U.S. Department
of Transportation
**Federal Highway
Administration**

Bridge and Structures Related Research - Summary

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Federal Highway Administration
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Transmittal Memo

The following summary of the Federal Highway Administration bridge and structures related research program is provided for your general use and information. The goal of the research program is to develop a range of technologies to not only preserve and maintain our nation's bridges and structures, but to advance and develop new materials, new inspection techniques, and better design methodologies. The ultimate outcome of this research is expected to result in a reduction in construction/rehabilitation time and costs, and an increase in safety through fewer closures and work zone detours. To sum it up, our research is aimed at making bridges better and safer in your State. Our research efforts include:

- Development of high performance grades of steel to improve the quality and economy of steel bridge structures; plus, the development of environmentally acceptable coating systems for corrosion protection of steel structures.
- Design and construction of high performance concrete bridges to improve the strength, durability and economy of concrete structures; plus, the development of improved corrosion protection systems for concrete structures.
- Development and use of fiber-reinforced polymer (FRP) composites for bridge construction.
- Development of wood technology for transportation structures.
- Identification and development of nondestructive evaluation (NDE) technologies to support bridge inspection and bridge management systems.
- Assessment of seismic vulnerability of existing highway structures, and development of seismic design standards for new, and retrofit criteria for existing bridges.
- Identification and development of improved design methods for bridge and retaining wall foundation systems; and of rapid load testing and verification systems for bridge foundation elements such as piles, drilled shafts, and spread footings.
- Tests, refinements, and development of techniques for evaluating and simulating hydraulics, scour potential, and sedimentation processes for vulnerable bridge piers and foundations.

More specific information regarding each study is available from the contacts listed under each program and/or study.

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STEEL

The steel bridge research prc gram covers research into development and deployment of high performance steel, fundamental research into curved steel bridges, and research into bridge paints and coatings.

1. Curved Steel Bridge Research Study

This research is a coordinated effort between the Federal Highway Administration (FHWA), and participating States under a Pooled Fund Study. The objectives are to (A) conduct fundamental research into the structural behavior of curved steel members and (B) address construction issues, in order to provide adequate information to develop and clarify design specifications. This work consists of:

a. A comprehensive literature review and preparation of a synthesis. [This is complete, and a report titled, "*Curved Steel Bridge Research Project Interim Report I:Synthesis*" FHWA-RD-93-129 is available through the FHWA Report Center].
b. The study of construction issues.
c. Analytical and experimental study on the effects of nominal bending and nominal shear strength; and of the behavior of diaphragms, crossframes, and lateral bracing and their connections.
d. Investigation of serviceability considerations.
e. Experimental testing of I-girder components and a full scale I-girder bridge, at the Turner-Fairbank Highway Research Center, to determine the bridge's response and verify analytical work.

Contractor: **HDR Engineering, Inc.**
FHWA Contact: **Sheila Rimal Duwadi**

2. Curved Girder Bridge Analysis Techniques

This study will be conducted under the Graduate Research Fellowship Program. The objective is to determine limiting parameters for at least three different levels of analysis for horizontally curved bridges. This study will be started in FY97.
FHWA Contact: **Sheila Rimal Duwadi**

3. High Performance Steels for Bridge Construction

This study is developing new high performance grades of steel for use in bridge construction. The goal is to develop steels with 480 and 690 MPa yield strength that posseses excellent weldability and toughness compared to steels that are currently available. Thermo-mechanical processing, micro-alloy additions,

and other mechanisms are being investigated to provide the optimum combination of properties at a cost effective price. This program is being conducted through an interagency agreement with the **U S. Navy - Carderock Div. Naval Surface Warfare Center**, and it is being conducted cooperatively with the industry through the **American Iron and Steel Institute**. The result should be a new family of high performance steels that will improve the quality and cost effectiveness of steel bridge construction. The first product of this research (HPS-70W grade steel) is commercially available, and two demonstration bridges are planned for construction in fiscal year 1997. Currently the girders are being fabricated. Research is continuing on an advanced grade of 70W steel and on the 100W steel.
FHWA Contact: **William J. Wright**

4. Innovative Bridge Designs Using Enhanced Performance Steels

This project is investigating the potential for high performance steels to improve the quality and economy of steel bridge construction. There are two main objectives, one to determine the potential for using high performance steels in bridges as we build them today; and second to explore innovative design concepts to take better advantage of the attributes of high performance steel. Results are showing that HPS-70W has the potential to reduce steel weight by about 20% in many structures resulting in lower first cost. Many innovative design concepts were identified that show the potential for even greater savings. A final report for this project will be published in August, 1997.
Contract: **Modjeski & Masters/Lehigh University**
FHWA Contact: **William J. Wright**

5. Telemetry System for Remote Data Acquisition

A system to acquire data from bridge structures and relay this data off the bridge using telemetry was developed through a previous FHWA research contract to Invocon, Inc. in Conroe, Texas. This system eliminates the need for installing cables that are currently required for bridge monitoring. The system enables a drastic reduction in the cost associated with measuring the response of structures, and should lead to increased usage of this technique both for research purposes and for load rating of structures. This system is currently being evaluated for bridge monitoring by researchers at FHWA, Lehigh University, and the University of Texas/Austin.
FHWA Contact: **William J. Wright**

6. Evaluation of Peening Techniques for Improving the Fatigue Performance of Weldments

A new ultrasonic technique for peening toe of fillet welds was developed in

Russia that has the potential for improving performance of bridge structures. This technique was demonstrated at the FHWA's laboratory where portions of a welded plate girder were treated. Fatigue testing performed to date is showing that it is possible to elevate the fatigue strength of category C details to that of category B. Comparisons are also being made to more conventional peening techniques such as shot peening and hammer peening. A final report will be issued in summer, 1997.
FHWA Contact: **William J. Wright**

7. Investigation of Weld Cracking in 70 ksi Steel Bridges

The FHWA staff are assisting researchers at the Virginia DOT to determine the cause of weld cracking in several bridges, and are applying the latest fracture mechanics research to assess their criticality. The finding is that the cracking appears to be caused by excessive levels of hydrogen in the weldments. Fatigue has been ruled out as a cause through field measurements using FHWA's telemetry data acquisition system. Recommendations are being developed to prevent the occurrence of this type of problem in future structures.
FHWA Contact: **William J. Wright**

8. The following research studies are being conducted under the **Graduate Research Fellowship Program**, under the technical guidance of **Mr. William J. Wright**:

- Fracture Toughness of Bridge Steels
  This study is investigating the potential to use advanced fracture mechanics test procedures to evaluate the fracture reliability of bridge steels. A vast series of tests are being performed on 1 in. and 2 in. thick steel plates at a variety of temperatures to fully characterize material toughness for common bridge steels. Additionally, tests are being conducted on some high performance steels with toughness far exceeding that of currently used bridge steels. The results will provide a basis for performing better analyses of the fracture reliability of bridge structures. (GRF students: Joey Hartman, and Hernando Tjiang)

- Practical Application of Fracture Mechanics to Assess Cracking in Steel Bridges
  This study is developing the equations and methodology to apply fracture mechanics concepts for evaluating cracking in bridge structures. Currently, fracture mechanics analysis is very complicated to perform and only a limited number of experts are capable of evaluating bridges. The goal of this project is to develop a simplified guideline that practicing engineers can use to make

immediate evaluations when cracks are discovered in structures. This will assist consulting engineers and highway departments to make critical decisions on scheduling retrofit of structures and determining how long a cracked structure can safely be left in service until retrofit. Equations developed through this study are currently being applied to predict fracture of test girders at FHWA (GRF students: Xiaoguang Chen, Daging Feng)

9. Fatigue and Fracture Performance of I-girders Fabricated from High Performance Steel (HPS)

A series of full-scale test girders will be fabricated for this staff study from the different grades of high performance steel that are becoming available through other research. The fracture toughness of these steels is typically much higher than those used today for bridge construction. The girders will be loaded to grow fatigue cracks and subjected to overload in order to test the fracture performance. Results to date are showing that the HPS girders can tolerate much larger cracks without fracture than girders fabricated from conventional steel. Results will be analyzed to determine the effect of the higher toughness on bridge redundancy, performance, and inspection requirements.
FHWA Contact: **William J. Wright**

10. Containment Efficiency: Environment and Worker Exposure

The objective is to develop a field containment evaluation and monitoring plan for abrasive blasting containment systems, containment air flow and dust level, and nonabrasive blast operations, and to evaluate the operational safety factors for type CE air fed hoods.
Contractor: **VERSAR, Inc.**
FHWA Contact: **Bob Kogler**

11. Adhesion Criteria Between Water-Based Inorganic Coatings and Their Topcoat for Steel

The objective is to identify the cause of failure for both the coated and uncoated inorganic zinc coatings and to develop a quality control field testing procedure that will identify if the primer is in a condition for exterior exposure and/or topcoating. This program is being conducted as a pool-fund study.
Contractor: **Ocean City Research Corp./BIRL-Northwestern University**
FHWA Contact: **Shuang-Ling Chong**

12. Characterization of the Environment

The objective is to characterize the corrosivity of environments in different regions of the country. The resulting data and guidelines will be useful in specifying appropriate bridge coatings and weathering steel during the design

process.
Contractor: **Ocean City Research Corp**
FHWA Contact: **Bob Kogler**

13. Service Life Prediction Methodology

The objective is to develop a statistically meaningful method to analyze coatings by testing results using laboratory accelerated data as well as shorter-term natural exposure data.
Contractor: **National Institute of Science and Technology**
FHWA Contact: **Shuang-Ling Chong**

14. Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges

The objective of this study is to determine the relative performance of the various newly available bridge coatings that meet current and pending environmental restrictions for solvent and heavy metal content. This project is complete with the final report currently pending.
Contractor: **Ocean City Research Corp.**
FHWA Contact: **Bob Kogler**

15. Guidelines for the Repair of Bridge Coatings

This study is developing data on the performance of various "overcoating," or maintenance coating materials. In addition, this study will investigate the technical criteria used to determine the feasibility of overcoating bridge structures.
Contractor: **Ocean City Research Corp.**
FHWA Contact: **Bob Kogler**

16. Health and Safety Aspects of Bridge Painting

This is a cooperative training course development with the National Highway Institute. The objective of this course is to provide a training forum for FHWA and State bridge engineers in the area of bridge coatings maintenance and specification. This course will include guidance on coatings selection, surface preparation specification, and environmental and worker safety issues.
Contractor: **KTA/SET Environmental**
FHWA Contact: **Larry Jones**

17. Performance of Moisture-Cured Polyurethanes

This is a two-year in-house research project. The objective is to study and to compare the performance of different moisture-cured polyurethane systems on steel. Two types of coating systems are evaluated; they are coatings for new construction and for maintenance. The effect of chloride contaminated surfaces

on the coating performance is also investigated.
FHWA Contact: **Shuang-Ling Chong**

18. Cost-effective, Alternative Methods for Steel Bridge Coating System Maintenance

This study identifies and evaluates promising technologies for maintenance removal and application of coating systems for steel bridges. Candidate technologies will be assessed in the laboratory and in the field. Benefits will be assessed versus current state-of-the-practice. This study will be awarded in FY97.
FHWA Contact: **Bob Kogler**

CONCRETE

The focus areas in concrete research are High Performace Concrete and Corrosion Protection. High Performance Concrete (HPC) is a major FHWA Structures Technology Program initiative. The Program is being led by the HPC Bridge - Techlology Delivery Team (TDT) that was formally established in May 1997. A goal of the HPC Bridge TDT, along with the AASHTO HPC Lead States Team is to implement this proven technology through completion of at least one HPC bridge project in every State by the Year 2002. The HPC Bridge TDT consists of FHWA staff from Research and Development, Office and Technology Applications, Office of Engineering, FHWA field offices, plus academia and the private sector. In addition to HPC the other focus area 'Corrosion Protection' is aimed at developing improved corrosion protection systems for bridge steels used in reinforced, pretensioned, and postensioned concrete structures.

1. High Performance Concrete Bridge Projects

The FHWA has initiated of number of high performance concrete (HPC) bridge projects. A number of participating states have selected one or more bridges as demonstration HPC sites where improvements in concrete durability and/or strength can be made. Each project includes some degree of research, design, instrumentation, construction, and technology transfer. The FHWA shares funding for the HPC bridge with the individual State where the project is located. Some projects have also been partially funded by a group of 10 states which combined their research funds into a "pooled-fund" effort. The FHWA Research & Development HPC Bridge TDT contacts are **Susan N. Lane, Marcia Simon, and Sheila R. Duwadi**. Current projects are listed below; others are under negotiation.

- **Texas** - The Louetta Road Overpass near Houston, TX and the San Angelo Bridge in San Angelo, TX are currently under construction. Both incorporate HPC in the deck, girders, and substructure. A Showcase was held in Houston, TX during March 1996 to transfer this technology to a regional and national audience. Construction is scheduled to be completed on the two bridges during 1997.

- **Virginia** - The Virginia DOT plans to build 7 to 10 bridges utilizing HPC in the deck and/or the superstructure. A number of these bridges have been completed. The Richlands Bridge near Bristol, VA will be the first one in Virginia to utilize the 0.6-in diameter prestressing strands in the HPC girders. A Showcase to transfer this technology for FHWA Region 3 states will be held in June 24-26, 1997.

- **Nebraska** - The 120th Street and Giles Road Bridge was completed in 1996 in Sarpy County, NE. This bridge incorporates HPC in the deck and girders. A Showcase was held for FHWA Region 7 states in November, 1996.

- **New Hampshire** - The Route 104 Bridge crossing the Newfound River at Bristol, NH was completed in 1996. This bridge also incorporates HPC into the deck and girders. A Showcase for FHWA Region 1 states will be held in September 22-23, 1997.

- **Ohio** - The State Route 22 Bridge at Mile Post 6.57 in Guernsey County, Ohio is currently under design. Structural experimentation on HPC box beams will be conducted in the Spring of 1997.

- **Colorado** - The Interstate 25 Bridge over the Yale River in Denver, Co is currently under construction. Construction on this project began in November, 1996 and is expected to continue into late 1998. A Showcase for FHWA Region 8 states is planned for February, 1998.

- **Washington** - The Eastbound State Route 18 Bridge over State Route 516 in King County, WA is currently under construction. The construction contract was awarded in July 1996 and the bridge is scheduled to be completed in July 1997. A Showcase for FHWA Region 10 states will be held in August 18-20, 1997.

- **Alabama** - The Alabama Highway 199 Bridge over Uphapee Creek in Macon County, GA is currently under design.

- **North Carolina** - The U. S. 401 Bridge over the Neuse River in Wake County, NC is currently under design.

- **Georgia** - The Georgia HPC bridge on State Route 920, Jonesboro Road, in Henry County, GA. is currently under design.

2. Optimized Sections for High Strength Concrete Bridge Girders

- **Phase 1**: This phase analyzed the feasibility of using high-strength concrete with current prestressed concrete girder cross-sections. Sections included Bulb-Tee sections, AASHTO Type VI sections, the Texas U-Beam, the Nebraska NU girder, and modified sections from Florida, Washington, and Colorado. The analyses indicated that using concrete compressive strengths up to 10,000 psi allowed longer span lengths and more economical structures.

The researchers also identified possible modifications to current practice which would allow high-strength concrete to be used more cost-effectively. The final report for this phase will be printed soon.

- **Phase 2**: This phase evaluated the effect of using high performance concrete (HPC) in bridge decks. It concentrated on the structural effects of using HPC rather than on the durability effects. The effect of using HPC in the deck on the flexural strength, ductility, prestress losses and long-term deflections of the superstructure were evaluated. Cost analyses were also performed. The draft final report for this phase has been completed and is currently under review.

Contractor: **Construction Technology Laboratories, Inc. and Henry Russell, Inc.**
FHWA Contact: **Susan N. Lane**

3. High Performance Concrete State-of-the Art Report

This effort is an update of the Strategic Highway Research Program (SHRP) report No. SHRP-C/FR-91-103, "High Performance Concretes: A State-of-the-Art Report." A draft final report is currently under review.
Contractor: **North Carolina State University**
FHWA Contacts: **Lou Colucci & Susan N. Lane**

4. Fatigue of High-Strength Concrete Bridge Girders

This study is a continuation of a study funded by Minnesota DOT; the continuation of the study is funded by a "pooled-fund " research effort of nine State DOTs. It examines the fatigue performance of high-strength prestressed concrete girders. Draft final reports are under review.
Contractor: **University of Minnesota**
FHWA Contact: **Susan N. Lane**

5. Investigation of Development Length of Uncoated and Epoxy-Coated Prestressing Strand

The objective of this staff study is to investigate the validity of AASHTO Equation 9-32 for predicting both the transfer length and development length for fully-bonded, uncoated and epoxy-coated prestressing strand. Toward this end, the effects of strand diameter (3/8, 0.5, and 0.6 in), concrete strength, and strand coating (uncoated or epoxy coated) on development length will be evaluated.

- **Phase I**: Fifty rectangular prestressed concrete specimens were fabricated in our Structures Laboratory beginning in September, 1990. These specimens ranged in size from: 4" x 4" x 12'-0" to 14" x 14" x 28'-0".

Experimentation to determine transfer length for these specimens was conducted for one year. Development length experimentation followed and was completed in Fall 1992. Analysis and report writing is continuing.

- **Phase II**: Sixty-four full-size prestressed concrete I-girders and deck panels were fabricated during February through May 1994 at Shockey Bros. precast concrete plant in Winchester, VA. The members were constructed with either normal strength (f'c = 5000 psi) or high strength (f'c = 10,000 psi) concrete. Transfer and development length experimentation on these members began in May 1994 and was completed in June 1995. A new development length equation has currently being developed with assistance from the Construction Technology Laboratories, Inc. The equation is under review.

FHWA Contact: **Susan N. Lane**

6. Investigation of Transfer and Development Lengths for Lightweight Prestressed Concrete Members

The goal of this Graduate Research Fellowship project is to determine the transfer and development lengths for prestressed concrete members made with lightweight concrete. Expanded shale, clay, and slate were donated for this project by the lightweight concrete industry. The members were fabricated at Shockey Bros. precast concrete plant in Winchester VA during February and March 1994. The members were then shipped to our Structures Laboratory for experimentation to determine the transfer and development lengths for the members. This experimentation has been completed. A final report is under review.

FHWA Contact: **Susan N. Lane**

7. Monitoring of North Halawa Valley Viaduct

This research study involves monitoring of instrumentation already installed on the North Halawa Valley Viaduct in Hawaii. Data collected on prestress losses in prestressed concrete girders, creep and shrinkage of concrete, bridge deflection, and span rotation over a three-year period (1996-1999) will be analyzed .

Contractor: **University of Hawaii and T. Y. Lin International**

FHWA Contacts: **FHWA Hawaii Division, Region 9, & Susan N. Lane**

8. Delayed Ettringite Formation in Concrete

The goal of this program is to investigate the expansive cracking of concrete associated with the formation of ettringite. This problem has been identified in Texas and may be occurring in a number of other states. The program has three

major elements: 1. Understanding the specific mechanism of damage, 2. Establishing the range of conditions under which it occurs, and 3. Developing nondestructive test methods for evaluating the extent of damage.

At Turner Fairbank Highway Research Center (TFHRC), chemical thermodynamics models are being developed to determine the conditions under which ettringite forms. Also samples of damaged concrete will be evaluated by a combination of conventional materials characterization techniques such as X-ray diffraction. Neutron diffraction instruments at the National Institute of Standards and Technology in Gaithersburg, MD will be used to verify the thermodynamic models, and to scan sections of damaged concrete for the presence of ettringite and associated minerals. Finally, new types of scanning microscopes using sound or lasers at the Mineral Physics Group of the University of Hawaii will be used to investigate the physical mechanism of the ettringite damage.

A nuclear measurement instrument developed at TFHRC will be taken to Texas to scan the concrete for elevated levels of potassium and sulfate, which are believed to be major factors in ettringite formation. In addition, a magnetic system developed by Southwest Research Institute will be applied to measure the loss of bond between the concrete and the steel prestress tendons. Finally, to evaluate the microcracking of the concrete itself, an advanced impact-echo ultrasonic system developed by Cornell U. will be used.
FHWA Contacts: **FHWA Texas Division, Region 6 & Richard A. Livingston**

9. Prediction of Chloride Penetration in Concrete

The broad objective of this research is to develop a new method or methods for predicting chloride ion penetration into portland cement concrete contained in bridges and pavements, and to correlate the results from this new test or tests with a long-term ponding test. The new method(s) will be utilized for predicting resistance of concrete to chloride ion penetration for use in evaluating new mixes, accepting or rejecting new concrete according to specifications, and evaluating in-place concrete. This project will be awarded in FY97.
FHWA Contacts: **Susan N. Lane and Marcia Simon**

10. Field Evaluation of CP Systems on Prestressed Concrete Bridge Components

The objectives of this contract are to: install durable cost-effective state-of-the-art Cathodic Protection (CP) systems on prestressed concrete bridge (PS/C) components; evaluate effectiveness of the applied CP systems in combating corrosion process; and identify all limitations of the system and potential risks to the structure due to application of CP for the remaining life of the bridge. To meet these objectives CP systems utilizing catalyzed titanium mesh, conductive rubber,

and arc-sprayed zinc anodes were installed on prestressed pilings and girders of the Howard Frankland Bridge in Tampa, Florida; and CP systems utilizing flame-sprayed zinc and conductive paint anodes were installed on soffits of prestressed box beams of the Abbey Road bridge and the West 130th Street bridge near Cleveland, Ohio. These three bridges have been evaluated for two years. An interim report on the installed CP system (FHWA-RD-95-032) is available. The final report is under preparation.
Contractor: **Eltech Research Corporation**
FHWA Contact: **Dr. Y.P. Virmani**

11. Long-Term Effects of Cathodic Protection on Prestressed Concrete Bridge Members

The objective is to conduct laboratory research in order to develop solutions for various issues and concerns on the application of CP technology to PS/C bridge members as a routine maintenance and rehabilitation tool and at par with R/C. To date the findings indicate: (1) prestressed concrete structures can be qualified for cathodic protection based upon the amount of uniform and localized corrosion and section loss in the prestressing strands; (2) loss of bond within the anticipated remaining service life of most prestressed concrete structures should not be a concern provided current density is within the normal range and is not locally concentrated. These and related findings are evaluated within the context of standards for prestressing steel and criteria for cathodic protection. An interim report on above findings is available (FHWA-RD-96-029).
Contractor: **Florida Atlantic University**
FHWA Contact: **Dr. Y.P. Virmani**

12. Corrosion Protection Systems for Bridges in Corrosive Environment

The objectives are to define the concentration of species and environmental conditions corrosive to reinforcing and prestressing steel. This research focuses on two main issues: (1) to define the desired physical and chemical properties that must be possessed by concrete for patching and overlays (rehabilitation), and (2) to define the desired physical and chemical properties required by concrete in new construction if it is to avoid the corrosion-induced concrete deterioration in the presence of well defined corrosive conditions. The research is divided into three major tasks: Task A - Corrosive environments studies; Task B - Concrete chemical and physical properties and Task C - Long-term corrosion performance. A draft interim report (FHWA-RD-96-207) containing the results of Tasks A and B is available.
Contractor: **Columbus Technologies**
FHWA Contact: **Dr. Y.P. Virmani**

13. Sacrificial Cathodic Protection Systems Project I

The objective is to develop sacrificial CP anodes as an alternative to impressed current CP anodes for both R/C and PS/C bridge components. Field evaluations of installed sacrificial CP systems was carried out. Based on this information, a detailed laboratory and field study on newly developed sacrificial CP anodes was conducted. A sacrificial anode alloy AL-20 Zn-0.2 developed under this program performed well in the laboratory studies. Therefore, this anode was installed on selected prestressed piles of Byrnt Patton Bridge near Tallahassee, Florida. The CP has been in operation for one year and is performing satisfactorily. A draft interim report (FHWA-RD-96-171) is available.
Contractor: **Corrpro Companies Inc**
FHWA Contact: **Dr. Y.P. Virmani**

14. Sacrificial Cathodic Protection Systems - Project II

The objectives are to investigate the development of sacrificial anode systems for substructure and superstructure in the laboratory, and to install the developed anode systems in the field to protect both R/C and PS/C bridge components. The laboratory studies demonstrated that aluminum alloys are unsuitable as anodes in contact with hydrogel adhesives. The aluminum and its alloys exhibited either unstable passive behavior or low anode working potential. Therefore, zinc was selected as the sacrificial anode for installation in field validation trials. Commercially available hydrogel adhesives also proved to be unsatisfactory for CP systems. However, further research resulted in the development of a hydrogel with adequate performance and life expectancies.

About 1,000ft^2 (100 m^2) of zinc/hydrogel composite was installed on the pilings, pile caps, and double-tee beams of a fishing pier in Ft. Pierce, Florida. Another field installation was carried out on five V-piers off the Long Key Bridge in Florida. These systems were installed to mitigate corrosion of reinforcing steel above bearing pads of the piers. A third installation of 750 ft^2 is scheduled for June 1997 at Capt Perpetua Bridge in Oregon. An interim report on the above findings and installation is available (FHWA-RD-96-073).
Contractor: **Eltech Research Corporation**
FHWA Contact: **Dr. Y.P. Virmani**

15. Corrosion Resistant Reinforcement for Concrete Components

The objective is to develop a cost-effective new breed of bridge coatings (e.g., organic, inorganic, ceramics, metallic) and metallic alloys (as reinforcement) which are significantly more corrosion-resistant than the fusion-bonded, epoxy-coated reinforcement presently used for reinforced concrete (R/C) bridge application in adverse environments. The following three interim reports have

been prepared:

- *The Performance of Bendable and Nonbendable Organic Coatings for Reinforcing Bars in Solution and Cathodic Debonding Test,* Interim Report, FHWA-RD-94-103.

- *The Performance of Bendable and Nonbendable Organic Coatings for Reinforcing Bars in Solution and Cathodic Debonding Test: Phase II Screening Tests,* FHWA-RD-96-021.

- *The Corrosion Performance of Inorganic-, Ceramic-, and Metallic-Clad Reinforcing Bars and Solid Metallic Bars in Accelerated Screening Tests,* Interim Report, FHWA-RD-96-085.

Based on screening tests on 57 different organic, inorganic, ceramic, metallic-clad and alloyed rebars; 11 rebar types were chosen for in-concrete testing for a period of 96 weeks. Significant results to date and after 48 weeks of in-concrete testing are as follows:

- Previous research, field data and research under progress all indicate better performance when both reinforcing mats are of the same material over black rebar in the bottom mat.

- The use of steel surface chemical pretreatments did not appear to increase the corrosion performance for epoxy-coated rebars (ECR)when bottom mat was black steel. At hole (purposely damaged ECR bar or a large damaged area) adhesion does not always correlate to better corrosion performance.

- Stainless steel 304 showed excellent performance in concrete at 48 weeks of ponding (Cl^- concentrate at steel level of about 20 lbs/yd^3). Further ponding indicated some increase in measured macro-cell corrosion current. Demolition of the specimen after 96 weeks of ponding will provide additional information about its performance.

- To date, 316 stainless steel appears to perform better than 304 stainless steel.

- In general, copper-clad rebars have shown good performance and are comparable or better than ECR.

- Not surprisingly, defects and holidays diminish the ECR performance.

- In general, bent bars (both ECR and metallic-coated) showed inferior performance over straight bars.

- Short term cathodic disbondment, hot water immersion, and salt spray screening tests for ECR did not correlate well when tested in fabricated reinforced concrete specimens under longer duration.

Contractor: **Wiss, Janey, Elstner Associates, Inc.**
FHWA Contact: **Dr. Y.P. Virmani**

16. Verification of Effectiveness of Epoxy-Coated Rebars

The objective of this regional pooled fund study is to investigate the field performance of epoxy-coated reinforcing steel in bridge decks in the States of Pennsylvania and New York. To accomplish the slated objective 240 cores were extracted from 80 selected bridge decks. The 80 bridges were visually surveyed. The extracted cores will be tested in the laboratory for permeability of concrete, chloride content at rebar level, and detailed evaluation of extracted ECR segments with regards to holidays, coating thickness, adhesion loss, and observed corrosion on bare areas and under the coatings. Laboratory and visual survey data will be statistically analyzed for evaluation of ECR as a corrosion protection system.
Contractor: **ConCorr Inc.**
FHWA Contact: **Dr. Y.P. Virmani**

17. Improvement in Graphite Reference Cells for Reinforced Concrete-SBIR Phase II

The primary objectives of this study are to further develop the modified graphite electrode, test its long term performance, and identify the best graphite and the modification process that can provide the reproducibility desired for low-cost man production. Draft report is under preparation and will be available in September 1997.
Contractor: **ConCorr Inc.**
FHWA Contact: **Dr. Y.P. Virmani**

18. Rehabilitation of Prestressed Concrete Bridge Components by Non-electrical (conventiona) Methods

The study will focus on conventional technology and develop method for rehabilitating salt contaminated prestressed concrete (PS/C) bridge members without using cathodic protection. The study will identify suitable materials and develop necessary techniques to reduce corrosion of existing prestressing steel in PS/C bridge members. An interim report on the condition of surveyed PS/C bridge is available (FHWA-RD-93-037).
Contractor: **Construction Technology Laboratories**

FHWA Contact: **Dr. Y.P. Virmani**

19. Magnetic-Based System for NDE of Prestressing Steel in Pre-Tensioned and Post-Tensioned Concrete Bridges

The objective of this study is to design, fabricate and demonstrate a nondestructive evaluation (NDE) system based upon principles of magnetic field variation for detecting and locating imperfections such as corrosion and fracture of steel elements in reinforced, pre-tensioned, and post-tensioned concrete bridge members. Interim design report includes a brief summary of the technical developments in the area of magnetic flux leakage and the proposed refinements for fabricating an automated NDE systems consisting of (a) basic sensing unit; (b) Beam-Rider unit; (c) Push Cast unit for horizontal surfaces; and (d) Pier Inspection system. Contractor: **University of Wisconsin-Milwaukee**
FHWA Contact: **Dr. Y.P. Virmani**

20. Development of an Embedable Microinstruments for Reinforced Concrete

The objective of this study is to develop an inexpensive micro-instrument that will serve as an integrated, intelligent system for performing electrochemical measurements such as rate of corrosion of embedded steel, chloride at steel level, and pH of concrete at steel interface. This micro-instrument circuit board has been fabricated and has been successfully tested for rate of corrosion of black steel in simulated concrete pore water solution contaminated with chloride ions. The results were presented at the National Association of Corrosion Engineers (NACE) annual meeting, Corrosion/97. The paper presented at the meeting is available.
Contractor: **Virginia Transportation Research Council and University of Virginia**
FHWA Contractor: **Dr. Y.P. Virmani**

21. Investigation of Some Issues Related to Electrochemical Chloride Extraction (ECE) from Reinforced Concrete

The objectives of this investigation are: (1) to develop a set of definite procedures for estimating, before an ECE treatment is applied to a concrete structure, the optimum treatment time for the structure; and (2) to formulate a model with which the expected beneficial life of the treatment for a concrete structure can be estimated.
Contractor: **Virginia Transportation Research Council and University of Virginia**
FHWA Contact: **Dr. Y.P. Virmani**

22. Field Evaluation of Corrosion Inhibitors for Concrete

The objective of this national pooled fund study is to evaluate the effectiveness of available corrosion inhibitors for rehabilitation and repair of salt-contaminated reinforced concrete bridge members. Specifically, the study will evaluate corrosion inhibitors for:

- Ability to mitigate corrosion in short-term and long-term repairs.
- Effect on behavior of anodic regions around repairs.
- Compatibility with portland cement-based repair mortar and concrete mixtures.

Both laboratory and field studies will be performed to evaluate the above parameters.

Contractor: **Virginia Transportation Research Council**
FHWA Contact: **Dr. Y.P. Virmani**

23. Corrosion Inhibitors in Concrete

The objective of this study is to evaluate the use of corrosion inhibitors mainly for new construction with limited effort on rehabilitation. The study has the following objectives:

- Establish the use of corrosion inhibitors for new construction corrosion prevention and evaluate the ability of the corrosion inhibitor to be physically present at the rebar surface after long periods (30-50 years) following construction.
- Estimate the effectiveness of the corrosion inhibitor after 30-50 years of aging in concrete.
- Determine the extent of possible negative side effects of the corrosion inhibitor presence.
- Quantitatively assess the extension of the corrosion initiation and propagation periods as a function of amount of corrosion inhibitor introduced.
- Establish the suitability of the corrosion inhibitor for rehabilitation of corroding structures.

Contractor: **Florida Department of Transportation and University of South Florida**
FHWA Contact: **Dr. Y.P. Virmani**

FIBER-REINFORCED POLYMER (FRP) COMPOSITE MATERIALS

Fiber-Reinforced Polymer Composites is a major emphasis research area for the FHWA as a means of developing new higher performance alternative material for highway structures. Following are descriptions of projects underway or planned for the near future. In addition, the FHWA, as part of an interagency cooperation, continues to provide technical advice to the Advanced Research Projects Agency (ARPA) Technology Reinvestment Project (TRP) in its projects involving seismic column wrapping and lightweight deck development, and to the National Institute of Standards and Technology (NIST) Advanced Technology Program (ATP) in its low-cost manufacturing technology projects: Vacuum-Assisted Transfer Molding; Phenolic-Based (Note: Phenolics are fire- and heat-resistant resins) Structural Shapes; Seismic Retrofit Manufacturing Process (related to ARPA project); and Machining of Composite Structural Members. Information on specific projects in the area of FRP may be obtained through the FHWA contact - **Eric Munley**.

1. Modular Concepts for FRP Bridge Decks

This study examined available methods for developing models for structural behavior from the fundamental mechanics of the FRP material and developed analytical models for use by bridge designers. The study is complete. The following publications are available:

- *Local Buckling of Fiber-Reinforced Polymeric Structural Members Under Linearly-Varying Edge Loading*
- *Preliminary Designs of Fiber-Reinforced Polymeric Bridge Decks*

Contractor: **Georgia Institute of Technology**

2. Behavior of Adhesive Joints in Highway Structures

This study determined the long-term cohesive performance of adhesive joints subjected to natural (temperature/moisture/UV, alone and interactively) and man-made (deicing salts, solvents, fires) environments found on highway bridges. The study is complete. FHWA research report, *Cohesive Behavior of Adhesive Joints in Highway Structures,* has been prepared and will be available in mid-1997.
Contractor: **TRI**

3. Advanced Composite Cable-Stayed Bridge

A cable-stayed two-lane vehicular bridge, with a 435' clear span is being proposed for construction in San Diego. FHWA conducted a systems development study for the bridge as mandated by Congress. The study is complete. Three alternative superstructure designs were evaluated, and pilot experimental work was conducted on each of the alternatives. A carbon shell concrete superstructure frame system was recommended for further development.

FHWA research report, *The I-5/Gilman Advanced Composite Cable-Stay Bridge Study* will be published in mid-1997.
Contractor: **University of California at San Diego**

4. Use of FRP in Highways

This Congressionally mandated study continued and extended the work of a previously completed study in FRP rebar reinforcement of concrete, and developed design data for FRP structural shapes. This study is complete. A series of FHWA/WVDOH-published HPR reports covering the topics of Compression Behavior, Cellular Decks and their Connections, and Rebar development is available.
Contractor: **West Virginia University**

5. Accelerated Test Methods to Determine Long-Term Behavior in FRP Composite Structures

This 4 year study will build a series of test methods to measure FRP structural behavior for a range of FRP materials under a broad range of environmental and loading conditions. The test method must also be rapid enough to predict structural performance for a 50+ year period in a reasonable amount of time.
Contractor: **Georgia Institute of Technology / Pennsylvania State University / Catholic University**

6. Fiber-Reinforced Composite Hanger Cables

These series of studies will evaluate the performance of an FRP Composite Cable for use as a hanger element on suspension and tied-arch bridges, concentrating on end-anchorage details. Design criteria for cables and end connections were developed as a result of previous experiments. A 10-foot hanger cable will be installed by CalTrans on the Desmond Memorial Bridge in Long Beach, California, to study the performance of the cable under service loads and environmental conditions. The FHWA is performing supporting studies prior to the California installation.
Contractor: **California State University at Long Beach**

7. FRP Prestressing for Highway Bridges

This 4-year study will develop economical tendon and anchorage systems, which would allow construction with existing techniques, for FRP prestressing tendons (both cables and bars). This study will develop designs for FRP prestressing tendons, including tendon profiles, and will develop structural material and design specifications and construction procedures for both pre- and post-tensioned systems.
Contractor: **University of Wyoming / Pennsylvania State University**

8. Bonded Structural Repair Systems for Highway Bridges: FRP- Concrete

This 4-study will produce preliminary mandatory long-term performance specifications for FRP repair and retrofit materials and systems bonded to concrete structural elements. It will produce recommended qualification and acceptance test standards for material components and systems, and recommended test standards to develop design data based on predicted material and system long-term properties. It will produce preliminary specifications and guidelines for the analysis, design, and construction of four designated highway bridge applications using FRP repair systems bonded to concrete structural elements. Finally, it will produce recommendations for methods to conduct field investigations of long-term mechanical behavior and environmental durability of bonded FRP repair systems. This project will be awarded in FY97.

9. Field Study of a Modular FRP Bridge Deck

This study, partially-supported under the Graduate Research Fellowship Program, will monitor the performance of a 15' modular FRP deck installed in an approach ramp at the Troutville (Va.) Truck Weigh Station on I-81. (**California State University at Long Beach)**

10. Technical Support

Technical support for the following OTA-funded studies is being provided by the Structures Division. A number of additional projects will be added in FY 97.

- Bixby Creek, CA Seismic Retrofit
- Arroyo Seco, CA Seismic Retrofit
- Alfalfa Ditch, CA Superstructure Replacement
- Murray Co, GA Pile Bent Cap Bonded Repair
- FRP-Bonded Repair of an AASHTO Type II Concrete Girder (GA DOT)
- Magazine Ditch and Glasgow, DE Superstructure Development projects
- New Castle Av., DE Column Bent Cap VARTM Repair
- Troutville, VA Modular Bridge Deck Field Evaluation

TIMBER

Timber bridge research is being conducted under an interagency agreement with the Forest Service - Forest Products Laboratory (FPL). Individual studies are conducted in six topical areas defined in the ISTEA legislation. Each study is a cooperative study with universities, local governments agencies and industry. Projects are advertised and awarded each year. Information on specific projects may be obtained through the FHWA contact - **Sheila Rimal Duwadi** or the FPL contact - **Michael A Ritter**. The following represents studies sponsored by the FHWA. A more comprehensive summary of the combined FPL/FHWA program on timber bridge research is also available.

Area I: System Development and Design

1. National bridge monitoring program

Field performance of timber bridges including stress-laminated decks, T, and box designs constructed of sawn lumber, glued laminated timber and structural composite lumber is being investigated. These structures are located across the United States and include bridges constructed as demonstration bridges as well as those built by local governments and the Forest Service. Monitoring activities for each bridge typically include a 2-3 year assessment of wood moisture content and bar force levels, two or more load tests and intense visual inspections. Additional information is also collected depending on specific site requirements. The information obtained from these activities is being used to develop improvements in design, fabrication, and construction procedures. At the present approximately 35 bridges are being monitored in over 20 States (Cooperators: numerous governmental agencies and universities).

2. Field evaluation of a timber bridge constructed with metal plate connected trusses (FP-93-1972)

The objective is to evaluate the field performance of the first timber bridge in the U.S. constructed of metal plate connected trusses. This is a two span bridge where the first span is constructed of stress-laminated trusses, and the second span is constructed of truss girders with a bolt-laminated lumber deck.
Cooperator: **University of Alabama**

3. Develop long-span timber bridge systems using glued laminated timber (FP-90-1352, FP-92-1875)

This study is aimed at developing stress-laminated box beam bridges using glued laminated timber. The first phase involved evaluation of individual box and I sections to establish behavioral characteristics. This second phase involves developing analytical methods for analyzing multi-cell box beam bridges and formulating recommended design guidelines. The research work has been completed.
Cooperator: **University of Wisconsin**

4. Development of stress-laminated truss bridges using light-frame metal plate connected trusses (FP-90-1409, FP-92-1871, FP-94-2309)

This research is aimed at developing stress-laminated truss bridges using light-frame

metal plate connected (MPC) trusses. The study includes evaluation of cyclic moisture content, preservative treatment, fatigue load effects on connections, and connection durability under environmental conditions.
Cooperator: **University of Maine**

5. Evaluate cold temperature effects on stress-laminated timber decks (FP-92-1874)

This research study is investigating the effects of cold temperatures on the performance of stress-laminated timber decks. The study involves several stress-laminated decks constructed of Red Pine lumber which will be evaluated under controlled laboratory conditions to determine temperature effects for different temperature ranges and moisture contents. Results of this work will be combined with results from the previous study to formulate design recommendations for stress-laminated bridges used in cold regions.
Cooperator: **University of Minnesota**

6. Dynamic evaluation of timber bridges (FP-92-1877)

This study is evaluating the dynamic behavior of timber bridges through analytical and field evaluations of superstructures constructed of sawn lumber, glued laminated, and stressed laminated timber. Results will be used to improve design procedures and formulate recommendations for changes to the current AASHTO specifications.
Cooperator: **Iowa State University**

7. Stress-Laminated Wood T and Box Beam Bridge Superstructures (96-RJVA-2821)

The objective of this study is to conduct an independent evaluation of stress-laminated T and box beam bridge research and field performance, and to formulate recommendations as to the technical and economical feasibility of these bridge systems and additional research needs.
Cooperator: **Auburn University**

8. LRFD Calibration for Wood Bridges (96-RJVA-2822)

The objective of this study is to refine the Load & Resistance Factor Design (LRFD) criteria for wood bridges currently given in the AASHTO LRFD Bridge Design Specifications.
Cooperator: **University of Michigan**

9. Evaluation of Alternative Prestressing Elements

Through field monitoring of stressed-laminated timber bridges it is becoming evident that alternate stressing system needs to be developed for these bridge types. The objective of this staff study is to evaluate different stressing elements such as prestressing strands, and fiber-reinforced rods or strands. The feasibility and effectiveness of the different types of elements will be evaluated on test decks constructed at FPL, and recommendations for the applicability, use, construction, and performance of the various elements will be formulated.

10. Effect of Seismic Loadings on Timber Bridges

Within the past several years there has been significant seismic activity in the United States and elsewhere where numerous bridges have been damaged due to earthquakes. Performance of steel and concrete highway bridges have generally been documented, and significant research has gone into developing better details for these structures. This study will document the performance of timber bridges in seismically active regions, and make recommendations if necessary for design changes, better details, etc. This project is being advertised for award in FY97.

11. Structural Composite Lumber

Structural Composite Lumber is a relatively new engineered wood product for bridge applications. The objective of this study will be to assess creep and deflections characteristics, evaluate effects of cyclic moisture changes, exposure to ultraviolet light, effect of preservatives, and general long term structural integrity of the product for bridge applications. This study is being advertised for award in FY97.

Area II: Lumber Design Properties

12. Shear strength of sawn lumber beams (FP-94-2266)

The object of this study is to determine the shear strength of non-checked and checked solid sawn lumber beams in order to develop the AASHTO shear design criteria for beams subjected to edgewise bending. Tests will be conducted on three species and will involve beam tests, shear block tests and fracture constant tests. Revised AASHTO criteria will be applicable to the design of new bridges, and to the analysis and load rating of existing structures. Publication:*Experimental Shear Strength of Unchecked and Solid-Sawn Douglas-fir*, FPL-RP-553.
Cooperator: **Washington State University**

Area III: Preservatives

13. Accelerated laboratory testing of new wood preservatives- ecosystem studies (FP-93-2022)

This project will test 10 different wood preservatives that currently are in use or show promise for bridge applications. Accelerated testing using small wood beams are being conducted under laboratory and field conditions to determine efficacy for protecting various softwood and hardwood species commonly used for timber bridges. The specimens will be subjected to complexes of wood degrading fungi and to termites. The results of this study are necessary for the formulation of proposed treatment specifications for bridge members.
Cooperator: **Michigan Technological University**

14. Accelerated laboratory testing of new wood preservatives - pure culture studies (FP-93-2023)

The objective is to test 16 different wood preservatives that currently are in use or show promise for bridge applications. Accelerated testing using small wood specimens will be conducted under laboratory conditions to determine efficacy for protecting seven

softwood and eight hardwood species commonly used for timber bridges. The results of this study are necessary before field trials can be completed for code acceptance.
Cooperator: **Oregon State University**

15. Treatments and methods for field treating bridge members (FP-93-2024)

This study will develop treatments and methods for field treating bridge members. It will identify and/or develop equipment, preservative formulae and procedures for effectively treating field cuts, bore holes and other breaks in preservative treatment encountered during bridge construction and maintenance operations. The project will result in a comprehensive users guide to remedial treatments for timber bridges.
Cooperator: **Oregon State University**

16. Performance characteristics of various wood preservatives for stress-laminated bridge applications (FP-92-1880)

This project is evaluating the effects of various wood preservatives and anchorage configurations on the dimensional stability of stress-laminated decks constructed of Southern Pine lumber. Seven different wood preservative formulations and three anchorage systems are being evaluated using full-scale stress-laminated decks.
Cooperator: **Florida A&M/Florida State University**

17. Manual on wood preservatives for transportation structures

The objective is to develop a comprehensive manual on the use of wood preservatives for wood transportation structures. The manual will provide a practical background on wood deterioration processes, wood preservatives and environmental issues, and guidelines for specifying and using treated wood. In addition, information will be included for wood treaters including recommendations for processes and procedures for treating wood for transportation structure applications.

18. Treatability of heartwood (FP-94-2271)

This study will evaluate the treatability and durability of heartwood in various softwood and hardwood species as applicable for utilization in transportation structures through analysis of existing data. It will consider both emerging and conventional wood preservatives including oilborne and waterborne systems.
Cooperator: **Michigan Technological University**

19. Copper Naphthenate Preservative for Bridge Applications (95-RJVA-2622)

Naphthenic acid, as commercially derived from crude oil, is a complex mixture of saturated monocarboxylic acids containing one or more cycloalkane rings. Naphthenic acid is used as one of the basic components in manufacturing copper naphthenate, an important wood preservative. However, it is currently difficult to determine the relative composition of naphthenic acids, and the effectiveness of the components of copper naphthenate wood preservative against wood decay fungi. The objective of this research is to develop a means for quantitative separation of naphthenic acid components and to evaluate the effectiveness of the components against decay fungi.
Cooperator: **Michigan Technological University**

20. Environmental Effects of Wood Preservatives (96-RJVA-2828)

The objective of this research is to develop recommendations and guidelines on the potential environmental impacts associated with the use of wood preservatives in transportation structures.

Cooperator: **Oregon State University**

21. Moisture protection for timber members (96-RJVA-2820)

The objective of this study is to develop, refine, and evaluate coatings and other protective coverings for protecting timber members from moisture. Emphasis will be placed on end grain and vertical or horizontal side grain in exposed locations or concealed joint locations where moisture exposure could lead to premature deterioration. The protection may include or supplement preservatives or may involve non-chemical alternatives.

Cooperator: **Pennsylvania State University**

Area IV: Alternate Transportation System Timber Structures

22. Development of crashworthy bridge rail systems; PL-1 (FP-89-1183-A1,A2), and PL-2 (FP-89-1183-A3)

These studies are complete. The following bridge rail systems for use on longitudinal timber decks have been successfully crash tested at AASHTO Performance Level One (PL-1):

1. Glued laminated timber rail with curb;
2. Glued laminated timber rail without curb;
3. Steel rail without curb;
4. Approach rail transition for a glued laminated timber rail to a steel approach rail.

The following bridge rail systems for use on longitudinal timber decks have been successfully crash tested at AASHTO Performance Level Two (PL-2):

1. Glued laminated timber rail with curb;
2. Steel rail without curb;
3. Steel approach rail transition for use on the glued laminated timber rail.

Standard plans for these systems are available.

Cooperator: **University of Nebraska, Lincoln**

23. Timber bridge rail testing and evaluation - transverse deck; PL-1

This study is complete. Three different bridge rails and one transition, for use on transverse deck timber bridges, were successfully crash tested to meet PL-1 criteria. .

1. PL-1 glulam bridge rail on transverse glulam deck supported by steel beams.
2. PL-1 glulam transition rail.

3. PL-1 glulam bridge rail on transverse glulam deck supported by glulam beams.
4. PL-1 steel rail on transverse glulam deck supported by steel beams.

Contractor: **West Virginia University**

24. Delaware and Raritan Canal Project

The objective of this study is to develop timber bridge rails for approximately 24 historical bridges on the Delaware and Raritan Canal, New Jersey. The state has contracted with a consultant to develop the rail systems. These will be crash tested at the Pennsylvania Transportation Institute, in accordance with NCHRP Report 350.
Contractor: **A.G. Lichtenstein & Associates**

25. Development of Sound Barriers

This study will evaluate and develop designs of wood sound barriers with an emphasis on acoustic characteristics, stability and longevity. The study will consider various wood products and will result in recommended design criteria and designs for wood sound barriers, including proposed changes to national standards.
Cooperator: **Pennsylvania State University**

26. Development of Crash-Tested Bridge Railings - Transverse Deck; TL-4 (95-RJVA-2630)

The original objective of this project was to develop and crash test two Test Level 4 (TL-4) bridge rails and approach rail transitions, in accordance with NCHRP Report 350, for use on timber bridges with transversely laminated decks. TL-4 is approximately equivalent to a AASHTO PL-2 level rail. The project has been modified to include development and testing of two additional bridge rails at Test Level 2 (TL-2) for use on transverse timber bridge decks, and development of timber rails on concrete decks.
Cooperator: **University of Nebraska, Lincoln**

Area V: Inspection/Rehabilitation

27. In-place evaluation of timber bridges using stress wave technology (FP-93-2025)

The objective is to develop guidelines for applying existing nondestructive testing technology for in-place evaluation of timber bridges. The study will develop and present guidelines for equipment use and interpretive procedures for evaluation of various bridge components based on field and laboratory research.
Cooperator: **Washington State University**

28. Equipment and methods for determining the in-place stiffness of stress-laminated timber decks constructed of sawn lumber

The objective of this staff study is to adapt existing NDE technology to develop a simple procedure for determining in-place stiffness of individual laminations within existing stress-laminated lumber bridges. This information will be used to evaluate field performance and assess structural integrity.

29. Guidelines for the design and application of waterproof asphalt wearing surfaces for timber decks. (FP-94-2272)

This project will examine the behavioral characteristics of various types of timber deck systems and develop recommendations for the design and application of waterproof asphalt wearing surfaces using membranes and/or geotextile fabrics.
Cooperator: **Virginia Polytechnic Institute**

30. Manual for timber bridge inspection (95-RJVA-2629)

The objective of this research is to develop a comprehensive manual for the inspection of timber bridge superstructures, and substructures that will supplement the FHWA's Bridge Inspectors Training Manual 90. The manual will document and explain the causes and processes of timber deterioration and the traditional procedures and equipment for inspection. It will also present an overview of the Non Destructive Evaluation techniques that can be used for inspection.
Cooperator: **University of Tennessee**

31. Development of NDE Techniques for Wood Transportation Structures (96-RJVA-2825)

The objective of this research is to develop NDE techniques for the inspection, condition evaluation, and in-situ strength assessment of wood transportation structures.
Cooperator: **Washington State University**

32. Remedial Treatments for Bridge Applications (FY-97)

The objectives of this research are to investigate new and current remedial treatments such as fumigants that will stop internal decay in bridge structural components, and to provide guidelines on their use, application, and effectiveness for applications involving wood bridge members. This project is being advertised for award in FY97.

Area VI: Technology and Information Transfer

33. Meetings toward development of AASHTO Specifications for timber bridge design

This project is set up to sponsor meetings to develop proposed revisions to the AASHTO Standard Specifications for Highway Bridges related to timber structures.

34. Standard plans and specifications for timber bridge superstructures (FP-93-2021)

This project will develop standard plans and specifications for the following types of timber bridge superstructures:

- Glulam beams with transverse glulam deck
- Longitudinal glulam deck
- Longitudinal stress-laminated deck
- Longitudinal spike-laminated deck
- Longitudinal nail-laminated deck
- Transverse nail-laminated deck

- Timber decks on steel beams

The design details and specifications will be available as half-size drawings and on computer disks for use in computer aided drafting systems.
Cooperator: **Laminated Concepts, Inc.**

35. National Conference on Wood Transportation Structures

The FHWA and FPL are jointly sponsored a conference on Wood Transportation Structures. The conference presented state-of-the-art information on wood utilization in transportation applications including bridges, noise barriers, and marine facilities. The conference was held in Madison, Wisconsin, October 23-25, 1996. Proceedings of the conference is available. Publication: *National Conference on Wood transportation Structures*, General Technical Report, FPL-GTR-94.

36. Computer Program - Design, Rating & Drafting of Wood Bridge Superstructures - Beta Testing (FY-97)

The University of Wyoming under contract with the Forest Products Laboratory developed a program for design of the following wood bridge superstructures:

- Glulam beams with transverse glulam deck
- Longitudinal glulam deck
- Longitudinal stress-laminated deck
- Longitudinal spike-laminated deck
- Longitudinal nail-laminated deck

In this study the program will be undergoing 'beta testing' before release.

37. Update of the Research Needs Study (FY-97)

A six year research needs assessment for timber transportation structures was completed in 1992, and forms the basis of the FPL/FHWA research program. Under this project, this needs assessment will be updated to include a summary of work completed to date, and will include development of the next six years of research needs for wood transportation structures.

38. Development of CD Rom (FY-97)

Under this project two CD roms will be developed containing information from the wood in transportation program. The first will include proceedings of the Conference on Wood Transportation Sructures, drawings of the crash tested bridge rails, field evaluation reports and other publications under this program available this year. The second will include additional publications, etc. from studies that are currently underway.

NONDESTRUCTIVE EVALUATION (NDE) OF HIGHWAY BRIDGES

The development of nondestructive evaluation techniques and equipment for inspection, and condition assessment of highway bridges is another emphasis area for the Office of Engineering Research and Development. The NDE program is divided into six areas and a Nondestructive Evaluation Validation Center. Information on specific projects, and programs may be obtained from the FHWA contacts: **Dr. Steven B. Chase, Dr. Richard Livingston, or Mr. Glenn Washer.**

Area I: Advanced Bridge Deck Inspection Technology

1. Development of Dual-Band Infrared Thermography Imaging System for Bridge Deck Inspection

This project is adapting defense technology developed for buried land mine detection to the quantitative inspection of bridge decks. Looking at bridge decks using two different infrared wavelengths simultaneously overcomes some of the operational problems (primarily surface emissivity variations) that have been experienced with infrared thermography as applied to the detection and quantification of delaminations on bridge decks. A first phase evaluation on test slabs demonstrated that dual-band infrared thermography could detect delaminations in both bare concrete and asphalt-covered concrete and that surface emissivity variations could be compensated for by application of image processing techniques. A fully operational mobile IR imaging system was delivered to FHWA in February 1996. It is currently undergoing field testing to more fully evaluate the benefits of dual-band infrared thermography on actual bridge decks.

2. Ground-Penetrating Radar Imaging for Bridge Deck Inspection

This project will develop an engineering prototype of a new generation ground-penetrating radar for bridge deck inspection. The system will use impulse radar, synthetic aperture techniques, and sophisticated signal processing and imaging algorithms to image a 2 meter wide width of a bridge deck at one time. The goal is to develop a system that will travel at traffic speeds, image a lane width of a bridge, and provide two and three dimensional images of the interior of the bridge deck. Using a small scale prototype, preliminary tests have been able to provide images of the interior of a reinforced-concrete test bed that show test voids and reinforcement. The prototype is currently being assembled with completion scheduled for January 1997. A portable hand held imaging system is

also planned.

Area II: Advanced Bridge Testing and Health Monitoring Projects

3. Global Bridge Measurement using Coherent Laser Radar

This project is an adaptation of a system developed for NASA. It is a portable laser scanning system which quickly measures the deflected shape of a bridge with sub-millimeter accuracy. It also measures the vibration of a bridge and has potential to facilitate the application of modal analysis as a bridge inspection tool. The system has been demonstrated in the field and was delivered to FHWA in February 1996. This system has been used to scan large test beams and substructure units as well as to measure bridge deflections under controlled loading. It will continue to undergo further test and evaluation thru 1997.

4. Global Bridge Monitoring with Wireless Transponders

This project is developing a wireless global bridge monitoring system. It consists of a number of sensor/transponder modules which communicate via spread spectrum radio to a local controller. The system development emphasizes the use of off-the shelf components developed for cellular telephone and automotive applications and consequently minimizes technical risk. There are modules which measure strain and rotation. The goal is to develop the technology to instrument a bridge at a dozen locations for a cost of less than $5000. A prototype system consisting of a master controller and four transponders has been delivered to the FHWA. An additional master controller and 12 additional transponders are planned to be purchased. The systems will undergo field and laboratory testing. Further development will be conditioned upon getting a minimum of 10 States to participate in a pooled fund study.

5. Bridge Deflection Measurement using Precision Ditferential Global Positioning System

An innovative approach to monitoring and measuring large bridges is being developed under another contract initiated in October of 1995. This project makes the transition from a proven concept into an operational system prototype. The concept was proven under a research sponsored by the Louisiana and Texas DOTs. The objective of this study is to produce a system which can be easily configured, installed and affordably operated by state and local authorities. The system will provide a cost effective means of performing structural deformation surveys. The resolution of the system (sub-centimeter) limits its application to large bridges. The system has been tested on the Fred Hartman bridge in Texas.

6. Bridge Overload Measurement and Monitoring using TRIP Steel Sensors

A major contributing factor to the deterioration of the nations bridges are overloads. These overloads could be caused by heavy trucks or a seismic event. A very useful tool, from a bridge management perspective and as a tool for helping to make the most efficient use of bridge inspection resources, would be a passive device which could detect and measure the maximum load experienced by a bridge. Continuing with work which was initially sponsored by the Georgia Department of Transportation, a contract was awarded in November of 1995 to develop such a system. The system is based upon the use of transformation induced plasticity (TRIP) steel sensors. This steel undergoes a permanent change in crystal structure in proportion to peak strain. It changes from a non-magnetic to a magnetic steel. This change can be easily measured. This project will improve the design and development of these peak strain sensors and test their performance on instrumented bridges. These sensors could provide a reliable, inexpensive and easy to implement means for quantitative bridge assessment as a key element of a comprehensive bridge management system.

Area III: Advanced Fatigue Crack Detection and Evaluation Projects

7. NUMAC, an improved fatigue crack detection system

The NUMAC (New Ultrasonic and Magnetic Analyzer for Cracks), a new fatigue crack detection system combining ultrasonic and magnetic inspection capabilities into a single instrument has been successfully developed, demonstrated and delivered to FHWA. This system consists of a backpack computer, a heads-up display and features one hand operation (essential for use on a bridge). This system will greatly improve our capabilities to detect and quantify fatigue cracks in steel bridges, even when covered with paint. The prototype system has been delivered to FHWA and has been loaned to the Colorado and Delaware DOT's for further evaluation.

8. Thermographic Imaging to Detect and Quantify Fatigue Cracks in Steel Highway Bridges

This Small Business Innovative Research (SBIR) project was initiated in October of 1995. It is based upon the use of commercially available high resolution thermographic imaging systems to detect surface breaking fatigue cracks. The method, called forced diffusion thermography, uses active heating of the bridge surface with a high wattage light to detect cracks. A special pattern of hot and cold regions are created on the steel bridge, enabling the thermographic imaging system to present the operator with an image of heat flow patterns. If a crack is present, a characteristic pattern is observed. First phase of the study proved the concept to be feasible by demonstrating its ability to detect fatigue cracks covered by paint. Second phase has been initiated to develop a field able

and commercially viable system.

9. Acoustic Emission Monitor for Bridges

The FHWA solicited for a cooperative agreement in 1995 to work with industry to co-sponsor the development of an acoustic emission monitoring system specifically engineered and packaged to monitor fatigue cracks on in-service highway bridges. The result was a cooperative agreement where the FHWA and Physical Acoustics Corporation are sharing costs to develop such a system. This new system will be small, rugged, battery powered, and designed to be left in place unattended for up to one week. This AE system will also be able to determine effectiveness of a fatigue crack retrofit.

10. Wireless Strain Measurement System

One of the impediments to the measurement of fatigue loading is the need to install a strain gage near a fatigue crack, and then to monitor the random variable amplitude strains for a period long enough to capture the loading spectrum. With traditional strain gages this has proven to be cumbersome due to the difficulty of access to locations where fatigue cracks typically form and the need for long wire runs back to a data acquisition system. What was needed was a portable, rugged, yet accurate system for measuring strains at inaccessible locations. The Small Business Innovative Research Program was used to sponsor this study to develop a wireless strain measurement system. This highly innovative system consists of rugged, battery powered (solar cells optional), radio transponder modules. These modules feature the ability to accept up to four standard resistive strain gages with all power and signal conditioning provided by the transponder. The system features 16 bit analog to digital conversion and an effective 500 Hz sampling rate. Up to ten of these transponders can be used simultaneously. They can be configured to form local radio telemetry networks with extensive data error checking and multi-path redundancy for very stable and accurate wireless data transmission. A local transponder is attached to a PC for data acquisition. This system should greatly facilitate the field measurement of fatigue loads.

11. A Passive Fatigue Load Measurement Device

The wireless strain measurement system is an excellent tool, but it is somewhat expensive (about $6,000 per transponder) and has a limited battery life. A totally passive and inexpensive device for measurement of fatigue loading was needed. Under a contract, initiated in October of 1995, a low cost, passive fatigue load measurement device is being developed. It is based upon the use of two, precracked fatigue coupons which undergo the same strains as the bridge. The cracks in the two coupons, made of different materials, grow at different rates. Special gages are attached to the coupons to accurately measure the lengths of the

cracks. The measurement is made by plugging in a crack length reader into the device. This device will make it possible to measure fatigue loading by measuring the crack growth rate.

12. Fatigue Loading Measurement using Electromagnetic Acoustic Transducers

As a part of a congressionally mandated study with the Constructed Facilities Center, West Virginia University, a device that will measure cumulative fatigue loading of a typical highway bridge using an innovative strain measurement technology is under development. This technology uses electromagnetic acoustic transducers which generate and detect high frequency stress waves in steel using electromagnetic fields. The system can measure the strain in steel members by detecting the change in travel time of stress waves. The advantage of this system is that it attaches magnetically to the steel bridge (very little surface preparation is required) and dynamic stress measurements can be quickly taken. A separate but concurrent development effort by Sonic Force Corporation has developed a commercial product based upon this technology and further development of this system by FHWA is not anticipated.

Area IV: Advanced Corrosion Detection and Evaluation Projects

13. Magnetic Flux Leakage Inspection System for Bridge Cables

This project is the continuation of the development of a specialized inspection system for bridge cables. A prototype system using an array of shuntable, permanent magnets has been designed and fabricated. The magnets in this system detect changes in the strong magnetic field when a broken or corroded cable is present. There are commercially available systems which inspect smaller cables using similar technology, but typical bridge stay cables are too large. The prototype system is planned to be upgraded and developed into a dedicated cable-stay inspection system.

14. Impact Echo System for Detection of Voids in Post-tensioning Ducts

A project was recently completed which developed a device for the detection of voids in the grout on post-tensioned bridges. The long term reliability and safety of these bridges depends upon the integrity of the post-tensioning system. This device uses impact echo principle of striking a concrete surface with a known energy pulse and measuring the local response using a piezoelectric transducer. The frequency and energy content of the response can be used to detect voids in grouted ducts. This system is smaller and more suited for use on vertical and irregular surfaces than the other impact echo system designed primarily for bridge deck evaluation. The system is currently on loan to the Maine DOT.

15. Embedded Corrosion Micro sensor

In cooperation with the Virginia Transportation Research Council an embedded micro sensor is being developed which will quantitatively measure the corrosion activity inside concrete. The integrated circuit will provide electrochemical measurements of corrosion rate with polarization resistance, measure chemical parameters such as pH, chloride ion concentration and temperature in an embeddable package. The sensor will be powered and it will telemeter sensor data via wireless communications. The objective is to develop a small and inexpensive package that will allow hundreds or thousands of sensors to be embedded in concrete structures. It will then be possible to quickly scan a concrete structure and to quantitatively measure the rate and location of corrosion before visible deterioration has occurred. A prototype integrated circuit has been fabricated and further development is ongoing.

16. Magnetic-Based System for NDE of Prestressing Steel in Prestressed Concrete

This project will develop a portable and versatile inspection tool for the detection and quantification of corrosion and strand breakage in prestressed concrete. The concept applies concepts and principles used in other projects. It is similar to the Magnetic Flux Leakage Inspection System for Bridge Cables and it also uses wireless communications. The system is built around a magnetic scanning head. The scanning head includes a strong permanent magnet, a Hall-effect sensor array (this detects changes in magnetic field strength), a position encoder, and a wireless communications unit. This portable, self-contained system will be used to scan prestressed concrete girders and beams and telemetry the information back to a portable PC for signal processing and analysis. The results can be displayed as an image for rapid anomaly identification. It might also be useful for inspecting decks, columns and abutments.

Area V: Other Advanced Nondestructive Evaluation Projects

17. Bridge Substructure Evaluation using Forced Vibration Response

Substructure deterioration is a major reason for structural deficiency of bridges. There is also a pressing need to evaluate substructures for scour vulnerability and for post earthquake evaluation. An innovative approach for quantitative substructure evaluation will be tested under a contract awarded in November 1995. This project will use measured structural movements due to induced vibrations to determine the condition of a substructure. The response will enable engineers to determine the presence of piles and to establish a base line response for subsequent evaluations. This technology could help evaluate the scour vulnerability of approximately 100,000 bridges with unknown foundations.

18. Cable Stay Force Measurement Using Laser Vibrometers

Dynamic analysis will be the basis for a new approach to the quantitative measurement of forces in stay cables. This innovative approach will use non-contact laser vibrometers (commercially available) to provide a rapid, low cost, yet accurate method for force measurements. Forces in the stay cables are excellent indicators of the overall structural health of these bridge types. This concept was tested on the Stubenville Bridge in West Virginia in October 1996. The coherent laser radar system being developed in a separate project could also be used to perform dynamic cable stay measurements.

19. Integration of Quantitative Nondestructive Evaluation Methods into Bridge Management Systems

This first of its kind study will investigate how to develop a unified quantitative methodology for integration of nondestructive bridge evaluation into bridge management systems. The study will establish relevant measures of damage for bridge components, it will establish formal links between the results of NDE measurements and condition states, and it will develop a methodology for NDE assisted bridge inspections. The methodology and procedure will be demonstrated in field inspections on at least twelve highway bridges in six states. Deliverables from this contract will include complete damage descriptions of all commonly recognized elements, a complete basis for the translation of NDE measurements to condition states and guidance in the application of NDE assisted inspections for highway bridges. This will be an ambitious step toward the development of bridge management for the next century. This study will be initiated in FY97.

20. Improved Bridge Deck Condition State Descriptions Using Quantitative Nondestructive Evaluation Methods

This study will take the results of previous research sponsored under the Strategic Highway Research Program in measuring and predicting the condition of concrete bridges decks. This study will develop methodology to improve bridge deck deterioration models, to develop a methodology to incorporate preventative treatments into bridge management systems, and to develop criteria to use nondestructive testing for these purposes.

Area VI: Exploratory Research Projects

21. Fundamental Research in Acoustic Emission

The FHWA is funding exploratory research at the National Institute of Standards and Technology at Boulder, Colorado to develop an improved wide-band E detector. The unique E laboratory test system providing the ability to

generate and detect fatigue cracks in different extension modes, and advanced finite element modeling of acoustic emission generation, propagation and detection will soon be available commercially.

22. Fundamental Magnetostrictive Sensor Research

The FHWA is funding fundamental research in the development of sensors based upon magnetostriction. A magnetic field produces small changes in the physical dimensions of ferromagnetic materials. By coupling a coil of wire with a bias magnet an elegant yet useful sensor can be constructed. Such senors would be low cost, simple and rugged. Possible applications include detection and measurement of corrosion and breakage in prestressing strands, and monitoring the curing of concrete. It can also be used as embedded acoustic emission sensors.

23. Use of Microwaves to Detect and Quantify Fatigue Cracks

Another topic where FHWA is funding exploratory research is in the development of small microwave waveguide sensors. If a microwave waveguide is placed against a steel plate it is effectively short circuited and a characteristic standing wave is created. This standing wave can be detected with a very inexpensive diode. If a fatigue crack is present in the plate the standing wave changes. A very rapid, yet low cost fatigue crack detector could be produced. The focus of current studies are evaluation of lift off (most steel bridge are painted) and the detection of crack edges.

24. Fiber optic Strain Sensor

The FHWA is sponsoring development of a fiber optic strain sensor with the Naval Research Laboratory. This project has demonstrated that it is feasible to use the Bragg Grating Interferometric method to measure strains in concrete bridge beams. A prototype system which could measure strain at up to sixteen locations simultaneously is being developed.

Nondestructive Evaluation Validation Center

A need was identified for better facilities and capabilities to evaluate and validate the new nondestructive evaluation technologies and systems being developed by the FHWA and others. Special funding was provided in fiscal year 1996 to support the design and construction of a new **NDE Validation Center** at the Turner-Fairbank Highway Research Center. A contract was awarded to Wiss Janey Elstner and Associate in September of 1996 to design, construct and operate this center. The center will renovate the existing small structures laboratory at TFHRC to provide a modern and fully equipped NDE testing facility. In addition

three highway bridges within 150 miles of TFHRC will be made available for full scale testing of NDE technologies under actual field conditions. The center will also acquire a wide variety of specimens from highway bridges which contain typical defects which will be fully characterized. These specimens, ranging from steel element with fatigue cracks to full scale girders and decks will be maintained in a library of specimens which will be used by FHWA and other researchers and developers to test and validate existing and new NDE technologies. One of the first studies to be undertaken once the center is operational is a probability of detection study of visual inspection of highway bridges.

AERODYNAMICS

The FHWA research program in the area of aerodynamic response of bridges and structures includes analytical, laboratory, and field studies through staff research, and graduate research fellowship programs. The TFHRC maintains an Aerodynamics Laboratory where scale models of structures can be tested. The FHWA contact for all aerodynamics related research is **Harold R. Bosch**.

1. Aerodynamic Response of the Deer Isle-Sedgwick Suspension Bridge (2D1a2012)

The objectives of this staff study are to perform section model studies and full scale measurements to determine source of aerodynamic problems exhibited by this existing suspension bridge in Maine; and identify retrofit measures and monitor structural behavior after modification. Note: An aerodynamic retrofit has been implemented and post-retrofit behavior is being monitored. Field operations and instrumentation are being managed remotely from the Aerodynamics Laboratory at Turner-Fairbank. Data analysis is being performed in a production fashion and results are being compiled. Detailed wind tunnel tests are continuing with focus on special issues of interest. An evaluation of blockage of the sidewalk grates and its impact on the bridge's stability is currently underway.

2. Aerodynamic Response of the Mississippi River Bridge at Luling (2D1a2102)

The objectives of this staff study are to maintain automated instrumentation on and monitor the aerodynamic performance of the first major steel cable-stayed bridge in the United States to be located in a hurricane zone; and to compare the results of the full scale measurements with predictions from model studies conducted in the TFHRC Aerodynamics Lab. Note: Data collection and evaluation continues at the site. Field operations and instrumentation are being managed remotely from the Aerodynamics Laboratory. While significant storms continue to be recorded, no hurricane events have yet been detected. Mainframe software for analysis of this data has been converted for use on PC platforms. This should result in more efficient handling and processing of field information. Precipitation gauges and humidity sensors are being added to the instrumentation complement to enable study of wind-rain induced vibration of the stay cables.

3. Wind Forces on Generic "I" Sections (2D1a2112)

This staff study will perform static and dynamic force measurements on a series of section models with typical I-beam proportions, and assemble aerodynamic properties into a master catalog for design use. Static testing is

complete. Dynamic testing is pending the availability of the wind tunnel.

4. Wind Forces on Generic "Box" Sections

The objective of this staff study is to perform static and dynamic force measurements on a series of section models with typical Box-beam proportions. Aerodynamic properties will be assembled into a master catalog for design use. Note: Models have been designed and fabricated; testing is awaiting the avalability of the wind tunnel.

5. Wind Forces on Generic "Bridge" Sections

The objective of this staff study is to perform static and dynamic force measurements on a series of section models representing common bridge cross sections. Aerodynamic properties will be assembled into a master catalog for design use. Note: Models have been designed and fabricated; testing is awaiting the avalability of the wind tunnel.

6. Aerodynamic Properties of Tapered Cylinders

This staff study will investigate the static, dynamic, and aerodynamic properties of cylinders, concentrating on tapered cylinders; and conduct wind tunnel tests on section models representative of common structural shapes. This study is the continuation of preliminary research begun under fellowship project GRF91-22A, which included literature review, model design and fabrication, and baseline testing. This research is related to work under NCHRP 10-38. About 164 tests have been completed on 53 section models to measure static and dynamic wind forces in laminar (smooth) flow. These models include circular, octagonal, and hexagonal shapes with varying diameters and taper ratios.

7. The following research studies are being conducted under the **Graduate Research Fellowship Program**, under the technical guidance of **Mr. Harold R. Bosch**.

- Design of Scaled Models for Wind Tunnel Testing of Highway Structures (GRF95-17)

This study will design three aeroelastic models needed for wind tunnel experiments planned in the Aerodynamics Laboratory. These models will replicate not only the geometric properties of the prototype structures, but also the stiffness and mass properties. The models will include a bridge tower, a cable-stayed bridge, and a deck arch bridge. Note: Preliminary designs have been completed for the three models and fabrication drawings have been prepared for one of the models. (GRF Student: Jianmin You)

- Analysis of Wind and Bridge Response Data (GRF95-16)

This study will develop detailed finite element models of two long-span bridges. It will analyze wind and bridge response data measured at the two bridge sites and compare with predicted bridge behavior. Lastly, it will develop procedures for modal updating which enable improved prediction capability. Note: Extensive literature review has been completed and comprehensive finite element models have been developed for both of the bridges. Results of the analysis are being compared with information available from full scale measurements. (GRF Student: Arthur Wolek)

8. The following studies are being conducted under **Technical Work Requests** under the Aerodynamics Laboratory Support Contract:

- Improved Techniques for Study of Wind Effects on LongSpan Bridge Structures (TWR #20)

This task will explore the application of new or emerging analysis tools in the assessment and mitigation of wind effects on long-span bridges and other highway structures. The work will consider the use of novel waveform analysis techniques, such as wavelet and proper orthogonal decomposition, as a means to evaluate wind and bridge response data. The work will also investigate the utility of various Computational Fluid Dynamics (CFD) techniques, such as large eddy simulations (LES) with various subgrid-scale (SGS) schemes, for simulation of flow around structures and prediction of forces on structures. Finally, this work will investigate the feasibility of robust, active control strategies for bridge aerodynamic stability.

- Enhancements of the FDM Wind Flow Simulation Code for Improved Performance in the Workstation Environment (TWR #21)

This task will develop a more computationally efficient numerical scheme for the simulation of wind flow around and prediction of wind forces on bluff bodies. The work will investigate the feasibility of merging finite-difference methods (FDM), boundary-element methods, and boundary-fitted curvilinear coordinate systems to more effectively model and simulate the fluid-structure interaction. Existing software codes will be modified and new codes will be developed for implementation on engineering workstations.

SEISMIC

The FHWA program in the area of seismic research includes studies to advance the understanding of earthquake resistant designs, construction, and the retrofit of highway bridges through development and refinement of nationally applicable specifications and guidelines of recommended practice.

1. Seismic Vulnerability of the Highway System

This $12 million study is developing better means of assessing the vulnerability of existing highways, bridges & tunnels; and of retrofitting structures, foundations and embankments. Besides superstructures, this contract is studying substructures, foundations, retaining structures, soils, tunnels, pavement and landslides. Some tasks are ground motion study and dynamic analysis of small to moderate size bridges, evaluation and remediation of liquefaction. Seismic hazard mapping and field testing of a seismically-isolated bridge have been completed. A new "*Seismic Retrofitting Manual*" has been published and a supplementary volume containing details and design examples is being written.

Contractor: **NCEER, SUNY @ Buffalo**
FHWA Contacts: **John D. O'Fallon** and **Dr. Wen-Huei P. (Phillip) Yen**

2. Seismic Research Program

This $2.24 million contract is developing seismic design standards and criteria for new bridges, tunnels and pavements. The development of analytical and design procedures for abutments and retaining walls is complete. Details to ensure ductility in columns and walls are being developed. Since this study is being conducted in parallel with "Seismic Vulnerability", its period of performance has been lengthened by two years to match that of the larger study. A report titled "*Review of Seismic Design Criteria*" will be published in June 1997. This report covers the world's most important current seismic design specifications for bridges.

Contractor: **NCEER, SUNY @ Buffalo**
FHWA Contacts: **John O'Fallon** and **Dr. Wen-Huei P. (Phillip) Yen**

3. Performance Testing of Seismic Isolation and Energy Dissipation Systems

In recent years, many passive seismic isolation systems have been proposed by different manufacturers to the bridge industry in the U.S. However, the proprietary nature of these systems and the lack of knowledge of their long term performance have made them less desirable to many engineers. Federal Highway Administration (FHWA) recognized the need to develop a testing and evaluation program for passive systems for both retrofit and new construction applications in

bridges. The test plan was developed with the collaboration of FHWA, California Department of Transportation (CALTRANS) and Highway Innovative Technology Evaluation Center (HITEC). Fourteen manufacturers are participating in this program. The program will provide verifiable, credible information on the functional performance (seismic and non-seismic), practicality, durability, materials characterization, and dynamic behavior of various systems and components submitted for evaluation. The program is unique for its full scale dynamic testing of all the systems which is being conducted at the Energy Technology Engineering Center (ETEC), a California site owned by the U.S. Department of Energy (DOE). The project is funded by ISTEA under the Applied Research and Technology (ART) Grant program.
FHWA Contact: **Dr. Hamid Ghasemi**

4. Load Path Effects on the Seismic Performance of Reinforced Concrete Bridge Columns

The objective of this project is to develop a performance-based approach to seismic design, retrofit and repair of reinforced concrete bridge piers. This approach would supplement the current AASHTO code, and would appear as an alternative design procedure in the appendix of the AASHTO Specifications. The performance will be measured in terms of the extent of damage suffered by a column in an earthquake. The damage will be quantified by a numerical damage index that is calibrated directly with laboratory tests and analytical studies of the seismic performance of bridge columns and piers. The experimental work is complete. A draft report has been written, and is under review.
Cooperator: **National Institute of Standards and Technologies (NIST)**
FHWA Contact: **Dr. Wen-Huei P. (Phillip) Yen**

5. Comparative Seismic Design of U.S. and Japanese Highway Bridge

This cooperative research study to improve design criteria for bridge piers under seismic loads was initiated at the Third US-JAPAN Workshop on Advanced Technology in Highway Engineering, September, 1994. The task includes designs of a single column bridge pier using both the U.S. and Japanese seismic design codes. Scale models of the columns will be constructed and tested using a shake table at the Public Works Research Institute (PWRI) in Japan. The prototype bridge pier designs using both codes have been completed, and the results were exchanged in December, 1995. Three one-sixth scale models of bridge piers were built and tested in July 1996. Results of the shake-table tests are current under study at both the US and Japan.
Cooperator: **PWRI, Japan**
FHWA Contact: **Dr. Wen-Huei P. (Phillip) Yen**

6. Analytical Studies for Base Isolation of Bridges

This study is developing a finite element code, computer software and design methodologies for: a) modelling the two- and three-dimensional behavior of rubber and rubber & lead-plug base isolators, and b) modelling the bridge piers and superstructure with three dimensional plate and frame finite elements. So far, a two-dimensional program has been developed. The final report will be available in late 1997.

Graduate Research Fellow: **Wane-Jang Lin, Univ of Maryland**
FHWA Contact: **John O'Fallon**

GEOTECHNOLOGY

As with other programs, the FHWA program in geotechnical research is supported through staff research, and contract research. The FHWA maintains onsite a Geotechnical Laboratory Complex, which consists of soil mechanics, soil behavior, and foundations testing facilities. The program manager for geotechnical research is **Albert Dimillio**.

1. Design and Analysis of Drilled Shafts in Intermediate Geomaterials

This study developed and presented guidelines for the design of drilled shafts in materials that are neither soft (clays) or hard (rock) which are reasonably well characterized. These materials include clay shales, limerock, marls, and sands cemented to varying degrees, tills, mudstones, conglomerates, etc. The research addressed the effects of construction on the properties of these intermediate geomaterials, particularly as they relate to properties indicated by insitu and laboratory testing. The study is complete and the information is currently being incorporated into the National Highway Institute course #13214 - Drilled Shafts. The final report (FHWA-RD-95-172) is available from the FHWA Report Center.
Contractor: **PSC Associates**
FHWA Contact: **Carl Ealy**

2. Durability of Geosynthetics

The objective of this study is to develop procedures for predicting long term strength losses of geosynthetics used in highway applications. The study is divided into a laboratory durability evaluation (hydrolytic and oxidative degradation) and a field study. Laboratory tests will be performed on both new material and old material exhumed from the field. New material tests will include damaged (simulated construction damage) and undamaged samples. The effects of soil pH, ion conditions, moisture availability, and temperature will also be investigated. Field tests will be performed to verify lab results. As research information becomes available it will be incorporated into Demonstration Project 82. An interim report titled, "*Durability of Geosynthetics for Highway Applications*" FHWA-RD-95-016 is available from the FHWA Report Center.
Contractor: **Earth Engineering Sciences, Inc.**
FHWA Contact: **Albert Dimillio**

3. National Geotechnical Test Sites

The objective of this on-going study is to develop a national system of designated experimental sites that will consolidate research efforts at a few highly efficient locations. Geotechnical tests sites that have been extensively tested will be used for R&D projects that require an accurate knowledge of insitu soil

conditions. The use of these sites will increase the accuracy and consistency of future research while substantially reducing their cost. This cost reduction, and the information available in the data repository, will allow researchers the opportunity to perform accurate and effective work. A data repository has been developed. Under this contract, 81candidate tests sites have been evaluated and rated. To date, nine tests sites have been approved: two level one sites, Texas A&M, and Treasure Island (San Francisco); three level two sites, University of Houston, Northwestern, and the University of Massachusetts (Amherst); and four level three sites, I-95 Embankment (Sauguf, Massachusetts), Norfolk (Virginia), Imperial Valley Wildlife Refuge (California), and Hamilton Air Force Base (California). The top five sites were selected for special funding to improve soil profile documentation and site conditions. Most of this work is completed and the sites are now operational.
Contractor: **University of New Hampshire**
FHWA Contact: **Albert Dimillio**

4. Permanent Ground Anchors

The objective of this research study was to evaluate and improve existing design and construction guidelines for permanent ground anchors. This study is near completion. Model and full scale test results were conducted and used to determine rational allowable loads for permanent ground anchored walls. Measurements were made on the anchors, soldier piles, and the back side of the wall. The results of these measurements were used to determine soil-anchor interaction, earth pressure on the wall, grouting requirements, bond zone load transfer, angle of wall friction, and soldier pile load transfer. A computer program for the design of anchor walls was also developed under this contract. The draft final report and beta version of the computer program is due in May, 1997.
Contractor: **Schnabel Construction Company**
FHWA Contact: **Michael Adams**

5. Pile Drivability

This study is on the re-examination of the current soil model used in dynamic analysis (Wave Equation, Pile Driving Analyzer, CAPWAP), and the appropriateness of using soil quake and damping factors. The study also focuses on determining the static and dynamic soil properties from insitu and laboratory testing. Literature search and acquisition of load test data is complete. Development of new correlations and model are complete. Several field tests to validate the new model have also been conducted. The three-volume final report (FHWA-RD-96-179, 180, 181) is available from the FWHA Report Center.
Contractor: **Goble Rausche and Likins (GRL)**
FHWA Contact: **Carl Ealy**

6. Pile Load Test Data Base

This staff study will provide a high quality pile load test data base for driven, drilled, and vibration installed piles. Test data and soils information from hundreds of pile load tests have been collected and evaluated for inclusion into the data base. New data was also generated by installing instrumentation and conducting load tests on active bridge construction projects. The data base program includes: static load test results, complete with load settlement plots; dynamic test results; pile instrumentation results; pile driving records; boring logs; SPT testing; ECPT testing; Dilatometer testing; laboratory testing; and the Coyle method for static analysis. At this time approximately 1100 good data sets have been input into the data base. Data base is expected to be ready for beta testing by June 1997.

Contractor: **FHWA research staff**
FHWA Contact: **Carl Ealy**

7. Shallow Foundations Research

The scope of this study includes: (a) development of a spread footing performance data base similar to the deep foundations data base; (b) spread footing load tests; (c) a settlement prediction symposium (ASCE & FHWA); (d) dynamic testing of spread footings; and (e) evaluation of existing prediction methods and possible development of a new settlement prediction method. This study is complete, and the final report is being processed for printing.

Contractor: **Geotest of Houston**
FHWA Contact: **Michael Adams**

8. Synthesis of Micropile Research

This study is a critical review and analysis of current design and construction techniques for using micropile technology for new bridges and rehabilitation and/or repair of existing bridges including seismic retrofit. The study is completed and the final report is being processed for publication.

Contractor: **Nicholson Construction Co.**
FHWA Contact: **Albert Dimillio**

9. Seismic Behavior of Micropile Systems

The objective of this study is to develop improved recommendations for the design of micropile systems to withstand seismic forces applied to bridge foundations. An evaluation of current seismic design practice will be performed concurrently with the development of an analytical and laboratory investigative program on isolated piles and then groups of piles. Centrifuge and shake table testing will be included in the laboratory evaluation. Later research under this study will evaluate physical and numerical modeling of the response of reticulated

micropile or "network" systems to seismic loading in selected soil types.
Contractor: **Polytechnic University of New York**
FHWA Contact: **Albert F. DiMillio**

10. Large Model Spread Footing Load Tests on Reinforced Soil Foundations

The potential benefits of geosynthetic reinforced soil foundations are being investigated using large scale model footing load tests. A total of 34 load tests were performed in the TFHRC test pits to evaluate the effects of single and multiple layer of reinforcement placed below shallow spread footings. Two different geosynthetics are being evaluated; a stiff biaxial geogrid and a geocell. Parameters of the testing program include: number of reinforcement layers; spacing between reinforcement layers; depth to the first reinforcement layer; plan area of the reinforcement; type of reinforcement; and soil density. Preliminary evaluation of test results indicate that use of geosynthetic reinforced soil foundations may increase the ultimate bearing capacity of shallow spread footings by a factor of 2.5. Final analysis and report preparation are underway.
Contractor: **FHWA research staff**
FHWA contact: **Michael Adams**

11. Performance of a Prestrained Geosynthetic Reinforced Soil Bridge Pier

A full-scale instrumented bridge pier was constructed and load tested at the Turner Fairbank Highway Research Center (TFHRC) in McLean, Virginia. The pier was 5.4m high and, at it's base, was3.6m x 4.8m. The pier sucessfully sustained a maximum load of 980kN (2200kips) which is equivalent to a pressure of 900kPa (9.4tsf). The purpose of the experiment was to demonstrate the performance and ability to construct a reinforced soil bridge pier with segmental blocks. This method utilizes closely spaced high-strength geosynthetic reinforcement and quality compacted road base. The pier was instrumented to monitor load, lateral deformation and vertical settlement. Several layers of the reinforcement were instrumented with strain gauges to monitor creep and strain in the fabric. A method of prestraining the reinforced soil mass was also tested. Changes in the properties of the reinforced soil due to prestraining are being evaluated. The pier was hydraulically loaded to squeeze the reinforced soil vertically. Data analysis and report preparation are underway.
Contractor: **FHWA research staff**
FHWA Contact: **Michael Adams**

12. Design and Construction of Backfill Envelopes - Foundations and End Treatments for Underground Structures a.k.a. Buried Pipe Installation

This analytical and experimental (lab and field) study has investigated the fundamental interactions between pipe, backfill and in-situ soil, that occur in the

process of excavating a trench, preparing sub-grade, installing the pipe, and placing and compacting backfill. RCP, CMP, and HDPE pipes were tested in the lab, and in narrow and wide trenches in cohesive and granular soils. Measurements were taken of soil density and moisture content, pipe-soil interface pressure, horizontal soil pressure between backfill and in-situ soil, vertical soil pressure on the pipes, soil and pipe wall strains, and the pipe profile. The first three reports for this study have been written; the major and final report is in preparation. It is expected that the study will be complete by 9/30/97.
Grantee: **University of Massachusetts** (Through an Interagency Agreement between **FHWA and the National Science Foundation**)
FHWA Contact: **John O'Fallon**

HYDRAULICS AND HYDROLOGY

Understanding hydraulics and hydrology as they apply to highway structures is a necessity for the proper design of bridges and structures to withstand stream flow in normal conditions and major floods and washouts in extreme events. To this end the FHWA maintains a Hydraulics Laboratory to conduct research to understand the hydraulic capacity of bridges, and other drainage structures. Goals of the program are accomplished through FHWA staff, and contract research studies. The program manager for Hydralics and Hydrology research is **J. Sterling Jones**.

1. Seismic and radar scour instrumentation

The objective and scope of the project is to investigate the feasibility and develop guidelines for using Ground Penetrating Radar and other geophysical techniques for detecting refilled scour holes after a flood has passed. The project is complete, and a report has been published as a USGS Water Resources Investigations open file report 95-4009.
Contractor: **USGS (Pete Haeni and Gary Placzek)**
FHWA Contact: **J. Sterling Jones**

2. Strategies for managing unknown bridge foundations

The objective and scope of the project is to develop a strategy for dealing with bridges with unknown foundations as part of the bridge scour evaluation program. A publication, FHWA-RD-92-030, has been printed and distributed. HYRISK, a computer program for prioritizing bridges for scour evaluation, was developed as part of this contract. HYRISK, based on information that can be obtained from the National Bridge Inventory, was developed originally for prioritizing bridges with unknown foundations but has utility for any set of bridges waiting for evaluations.
FHWA Contact: **Roy E. Trent**

3. Finite element surface-water modeling system (feswms-2dh)

This project will enhance two dimensional finite element surface water computer model to include scour, sediment transport, alluvial fan, and convenient input/output shell algorithms. The contract was awarded in 1991. Documentation for the Surface Water Modeling System (SMS) an input/output shell developed by the Brigham Young University, and for the FESWMS was received on Feb 6, 1996. Preliminary copies of the documentation and software have been distributed to Hydraulic units in each State Highway Agency. A training course was conducted at BYU in April 1997. The final documentation is scheduled for completion in Sept. 1997.

Contractor: **University of Kentucky**
FHWA Contact: **Larry Arneson**

4. Scour instrumentation and deployment methods, mobile equipment

This project will develop and test portable equipment and instrumentation for collecting detailed site information around a bridge during flood conditions. A remote-control boat, positioning system, telemetry data acquisition has been developed. Draft report has been submitted. Final report has been postponed due to heavy workload in monitoring bridge scour during the 1997 floods.
Contractor: **USGS (Landers & Mueller)**
FHWA Contact: **J. Sterling Jones**

5. Bri-stars enhancement and development

The objective and scope includes enhancements of practical, theoretical, and computational aspects of the BRIdge Stream Tube model for Alluvial River Simulation & sediment transport (BRI-Stars) microcomputer program to provide hydraulic and fluvial design criteria for highway stream crossings, floodplain encroachments and flow control structures. A working version of the model has been developed and is being offered as part of a short course scheduled for June 1997, in Austin, TX.
Contractor: **Hydrautech (Molinas)**
FHWA Contact: **J. Sterling Jones**

6. Q-500

This study conducted in cooperation with FEMA will develop a procedure to extrapolate an estimate for the 500 year discharge from the USGS flood frequency studies for any Hydrologic Region in the country for bridge scour and risk analyses. This is an interagency study that was jointly funded by several agencies. The study is near completion. The National Flood Frequency (NFF) computer program has been included in HYDRAIN, Version 5. The NFF documentation with a diskette is published as USGS WRI Report 94 :002. The USGS is currently looking for funding to enhance NFF to include a windows version with updated equations from several States and availability through Internet.
Contractor: **USGS**
FHWA Contact: **J. Sterling Jones**

7. Effects of gradation and cohesion on scour

Laboratory model studies were conducted to determine the effects of coarse grain fractions and cohesive bed materials. An improved K4 factor, in the pier scour equation in version three of HEC-18, was derived by the contractor after

HEC-18 was reprinted; it will be considered for an addendum or the next printing of HEC-18 . The original contract was closed out, but a separate Purchase Order was issued to the Principal Investigator to revise the final reports to meet FHWA Technical Report publication standards. The revised reports are scheduled for completion in Oct. 1997.
Contractor: **CSU (Molinas)**
FHWA Contact: **J. Sterling Jones**

8. Performance of bridges during floods, "national scour study"

This study will develop a data base of field bridge scour measurements with the associated hydraulic and bed material data for a range of bridge and flood conditions. The focus will be on local pier scour. The first phase final report has been reviewed. The report has been completely digitized and will be sent to the FHWA "Scour Team" for further technical evaluation prior to printing. It will be published as FHWA-RD-95-184. The second phase of the contract is scheduled for completion in 1997, but an extension is planned subject to availability of funding.
Contractor: **USGS (Mueller)**
FHWA Contact: **J. Sterling Jones**

9. Remote methods for underwater inspection of bridge structures

The objective is to develop an articulated arm to deploy instrumentation to measure cross sections and scour from a bridge deck during flood conditions. The articulated arm has been developed. It was used during the '94 floods in GA. Final report was submitted Aug. 1995. Contract was extended through Nov. 1995 to allow the fabrication of a heavy duty cover and to ship the monitor to USGS in Louisville, KY. The contract is complete. The final report is currently being editted for publication as FHWA-RD-95-061.
Contractor: **Sonsub (Bill Bath)**
FHWA Contact: **J. Sterling Jones**

10. Pressure flow scour

The objective and scope is to conduct live bed laboratory experiments to develop a procedure to estimate scour at bridges when the deck becomes inundated during large floods. The live bed experiments are an extension of previous work done at FHWA and CSU. A revised procedure for FHWA's HEC-18 "Evaluating Scour at Bridges" is expected to be developed during 1997.
Contractor: **CSU/FHWA Staff**
FHWA Contact: **Larry Arneson**

11. Debris loading [hazards] to highway bridges

This project will provide regional estimates of the quantity, size, mass, and character of debris and ice for various discharges and watersheds used as input to NCHRP Project 12-39. The draft final report is complete.
Contractor: **USGS (Tim Deihl)**
FHWA Contact: **Dr. Steven B. Chase**

12. Enhanced abutment scour studies for compound channels

This study will conduct laboratory experiments of bridge abutments set back various distances from the bankline of compound channels to develop a more practical procedure for estimating abutment scour at stream crossings. A chapter on Abutment scour evaluation procedures for FHWA's HEC-18 will be prepared as part of this study. The study is scheduled for completion in Oct. 1997.
Contractor: **Georgia Tech Research Corporation (Terry Sturm)**
FHWA Contact: **J. Sterling Jones**

13. Extrapolation of Laboratory Model results to Field Design Conditions

This is new study to conduct large scale and high velocity experiments in fine bed materials to develop a procedure for adjusting the site specific model study results derived for incipient motion velocities to be applied to design conditions where velocities are much higher than incipient velocities. The study has three primary objectives. The first is to determine if very fine grain sands have a second peak scour depth in the live bed range where velocities are several multiples of the incipient motion velocity. The second is to determine if there is a reduction in scour depths when the pier size to sediment size ratio gets very large. The third is to set forth mimimum modeling guidelines for an acceptable model study for bridge scour.
Research Partner: **Florida DOT**
FHWA Contact: **J. Sterling Jones**

14. FHWA Hydraulics Laboratory Studies

The following including laboratory studies at the TFHRC Hydraulics Laboratory. The objective/scope include improvements to the transportation system by testing hydraulic capacity of drainage structures, solving hydraulic and stream stability problems attendant to highways, and supporting operational engineers with design guidance.

- Storm drain energy losses in junctions - Results have been incorporated into the HGL routine of HYDRA module of HYDRAIN. Additional tests are being planned for junctions with various sized pipes to verify or modify the theoretical procedure that was derived in the original study. (GKY/ Woo/ Jones)

- Pressure flow scour- Investigated scour when deck is inundated. Interim procedure based on this study will be in version 3 of HEC-18. (GKY/Jones)

- Culvert entrance loss coefficients. Travaglini GRF study is complete. Several inlets were retested for S. Dakota to investigate the effects of bevels that are offered by prefabricators, parapets and the 2:1 fill slope that is commonly used with mitered inlets. An unpublished lab report for the S. Dakota tests was prepared in 1996. An overall summary report including Travaglini's results, multiple barrel results and previously tested wide span culverts will be prepared during 1997.

- Scour Around exposed foundation pile groups - Results of the study were presented on Oct 20,1995. A technical paper based on this study was published in the Proceedings of theASCE 1996 North American Water and Environment Congress. (GRF Student -Mohammad Salim)

- Culvert sedimentation countermeasures, COOP WVU-Deidra Begley used the FHWA culvert test facility to investigate potential retrofits to decrease sedimentation problems in multiple barrel culverts. Lab work was completed in May 1995.

- Energy losses for flow through inundated bridges. Stephanie Graff measured Manning's "n" values for the underside of bridge decks with various structural beam patterns and various levels of inundation. Results are published in a M.S. Thesis at the Univ of Maryland C.E. Dept.

- Model testing of the Bonner bridge over the Oregon Inlet in N.C - Provides design guidelines for expected pier scour at complex foundations that feature drilled shafts that will be capped near the water surface. The estimated scour depths drive the structural design of the pier foundations that must be designed to withstand heavy ship impact loads.

- Stream power experiments to develop a procedure, in cooperation with the Colorado DOT, to estimate maximum local scour in erodible rock.

Contractor: **GKY & Assoc. (Stuart Stein)**
FHWA Contact: **J. Sterling Jones**

15. <u>3-D Sediment Transport Modelling to Estimate Local Pier and Abutment Scour</u>

This is a Graduate Research Fellowship project. It is a very promising model

that has done an excellent job of reproducing laboratory scour results.
Reserarch Fellow: **Xibing Dou**
FHWA Contact: **J. Sterling Jones**

GENERAL

This category of studies include those that do not easily fit into previous broad program areas. They include studies as related to the safety & health of workers, development of cirruculum for bridge construction workers, study in the area of bridge culverts, and studies in the newly formed bridge management informations systems area. Most are highly focused studies with very specific expected products; or they are precursor studies to future emphasis area of research.

1. Health and Safety-Related Aspects of Bridge - Rehabilitation and Restoration

The objectives of this grant are to develop comprehensive safety and health guidelines for contractors (and employees thereof) engaged in highway bridge rehabilitation and restoration work involving lead-based paint; and to develop training plans that will enable employees to avoid these health hazards. This training is to be given by contractors and highway agencies, and will conform to OSHA industry standards. The guidelines have been reviewed and tested by several contractors; and the feed-back is very positive. The grant has been extended to 9/30/97, by which time the work should be completed.
Grantee: **Laborers' Health & Safety Fund of North America (LHSFNA)**
FHWA Contact: **John O'Fallon**

2. Carpentary Training for Bridge Construction

The objectives are to study bridge construction techniques; and develop a comprehensive training program for journeymen, apprentices, and laborers in the area of bridge construction. The study will focus on changing technology and implement training needs as appropriate. The grantee will develop and conduct a minimum of 5 training courses related to bridge construction techniques.
Grantee: **United Brotherhood of Carpenters Apprenticeship and Training Fund of North America (UBC A&T Fund)**
FHWA Contact: **Sheila Rimal Duwadi**

3. Durability of Culverts and Special Coatings

The objective of this study is to update and extend the information, contained in Report FHWA-FLP-91-006, that is relevant to corrugated steel pipe (CSP) culverts with Aluminum-Type 2 coating. The primary effort in this study was to reinspect (and reevaluate if necessary) the fifteen CSP culverts with Aluminum-Type 2 coatings, while inspecting and reporting on five more pipes of this same type in Maine. A second field trip was made to revisit three of the culverts on the Natchez Trace. The second draft final report has been reviewed by the panel as well as industry representatives, and the contractor is incorporating the comments (as appropriate) into the final report. The final report is expected to be ready for publication by 8/30/97. The title of the final report will also be changed to more

precisely reflect the actual research.
Contractor: **Ocean City Research Corporation**
FHWA Contact: **John O'Fallon**

4. Analysis of Structural Response Data from Weigh-in-Motion (WIM) Instrumentation on Bridges

A recent FHWA study tested 35 bridges using WIM instrumentation to acquire data on bridge response to truck loads. In addition to those installed for WIM purposes, transducers were also installed elsewhere on primary and secondary members, decks and parapets to measure stress levels under service conditions. Unfortunately, the records contain some unusable strain data, which must be identified and separated from the data base. Much of these redundant strains are due to residual vibrations from preceding truck passages. This study will develop a means of removing these stagnant vibrations from the records and a means of processing, analyzing and presenting the data in an engineering format suitable for evaluation and incorporation into other related studies.
Graduate Research Fellow: **Qinghui Mu, Univ of Maryland**
FHWA Contact: **John O'Fallon**

5. Bridge Management Information Systems

Through the National Bridge Inspection program, there has been significant data collected and maintained on the composition and condition of the nation's highway bridges. This information is maintained within the National Bridge Inventory (NBI) and has been collected over the last 25 years. The NBI is primarily utilized to support the Highway Bridge Repair and Replacement Program; however, these datasets also represent a valuable resource for engineering analysis. The **Bridge Management Information Systems laboratory** has been established to focus upon analysis of available Nationwide bridge inventory and inspection information, including the NBI. Information on these studies can be obtained from FHWA contacts **Steven B. Chase, or Edgar Small.** The following studies are currently underway in the BMS laboratory:

- Characterization of the National Bridge Inventory
  The development of an exploratory data analysis system has been initiated within the Bridge Management Information Systems laboratory. Work to date has focused upon the completion of a comprehensive statistical analysis of the NBI database utilizing this exploratory system. Preliminary results of this analysis have already provided new insights and valuable support for other research conducted within the Structures Division. Continuing development on the system will enable more sophisticated analysis of the available NBI data. With expanded capabilities, research will employ rigorous analytical

techniques including time-series analysis and probabilistic predictive analysis. General statistical information and interesting relationships have been compiled within a technical publication submitted to the ASCE Journal of Bridge Engineering for publication. A comprehensive analysis of statistical relationships developed through this effort is scheduled for publication as an FHWA report this year.

- Development of a Relational Database Management System to Support Bridge Management
  The NBI datasets are maintained as text files. With close to 700,000 records per year, the databases are approximately 300 megabytes in size. To maintain 25 years of the NBI, approximately 7.5 gigabytes of data storage is required. Analysis of such a large dataset is extremely cumbersome and time consuming. This project focuses upon the development and implementation of relational database management systems to enable data storage and analysis. Relational models developed for the NBI have evolved over time in response to data requirements. The project is being performed utilizing the RDBMS Software employed for the FHWA Deep Foundations database development.

- Geographic Information System Development and Integration
  While the National Bridge Inventory (NBI) database is very valuable as a source of bridge data, it does not contain other potentially relevant and significant data. For example, the NBI database does not contain data on seismic loading, minimum or maximum service temperatures, corrosivity of its location or annual maintenance expenditures. To adequately support a broad range of bridge related research, the exploratory data analysis system requires the linkage of the NBI database with other sources of data. These capabilities are being incorporated through the use of geographic information systems (GIS). The GIS has the ability to spatially join disparate databes using locational attributes. GIS development and integration efforts have been initiated and are currently underway with completion anticipated in the near future. Techniques for spatially joining these disparate data sources are being examined to explore the relationships between bridge deterioration and other factors, previously not investigated.

- Refinement of Spatial Information and Bridge Locational Data
  The present spatial analysis capabilities of the system have proven to be very useful for extracting and correlating information. However, the analytical capabilities are still very limited. Much of the analysis, performed to date, has utilized county level resolution. The resolution afforded by county maps is

rather coarse for a large portion of the western United States. The applicability of spatially locating structures within the GIS system utilizing latitude and longitude coordinate information from existing bridge inventories is being examined and efforts are underway to develop refined digital bridge locations. Additional digital databases with finer spatial resolution will be added to the system. Applicable alternative datasets include census tract and zipcode maps. A uniform gridded dataset for the United States will also be created. These strategies are examined to enable more refined spatial analysis and display.

LABORATORY SUPPORT CONTRACTS

1. Support Services for the Aerodynamics Laboratory

This contract provides technical services to support the research activities in the Aerodynamics Laboratory. Work includes assistance with all activities necessary to carry out the operation of the lab, fabrication and testing of small scale models, analysis of laboratory and field data, and the planning of special studies.

Contractor: **Engineering, Inc.**
FHWA Contact: **Harold. R. Bosch**

2. Support Services for the Structures Laboratory

This contract provides for technical services to support the research activities in the structures laboratories at the Turner-Fairbank Highway Research Center in McLean, Virginia. Their work includes assistance with all services necessary to carry out the operation of the labs., testing of structural models and specimens, and planning and conducting special studies.

Contractor: **Construction Technology Labs., Inc.**
FHWA Contact: **William J. Wright**

3. Support Services for the Hydraulics Laboratory

This contract provides support personnel to operate the hydraulic lab, and serve as co-investigators of staff studies.

Contractor: **GKY & Associates**
FHWA Contact: **J. Sterling Jones**

4. Support Services for the NDE Validation Center

This contract provides support services to test and evaluate new nondestructive evaluation technologies being developed under the NDE program. This test and evaluation phase is an essential step for validating the new NDE products before implementation by the States.

Contractor: **Wiss, Janney, Elstner Associates, Inc.**
FHWA Contact: **Glenn Washer**

5. Support Services for the Bridge Management Informations Systems Laboratory

This contract provides an on-site support engineer working with databases, information technology, and geographic information systems. The support engineer assists FHWA personnel with staff studies performed in area of bridge management.

Contractor: **GIS/Trans, Ltd.**
FHWA Contact: **Dr. Steven B. Chase**

6. Support Services for the Geotechnical Laboratory

This contract provides technical support services for the Geotechnical Research Team at TFHRC. Work includes technical and administrative assistance with all activities necessary to carry out the operation of both the indoor and outdoor lab facilities such as fabrication, set-up, and testing of small scale and medium scale model foundation elements, soil characterization testing, calibration and instrumentation activities, collection and analysis of data, data base maintenance and management, and report preparation.
Contractors: **SALUT, Inc.** (indoors lab)
Outdoor: **EBA Engineering, Inc.** (Outdoors lab)
FHWA Contact: **Albert F. DiMillio**