Concrete and Structures:

Progress and Products Update

November 1989

Strategic Highway Research Program
National Research Council

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Concrete and Structures: Progress and Products Update

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Contents

Foreword

Concrete and Structures: Progress and Products Update describes the Strategic Highway Research Program's projects in the Concrete and Structures area. It covers the objectives of the research in broad economic and technical terms, as well as progress as of the date of publication.

This *Progress and Products Update* is the first of four to be published by SHRP in the fall of 1989, covering each of SHRP's four technical research areas (Asphalt, Concrete and Structures, Highway Operations, and Long-Term Pavement Performance). The *Progress and Products Updates* are intended to meet the need, midway through the five-year research effort, for comprehensive program descriptions that document the program evolution that has occurred since *Strategic Highway Research Program: Research Plans* was published by the Transportation Research Board in 1986.

How This Report is Organized: The mission and economic significance of the Concrete and Structures program are presented in Section I, along with a brief overview of the research.

Sections II and III contain detailed discussions of the objectives and expected products of the research. Section II covers the Concrete research, and Section III covers the Structures research. These sections also include Contract Plans for each subprogram. The Contract Plans tell how the work is divided into research contracts, and how the contracts interrelate.

Section IV of this *Progress and Products Update* contains one-page Project Summaries for each of the contracts in the Concrete and Structures area. These will be revised periodically as the research progresses.

I. Introduction

Program Mission

SHRP's program in Concrete and Structures is divided into two subprograms: Concrete, and Structures. The mission of the Concrete research is to increase the durability of portland cement concrete in highway applications. The mission of the Structures research is to develop improved techniques and equipment for condition assessment of concrete bridges, and for rehabilitation and protection of corroded steel-reinforced concrete bridges. In both cases, the research has been planned to result in tangible products that can be applied immediately and that have the potential to result in substantial savings in the operations budgets of highway agencies.

The budget for Concrete and Structures research contracts will total approximately $19 million; with about $10 million in Concrete contracts (Figure 1) and $9 million in Structures contracts (Figure 2).

Economic Significance

The potential economic benefits of applied research in portland cement concrete are huge because so much of it is used. The U.S. highway industry spends about $1 billion annually on portland cement, accounting for about 16 percent of U.S. portland cement sales. Almost all bridge decks are portland cement concrete, as are piers and abutments, even where steel is used for the superstructure. Over 85,000 miles of U.S. roads are paved with portland cement concrete, which also is the material most often used for curbs, sidewalks, and median dividers.

SHRP's Structures research is tackling a national problem of enormous economic significance. Thousands of bridge decks constructed in the United States between 1950 and the mid-1970s are

CONCRETE CONTRACTING PLAN

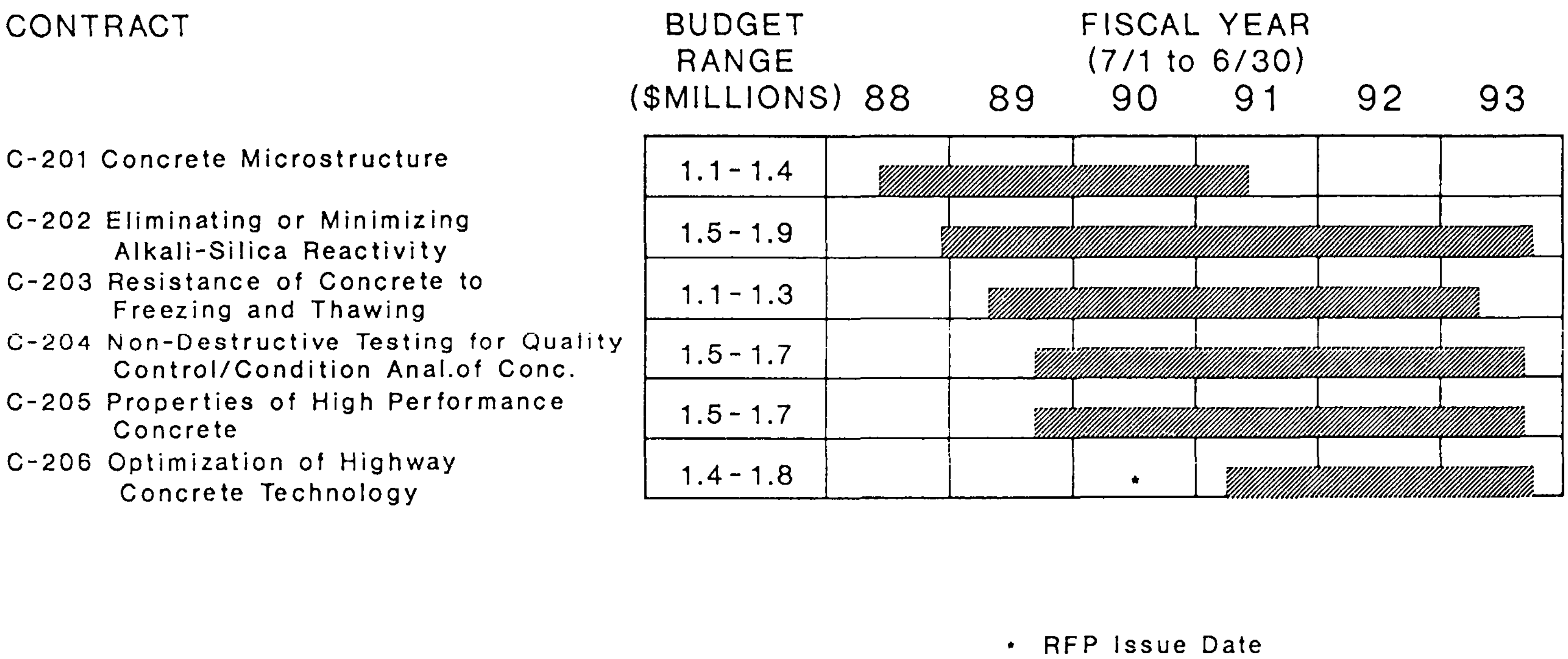
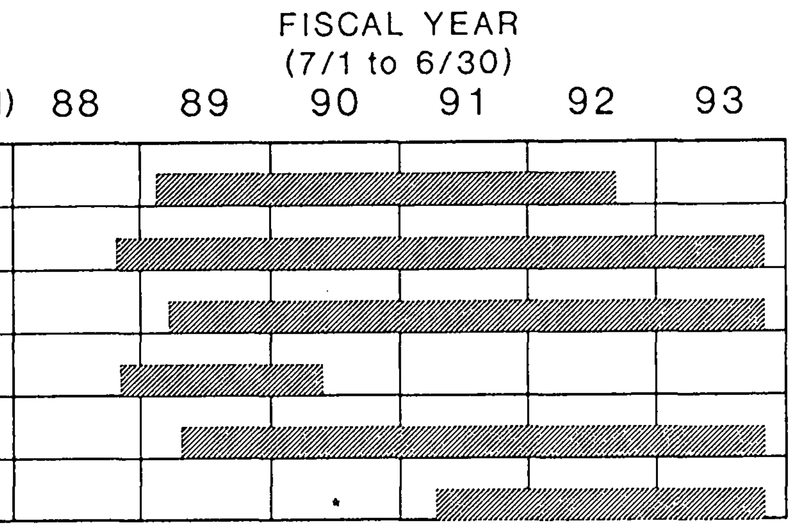


Figure 1

STRUCTURES CONTRACTING PLAN

CONTRACT	BUDGET RANGE ($MILLION)
C-101 Assessment of Physical Condition of Concrete Bridge Components	2.2 - 2.4
C-102A Electrochem. Chloride Removal & Protection of Conc. Bridge Components	0.8 - 1.0
C-102B Cathodic Protection of Concrete Bridge Components	1.8 - 2.0
C-102C Synergistic Inhibitors for Corrosion Protection	0.15 - 0.2
C-103 Concrete Bridge Protection & Rehab, Physical & Chemical Methods	2.6 - 2.8
C-104 Methodology for Protection and Rehab. of Existing Conc. Structures	0.4 - 0.6



• RFP Issue Date

Figure 2

suffering from corrosion damage because of inadequate concrete cover over the top layer of reinforcing steel. Few, if any, of these bridges were built with epoxy coating on the reinforcing steel or other methods of corrosion protection that subsequently have come into widespread application. The nation currently faces a $20 billion repair bill for corroded steel-reinforced concrete bridges, and that figure is growing by about $500 million annually. Development of more economical methods for repair and prevention of concrete bridge corrosion has the potential to save highway agencies millions--or perhaps billions--of dollars.

Research Overview

SHRP's Concrete research is developing improved testing and quality control/quality assurance procedures for new concrete construction; nondestructive techniques for condition evaluation of existing concrete pavements and structures; innovative repair methods; and engineering criteria for improved concrete-making materials, including admixtures.

Rehabilitation of corrosion-damaged reinforced concrete decks and substructures is a major thrust in the Structures research. SHRP also is conducting an assessment of cathodic protection systems for undamaged structures, and developing needed specification and performance criteria for their use.

Assessment of conventional and chemical bridge protection techniques also is being conducted. Development of nondestructive tests for condition assessment is another important aspect of the SHRP Structures program.

A bridge repair manual covering innovative technologies as well as the more conventional protection and repair techniques will be the key product of the Structures research.

II. The Concrete Research

Objectives

SHRP's Concrete research addresses both existing and new construction. The overall research objectives are to:

(1) Enhance the constructability and durability of portland cement concretes.

(2) Develop techniques for increasing the service life of existing pavements and highway structures.

(3) Develop better techniques for quality assurance and quality control.

(4) Develop and assess new concrete materials that have high-performance characteristics.

Each of these broad objectives will be discussed in turn.

1. Enhance the constructability and durability of portland cement concretes.

More "constructable" concrete will be easier to build -- that is, less prone to mistakes in specification of the materials, in mix design, in mixing, in placement, or in curing.

Mistakes in mix design involve use of the wrong materials or the wrong combinations of materials. SHRP is developing new tests that will permit rapid, accurate characterization of the performance-related properties of cements, admixtures, and aggregates, as well as improved guidelines for materials selection.

Mistakes in the construction stage--that is, in mixing, placement, or curing--can be reduced through better Quality Control/Quality Assurance techniques. SHRP is developing an improved Quality Control/Quality Analysis system, which is described in more detail under objective number three below.

2. *Develop techniques for increasing the service lives of existing concrete pavements and highway structures.*

As the nation's highway system ages, prolonging the service lives of existing pavements and structures is more important than ever. SHRP is developing new nondestructive tests for assessment of the condition of in-place concrete, as well as new methods for repair and prevention of further deterioration.

3. *Develop better techniques for quality control and quality assurance.*

Quick, accurate, easy-to-use field tests are the key to more consistently high-quality concrete construction. SHRP is developing non-destructive field tests for quality control that can be applied by minimally trained personnel, and will produce quick, accurate results. These tests will form the basis for more rational acceptance criteria, as well as for new guidelines for interim controls such as curing, form stripping, and limiting construction traffic.

4. *Define new concrete-making materials with high-performance characteristics.*

SHRP is evaluating new concrete-making materials that are resistant to deterioration. The goal is to determine those concrete processing techniques and materials that have the best potential for superior performance with a wide range of aggregate types, and to develop criteria and recommendations for their development and application. The four broad objectives discussed above are interrelated. All of SHRP's Concrete research projects relate to one another synergistically.

Project C-201 is an investigation of the chemistry and physics of concrete microstructure development, and forms a foundation for the other research.

Two other projects are investigations of specific performance problems: alkali-silica reactivity (C-202), and freeze-thaw damage (C-203).

Project C-205 is an investigation of the mechanical properties and performance of high-performance concretes containing admixtures.

In turn, each of these projects will feed into project C-204, which involves development of an improved Quality Control/Quality Assurance system for new construction and a quality evaluation system for existing construction. The products of project C-204 will include new, rapid, reliable site tests for Quality Control/Quality Assurance, as well as engineering guidelines for Quality Control/Quality Assurance, including an applications manual.

A wrap-up project, C-206, will use the results of all of the other research to develop specifications for superior concrete materials.

The goals and expected products in each of these areas are discussed in more detail below.

Microstructure Development

The foundation of the SHRP Concrete research program is investigation of the chemistry and physics of cement and concrete systems at the microstructure level under project C-201. Control of the physical and chemical processes that take place during the mixing, placing, and curing stages is a fundamental step toward advancement of concrete technology.

The C-201 contractor, Pennsylvania State University Materials Research Laboratory, is investigating concrete microstructure to determine:

- How to reduce the permeability of concrete so that water and other potentially aggressive liquids have difficulty entering; and
- how to strengthen the bond between cement paste and aggregate to enhance strength and other physical properties.

SHRP's microstructure research includes:

- Investigation of the effects of chemical admixtures and pozzolanic materials on concrete microstructure; and
- development of recommendations for specifications for concrete-making materials that will optimize durability and performance.

The three-year microstructure project is scheduled to conclude in December 1990.

Building on the results of this research, SHRP will develop specific tools for avoiding and correcting two performance problems: alkali-silica reactivity, and freeze-thaw damage (including D-cracking). Each of these research efforts is discussed in turn below.

Alkali-Silica Reactivity

SHRP's alkali-silica reactivity research is focused on development of products in four categories:

- Rapid and more accurate tests for identifying reactive aggregates prior to construction, as well as standards for their use.

- Engineering guidelines for permissible or required combinations of cementitious materials, aggregates, and environmental factors to avoid expansion due to alkali-silica reactivity.

- Nondestructive field tests for evaluation of alkali-silica reactivity in existing concrete.

- Techniques for minimizing expansion and deterioration due to alkali-silica reactivity in existing concrete.

The C-202 contract, "Eliminating or Minimizing Alkali-Silica Reactivity," was awarded to Construction Technology Laboratories in June 1988. The project is scheduled for completion in March 1993.

Alkali-Silica Reactivity Research Background

Silica substances in aggregates can react with alkali in the cement and absorb water, causing the concrete to expand. Within a few years, this may crack the concrete. The process is irreversible. It may eventually cause structural failure. There are no existing methods for treatment of damage due to alkali-silica reactivity (ASR) in existing concrete. When pavements are afflicted, the most common course of action is to rebuild the upper courses, recycling the damaged materials into base courses of the replacement pavements.

Highway agencies are under increasing economic pressure to use available aggregates, even if they present potential ASR problems. In some states, aggregate supply sources are limited due to resource depletion, land development restrictions, and environmental concerns. Many areas of the United States contain large deposits of mineral formations containing silica substances. Where reactive aggregates are locally plentiful, there is an economic incentive for local agencies to use them rather than transport other aggregates longer distances.

Where reactive or potentially reactive aggregates are used, current practice is to control reactivity problems by using either low-alkali cements or pozzolanic admixtures. Low-alkali cements reduce the amount of free alkalis available to react with the silica substances. Pozzolanic materials tie up the free alkalis and render them unavailable to react with silica. Both of these practices may increase costs.

Decisions on use of low-alkali cements or high-quality pozzolans to control reactive aggregates are based on economic considerations and local availability. In recent years the alkali content of cements in the United States has generally increased due to changes in processing techniques brought on by energy-conservation and pollution-control concerns.

Where low-alkali cements are used to avoid ASR problems, general practice is to use cements with less than 0.6 percent alkali content. The 0.6 percent rule-of-thumb is generally effective, but there are conditions under which it is not. Because there has been relatively little research in this area, environmental conditions that favor the development of ASR problems when low-alkali cements are used are not well defined.

For example, even low-alkali cements may not prevent alkali-silica reactions when the weather is extremely hot, dry, and windy at the time of placement. These conditions cause moisture to evaporate from the surface of the concrete. Water then migrates from the bottom of the slab, through the concrete, to the surface, where it also evaporates, resulting in a highly concentrated alkaline solution that can cause ASR failure.

Certain types of fly ash and other pozzolans, including blast furnace slag and silica fume, have been used successfully with numerous aggregates in varied climates, but there are no well-developed engineering criteria for the specification of pozzolanic admixtures as agents to counteract ASR. SHRP will recommend specifications for ASR-resistant concrete-making materials.

SHRP also is developing more rapid, reliable, and informative tests for determining the reactivity of aggregates. Such tests will be very valuable if they encourage the use of some inexpensive aggregates that are excluded currently based on existing tests.

Current practice is to screen aggregates through a combination of petrographic analysis and laboratory tests. The petrographic analysis will identify rock formations that are likely to contain significant amounts of silica. Existing laboratory tests are slow and can be inconclusive. The chemical test that is currently used for laboratory screening requires several weeks to complete and its results indicate only whether the aggregate has a *potential* reactivity problem. The follow-up mortar bar test for cement-aggregate reactions takes one year, and interpretations of the validity of the test procedures and the significance of the results may vary. The final result of the mortar bar test is a measurement of the amount of expansion, which reveals only indirectly the amount and type of reaction.

Some agencies do not use concrete aggregates determined to be potentially reactive in either petrographic or laboratory analysis. This approach is probably effective from a performance perspective, but it may be uneconomical. As aggregate sources become scarcer, many agencies may find that disallowing aggregate sources has become unacceptably expensive.

SHRP also is developing non-destructive field tests and guidelines for selection of concrete-making materials. The purpose of these tests and guidelines is to minimize the potential for alkali-silica reactivity, while encouraging the use of a broader range of materials.

Another product of the alkali-silica reactivity research will be engineering guidelines for diagnosis and assessment of damage to existing highway concrete resulting from alkali-silica reactivity (ASR). A final, and more difficult-to-achieve, objective is to develop a method for arresting the ASR-caused expansion in existing concrete structures.

Freeze-Thaw Damage

SHRP's research in the freeze-thaw damage area involves systematic investigation of the effects of frost action on hardened cement and aggregates, and the protective effect of entrained air. This includes investigation of the mitigation of freeze-thaw damage through the use of chemical admixtures and pozzolanic materials, through the use of aggregates with certain characteristics, and due to environmental phenomena such as partial drying and re-wetting. Based on the results of these investigations, SHRP will develop criteria and procedures for improvement of concrete freeze-thaw durability.

The objective of SHRP's freeze-thaw research is to develop the following products:

- o Air-void requirements for freeze-thaw durability of concretes presently in use, especially those containing pozzolanic materials and chemical admixtures.
- o Rapid tests for measurement of the freeze-thaw durability of aggregates.
- o Techniques for arresting D-cracking.

The contractor for Project C-203, "Resistance of Concrete to Freezing and Thawing," is the University of Washington. Completion of the four-year project is scheduled for December 1992.

Quality Control/Quality Assurance

Under Project C-204, SHRP is developing a quality assurance/quality control system for new construction, and a system for evaluation of existing concrete. The quality control/quality assurance system for new construction will ensure the structural soundness of the finished concrete and its adequacy for the intended purpose through a series of field tests applied at critical points in the construction process. The quality control/quality assurance system will include existing tests as well as the newly developed, rapid, reliable non-destructive tests and acceptance criteria developed through the other SHRP concrete research projects. These include tests to measure:

- o Water content of concrete mix
- o Air entrainment of fresh concrete
- o Moisture content, residual strength/functional capacity of in-place concrete

New Tests

Water Content of Concrete Mix: Among the new tests under development is a quick, accurate site test for measurement of the actual water content of concrete mix directly prior to placement.

The existing construction quality control test for measurement of the water content of concrete mix is the slump test. This test provides a gauge of the consistency of the mix, but does not measure water content directly. The consistency, or workability, of concrete mix also can be affected by cement and aggregate characteristics, admixtures, temperature, and the moisture content of the aggregate. Many of these effects -- particularly the effects

Background: Freeze-Thaw Damage Research

Freeze-thaw damage is caused by penetration of water into concrete, which, after repeated cycles of freezing and thawing, can cause the concrete to deteriorate. Damage usually can be prevented by combinations of:

- Minimization of the amount of water in the concrete at the time of mixing through the use of the proper water-to-cement ratio;
- control of the size and distribution of pores through proper air entrainment;
- minimization of the permeability of the hardened concrete; and
- use of aggregates that do not degrade in a wet, freezing environment.

Although the effect of air-entrainment in protection of concrete from freeze-thaw damage is well established, situations arise where even properly mixed and air-entrained concrete fails due to freeze-thaw damage. One such situation is where the concrete reaches critical saturation before the full curing time has elapsed. This process is exacerbated when deicing chemicals are applied. Chemical or mineral admixtures such as high-range water reducers, fly ash, ground slag, and silica fume also affect entrained air void systems. One objective of the SHRP concrete research is to quantify these effects.

As noted in the discussion of alkali-silica reactivity, methods for screening the aggregates for their alkali-silica reactivity and freeze-thaw durability are not well developed. Under Project C-203, SHRP is developing rapid, reliable and inexpensive tests that will screen out aggregates that are susceptible to damage due to freezing and thawing, as well as to D-cracking.

D-cracking, popouts, and other readily visible cracks and surface defects are caused by freeze-thaw failures within the aggregate particles themselves.

of chemical and mineral admixtures -- are only poorly understood, and slump test results alone do not account for them. Water content is sometimes increased if the required slump is not obtained at the job site. Concrete with extra water may be accepted if subsequent strength measurements are adequate, but the concrete will be less durable than it would have been without the additional water.

Air Entrainment of Fresh Concrete: Standard quality control/acceptance tests for air entrainment measure only the total volume of air incorporated in a mix sample. This measure is deficient because it does not indicate the number of air voids in the mix, or their size and dispersion. The size and dispersion of the air voids are directly related to the dissipating physical stresses caused by repeated freezing and thawing cycles. Another drawback of the existing, commonly-used air entrainment tests is that, in order to obtain consistently accurate and reproducible test results, they must be performed by specially trained personnel using calibrated equipment. Yet another shortcoming is that the test takes several minutes to complete, so every load of concrete delivered to a site is not tested.

The present methods for determining the size and average spacing of air voids are applicable only to hardened concrete. If the concrete is not acceptable, the only course of action is to remove the hardened concrete, which presents a serious problem.

SHRP is developing a new air void test that will accurately measure the size, number, and average spacing of air voids in the plastic concrete mix.

Non-Destructive Testing of In-Place Concrete: Another important objective of the C-204 project is to develop non-destructive moisture tests. Current methods do not measure the moisture content of in-place concrete directly. A direct test will be useful in control of all moisture-related deterioration problems, including alkali-aggregate reactivity, curling and warping, creep, drying, shrinkage, and corrosion of steel reinforcement, as well as freeze-thaw damage. The tests will facilitate the planning of maintenance activities by indicating which pavements and structures need the most immediate attention.

The C-204 contractor, Trow, Inc., also is developing a field manual providing test procedures for estimation of the residual strength and functional capacity of in-service concrete, which will also be of useful in planning maintenance and rehabilitation activities.

The four-year C-204 project is scheduled for completion in March 1993.

Guidelines for Construction of High-Performance Concretes

Under Project C-205, SHRP will develop detailed data on the mechanical properties and behavior of high-performance concretes in highway applications.

The high-performance concretes to be investigated include high-strength concretes, high-early-strength concretes, and those containing pozzolans and other admixtures. The C-205 contractor, North Carolina State University, is investigating the effects of field environmental conditions -- moisture, humidity, temperature, exposure to marine environments, deicing agents, etc. -- on the mechanical properties and behavior of high-performance concretes. The objective is to develop guidelines and recommendations for the use of various materials (pozzolans, and other admixtures) for improvement of the mechanical properties and behavior of high-performance concretes.

It is expected that numerous sets of criteria will be developed to cover the range of structures and field conditions encountered in highway applications.

Optimization of Highway Concrete Technology

Building on the results of SHRP concrete research as well as on evaluation of recent developments in concrete technology, SHRP will select the concrete-processing techniques, materials, and material combinations that have the best potential for superior performance on the highways, and develop recommendations for development and application of these materials.

SHRP also will explore the value of an expert system based on the knowledge and data obtained from SHRP's concrete research program as well as information available elsewhere. It is not clear, at this stage, whether an expert system will be an effective and practical way to present and use new and available information for highway applications. However, such a system, if developed, would allow state highway agency engineers to diagnose concrete problems, select appropriate materials and mix designs for both new construction and rehabilitation and in the case of new construction, ensure optimum performance in the design environment.

Concrete Contracting Plan

The goals and objectives of SHRP's Concrete research were explained above. The following section explains how the work is packaged into contracts, and how the contracts fit together.

The Concrete research consists of several independent but interrelated projects that have been packaged into six research contracts. Five contracts were released in fiscal year 1988 and the first quarter of fiscal year 1989.

The products of the research conducted under these initial contracts will be interrelated because the projects address different aspects of the single problem of the durability of concrete in highway applications.

The results of the initial five contracts will be combined in the final project, C-206. This project, scheduled for contract award in fiscal year 1990, will compile the concrete research results into practical guidelines on the application and use of concrete materials.

Project C-201, Concrete Miscrostructure, is addressing the nature of concrete as a material, and its inherent strengths and deficiencies. The researchers are developing, in quantitative terms, relationships between the hydration reactions and the structure-property characteristics of concrete. Based on this analysis, SHRP is developing recommendations for optimization of concrete microstructure for desired performance properties. These modifications may be accomplished through adjustments in mix designs, improved tests, and specifications for concrete and concrete-making materials.

The C-201 contractor is Pennsylvania State University's Materials Research Laboratory. The planned contract period is December 1987 - December 1990.

Project C-202, Eliminating or Minimizing Alkali-Silica Reactivity, is developing practical tests for prediction of alkali-silica reactivity susceptibility, specifications for concrete-making materials that are resistant to alkali-silica reactivity in new construction, and techniques for mitigation of the harmful effects of alkali-silica reactivity in existing concrete pavements and structures. The key product of the project is a quick and reliable method for identification of potentially reactive aggregates. Criteria for avoidance of alkali-silica reactivity also will be developed based on quantitative definition of the environmental conditions, combinations of materials, and mix design specifications related to the phenomenon. Finally, and equally important, this project will attempt to develop techniques for effective control of alkali-silica reactivity damage to existing concrete pavements and structures.

The C-202 contractor is Construction Technology Laboratories, Inc. The planned contract period is June 1988 to March 1993.

Project C-203, Resistance of Concrete to Freezing and Thawing, is developing methods for avoidance of freeze-thaw durability problems. The contractors are examining the mechanism of air entrainment in protection of concrete from freeze-thaw damage, and determining how various cementitious materials affect the requirements for entrained air. Rapid and relatively inexpensive methods for identification and screening of non-durable aggregates also are under development in this project.

The C-203 contractor is the University of Washington. The planned contract period is October 1988 - December 1992.

Project C-204, Nondestructive Testing for Quality Control/Condition Analysis of Concrete, is developing improved quality control/quality assurance systems for assessment of new concrete construction in highway applications. These systems will be based on rapid, reliable, and nondestructive field tests that can be applied at critical points during the construction process. This project also includes development of a condition-evaluation system based on nondestructive techniques for measurement of those characteristics of in-service concrete that reveal its condition and help to predict its remaining service life.

The C-204 contractor is Trow, Inc. The planned contract period is March 1989 - March 1993.

Project C-205, Mechanical Behavior of High-Performance Concretes, is developing quantitative relationships between the mechanical properties and behavior of high-performance concrete in service, under varied environmental conditions (moisture, humidity, temperature, exposure to marine environments and deicing agents, etc.). These relationships will be used as a basis for development of engineering guidelines for use of the materials.

The C-205 contractor is North Carolina State University. The planned contract period is March 1989 - March 1993.

Project C-206, Optimization of Highway Concrete Technology, is scheduled to begin in the third year of the SHRP program. This project will build on the knowledge gained in the five initial projects, and extend it to development of new concretes and methodologies for increasing the durability and service life of highways. The C-206 project will critically evaluate new materials and processes in concrete technology and establish plans for using them in highway applications. Specifications for environment-specific superior concrete will be produced. An expert system will be developed for use in diagnosis of concrete durability problems and for extension of the service life of highway concrete. The contracts also will produce appropriate manuals and information-dissemination materials.

The C-206 contract is scheduled for release in the second quarter of fiscal year 1990 (fall 1989).

In addition to the planned contracts, SHRP has awarded five IDEA (Innovations Deserving Exploratory Analysis) contracts for research in the Concrete area. The SHRP-IDEA program encourages innovative approaches to achievement of the objectives of SHRP's planned contract research programs. The program awards contracts in the $100,000 range for about one year of exploratory research.

The Concrete Contracting Plan is graphically illustrated in Figure 3 (p. 18). Staff and contractor organization charts are shown on pages 31 and 32. Brief summaries of the scope of work and progress to date for each of the seven planned contracts and for the concrete-related SHRP-IDEA contracts awarded to date are included in Section IV.

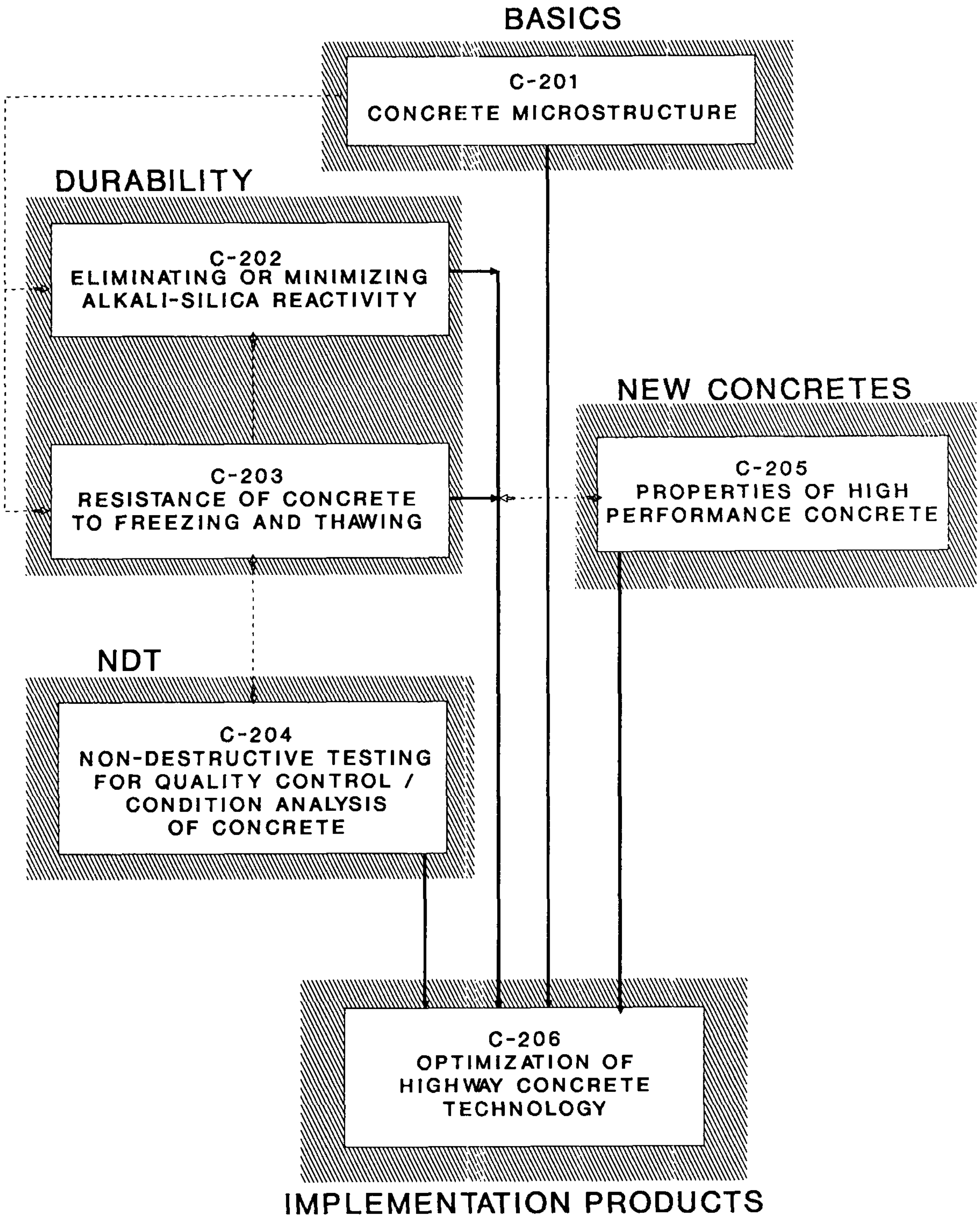


Figure 3. Concrete Research Contracting Plan

III. The Structures Research

Objectives

Repair of chloride-induced corrosion of concrete bridges is one of the most expensive problems facing highway agencies in the United States. Using existing techniques, the bill for repairing the nation's corroded concrete bridges will be more than $20 billion.

Because of the magnitude of the problem, new, more efficient and cost-effective techniques for bridge corrosion repair are urgently needed. Conventional techniques involve physical removal and replacement of damaged concrete, followed by sealing; this is both difficult and costly.

SHRP is evaluating the effectiveness and feasibility of innovative electrochemical techniques for bridge repair and protection, including cathodic protection and chloride removal systems.

SHRP is conducting field tests and will produce much-needed engineering criteria for the specification and performance of cathodic protection systems. Cathodic protection uses a low-voltage and current (typically in the range of 1-5 volts and 1-3 milliamps/sq. ft.) to immunize the reinforcing steel against corrosion using a surface-mounted anode (that is, an anode that is placed permanently on the bridge). Note that the system is devised to *protect* bridges from chloride-induced damage to the concrete rather than to repair the damage (remove the corrosion and salt) once it has occurred.

Cathodic protection systems are available commercially in the United States, and most states have one or two experimental installations. Missouri is the exception, with over 100 systems in place. The objective of the SHRP work is to accurately define the costs, benefits, and reliability of cathodic protection systems as well as to optimize their design.

The elements of chloride removal systems are similar to those used in cathodic protection systems, except a stronger electrical current is applied to pull the chloride ions away from the steel, and completely out of the concrete. This is a one-time treatment that does not require maintenance of a power supply or a permanent anode, as in the case of cathodic protection. In contrast to cathodic protection, chloride removal is not a proven technology; the objective of the SHRP work is to determine its feasibility and practicality.

Another important thrust in the Structures research is the development of nondestructive diagnostic techniques for measurement of corrosion before it results in visible spalling on the bridge surface, and for detection of delamination before it results in holes in the deck or the substructure. The use of infrared and radar seem particularly promising in this regard.

SHRP also is assessing conventional concrete removal-and-replacement methods to determine the amounts of concrete that must be removed and the relative merits of replacement materials under various conditions.

A bridge repair manual that incorporates all of the results of the SHRP structures research into diagnostic and repair guidance for highway agencies will be the final product of the Structures program.

The goals and expected products of SHRP's Structures research are discussed in more detail below. Background information on the structures research is provided on pages 25 and 26. Brief descriptions of each of the research contracts in the structures area begin on page 24.

Electrochemical Repair and Protection Techniques

Electrochemical Chloride Removal: In project C-102A, SHRP is investigating the feasibility and cost-effectiveness of electrochemical chloride removal. This technology has tremendous money-saving potential because it could make it possible, in the course of a month, to remove chloride from a bridge, and then seal the bridge against further damage with a coating or overlay. There is, however, a significant possibility of damage to the steel or the concrete.

Electrochemical chloride removal involves application of a *strong* electric field between a *temporary* anode on the concrete surface and the reinforcing steel to pull the chloride ions away from the steel and *out* of the concrete. This technique has been attempted only in small-scale applications.

The C-102A contractor is Eltech Research Corporation. Phase I began in May 1988 and is scheduled for completion in November 1989. If the Phase I investigations indicate the technology is feasible, the project will continue until March 1993.

SHRP's research in electrochemical chloride removal includes:

- o Laboratory studies to determine the limitations of electrochemical chloride removal and the likelihood of structural and material damage to the concrete and the reinforcing steel. If the laboratory tests indicate that electrochemical chloride removal is not feasible, the project will be terminated.

- o If feasibility is proven, SHRP will develop practical engineering methods for applying the technique, as well as methods for sealing the concrete after chloride removal to prevent recontamination.

- o After field testing, SHRP will develop an implementation package for use by highway engineers.

Cathodic Protection: Corrosion occurs at anodic sites, which are positively charged, but not at cathodic sites, which are negatively charged. Cathodic protection involves installation of a low-voltage electrical circuit between an external anode and the reinforcing steel, so that all of the steel becomes cathodic and immune to corrosion.

The feasibility of cathodic protection has been established over the past decade through successful applications to bridge decks and, to a lesser extent, to substructures. In project C-102B, SHRP is conducting further assessment, and will develop guidelines and formal engineering criteria for selection of the optimal systems for specific applications, which are much-needed if cathodic protection is to achieve widespread application. Cathodic protection is one of the few technologies that can stop corrosion regardless of the chloride content of the structure. The payoff for development of cathodic protection techniques that are reliable, easy to use, and easy to monitor would be substantial. SHRP's cathodic protection research includes:

- o A survey of the performance of existing cathodic protection installations, and field tests of deck and substructure systems in a range of environments.

- o Evaluation of the control and protection criteria used to operate of cathodic protection systems, as well as the long-term effects of cathodic protection systems and the durability of their components.

- o Development of a guide for installation of cathodic protection systems. This will provide highway engineers with information on design, construction, acceptance, activation, and monitoring of cathodic protection systems.

- o Development of recommendations for cathodic protection system specifications.

The C-102B contractor is Battelle Columbus Division. The planned contract period is September 1988 to March 1993.

Electrochemical Injection: An alternate method for protection of the steel from corrosion without removal of concrete is to inject the concrete around the reinforcing steel with protective chemical inhibitors. Under project C-102C, SHRP is investigating the feasibility of using an electric field to drive corrosion inhibitors into the concrete. The corrosion inhibitors are electrically charged, and can be attracted to the steel by forced diffusion through the pores of the concrete. If the inhibitors prove effective and stable, this innovative approach will provide a valuable new technique for protection of existing bridge components.

The C-102C contractor is SRI International. The project began in May 1988 and is scheduled for completion in November 1989.

Conventional Repair Techniques

Damaged Concrete Replacement: In addition to investigation of the electrochemical repair and protection techniques discussed above, SHRP is conducting assessments of conventional and chemical repair techniques. At present the prevalent repair technique is to remove and replace some or all of the cracked and chloride-contaminated surface concrete, and subsequently to add a low-permeability overlay to stop further salt ingress. This is an expensive and difficult process that is prone to failure if any chlorides remain.

Under project C-103, SHRP is assessing the cost-effectiveness of various methods for removal of salt-contaminated concrete, including high-pressure water jetting, scarification (milling and grinding), and jack-hammering.

These physical removal methods are being assessed in terms of speed, control, effectiveness, and damage risk.

SHRP is developing needed information about the amounts of concrete that must be removed (determining the minimal amount is an important economic consideration) and the relative merits of replacement materials.

Removal and replacement of cracked and delaminated concrete will not, by itself, permanently restore a structure, even when the damage to the steel is minimal, because the chloride ions that remain in the surrounding concrete will continue the corrosion process elsewhere. Therefore all the contaminated concrete must be removed, and the steel must be protected from further corrosion.

Chemical Protection: As part of the C-103 project, Virginia Polytechnic is conducting a field and literature survey of existing conventional and chemical repair and protection techniques to determine the feasibility of various new approaches to protection of corroded bridge components. These include: new techniques for repair and protection such as oxygen and chloride scavenging, chemical dewatering, corrosion inhibition, and polymer impregnation, along with techniques for limiting the volume of concrete removal while assuring protection of the steel from subsequent corrosion.
After field testing, SHRP will produce a manual that documents effective methods for application of the repair techniques found most effective.

The C-103 project began in September 1988 and is scheduled for completion in March 1993.

Development of Diagnostic Tools

Under Project C-101, SHRP is developing techniques for assessment of the physical condition of concrete bridge components, including:

- o A method for measurement of the corrosion rate of steel imbedded in concrete;
- o a method for detection of delamination and cracking in bridge component structures, and another to detect delamination under asphalt-covered decks;
- o methods for measurement of the effectiveness of membranes and sealers used on decks and substructures;
- o field techniques for measurement of the chloride content of concrete;

- o methods for measurement of the water and chloride permeability of existing concrete.

All of these techniques will be field tested, calibrated, and fully documented. A final objective is to develop recommended specifications for adoption by one or more of the national consensus standard-setting organizations, such as the American Association of State Highway and Transportation Officials and/or the American Society for Testing and Materials.

The C-101 contractor is Pennsylvania State University. The planned project duration is August 1988 - Feburary 1992.

Bridge and Structures Diagnosis and Repair System

Under project C-104, SHRP is developing a manual for repair of reinforced concrete structures suffering from salt-induced corrosion.

The manual will provide a rational, cost-effective approach to structure repair.

Drawing on the results of other SHRP Structures research, the manual will provide a decision model that will assist engineers in determining how to assess the rate of deterioration, options for repair, constraints on each option, and the life-cycle costs of repair options.

The decision model will be tested, validated, and calibrated through field trials by highway agencies. A users' manual will present the decision model and explain how it is used and adjusted for various field conditions.

Contract C-104 is scheduled for release in the second quarter of fiscal year 1990 (fall 1989).

Structures Contracting Plan

The SHRP Structures research is divided into six contracts. The first five contract projects are exploring bridge assessment, repair, and protection techniques, and were released in fiscal year 1988. The sixth project, scheduled to begin in fiscal year 1990, will combine the results of the earlier projects into an expert system designed to assist highway engineers in decision-making regarding repair of concrete bridges and structures.

Project C-101 is developing methods for assessment of the physical condition of concrete bridge components. Techniques (preferably nondestructive field test methods) are being developed for:

Background on the Structures Research

The Corrosion Process: Corrosion is an electrochemical phenomenon that occurs where both moisture and oxygen are present. Steel embedded in concrete is normally protected from corrosion by the high alkalinity of the water in the concrete pores. The alkaline substances help to form a protective oxide layer on the steel, which grows impervious to further corrosion.

The chloride ion in salt can break down the protective layer on the steel, allowing corrosion to proceed rapidly. Once in sufficient concentration at the reinforcing steel, the chlorides act as catalysts, promoting the corrosion reaction without being consumed. The product of corrosion--rust--is many times greater than the volume of the steel. Even very small amounts of rust generate pressure within the concrete. Concrete is brittle, and will crack and break with as little as one-hundredth-of-an-inch increase in the diameter of the reinforcement bar. Such a small amount of rust can be produced in one year of corrosion. Corrosion-induced deterioration leads to a continual cycle of failure and repair as corrosion proceeds to break off (delaminate) the concrete cover of the reinforcing steel.

Left unchecked, the chlorides can then proceed to cause severe corrosion in the steel, leading to fracture of the reinforcement and collapse of the structure. Structural collapse is rare in the case of bridges, however, because the deterioriation of the concrete usually will render the bridge unusable long before it is subject to structural failure. A number of steel-reinforced concrete parking garages have collapsed due to corrosion damage.

Diagnostic Techniques: Present methods for detecting the presence of corrosion before spalling becomes visible are generally inconclusive and indirect. One extensively used technique is to measure the electrical potential of the steel against a standard half cell. This measurement indicates the susceptibility of that particular area of the reinforcing to corrosion. This technique is limited in its applicability and is not always accurate. Another diagnostic method is to drag a chain across the bridge deck and listen for hollow sounds that would indicate delamination of the subsurface concrete. Neither method provides a direct measure of the amount of corrosion or its rate.

In the absence of effective diagnostic tools, corrosion usually goes undetected until damage is visible. Even then, highway engineers have difficulty assessing the amount of damage and its location.

At present there are no nondestructive methods for detecting cracking (delamination) under asphalt-covered decks or in bridge support structures without direct access. Nor are there methods for measuring the effectiveness of membranes and sealants that are used on decks and substructures to keep salt out. Bridge engineers need faster, nondestructive techniques for measuring the chloride content of the concrete, and its water and chloride permeability. SHRP will develop these needed tests and procedures.

Information regarding the rate of corrosion is useful in determining the best time and method for repair. Devices that can measure the rate of corrosion of steel in concrete are in the early stages of development. These devices have not been evaluated and field tested uniformly. If the available techniques prove effective, development of a standard application procedure would be useful.

If all of these field test methods are developed -- and it seems technically feasible to do so -- then highway engineers will, for the first time, have adequate means for diagnosis of the extent and location of chloride damage in bridges and other concrete structures, and for choosing the best repair technique.

- o Detection of delamination in exposed components (beams, piers, and abutments);
- o Determination of the condition of asphalt-surfaced concrete deck slabs;
- o Determination of the integrity and effectiveness of membranes and sealer materials in concretes;
- o Determination of the permeability of concrete to water and chloride ions.
- o Measurement of chloride content in-situ.

A field method for measurement of the corrosion rate of steel in concrete also is under development. This includes assessment of available devices, and exploration of new approaches for measurement of the steel corrosion rate. The more promising approaches are being investigated thoroughly through laboratory and small-scale field studies. A final product will be a field method for corrosion rate measurements suitable for adoption by national standards-setting organizations.

The newly developed test methods will be proven under field conditions. The project also involves critical evaluation of current test methods.

The final task under this contract will be preparation of a manual that documents procedures for condition assessment of in-place concrete components.

The C-101 contractor is Pennsylvania State University. The contract was awarded in August 1988 and is scheduled for completion in February 1992.

Project C-102A is exploring electrochemical methods for removal of chlorides and protection of concrete bridges. The first major task under this contract is to examine the feasibility of electrochemical chloride removal, and the best form of anode for cost-effective application. Eighteen months into the research program, SHRP will decide whether the electrochemical chloride removal method is feasible. If it is agreed that work should proceed, analysis and development of the method through field validation and documentation will be continued.

The C-102A contractor is Eltech Research Corporation. The contract was awarded in May 1988 and will run through March 1993.

Project C-102B is assessing the performance of various types of existing cathodic protection installations in application to bridge decks, beams, and substructures, and field testing cathodic protection systems in a range of environmental conditions in order to produce formal engineering documentation and evaluation. The final product will be a guide to the installation of cathodic protection systems that will provide highway engineers with information on how to tailor the design, construction, acceptance, activation, and monitoring of cathodic protection systems to various field conditions.

The C-102B contractor is Battelle Columbus Division. The contract was awarded in September 1988 and is scheduled for completion in March 1993.

Project C-102C is a short-term project conducted in close association with contract C-102A. C-102C is investigating the feasibility of injecting synergistic corrosion inhibitors into chloride-contaminated bridge components to prevent further corrosion after chloride removal, or as a method of corrosion prevention in its own right. The injection of chemical agents into the concrete to protect the reinforcing steel is possible, but very little work has been done in this field to date. The feasibility of using a special group of corrosion inhibitors that can be injected into the concrete by applying an electric field is being explored.

Early laboratory tests suggest that synergistic inhibitors become more efficient as chloride concentrations increase. If the feasibility study funded through this initial contract indicates further development is warranted, this technology has the potential to be developed into a powerful new weapon for combatting corrosion.

The C-102C contractor is SRI International. The contract was awarded in May 1988 and is scheduled for completion in November 1989.

Project C-103 is assessing conventional and chemical methods for concrete bridge repair and protection.

The project is evaluating existing and new techniques for concrete removal and surface preparation, and preparing recommended specifications for their use, covering such parameters as removal speed, depth control, and prevention of damage to remaining concrete. The project is exploring new chemical protection techniques, such as oxygen and chloride scavengers, chemical dewatering, corrosion inhibitors and polymers. It also is exploring rapid rehabilitation and protection methods such as patching techniques and polymer concrete overlays. The effect of weather conditions on these techniques is being established.

The project includes field tests to for validation of the effectiveness of the above methods in installations on decks, beam piers and abutments. A manual containing specifications and procedures is being prepared.

The C-103 contractor is Virginia Polytechnic Institute. The contract was awarded in September 1988 and is scheduled for completion in March 1993.

Project C-104 will combine the results of all of the other projects to develop a diagnosis and repair manual to guide the engineer through the evaluation, selection, application, and analysis process involved in structure rehabilitation. The manual will guide the engineer through the process of evaluating the condition of a structure, calculating the future rate of deterioration, selecting the optimum repair technique, applying it, and determining life-cycle costs for the repair of the structure.

The C-104 contract is scheduled for release in the second quarter of fiscal year 1990 (fall 1989).

In addition to the planned contracts, SHRP has awarded four IDEA (Innovations Deserving Exploratory Analysis) contracts for research in the Structures area. The SHRP-IDEA program encourages innovative approaches to achievement of the objectives of SHRP's planned contract research programs. The program awards contracts in the $100,000 range for about one year of exploratory research.

The Structures Contracting Plan is graphically illustrated on page 30. Staff and contractor organization charts are shown on page 31 and 32. Brief summaries of the scopes of work and progress to date for each of the Structures contracts and the Structures-related SHRP-IDEA projects are in Section IV.

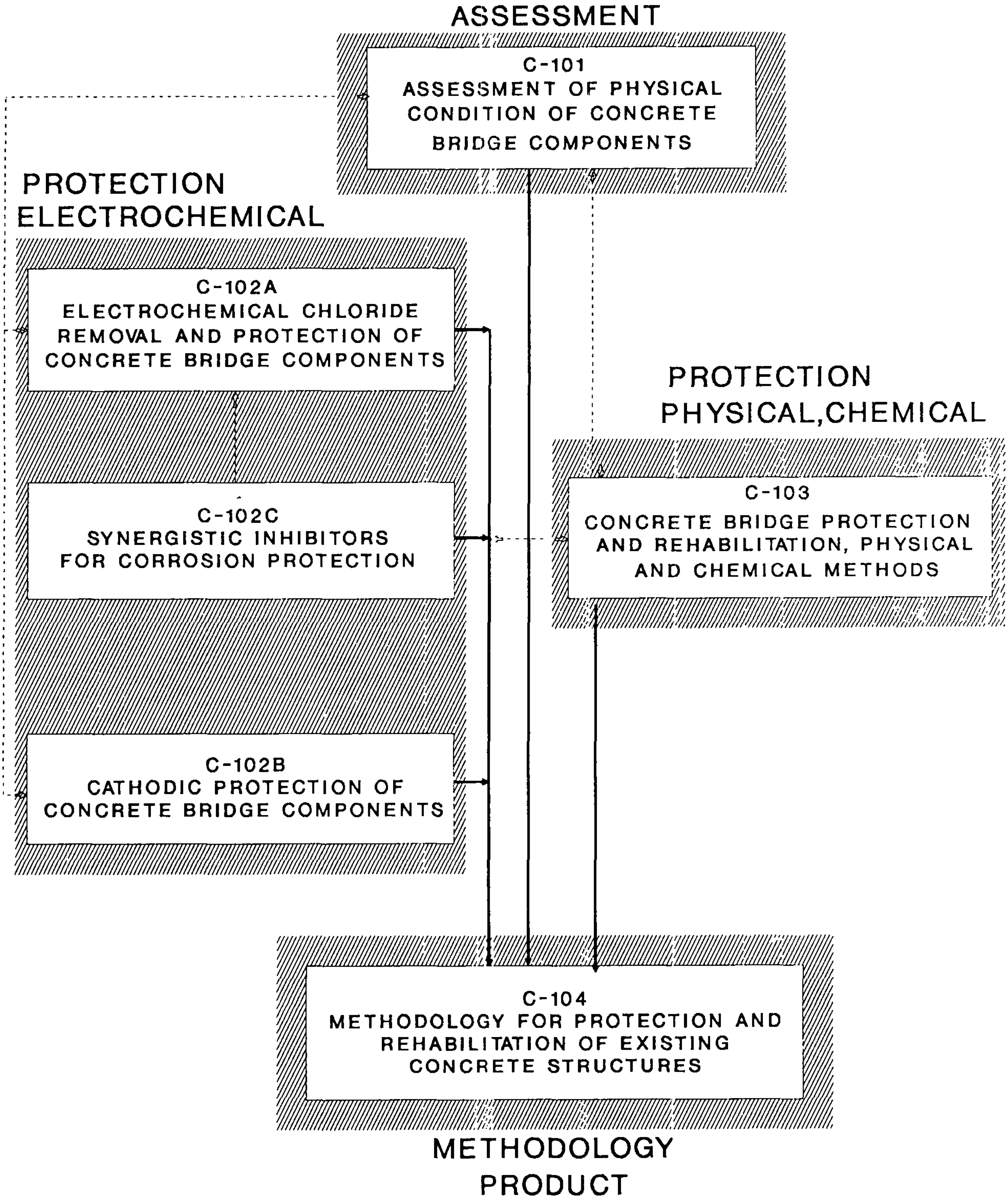


Figure 4. Structures Research Contracting Plan

Concrete and Structures Organization Chart

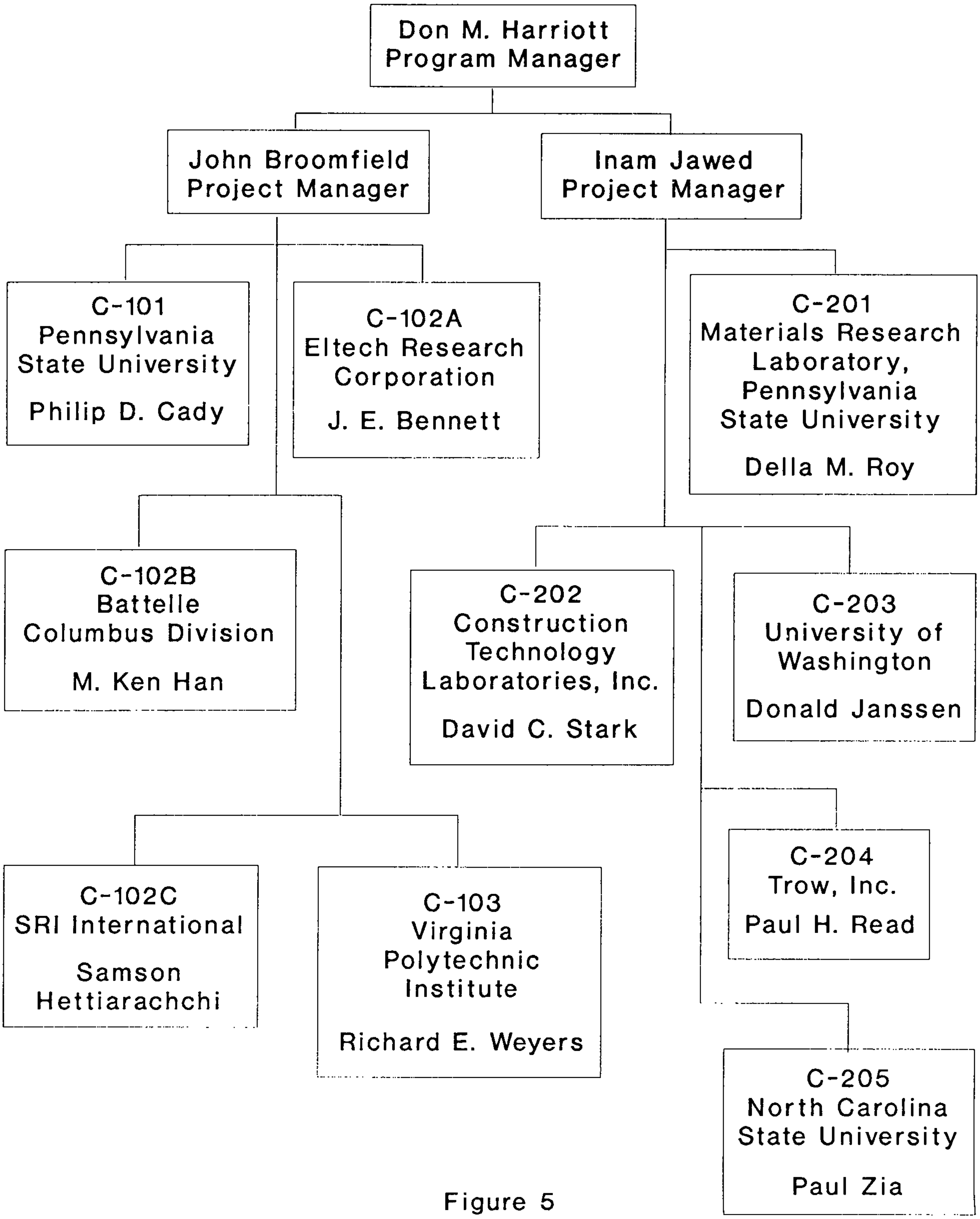


Figure 5

Concrete and Structures SHRP-IDEA Organization Chart

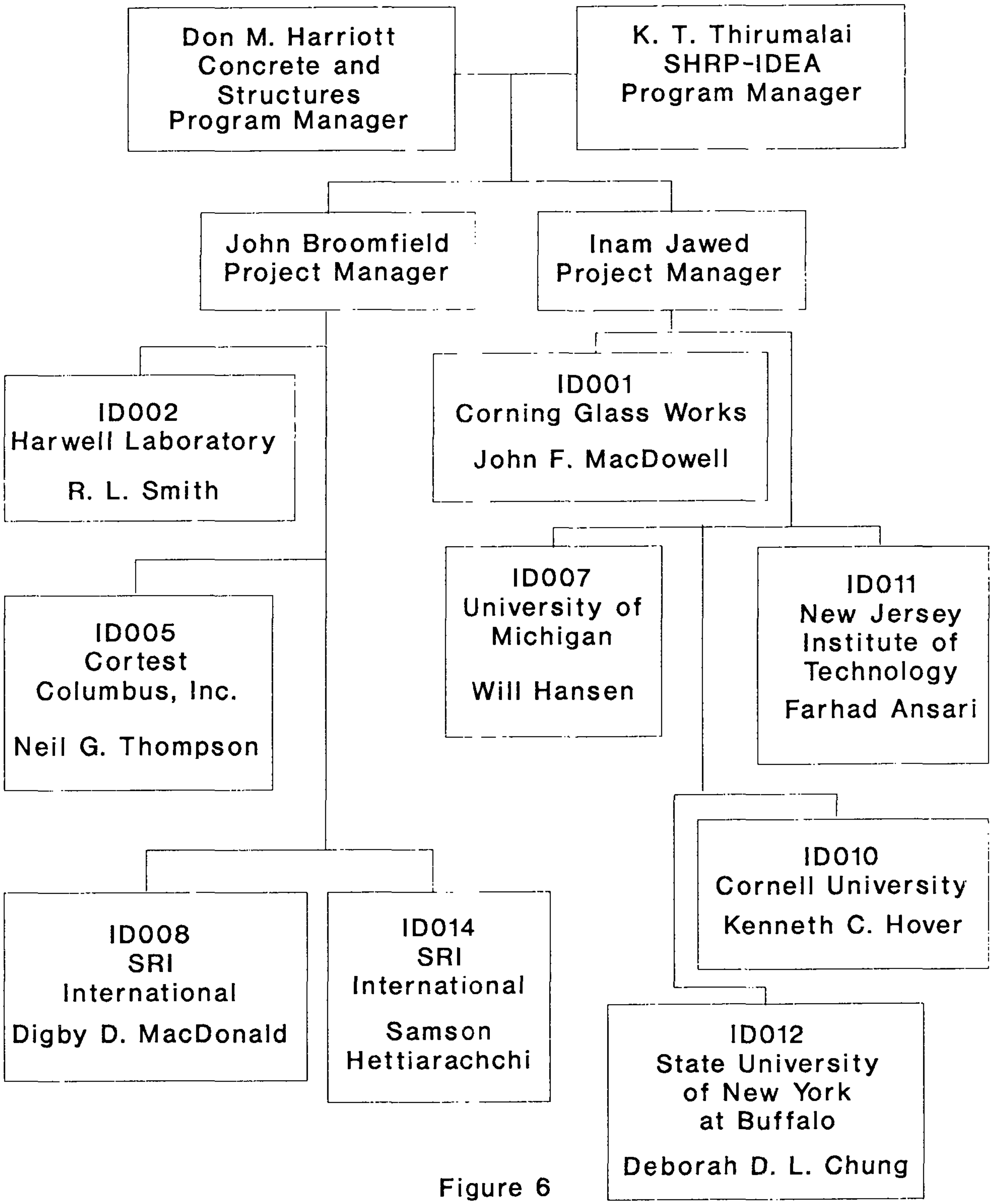


Figure 6

IV. Contract Project Summaries

CONTRACT C-101:	ASSESSMENT OF PHYSICAL CONDITION OF CONCRETE BRIDGE COMPONENTS
DURATION:	3 1/2 years (Aug. 1988 - Feb. 1992)
BUDGET:	$2,289,818
AWARD DATE:	8/11/88
CONTRACTOR:	The Pennsylvania State University 248 Calder Way, Suite 300 University Park, Pennsylvania 16801
PRINCIPAL INVESTIGATOR:	Philip D. Cady
STAFF MANAGER:	John P. Broomfield

DESCRIPTION:

The contractor will develop a number of non-destructive test techniques for use in evaluating the condition of deteriorating bridge components. At present there are limited methods of examining structures and determining the extent of deterioration. The aim is to develop economically viable procedures for determining the existing condition and predicting the future rate of deterioration. The project will develop the following:

- A method of measuring the corrosion rate of the steel embedded in the concrete. The most promising method(s) will be laboratory and field tested. The final product will be a field test method suitable for adoption by AASHTO/ASTM.

- A method of detecting delamination (cracking) in bridge support structures and another to detect delamination under asphalt covered decks.

- Methods to examine the permeability of the concrete, including methods for measurement of the effectiveness of membranes and sealers used on decks and on substructures respectively. A field technique for measuring the chloride content of the concrete also will be developed, along with methods for measuring water and chloride permeability.

- All techniques are to be field tested and calibrated, fully documented, for AASHTO or ASTM approval where possible.

PROGRESS:

Field work has been done using a Nippon Steel Corrosion Rate device and Radar. States use of Sealers has been surveyed and will be reported at TRB. Lab work continues on corrosion measurement and thermography. A decision will soon be made on whether to terminate work on thermography for substructures. Lab. work continues on corrosion rate measurement and integrity of membranes. Work on in situ chloride measurement is being written up. A disk containing the literature search has been produced.

Revised: October 30, 1989

CONTRACT C-102A: ELECTROCHEMICAL CHLORIDE REMOVAL AND PROTECTION OF CONCRETE BRIDGE COMPONENTS

DURATION:	5 years (May 1988 - Mar. 1993)
BUDGET:	$850,000
AWARD DATE:	5/04/88
CONTRACTOR:	ELTECH Research Corporation 625 East Street Fairport Harbor, Ohio 44077
PRINCIPAL INVESTIGATOR:	J. E. Bennett
STAFF MANAGER:	John P. Broomfield

DESCRIPTION:

This project will consider the use of a high voltage electric field to remove chlorides from concrete, thus preventing corrosion of the steel. It is high risk, and can therefore be terminated at an 18 months decision point if work shows that the technique will not be feasible. The technique of electrochemical removal should prevent corrosion initiation in concrete which has a high chloride level but has not shown signs of deterioration. By applying an electric field the negatively charged chloride ion can be removed from the concrete which can then be sealed against further chloride ingress. The contract is broken up into several tasks and decision points including:

- Laboratory studies of limitations to the technique and likely damage to the structure. Project terminates after 18 months if not feasible.

- Practical engineering methods for applying the technique and methods of sealing the concrete to stop recontamination after chloride removal.

- Field trials alongside those of C-102B.

- An implementation package for use by highway engineers.

PROGRESS:

A series of criteria for evaluating progress & achievement have been drawn up. These These have been achieved and work on developing practical techniques has been initiated. The anode selection has been narrowed down to steel or coated titanium. Rebar bond strength tests, large slab tests & embrittlement tests show acceptable results and are continuing. Methods of preventing chlorine gas relief heve been evaluated and several suitable candidates identified. A site evaluation of an Ohio bridge deck which had chloride removal done on it 3 years ago has been completed. An evaluation of a Norwegian process for chloride removal is underway, in collaboration with the Ontario Ministry of Transportation.

Revised: October 30, 1989

CONTRACT C-102B: CATHODIC PROTECTION OF CONCRETE BRIDGE COMPONENTS

DURATION:	4 1/2 years (Sept. 1988 - Mar. 1993)
BUDGET:	$1,900,000
AWARD DATE:	9/6/88
CONTRACTOR:	Battelle Columbus Division 505 King Avenue Columbus, Ohio 43201-2693
PRINCIPAL INVESTIGATOR:	M. Ken Han
STAFF MANAGER:	John P. Broomfield

DESCRIPTION:

The objective is to develop cost-effective and easily used cathodic protection systems for concrete bridge components and to produce specifications and a guide for installation of cathodic protection.

The contract is broken down into a series of tasks:

- State-of-the-art surveys will be carried out to assess the performance of present installations and to define appropriate starting points for the other tasks. A data base documenting in-service performance will be created.

- Laboratory and exposure plot studies to define long-term effects, both beneficial and adverse, of a cathodic protection system.

- Evaluation of the control and protection criteria used to operate cathodic protection systems. Durability of the components of the system also will be assessed.

- Field tests of deck and substructure systems will be carried out in a range of environments.

- A manual, describing design, construction, acceptance, activation, and monitoring, will be produced for use by highway engineers.

PROGRESS:

A survey of C.P. System installed by State DOT's has been completed. A draft report & database are under review. Laboratory work on criteria for control is progressing slowly. An evaluation of anodes and embedded monitoring probes is about to begin. A field survey of over 150 bridge CP systems is underway.

Revised: October 30, 1989

CONTRACT C-102C: INJECTION OF SYNERGISTIC INHIBITORS FOR CORROSION PREVENTION

DURATION: 1 1/2 years (May 1988 - Nov. 1989)
BUDGET: $178,619
AWARD DATE: 5/18/88
CONTRACTOR: SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025
PRINCIPAL
INVESTIGATOR: Samson Hettiarachchi
STAFF MANAGER: John P. Broomfield

DESCRIPTION:

This is a high risk project supplementing the main work in C-102A. It will specifically investigate a novel approach to corrosion prevention by impregnating chloride contaminated concrete with corrosion inhibitors to prevent them from attacking the steel. The aim is to produce a generic inhibitor that can be injected electrically into the concrete to inhibit the corrosive action of chlorides on the reinforcing steel.

Preliminary synergistic inhibitor studies will be undertaken to determine their effectiveness in the reinforced concrete environment. Work will then start on techniques for electrical injection of inhibitors and concurrent protection.

PROGRESS:

A Task 1 Report has been completed. The work in now underway on larger, more realistic specimens compared with the small mortar disks used in Task 1. Results are promising with inhibitors successfully passing through small mortar disks when current is applied. Results from the larger concrete specimens show a drop in corrosion rates and corrosion potentials. Destructive analysis has been delayed by loss of a technician. We expect a delay in completion of this project to January 1990.

Revised: October 30, 1989

CONTRACT C-103:	CONCRETE BRIDGE PROTECTION AND REHABILITATION: CHEMICAL AND PHYSICAL TECHNIQUES
DURATION:	4 1/2 years (Sept. 1988 - Mar. 1993)
BUDGET:	$2,694,482
AWARD DATE:	9/28/88
CONTRACTOR:	Virginia Polytechnic Institute and State University Blacksburg, Virginia 24061
PRINCIPAL INVESTIGATOR:	Richard E. Weyers
STAFF MANAGER:	John P. Broomfield

DESCRIPTION:

This contract is concerned with methods of removing chloride contaminated concrete from corroding bridge decks and substructures in a cost-effective manner, minimizing the volume of concrete removal while still protecting the steel from subsequent corrosion and new approaches such as oxygen and chloride scavenging, chemical dewatering, corrosion inhibitors, polymer impregnation. The task list is as follows:

- Field and literature survey of repair techniques.
- Feasibility studies of new approaches to protecting corroding bridge components.
- Evaluation of methods of removing salt contaminated concrete in terms of speed, control, effectiveness, and damage. Bar cleaning and surface preparation.
- Rapid repair techniques.
- Reinstatement and repair of bridges after concrete removal, including cementitious replacement materials, inhibitors, coatings, and sealers.
- Field evaluations of the most viable and cost effective techniques
- A manual will be produced, documenting the techniques developed in this project and those found in the survey.

PROGRESS:

Field surveys of State DOT's is underway to elicit rapid repair techniques. Field examination of a deep polymer impregnated bridge has been completed. A detailed database of rehabilitation techniques has been compiled and submitted to SHRP. Test techniques for innovative methods or repairs are being evaluated.

Revised: October 30, 1989

CONTRACT C-104:	METHODOLOGY FOR THE PROTECTION AND REHABILITATION OF EXISTING STRUCTURES

DURATION:	2 1/2 years (Oct. 1990 - Mar. 1993)
BUDGET:	$400,000 - $600,000
AWARD DATE:	Scheduled for October 1990
CONTRACTOR:	To Be Determined
PRINCIPAL INVESTIGATOR:	To Be Determined
STAFF MANAGER:	John P. Broomfield

DESCRIPTION:

The aim is to produce a repair manual for reinforced concrete bridges suffering from salt induced corrosion to ensure a rational, cost effective approach to bridge repair. This project will unify the elements in the previous contracts and will be mainly an office study. The project will develop a framework for a decision model, evaluating what is required in the model and ensuring that it is flexible and modifiable. Once fully developed, the manual will be tested under operational conditions by agency staff, and modified if necessary. The work will be carried out in the following stages:

- A set of equations will be developed to enable the engineer to take the measurements produced by techniques in C-101 and calculate the likely rate of deterioration of the bridge components.

- Flow diagrams will be developed to guide the user through the repair and rehabilitation procedure.

- Constraints limiting repair options will be identified, such as the need to maintain traffic flow, weather conditions, required lifetime, lack or availability of local expertise, etc.

- A decision model will be developed for use by agencies. This will include all options for repair, life cycle costs, and limitations or constraints of each option.

- The decision model will be tested, validated, and calibrated in the field by working with agencies.

- A user's handbook will be produced detailing the decision model, how it can be used, how to calibrate it, and how to modify it under field conditions.

Revised: October 30, 1989

CONTRACT C-201: CONCRETE MICROSTRUCTURE

DURATION: 3 years (Dec. 1987 - Dec. 1990)
BUDGET: $1,298,057
AWARD DATE: 12/1/87
CONTRACTOR: Materials Research Laboratory
Pennsylvania State University
University Park, PA 16802
PRINCIPAL INVESTIGATOR: Della M. Roy
STAFF MANAGER: Inam Jawed

DESCRIPTION:

The performance of concrete is a direct result of the microstructural development during its mixing, setting, and hardening processes. Practical problems such as early or retarded setting, excessive bleeding, drying shrinkage, inadequate strength, permeability, and frost damage can be traced to processes occurring on a micro or sub-microscopic level in the concrete matrix. An understanding of concrete at micro or sub-microscopic level is the initial and an important step toward achieving the means to control its microstructure and, hence, to improve its performance.

This research project will investigate factors that control the microstructure development in concrete, in particular the porosity and permeability, and will include the effect of chemical and pozzolanic admixtures. It will address how the microstructure affects the performance of concrete, and how it can be altered to improve the performance properties of concrete for highway use. The information generated will be synthesized into predictive models, along with recommendations for test methods, specifications and criteria for superior performance concrete.

PROGRESS:

Work on the relationships between mix design, packing and rheology of concrete has been completed. The task on concrete curing technology is almost complete. Tables, based on curing technology model, have been developed to specify proper curing conditions for various types of concretes under different environmental conditions. Modeling of pore size distribution is completed and correlations with permeability are being investigated. Device for measurement of concrete permeability has been developed, and is being tested. Work on the interfacial porosity and permeability is progressing well.

Revised: October 30, 1989

CONTRACT C-202:	ELIMINATING OR MINIMIZING ALKALI-SILICA REACTIVITY
DURATION:	4 3/4 years (Jun. 1988 - Mar. 1993)
BUDGET:	$1,720,103
AWARD DATE:	6/24/88
CONTRACTOR:	Construction Technology Laboratories, Inc. 5420 Old Orchard Road Skokie, IL 60077
PRINCIPAL INVESTIGATOR:	David C. Stark
STAFF MANAGER:	Inam Jawed

DESCRIPTION:

Alkali-silica reaction continues to be a significant cause of deterioration of highway concrete. Despite much research since the early 1940s, persistence of the problem shows the inadequacy of our current state of knowledge and methodology in controlling or avoiding this deleterious reactivity in concrete. Low-alkali cements have not always eliminated the problem. Test procedures do not always adequately identify potentially reactive aggregates. Even with relatively simple aggregates, there is controversy over the validity of test procedures and the significance of the results obtained.

This project will address issues of alkali-silica reactivity pertinent to the highway industry. It will develop reliable test methods and specifications for concrete-making materials that are resistant to alkali-silica reactivity. Environmental conditions favorable for this reactivity as well as requirements of the pozzolanic materials (fly ash, silica fume, etc.) to avoid or minimize it also will be established. In addition to new concretes, this research will also attempt to eliminate or control the reactivity in existing highway concrete structures.

PROGRESS:

Review of alkali-silica reactivity literature to identify gaps in current knowledge is being finalized. Experimental data for modeling alkali-silica reaction is being obtained which includes reaction kinetic data for representative aggregates, and data on inward progress of reaction in concrete cores. A prototype restraint system has been designed to simulate reaction when encapsulated in concrete. Field activity was carried out in a number of states (AL, CA, DE, GA, NC, SC, VA and NM). Evaluation of tests for reactive-aggregates has been initiated. Evaluation of polyether compounds for inhibiting alkali-silica reactivity in existing concrete continues.

Revised: October 30, 1989

CONTRACT C-203: RESISTANCE OF CONCRETE TO FREEZING AND THAWING

DURATION: 4 1/4 years (Oct. 1988 - Dec. 1992)
BUDGET: $1,184,222
AWARD DATE: 10/27/88
CONTRACTOR: University of Washington
Seattle, WA 98195
PRINCIPAL
INVESTIGATOR: Donald J. Janssen
STAFF MANAGER: Inam Jawed

DESCRIPTION:

Freezing and thawing is an important cause of concrete deterioration on the nation's highways. Previous research on the mechanism of frost action on hardened concrete established the protective effect of entrained air and led to the development of the void-spacing factor criterion as the basis for the assessment of the adequacy of the air-void system in concrete. However, even a properly air-entrained concrete suffers damage from cyclic freezing under certain conditions, such as when frozen at inadequate maturity or when non-durable aggregates are used. Admixtures, both chemical and pozzolanic, can modify the spacing factor requirements for resistance to freezing and thawing. Environmental factors such as partial drying and re-wetting have important effects on spacing factor requirements. Insofar as aggregate durability is concerned, D-cracking and pop-outs are the results of failure of aggregate particles due to freezing when critically saturated. Although various tests have been developed to identify and screen aggregates that cause these problem, the most reliable and informative methods are time-consuming and require rather expensive equipment.

This research will examine the mechanism of frost action, the conditions for air entrainment, and the protective effect of entrained air. It will determine how these mechanisms and conditions are modified by chemical and pozzolanic admixtures, aggregate characteristics, and environmental factors such as partial drying and re-wetting. The data will then be used to develop and improve criteria and test procedures to assess the potential resistance of concrete and aggregates to freezing and thawing.

PROGRESS:

Synthesis on factors affecting air voids and air void requirements for frost resistance of portland cement concrete has been completed. Development of experimental design and matrices has begun. Evaluation of concrete pore system has been initiated. States with unpublished useful data have been identified and contacted. Climatic data from states is being analyzed. Freezing rates for pavements have been determined, and similar data for bridge decks are being obtained. Aggregates durability data from states is being collected. Tests on aggregates durability have been initiated. A test method for identifying problem aggregates has been proposed and is being evaluated.
Revised: October 30, 1989

CONTRACT C-204: NON-DESTRUCTIVE TESTING FOR QUALITY CONTROL/CONDITION ANALYSIS OF CONCRETE

DURATION: 4 years (Mar. 1989 - Mar. 1993)
BUDGET: $1,599,843
AWARD DATE: 3/6/89
CONTRACTOR: Trow, Inc.
1595 Clark Blvd.
Ontario, Canada L6T 4V1
PRINCIPAL INVESTIGATOR: Paul H. Read
STAFF MANAGER: Inam Jawed

DESCRIPTION:

This research will address two areas of concern for the highway industry. The first deals with the assessment of the quality of concrete construction on highways. This assessment would be meaningful only if it could be done quickly and at the right time. Currently, quality assessments are based on monitoring the amounts and quality of the components going into the concrete mix, and periodic measurements of some properties of the mix--e.g. slump, air content, and unit weight--at the time the concrete is mixed and placed. From that time until a day or more later, when strength and profiling data become available, the contractor's primary tool for maintaining quality is visual inspection. This monitoring practice often has proven grossly inadequate. An improved QA/QC system should be based on rapid, reliable and, preferably, non-destructive techniques applied at critical points in the construction process, and designed to provide immediate quality feedback both to the contractor and the purchasing agency.

The second area of concern that this research will address is the evaluation of the condition of existing concrete in highway pavements and structures. Tests are needed to determine the internal condition of in-place concrete to allow effective planning and rehabilitation activities to extend the service life of the pavement or structure. A proper and acceptable quality evaluation system would be one based on rapid and reliable techniques to measure the particular characteristics of concrete which reveal its condition and predict its performance.

PROGRESS:

Prototype equipment for detecting alkali-silica reactivity in the field was assembled and demonstrated at the Construction Technology Labs., the C-202 contractor working on the alkali-silica reactivity problem. The effect of pressure on the rheology of fresh concrete is being investigated as part of development of modified air meter. Development of the impact echo technique (both hardware and software) is progressing well. Work on impedance measurements for determining the water/cement ratio of concrete has beein initiated. A questionnaire on non-destructive testing practice has been prepared, and is being sent to state highway agencies.

Revised: October 30, 1989

CONTRACT C-205:	MECHANICAL BEHAVIOR OF HIGH-PERFORMANCE CONCRETES
DURATION:	4 years (Mar. 1989 - Mar. 1993)
BUDGET:	$1,394,378
AWARD DATE:	3/1/89
CONTRACTOR:	North Carolina State University Raleigh, NC 27695
PRINCIPAL INVESTIGATOR:	Paul Zia
STAFF MANAGER:	Inam Jawed

DESCRIPTION:

High-performance concretes which normally contain materials such as fly-ash, silica fume, ground granulated slags, a variety of chemical admixtures, fibers, and other materials, individually or in various combinations, have been employed to provide significantly enhanced or improved mechanical properties or to obtain extraordinary properties at earlier ages. Highway engineers are increasingly using them for a variety of highway applications including new construction, repair, and rehabilitation. Higher strength concrete can enable more structural design flexibility and provide more options. Improved earlier age properties of concrete can facilitate construction and rehabilitation tasks and improve quality. To utilize these high-performance concretes most effectively, more information is needed about their mechanical properties and behavior in service under field environmental conditions (field curing, moisture, humidity, exposure to marine environment and deicing agents). This project is designed to address this need and will complement and supplement concrete-related work underway elsewhere in the SHRP program involving microstructure and durability issues such as alkali-silica reaction and freeze-thaw resistance.

PROGRESS:

An annotated bibliography of over 5000 entries, covering 13 subjects and dating back 15 years, has been completed. About 50% of these reference have been reviewed and screened. A bibliographic data base is being established. Contacts with private industries (Pyrament, Lone Star, Master Builders, Chem Tech) have been established.

Revised: October 30, 1989

CONTRACT C-206: OPTIMIZATION OF HIGHWAY CONCRETE TECHNOLOGY

DURATION: 2 1/2 years (Oct. 1990 - Mar. 1993)
BUDGET RANGE: $1.4 - 1.8 M
AWARD DATE: Scheduled for October 1990
CONTRACTOR: To Be Determined
PRINCIPAL INVESTIGATOR: To Be Determined
STAFF MANAGER: Inam Jawed

DESCRIPTION:

This project is aimed at unifying the results and products of all SHRP concrete research activities as well as recent developments in concrete technology. The goal is to present the user with tools (methodology and materials) for increasing the durability and service life of highway concrete. Products of this project will include field and training manuals, expert systems, audio-visual aids, and specifications for optimal highway concrete for designated uses.

This project will consist of the following tasks:

Task 1: This task will critically evaluate recent developments (including new proprietary materials and processes) in concrete technology and practice for highway applications. Building on this evaluation and the products of SHRP concrete research (C-201 through C-205), it will prepare a detailed workplan (Task 2) for optimization of concrete technology for highway applications.

Task 2: This task will test and validate materials and processes identified in Task 1 under a variety of environmental and service conditions. Based on the results, specifications for superior concrete materials for specific use under specific conditions will be prepared.

Task 3: This task will develop and test an expert system for use in diagnosing concrete durability problems and extending the service life of highway concrete. This expert system will use information generated by SHRP concrete programs as well as that available elsewhere to develop its knowledge bases. Such a system will allow the user to diagnose concrete problems, select concrete materials and mix designs for successful rehabilitation of older structures, and in case of new constructions, for designing for adequate performance in the environment of interest.

Task 4: This task will package the products of Tasks 2 and 3 in a form that is usable by the state highway agencies. These products will include field manuals, training texts, audio-visual aids and illustrations.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 001: STRATLINGITE-HYDROGARNET GLASS CEMENTS

DURATION:	1 year
BUDGET:	$75,000
CONTRACTOR:	Corning Glass Inc.
PRINCIPAL INVESTIGATOR:	John F. MacDowell
STAFF MANAGER:	Inam Jawed

DESCRIPTION:

This IDEA project evaluates the feasibility of using Stratlingite-Hydrogarnet glass (S-HG) cements for roadway, pavement, and bridge deck applications. S-HG cements are characterized by rapid curing, low porosity, low chemical reactivity, high strength, and low dependence on water/cement ratios. The suitability of five C_3A-based S-HG cement compositions will be tested in the laboratory. The proposal combines the material science and development expertise available at Corning with the engineering expertise available at Lehigh University-Engineering Research Center. Experimental tests will be performed jointly with Lehigh University-Fritz Engineering Laboratory (NSF Engineering Center).

This feasibility study on cement matrix composites may extend the use of S-HG cement materials into highway repair products for the SHRP program.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

Development of materials technology for highway repair using fast-setting and low-cost cementitious materials with low water/cement ratio.

PROGRESS:

The project work was initiated in November 1988 and is nearing completion. Tests on the setting time and early strength characteristics of a number of formulations were completed. Lehigh University is evaluating the durability and chemical stability of the materials. A 60 day no cost extension has been approved by SHRP for Lehigh to complete the final report on test results. Corning is currently negotiating with several construction materials manufacturers for Trial Testing the product in the field.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 002: THE USE OF LASER ULTRASONICS FOR THE RAPID NON-CONTACTING INSPECTION OF CONCRETE AND ASPHALT

DURATION:	9 Months
BUDGET:	$68,000
CONTRACTOR:	Harwell UK Atomic Energy
PRINCIPAL INVESTIGATOR:	Ronald L. Smith
STAFF MANAGER:	John Broomfield

DESCRIPTION:

The objective of this IDEA project is to evaluate an ultrasonic-based system for rapid non-contact inspection of concrete and asphalt structures, including pavements. The method involves measuring ultrasonic wave propagation induced by laser-pulsing. Laboratory tests will be carried out to evaluate the feasibility of the method for rapid detection of internal flaws in structures. The relative sensitivity of the method will be correlated using data from conventional impact devices currently used for pavement testing.

Laser ultrasonics methods have worked successfully in measuring defects in metals, ceramics, and composite materials, including concrete. The method has the potential to overcome the limitations of mechanical impactor methods for pavement testing.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

Development of a technique for non-contact pavement testing using pulsed lasers.

PROGRESS:

The SHRP-IDEA contract with Harwell was executed in September 1988. Harwell has completed experimentation on the feasibility of the technique. Thermal pulsing by a laser produced adequate thermo elastic response for pavement inspection. The results have shown the working of the concept in laboratory concrete samples and large test blocks of concrete and asphalt.

Harwell has successfully proved the feasibility of the method in the laboratory. The concept is now ready for prototyping and testing in the field. Negotiations are currently underway with several highway instrument manufacturers to explore cost sharing for prototyping and field testing phase.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 005: AN ELECTROCHEMICAL METHOD (EIS) FOR DETECTING ON-GOING CORROSION OF STEEL IN A CONCRETE STRUCTURE WITH CP APPLIED

DURATION: 1 year
BUDGET: $58,950
CONTRACTOR: Cortest Columbus
PRINCIPAL INVESTIGATOR: Neil G. Thompson
STAFF MANAGER: John Broomfield

DESCRIPTION:

A method for detecting ongoing corrosion in a cathodically protected reinforced concrete structure is not currently available. Previous studies by the investigator have established that the EIS method has applicability for monitoring corrosion.

Laboratory experiments will be performed to examine the applicability of the proposed method for detecting corrosion in small concrete specimens containing a single rebar, and large (5 feet x 5 feet) concrete slabs with two layers of rebars. Exposure plot studies will be made for different CP levels and chloride concentrations. Based on experimental data, a prototype field experiment will be designed for evaluating the practicality of the method.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

A technique for direct monitoring of rebar corrosion in structures which have cathodic protection.

PROGRESS:

The SHRP-IDEA contract was executed in September 1988. A series of small scale laboratory tests were completed. The efficacy of the concept to detect ongoing corrosion was established. Cortest proposed to perform additional larger scale tests in the laboratory to examine the viability of the method for prototyping and field testing as a supplemental effort. The request is currently being reviewed by SHRP staff.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 007: QUANTITATIVE AND RAPID MEASUREMENT OF AIR VOID SYSTEMS IN FRESH CONCRETE USED FOR PAVEMENT AND BRIDGE STRUCTURES

DURATION: 1 year
BUDGET: $77,366
CONTRACTOR: University of Michigan
PRINCIPAL INVESTIGATOR: Will Hansen
STAFF MANAGER: Inam Jawed

DESCRIPTION:

The objective of this IDEA project is to develop a field technique using a laser method for rapid and accurate measurement of the air void system in concrete immediately before and after placement. The method will be used to assess the durability of existing concrete pavement and bridge decks. If successful, the method will lead to significant improvement in quality control of new and existing concrete pavement and bridge decks.

The proposed study will be accomplished in three parts. Task 1 consists of evaluating results on hardened concrete with the laser method. In Task 2, techniques for coring in fresh concrete to measure air void systems will be developed. The data will be correlated with measurements on the same concrete in the hardened state. In Task 3, the influence of test time on the air void system prior to setting will be determined.

DELIVERABLE FOR HIGHWAY TECHNOLOGY:

A rapid field technique for measuring the air-void system in concrete during placement and setting.

PROGRESS:

The contract was executed in September 1988, and the project was initiated. A freeze drilling technique to recover cores from fresh concrete was designed and successfully tested. The project results have shown the feasibility of the method to measure air voids in concrete. A final report is under preparation.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 008: DEVELOPMENT OF ULTRALOW FREQUENCY AC IMPEDANCE SPECTROSCOPY (ULFACIS) FOR DETECTING AND LOCATING CORROSION ON REBARS IN REINFORCED CONCRETE

DURATION: 1 year
BUDGET: $95,101
CONTRACTOR: SRI International
PRINCIPAL INVESTIGATOR: Digby D. Macdonald
STAFF MANAGER: John Broomfield

DESCRIPTION:

This IDEA project assesses the viability of using the ultra-low frequency AC impedance spectroscopy (ULFACIS) method for monitoring and locating rebar corrosion in reinforced concrete. The concept presents a novel approach for quantitative non-destructive evaluation (NDE) of the onset of rebar corrosion in reinforced structures.

SRI has a preliminary theoretical study completed on the concept. Carefully designed experimental studies will be conducted to evaluate the concept and correlate the measured impedance characteristics associated with rebar corrosion.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

A new technique to locate and measure rebar corrosion in concrete structures.

PROGRESS:

The contract was executed in October 1988. Four concrete slabs with rebars were prepared for tests. The impedance measuring system was designed, and preliminary impedance data with reference electrodes placed on the concrete surface was obtained. Results show that the proposed concept may have some limitations for practical applications to bridge decks. A report on test results is nearing completion.

Based on the evaluation of the project by SHRP staff, the project work will not be considered for Phase II prototyping. The results will be made available to the highway community for potential further development.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 010: CONTROL OF ALKALI-AGGREGATE REACTION IN CONCRETE

DURATION:	1 year
BUDGET:	$86,550
CONTRACTOR:	Cornell University
PRINCIPAL INVESTIGATOR:	Kenneth G. Hover
STAFF MANAGER:	Inam Jawed

DESCRIPTION:

This IDEA project investigates the development of chemical agents which will neutralize the reactivity of deleterious aggregates, rendering them non-reactive (insoluble) in the presence of the alkalies. A two-pronged attack is planned to develop 1) admixtures to prevent the initiation of ASR in new concrete and 2) penetrating agents which will prevent or retard the progress of alkali-silica reactivity (ASR) in existing concrete.

In the first stage of this project, a number of chemical agents will be evaluated for their effectiveness in preventing the dissolution of reactive silica in a strong alkaline solution. On the basis of this work two most promising chemical agents will be selected for further study. The second stage will evaluate the effectiveness of the two chosen chemicals when used as admixtures to minimize ASR. A modified mortar bar expansion test will be used for evaluations.

The effectiveness of a series of chemicals for use as penetrating agents to mitigate ASR distress in existing concrete structures will be tested. The results will isolate suitable chemicals for use as penetrating agents for mitigating ASR distress in hardened concrete.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

This project, if successful, will provide a basis for developing an important class of alternative solutions to ASR problems.

PROGRESS:

The contract was executed in April 1989. Phase I of this study has been completed. Ten compounds were evaluated for their effectiveness in inhibiting silica dissolution. Of these, two compounds, zinc sulfate and pyragallol, have been identified for further tests in mortars and concrete.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 011: INSITU DETERMINATION OF ENTRAINED AIR IN FRESHLY MIXED CONCRETE USING FIBER OPTICS -- A NONDESTRUCTIVE APPROACH

DURATION: 1 year
BUDGET: $76,112
CONTRACTOR: New Jersey Institute of Technology
PRINCIPAL INVESTIGATOR: Farhad Ansari
STAFF MANAGER: Inam Jawed

DESCRIPTION:

The objective of this IDEA project is to develop a quality control method and apparatus to determine the amount and distribution of entrained air void systems in freshly mixed concrete using fiber optics technology. The technical basis for the measurement is the loss in light intensity outputs of thin optical fibers embedded in fresh concrete. Laboratory experiments will be conducted for developing the methodology. The outcome of the proposed project will be a hand-held device for insitu measurement of air content and its distribution within freshly mixed concrete.

DELIVERABLE FOR HIGHWAY TECHNOLOGY:

The method has a potential to develop cost effective and rapid quality control technique for estimating the amount and distribution of entrained air in fresh concrete.

PROGRESS:

The contract was executed in January 1989, and the research appears very promising. A special sensing tip was invented which is capable of measuring entrained air in less than a minute. Work is focusing on the design and fabrication of the air meter for field use.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 012: CARBON FIBER REINFORCED CONCRETE

DURATION:	1 year
BUDGET:	Phase I - $29,998 Phase II - $59,973
CONTRACTOR:	The Research Foundation of the State University of New York
PRINCIPAL INVESTIGATOR:	Deborah D.L. Chung
STAFF MANAGER:	Inam Jawed

DESCRIPTION:

The objective of the proposed IDEA project is to examine the use of carbon fiber reinforced cement (CFRC) improved by chemical agents. By using the proposed approach, short carbon fibers with 0.3 percent by volume of cement mortar, has a potential to double the tensile and flexural strengths as well as the ductility. Existing approaches require 4 percent by volume of carbon fibers in order to significantly increase failure strengths. This improvement would mean savings in material cost and ease of mixing during processing. Phase I project efforts are focused to prove the advantage of the concept in terms of enhanced strength characteristics by adding low volume of carbon fiber to concrete.

The Phase II project will extend the investigation and test this new technology for field applications. The mechanical properties, the freeze-thaw durability and the long-term chemical stability of the concretes will be tested. The quality of bonding between the carbon fiber reinforced cement mortar and the aggregates will be examined and possibly improved by adjusting the cement formulation.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

A cost effective CFRC Technology with high strength and more durable and resistant to cracking than using plain cement mortar.

If the project is successful, the investigators predict application in highways in about 3 years. CFRC use in highways and bridges will greatly reduce the cost of highway repair.

PROGRESS:

The contract was awarded on June 1, 1989. Phase I of the study has been completed. Using 0.5% carbon fibers by weight of cement, the contractor has shown about 40% increase in tensile strength as compared to ordinary portland cement concrete. The contractor has been asked to show the beneficial effect on actual highway concrete mixes.

Revised: October 30, 1989

CONTRACT SHRP-IDEA 014: FEASIBILITY STUDIES ON NONDESTRUCTIVE INCORPORATION OF A CONDUCTING POLYMER ANODE BED INTO BRIDGE DECK CONCRETE

DURATION:	1 year
BUDGET:	$74,954
CONTRACTOR:	SRI International
PRINCIPAL INVESTIGATOR:	Samson Hettiarachchi
STAFF MANAGER:	John Broomfield

DESCRIPTION:

The objective of the proposed IDEA project is to develop a cathodic protection (CP) technology by injecting conducting polymer anode network in the interior of concrete structures.

The project examines methods for insitu injection of conducting polymer anode network in the interior of the concrete by first injecting electropolymerizable monomers into concrete bridge decks with a low-field assisted transport process and subsequently polymerizing the monomers by increasing the electric field. The proposed approach, if successful, has a potential to reduce the effective separation between the anode and cathode (rebar) and thereby reduces the adverse impacts of increased power needed for CP operations.

DELIVERABLES FOR HIGHWAY TECHNOLOGY:

Design of a conductive polymer anode system in existing highway practices.

PROGRESS:

The project work was initiated in June 1989. Laboratory tests are underway to test the feasibility of creating a polymer anode network in concrete samples.

Revised: October 30, 1989