INNOVACIONES EN LA TECNOLOGIA DEL CONCRETO

por

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Sinopsis: Durante los últimos años, la industria del concreto ha experimentado avances excepcionales en el conocimiento relacionado con la tecnología del concreto y existe el potencial para continuar los avances durante la siguiente década. Nuestro principal problema parece ser la transferencia de estas innovaciones a los consumidores. El Contratista y el Diseñador continúan siendo los últimos de la cadena de transferencia de tecnología, en incorporar estos nuevos conocimientos a la práctica diaria.

El Programa Estratégico de Investigación de Carreteras (SHRP) recientemente ha completado un programa con valor de 150 millones de dólares para avanzar en el conocimiento de diseño y construcción de nuestras carreteras y puentes; el Cuerpo de Ingenieros del Ejército de los Estados Unidos ha terminado recientemente la Fase I e iniciado la Fase II del Programa de Investigación (72 millones de dólares) Reparación, Evaluación, Mantenimiento y Rehabilitación (REMR) para desarrollar nuevas técnicas para sobrellevar los problemas de infraestructura de las estructuras hidráulicas (presas, cortinas, represas, estructuras de acceso, etc.). Los fabricantes de están desarrollando nuevos e innovadores productos que proporcionan propiedades especiales al concreto. Este trabajo reporta algunas de estas innovaciones que están experimentándose en el área de la tecnología del concreto (1993).

Palabras clave: Puentes, concreto, presas, durabilidad, evaluación, estructuras hidráulicas, innovación, alto comportamiento, pavimentos, desarrollo de productos, investigación, tecnología.

INNOVATIONS IN CONCRETE TECHNOLOGY

by

John M. Scanlon

nopsis: The concrete industry has been experiencing exceptional advances in owledge relating to concrete technology during the last few years and the potential ists for continued advancements during the next decade. Our major problems seems to transferring these innovations to the users of concrete. The Contractor and the ecifier continue to be the last participant in the technology transfer chain to incorporate s new knowledge into every day practice.

e Strategic Highway Research Program (SHRP) has recently completed a 150 million lar program to advance the knowledge in designing and constructing our highways and dges; the U.S. Army Corps of Engineers has recently completed Phase I and initiated ase II of their Repair, Evaluation, Maintenance and Rehabilitation (REMR) Research gram (72 million dollars) to develop new technologies in dealing with the infrastructure blems of hydraulic structures (dams, levees, locks, intake structures, etc.). Products nufacturers are developing new and innovative products to provide specialty properties concrete. This paper reports on some of these innovations being experienced in the a of concrete technology (1993).

ywords: Bridges, concrete, dams, durability, evaluation, hydraulic structures, ovation, high performance, pavements, product development, research, technology.

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INTRODUCTION

In the past, very little definitive research has been appropriately funded in relatively large amounts in the technical area of concrete technology. Concrete has been in such wide use as a construction material that the agencies and organizations involved in concrete design and construction have mistakenly felt that "Concrete was all that it could be" and that "No additional research was needed because concrete can't be improved".

While serving as Chief, Concrete Technology Division of the U.S. Army Engineer Waterways Experiment Station in 1983, the author with others originated a major research program to address the repair, evaluation, maintenance and rehabilitation of Corps of Engineers hydraulic structures. This program became a 12-year 72 million dollar research program with approximately 25 million dollars allocated for research in the area of concrete and concrete structures. If we have to spend such a large amount of funds to research repair of existing concrete it is obvious that "Concrete was not all that could be" and "Additional research on concrete should improve the technology".

The originators of the Strategic Highway Research Program (SHRP) recognized the potential for cost effective research in concrete technology and included appropriate funding in SHRP to take advantage of this potential. Hydraulic cement concrete is an excellent building material; the knowledge of concrete technology has drastically improved during the past 20 years; SHRP has expanded on that technology and as a result of the SHRP Concrete and Structures Research additional knowledge will come available in the near future because of the site specific projects that are being evaluated on a long-term basis.

It is very surprising how many accomplishments have evolved during this relatively short period of SHRP and REMR existence. It has always been the feeling of concrete technologists that concrete improvements based on research evolve over long periods of time and that it seems that "accelerated research doesn't accelerate concrete knowledge". SHRP and REMR have disproved that theory and as a result, we not only have advanced knowledge today, we can expect additional knowledge in the future due to these research programs.

SHRP ACCOMPLISHMENTS

The accomplishments of SHRP (Strategic Highway Research Program) in the area of concrete technology have been in three major overlapping areas, bridge physical condition assessment, bridge protection and rehabilitation, and concrete materials.

Bridge Condition Assessment

__Guidance to evaluate bridge components__ -- Assess the condition of concrete bridge components using this new "how-to" manual--a toolbox of new and existing survey methods. With reliable information on the level and rate of deterioration in hand, you can readily choose a cost-effective plan of preventive or corrective action to protect bridge components. The manual gives step-by-step guidance on methods to detect deterioration in reinforced and pre-stressed concrete structures. Evaluation steps include initial visual inspections, subsequent routine condition surveys, and detailed condition surveys. Evaluation steps are adjustable for local conditions, materials, bridge types, and agency policies. Thirteen of the tests described in the manual are effective methods currently in use. Seven new tests developed through SHRP research are now available as additional tools to obtain the data needed for a complete bridge condition assessment.

__Sampling and testing for chlorides__ -- Before you protect or rehabilitate a concrete structure that is visibly deteriorating, you should first determine the extent of the chloride contamination. This commercially available chloride sampling and testing method is an inexpensive field procedure. Collect drilled powder samples from various locations and depths in the concrete, and then determine the amount of chloride ion in the concrete by using the specific chloride ion probe. Inspectors save time by immediately determining the amount of chloride present, thus making better sampling decisions. Field studies confirmed the test is accurate.

__Corrosion rate__ -- If you know the history of the corrosion rates for the steel in a reinforced concrete structure, you can predict time to corrosion distress and select an effective rehabilitation strategy. This survey method describes a non-destructive field test for determining corrosion rates and details the use of three commercially available devices that measure polarization resistance for calculating the corrosion rate. All three devices performed well in field tests.

__Measuring chloride corrosion__ -- Your field inspectors will produce more reliable bridge deck assessments using this new corrosion rate detector. This monitoring device detects corrosion using ultralow frequency impedance spectroscopy. Measurements are made by contact probes, and corrosion is quantified using customized and user-friendly computer software.

__Measuring concrete permeability__ -- Three new tests were developed for measuring the permeability of concrete. They are:

- surface - air flow device

- forced air under pressure device
- AC impedance testing

Success of concrete sealers -- Two devices for measuring the effectiveness of concrete sealers were developed. They are:

- the electrical resistance test
- water absorption test

Membrane integrity -- Now you can check the integrity of chloride barrier membranes installed on concrete bridge decks without tearing up the asphalt overlay. A membrane that is perforated of that no longer bonds to the bridge deck will not prevent chloride penetration. Usually, you cannot visually detect this condition. When membranes fail, chloride-induced corrosion is often accelerated because the chloride attack is concentrated in a particular area of the concrete deck. This modified, non-destructive test method uses ultrasonic pulse velocity as an indicator of membrane condition. Using an ultrasonic pulse velocity meter, the transit time of the pulse is measured from the time the signal penetrates the surface of the deck until it is reflected off the membrane. The pulse transit time was statistically correlated to a visual condition membrane rating scale during laboratory and field validation.

Evaluate bridges in depth -- Is the concrete deteriorating under the asphalt overlay on your bridge decks? Ground-penetrating radar (GPR) finds delaminated concrete hiding under the asphalt overlay without your having to stop traffic or pay the high cost of removing the overlay. The GPR unit moves at speeds up to 25 miles (40 kilometers) per hour while mapping subsurface conditions. GPR mapping reduces concrete bridge repair costs by enabling you to focus on critical bridges and to plan cost-effective repairs. The new, more effective GPR unit uses short-pulse radar with a special antenna system and new data acquisition software designed for bridges.

Bridge Protection and Rehabilitation

Removing chlorides -- With this new "how to" guide, engineers can do a better job removing chloride electrochemically from concrete structures. Reinforced concrete bridge elements that are high in chloride (with or without visible deterioration) may be candidates for electrochemical chloride removal. This practical guide also describes the effectiveness of electrochemical chloride removal on a structure deteriorating as a result of alkali-silica reactivity. In cases of extensive chloride-induced corrosion, concrete removal should take place only to the extent of removing loose concrete and replacing it with an appropriate patching material. The remaining sound, but contaminated, concrete is treated electrochemically. Once an electric field is applied, the negatively charged chloride ions move away from the reinforcement steel, toward the surface of the concrete. Equally important, the concrete in effect "re-alkalies" around the bar and "re-pacifies" the steel. Subsequent sealing of the concrete helps to retard future chloride migration back to the reinforcement steel. Chloride removal may sometimes aggravates alkali-silica reactivity. This problem can be controlled by putting lithium ions into the electrolyte. The guide and two companion volumes describe laboratory testing and field trials undertaken to refine this protection technique.

Cathodic protection -- Learn how to stop chloride-induced corrosion in reinforced concrete bridges through use of this proven, cost-effective protection technique. Whether you are inspecting your existing cathodic protection installations or designing new systems, this manual provides you with up-to-date evaluations and recommendations. Using these guidelines on design, installation, and maintenance of cathodic protection systems, you can more effectively control chloride-induced corrosion. This manual guides you through the process of selecting the best cathodic system for the specific bridge component being protected. Useful information is provided on costs, durability of system elements, and monitoring and maintenance requirements.

Nulling currents -- To optimize operation of cathodic protection systems for controlling chloride corrosion, this guide provides reliable information on selecting control criteria. Using laboratory tests and mathematical modeling, corrosion rates were observed for various degrees of cathodic protection. This manual presents time-dependent criteria that optimize cathodic protection. The "corrosion null probe" concept is a technically valid, yet simple approach to meeting the criteria without relying on the long-term stability of embedded reference electrodes. The manual also provides criteria for the lowest electrical current level needed, the effect of intermittent application, and other key characteristics of cathodic protection systems.

Cost effective concrete removal and rebar cleaning -- When faced with cracked and deteriorated chloride-contaminated concrete, you may need to remove the damaged concrete. The extent of removal is based on the level of chloride contamination or corrosion measurements, the location of the damaged area on the bridge, and the selection of a protection system or rehabilitation technique. You can save money by reducing the amount of concrete removed while still protecting the steel from further corrosion. This guide explains how to select the most cost-effective, efficient, and damage-limiting methods from several traditional concrete removal techniques. The guide identifies the advantages and disadvantages of the three most commonly used methods--- pneumatic breakers, milling, and hydro-demolition --in terms of characteristics, productivity, and costs. Removal of surface contaminants and concrete up to a depth of half an inch (13 millimeters) can be accomplished with scrabbling, plaining, sandblasting, or shotblasting. When the concrete removal exposes the reinforcing steel, the bars need to be cleaned of chloride contaminates and loose concrete. Sandblasting, wire brushing, and hydro-demolition are the most feasible methods for cleaning the reinforcing steel. This new guide presents "how-to" information, along with a specification for hydro-demolition.

Rapid bridge deck rehabilitation -- When time is of the essence in repairing bridge decks, this new manual on field-validated, rapid rehabilitation techniques and materials can help you select the right strategy. Conventional and innovative techniques for protection, rehabilitation, and replacement are discussed and compared in the manual. The manual also covers cost, service life, and specific limitations of each method. Rapid protection systems include bituminous overlays on membranes, polymer overlays, and penetrating sealers. Temporary repairs include high early strength portland cement concrete patches, and other hydraulic cement concrete patches. The rapid rehabilitation of a deck includes the use of patching systems followed by either a protection system or a high-performance concrete overlay. Rapid replacement systems include site-cast high performance concrete or pre-cast concrete deck panels.

Repairing marine structures -- Arc-sprayed zinc coatings, originally developed for reinforced concrete marine structures, effectively prevent corrosion of concrete structures in warm, humid, and salt-laden environments. Arc-sprayed coatings perform well and generally cost less to apply and to maintain than conventional impressed-current cathodic protection systems. The coating is installed by first cleaning the steel bar and surrounding concrete surfaces, and then applying arc-sprayed zinc directly on the exposed area and onto the cleaned concrete. This creates a simple, self-powdered, sacrificial anode-protection system. Information is available on how to apply this innovative technique.

Solving corrosion-induced distress -- Using design guidelines and decision criteria, you can easily select the most appropriate solution for protecting or rehabilitating an existing concrete bridge on a life-cycle basis. Once you know the condition of a bridge, you can select a cost-effective solution. A manual or computer program gives you costs, service life, and technical viability of a wide range of techniques. You can use a decision model to predict future corrosion-related distress. The computer program covers bridge decks. The manual covers both decks and substructure elements and includes flow charts, figures tables, nomograph, equations, and other aids.

Concrete Materials

SHRP accomplishments relating to concrete materials technology can be categorized into six different areas:

1. Concrete Performance
2. Alkali-Silica Reactivity
3. Freeze and Thawing Conditions
4. Nondestructive Testing
5. High Performance Concrete
6. Optimizing Highway Concrete Technology

Concrete performance -- Concrete has been such an amazing building material, we sometimes forget that it's performance can be improved. Invariably it performs the way the designer expects it to; maybe the designers should expect it to do more. With improved performance we can expect designers to revise future design criteria in order to take advantage of this improved performance as they become more familiar with these capabilities.

- Improved Concrete Mix Designs (proportions) Handbook.

This new handbook will prove helpful in producing a dense, hardened concrete with high strength and low permeability, which improves durability and service life. The handbook describes a procedure for designing concrete mixes using optimum blends of sand and coarse aggregate to yield the maximum packing density of the concrete mix components. The procedure is based on a mathematical model that predicts the packing density of the concrete mix by taking into the account the size and specific gravity of the various mix components. The model output is expressed in the form of tables and triangular diagrams (isodensity lines), from which the engineer can determine the optimum amount of each mix element. For highway applications, there appears to be a narrow range of mix compositions that will produce the maximum packing density.

- Ensuring Crack-Free Curing of Concrete

Place concrete with confidence under varied temperature conditions. Using this set of tables, engineers can predict thermal effects during the curing of concrete pavements and assess the potential risk of damage to the concrete in a particular environment. This guide identifies a range of possible actions to ensure crack-free curing of concrete. For possible combinations of concrete temperature, air and ground temperatures, and type and amount of cement in the mix, the guide provides tables that show which combinations are safe and which require special care. Using these tables, you can predict the thermal effects for concretes generally used in concrete construction. The thermal effects tables warn you if too high a temperature will be reached during curing of the concrete and whether thermal cracking will result from variation in the temperature of the concrete and the temperature of either the air of the subbase.

- Diagnosing Performance Problems With Concrete

This guide provides a procedure for diagnosing problems with concrete field performance using optical microscopy. Problems with concrete performance and durability can be detected by optical microscopy, which reveals the microstructural features of concrete. Thin sections of concrete are treated with fluorescent dyes, making it easier to identify the microstructural features of the specimen, such as porosity, homogeneity, and air entrainment. The equipment is commercially available.

Alkali-silica reactivity -- Alkali-silica reactivity (ASR) causes irreversible damage to concrete pavements and structures. ASR occurs when silica substances in aggregates react with alkali in the cement and absorb water to the extent that the