which provide information on the concrete mixture design, non-destructive testing data, and a historical photographic record of test specimens.

LIGHTWEIGHT CONCRETE AT TREAT ISLAND

The authors will now demonstrate how CANMET and US Army Corps of Engineers information systems can be used to retrieve information on the long-term performance of lightweight concrete in a severe marine environment. Data for all specimens in CANMET database is presented as tables with all the essential information about the concrete specimens, including the 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. Using the CANMET database, it is easy to pick particular specimens right from the table. This allows the photographs of several specimens to be displayed side-by-side on a computer screen and enables different specimens of similar age to be compared visually.

The table query is displayed in a report form. The report can be viewed on a computer screen and printed. In this paper we captured screen shots with specimen reports (Figures 1 - 4). Unfortunately, the CANMET database currently does not contain all the details on specimens and, therefore, when used for performance analysis, should be supplemented by data from the US Army Corps of Engineers Treat Island online database, that has more details on concrete mixture design and compressive strength testing.

CANMET Semi-Lightweight vs Normal Weight Concrete

For a side-by-side comparison of lightweight and normal weight concrete of the same age using the CANMET database, we chose specimens from two CANMET phases, Phase II and

Phase III. Phase II concrete prisms contain air-entrained concrete incorporating different percentage of fly ash, and pelletized blast-furnace slag as cement replacement. Phase II specimens were installed at Treat Island in 1979. Phase III specimens contain air-entrained semi-lightweight concrete incorporating different percentage of pelletized blast-furnace slag as a cement replacement. Phase III was installed in 1980. For Phase III concrete, expanded shale was used as the coarse aggregate. In our example, in order to account for the possible effects of cement replacement on concrete performance, for comparison purposes we are using control specimens of Phase II series D (normal weight) and Phase III series I (semi-lightweight) that contain 0% of cement replacement.

Normal weight concrete specimens D1, D5, D9 have water-to-cement ratio of 0.40 and cement content of 395 kg/m^3. Semi-lightweight concrete specimens I1, I5 and I9 have cement content of 480 kg/m^3. Based on the US Army Web-based information system data, the average 28 days compressive strength for control concrete prisms of series D is 33 MPa. 28 day compressive strength for control lightweight concrete prisms of series I is 35.7 MPa.

Photographs of representative control specimens D1 and I1 after 20 years of exposure at Treat Island are presented in Figure 1. Visual comparison shows that after twenty years of severe marine exposure in a mid-tide zone both concrete types exhibit approximately the same low level of deterioration, indicating that semi-lightweight concrete has the same durability as normal weight concrete of low water-to-cement ratio.

In addition, using the data in the CANMET database, we can compare not only historical photographs of specimens, but also can retrieve and compare the results of nondestructive testing for both types of concrete. Based on more than twenty years of nondestructive testing results for concrete prisms made of normal weight and semi-lightweight concrete (Figures 2 and 3), it is clear that for semi-lightweight concrete the relative modulus of elasticity based on resonant frequency results is somewhat lower than for normal weight concrete of comparable quality. However, the relative modulus of elasticity for lightweight concrete based on pulse velocity testing data was steadily increasing for up to 12 years after exposure indicating strength gain, and only after this started to go down, indicating some degree of deterioration.

It is important to note the CANMET database query report on semi-lightweight concrete control specimens of series H with lower cement content (360 kg/m^3) shown in Figure 4. According to this report, control semi-lightweight concrete specimens of series H performed better than control semi-lightweight concrete specimens of series I with higher cement content (480 kg/m^3) as shown in Figure 3. By comparing Figures 2 and 4 we can also conclude that specimens of series H also performed better than normal weight concrete specimens of series D with a higher cement content (395 kg/m^3).

Hibernia Concrete at Treat Island

Similar conclusions about the excellent performance of structural lightweight concrete could also be drawn from the test results posted on the Natural Weathering Exposure Station Treat Island US Army Corps of Engineers Web site. For example, we can easily examine the results of the Exxon Mobil program (26). This program contains Hibernia modified density concrete reference blocks and cylinders. Four large concrete blocks (600 x 900 x 900 mm) were cast from the Hibernia production concrete used for the splash zone of the outer perimeter of the structure and were installed at Treat Island in October 1996. While in-service, the Hibernia platform concrete in the splash-zone is subjected to continual wetting and drying, freezing and thawing during the winter season, and abrasion from floating debris and ice. The location of the structure and its exposure to the strong wave action of the North Atlantic makes it extremely difficult to perform proper evaluations of in-situ concrete while in-service. The Treat Island Hibernia concrete program is designed to provide information on the general durability of Hibernia concrete with the passage of time. Based on the posted online results of pulse velocity testing (26), the Hibernia concrete blocks at Treat Island are sound and are steadily gaining strength.

These two examples of concrete evaluation based on the data contained in the CANMET database and the US Army Corps of Engineers online information system demonstrate the ease of information retrieval, use, and performance analysis using these IT tools. However, the information contained in these two information systems is by no means complete and, for the purpose of decision-making, could be and, we believe, should be supplemented by other available experimental data from external research programs.

CONCLUSION

According to Mehta, "…the greatest challenge that the concrete industry faces during the 21st century is to achieve a sustainable pattern of growth" (27). 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. This paradigm shift will be supported by another shift related to the use of information technology to utilize knowledge on sustainable construction materials, including lightweight aggregates and lightweight concrete. Knowledge utilization in this case includes technology transfer, information dissemination and utilization, research utilization, innovation, and organizational change (28) and, according to Paisley's research (29) "Digital technology brings the most significant new communication capabilities to knowledge utilization…"

Internet is here to stay. After the dot.com bubble burst in 2000, the current usage of the Internet in Europe is up by 14% and the number of Internet users in US and Canada in 2002 increased by about 26 million as compared to the year 2000 (30). The construction industry is ready to accept the Internet as the new knowledge utilization mechanism. A recent survey of Canadian AEC (Architectural, Engineering and Construction) Industry found that that 86% of the architectural firms, 97% of the engineering firms, and 83% of the contractors surveyed are all connected to the Internet (31). Thus, the Internet has the capability to become a natural communication medium for efficient technology transfer to the construction industry.

One of the proposed steps in utilizing the power of the Internet to promote lightweight concrete is to set up an International Web Portal on lightweight concrete. This portal could be based on an existing industry association Web site, for example the ESCSI site that already incorporates some essential attributes of a vertical industry Web Portal such as links to scientific information and to an industry forum. According to research studies (32), professional associations have great potential to play a mediating role in the diffusion of knowledge. They provide a forum for the creation of inter-organizational networks that, in turn, create the necessary channels for diffusion of information, knowledge and ideas that enable companies and organizations to bring technological innovation. However, individual members of the professional association can benefit from these opportunities only if they attend workshops, branch meetings, etc, which can be costly and time consuming.

Internet technology is removing these barriers. With a development of a full scale Portal, ESCSI, as an international industry association, could become a worldwide source of credible information and expertise in the area of lightweight concrete and will be in a position to directly influence innovation and technology transfer to the industry. A comprehensive Lightweight Concrete Portal, containing a repository of scientific reports, testing data and, possibly, information from the CANMET database and links to the US Army Corps of Engineers Treat Island information system, could also provide unique collaborative work and e-learning opportunities (33).

The model of scientific communication in this case will come closer to the modern scientific communication model (34). The most important feature in this new communication model, discounting modernized technology that supports traditional publishing functions and e-publishing process, is to include repositories of raw data on Internet servers, for use by researchers that wish to build on findings of others, or to create new knowledge by combining their own data with the data of others. The evaluation of the performance of lightweight concrete based on CANMET database and US Army Corps of Engineers online system is a very simple example of the use of this technology.

The proposed Lightweight Concrete Portal can be based on this model. Some information could be provided free of charge and some could be for members and subscribers only, similar to the model adapted by the highly successful CorrosionSource.com Web Portal that contains a knowledgebase of corrosion protection resources and a popular Discussion Forum for corrosion community (35, 36). The proposed model of an online collaborative environment would also provide new opportunities for distance education of graduate students and young researchers (37), and create a valuable communication and collaboration channel between private companies and researchers.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support provided for the information systems development projects by the Canadian Federal Department of Supply and Services, CANMET, the US Army Corps of Engineers and the National Research Council Canada. The authors also would like to acknowledge valuable advice and guidance of the Honorary Research Professor Theodore W. Bremner in the design and development of the CANMET and US Army Corps of Engineers concrete durability information systems.

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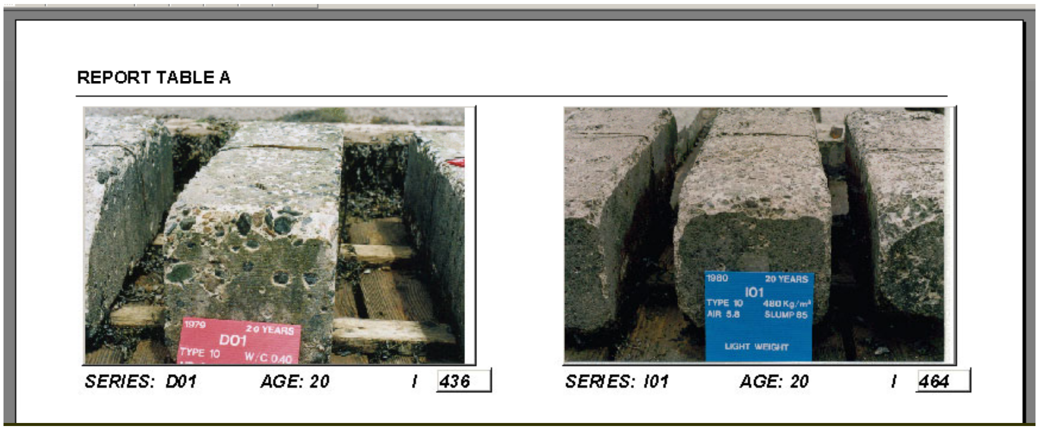

Fig. 1. Specimens comparison report for series D and I

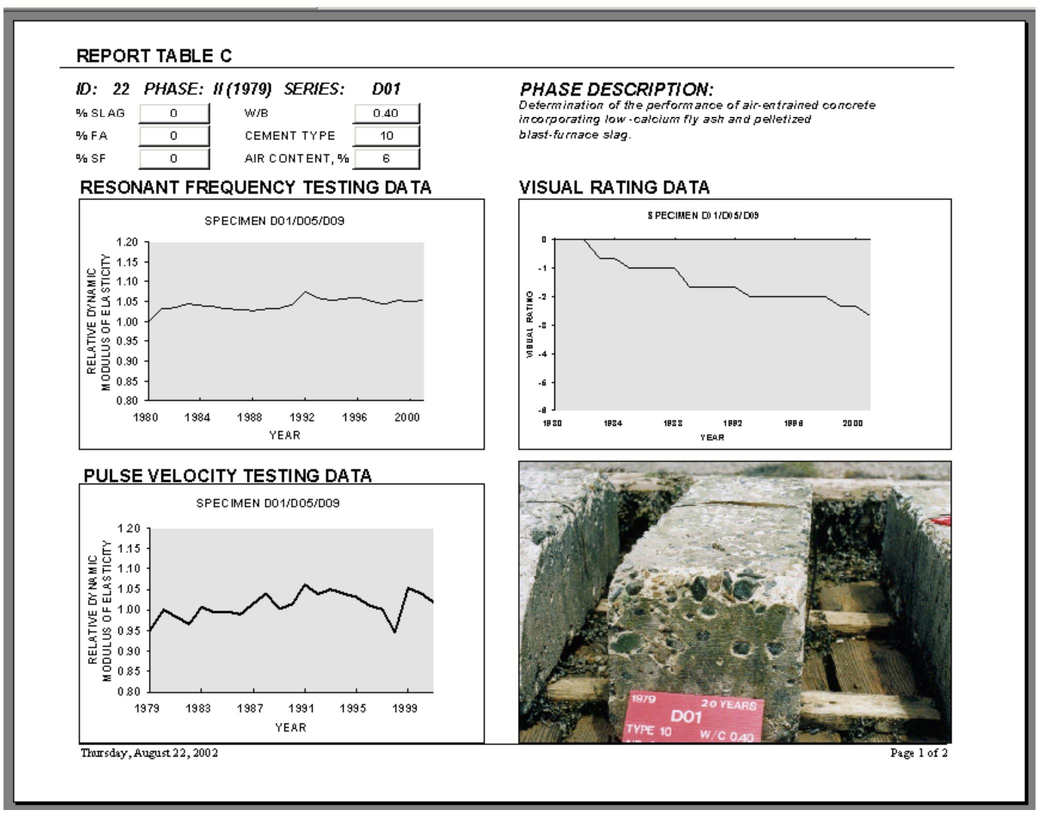

Fig. 2. NDT testing report for series D normal weight concrete specimens

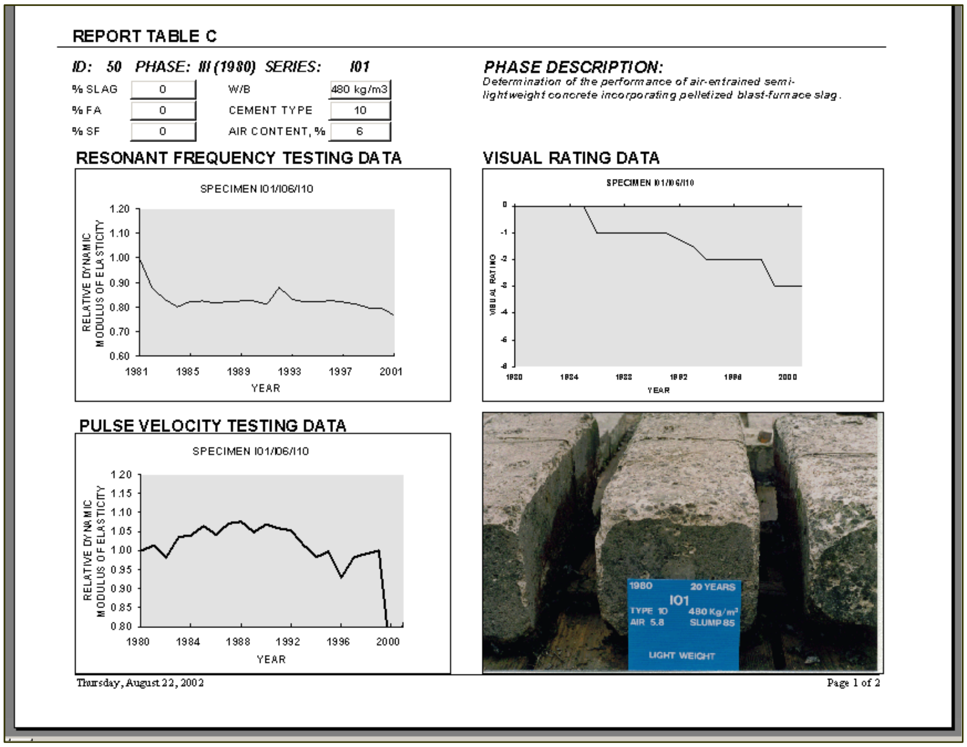

Fig. 3. NDT testing report for series I semi-lightweight concrete specimens

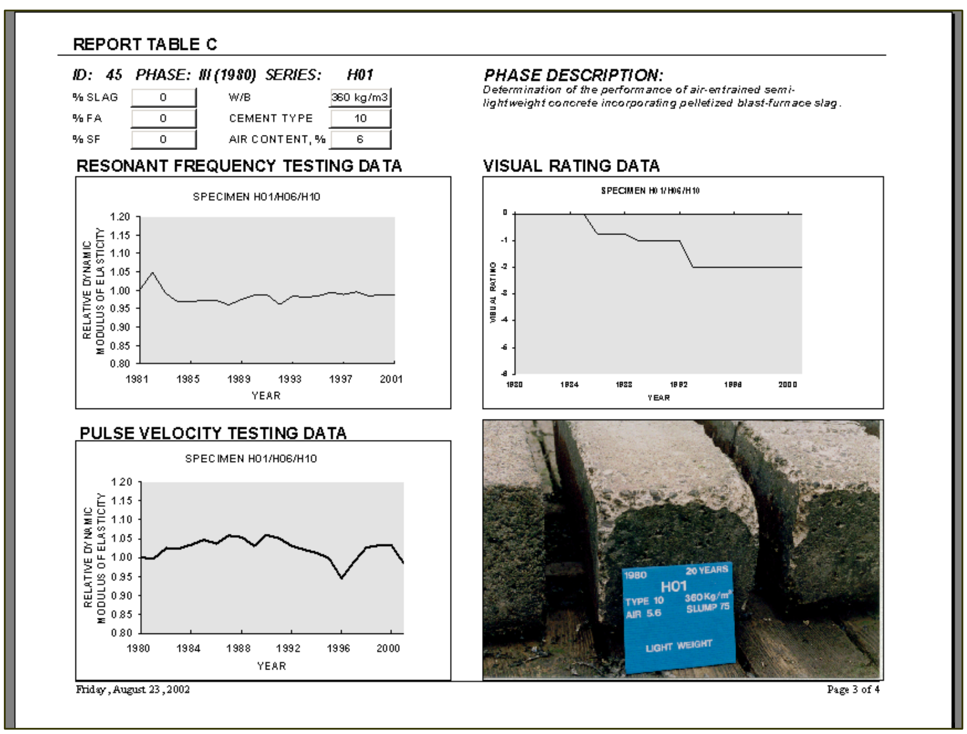

Fig. 4. NDT testing report for series H semi-lightweight concrete specimens