National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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Areas of Interest: 25 structures design and performance, 33 construction, 40 maintenance, 62 soil foundations (1 highway transportation, 2 public transit, 3 rail transportation)

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NCHRP Research on Bridge Engineering

An NCHRP staff digest of the progress and status of bridge engineering research under the National Cooperative Highway Research Program.

Since its inception in 1962 the National Cooperative Highway Research Program (NCHRP) has included numerous studies of interest to bridge engineers. In recent years, there has been a growing national awareness of bridge problems, and a substantial number of bridge research projects have been referred to NCHRP by the program sponsors, the American Association of State Highway and Transportation Officials (AASHTO), to the extent that, in the past 5 years, more than one third of NCHRP's funds have been allocated for studies of problems in the area of bridge engineering.

Many of these studies have been directed to development of improved methods of design and construction, with the ultimate goal of modifying the AASHTO Standard Specifications for Highway Bridges, but, in recent years, an increasing amount of research has been aimed at problems in evaluation, repair, or rehabilitation of existing bridges.

About one-half of the approximately 600,000 highway bridges in the United States were built before 1940, and many have not been maintained adequately. Most bridges in service today were designed for less traffic, smaller vehicles, slower speeds, and lighter loads. In addition, deterioration caused by environmental contamination is a growing problem. Almost 40 percent of the Nation's bridges are classified, according to the Federal Highway Administration's (FHWA) criteria, as deficient and in need of rehabilitation or replacement. More than 100,000 of these are judged to be structurally deficient because of deterioration or distress, and another 100,000 are considered functionally obsolete or inadequate for current requirements. In recent years the Federal Highway Bridge Replacement and Rehabilitation Program has provided about $1 billion annually (scheduled to increase to $2 billion in FY '86) to cover the 80 percent Federal-aid share of the cost of work on deficient bridges. However, FHWA currently estimates the program's needs at almost $50 billion, and this estimate does not include future inflation or the cost of additional needs that will develop while the presently identified, deficient bridges are being eliminated.

It is clear, therefore, that engineers will have to contend with large numbers of deficient bridges for many years to come. Many urgent, researchable problems related to existing bridges remain to be solved. For example, practical, effective procedures and equipment need to be developed and evaluated for use in the following areas: inspection of various types of bridge components, assessment of the effects of deterioration and distress, load rating, and estimating remaining life. In addition, research and development are needed on materials, equipment, and techniques for repair, rehabilitation, and reconstruction of bridge components built of various material using various construction techniques with various forms of damage, distress, and deterioration resulting from various loading and environmental conditions.

The magnitude of the effort required to deal with the Nation's deficient bridges is such that an investment in R&D resulting in an improvement of only 1% in the overall efficiency of performing this task will return something on the order of $500 million. The current, strong emphasis on bridge research in the NCHRP reflects AASHTO's recognition that, for bridge engineers to continue to do their part in expanding and maintaining the Nation's highway system in the face of limited resources, research will be necessary to find better methods of bridge design, construction, maintenance, repair, and rehabilitation.

The purpose of this Research Results Digest is to outline for easy reference (see Tables 1 through 4) the status of all NCHRP research related to bridges. Included are projects completed, in progress, and under development. A listing of all related research reports is also provided, with directions for obtaining copies. This digest supersedes RRD 132 published in May 1982.

NCHRP research covers a wide range of problem areas related to design, construction, and maintenance of bridges. Nevertheless, the studies listed comprise only a portion of all bridge research carried out in the United States in recent years. A more comprehensive listing of current and planned research, including FHWA-sponsored contracts and state Highway Planning and Research (HP&R) studies, can be found in the documentation for FHWA's Federally Coordinated Program for Research and Development (FCP), which may be obtained from Mr. Charles F. Galambos, Chief, Structures Division, Office of Research, Development & Technology, HNR-10, Federal Highway Administration, 6300 Georgetown Pike, McLean, VA 22101, 703/285-2087.

All NCHRP publications on bridge research are listed chronologically in Table 1. Some 50 relevant publications in the NCHRP Report series are included in Table 1(a). Several of the earlier reports, included for the sake of completeness, should no longer be considered to be thorough, up-to-date treatments of the particular subjects. NCHRP Syntheses of Highway Practice concerned with bridge problems are listed in Table 1(b). These reports emanate from NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems." Table 1(c) includes NCHRP Research Results Digests on studies of bridge problems.

Copies of publications listed in Table 1 can be obtained from the Publications Office, Transportation Research Board, 2101 Constitution Avenue, NW, Washington, D.C. 20418. A check or money order payable to Transportation Research Board must accompany orders totaling $10.00 or less.

Uncorrected copies of agency reports listed in Table 2 can be obtained as noted in the table.

Bridge engineering research projects currently in progress are listed in Table 3. Details on these studies can be found in the NCHRP Summary of Progress Through 1983.

Research projects in the developmental stage or expected to start in the near future are listed in Table 4.

TABLE 1 - REPORTS AVAILABLE

No.	Title	Proj. No.	Research Agency	No. of Pages	Cost	Year of Publ.
			(a) NCHRP Report			
1 *	Evaluation of Methods of Replacement of Deteriorated Concrete in Structures	6-8	Bertram D. Tallamy Associates	56	*	1964
4 *	Non-Chemical Methods of Snow and Ice Control on Highway Structures	6-2	Roy Jorgensen and Associates	74	*	1964
16 *	Protective Coatings to Prevent Deterioration of Concrete by Deicing Chemicals	6-3	Battelle Memorial Institute	21	*	1965
23 *	Methods for Reducing Corrosion of Reinforcing Steel	6-4	Battelle Memorial Institute	22	*	1966
74	Protective Coatings for Highway Structural Steel	4-6	Steel Structures Painting Council	64	2.80	1969
74A *	Protective Coatings for Highway Structural Steel--Literature Survey	4-6	Steel Structures Painting Council	275	*	1969
74B *	Protective Coatings for Highway Structural Steel--Current Highway Practices	4-6	Steel Structures Painting Council	102	*	1969
80 *	Oversize-Overwieght Permit Operation on State Highways	2-10	Roy Jorgensen and Associates	120	*	1969
83 *	Distribution of Wheel Loads on Highway Bridges	12-2	Iowa State University	56	*	1970
86	Tentative Service Requirements for Bridge Rail Systems	12-8	Texas A & M University	62	3.20	1970
90	Protection of Steel in Prestressed Concrete Bridges	12-5	University of Denver	86	4.00	1970
101 *	Effect of Stress on Freeze-Thaw Durability of Concrete Bridge Decks	6-9	University of Illinois	70	*	1970
102	Effect of Weldments on the Fatigue Strength of Steel Beams	12-7	Lehigh University	114	5.40	1970
105 *	Dynamic Pavement Loads of Heavy Highway Vehicles	15-5	General Motors Corporation	94	*	1970
106 *	Revibration of Retarded Concrete for Continuous Bridge Decks	18-1	University of Illinois	67	*	1970
109 *	Elastomeric Bearing Research	12-9	Battelle Memorial Institute	53	*	1970
116 *	Structural Analysis and Design of Pipe Culverts	15-3	Northwestern University	155	*	1971
141 *	Changes in Legal Vehicle Weights and Dimensions: Some Economic Effects on Highways	19-3	Wilbur Smith and Associates	184	*	1973
147	Fatigue Strength of Steel Beams with Welded Stiffeners and Attachments	12-7	Lehigh University	85	4.80	1974
149	Bridge Rail Design--Factors, Trends, and Guidelines	12-8	Texas A & M University	49	4.00	1974
153	Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances	22-2	Southwest Research Institute	19	3.20	1974

TABLE 1 - continued

No.	Title	Proj. No.	Research Agency	No. of Pages	Cost	Year of Publ.
163	Design of Bent Caps for Concrete Box-Girder Bridges	12-10	Portland Cement Association	124	6.80	1976
164	Fatigue Strength of High-Yield Reinforcing Bars	4-7	Portland Cement Assciation	90	5.60	1976
165	Waterproof Membranes for Protection of Concrete Bridge Decks--Laboratory Phase	12-11	Materials Research and Development	70	4.80	1976
180	Cathodic Protection for Reinforced Concrete Bridge Decks	12-13	USS Engineers and Consultants	135	7.00	1977
181	Subcritical Crack Growth in Steel Bridge Members	12-14	U. S. Steel Corporation	82	5.60	1977
182	Economic Evaluation of Ice and Frost on Bridge Decks	6-11	Midwest Research Institute	73	4.80	1978
188	Fatigue of Welded Steel Bridge Members Under Variable Amplitude Loadings	12-12	U.S. Steel Corporation	113	6.40	1978
190*	Use of Polymers in Highway Concrete	18-2	Lehigh University	77	*	1978
198	State Laws and Regulations on Truck Size and Weight	20-16	R.J. Hansen Associates	117	7.20	1979
201	Acceptance Criteria for Electroslag Weldments in Bridges	10-10	U.S. Steel Corporation	44	5.20	1979
203	Safety at Narrow Bridge Sites	20-7 Task 7	Texas A&M University	63	6.00	1979
204	Bridge Deck Joint-Sealing Systems - Evaluation and Performance Specification	10-11	Howard Needles Tammen & Bergendoff	46	5.60	1979
206	Detection and Repair of Fatigue Damage in Welded Highway Bridges	12-15 & 12-15(2)	Lehigh University	85	6.80	1979
222	Bridges on Secondary Highways and Local Roads—Rehabilitation and Replacement	12-20	University of Virginia	132	$ 9.20	1980
226	Damage Evaluation and Repair Methods for Prestressed Concrete Bridge Members	12-21	G. O. Shanafelt & W. B. Horn	66	7.20	1980
227	Fatigue Behavior of Full-Scale Welded Bridge Attachments	12-15(3)	Lehigh University	47	6.40	1980
230	Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances	22-2(4)	Southwest Research Institute	42	6.00	1981
234	Galvanic Cathodic Protection for Reinforced Concrete Bridge Decks—Field Evaluation	12-13A	Portland Cement Association	64	6.80	1981

239	Multiple-Service-Level Highway Bridge Railing Selection Procedures	22-2(3)	Southwest Research Institute	161	10.40	1981
240	A Manual to Determine Benefits of Separating Pedestrians and Vehicles	20-10(2)	SRI International	56	7.20	1981
242	Ultrasonic Measurement of Weld Flaw Size	10-13	The Welding Institute England	76	8.00	1981
243	Rehabilitation and Replacement of Bridges on Secondary Highways and Local Roads	12-20	University of Virginia	46	6.80	1981
244	Concrete Sealers for Protection of Bridge Structures	12-19A	Wiss, Janney, Elstner & Associates, Inc.	138	10.00	1981
248	Elastomeric Bearings Design, Construction, and Materials	10-20	University of Washington	82	8.40	1982
251	Assessment of Deficiencies and Preservation of Bridge Substructures Below the Waterline	10-16	Byrd, Tallamy, MacDonald and Lewis	80	8.40	1982
257	Long-Term Rehabilitation of Salt-Contaiminated Bridge Decks	18-2(3)	Lehigh University	32	6.40	1983
265	Removal of Lead-Based Bridge Paints	10-23	Midwest Research Institute	72	8.00	1983
267	Steel Bridge Members Under Variable Amplitude Long Life Fatigue Loading	12-15(4)	Lehigh University	26	6.40	1983

(b) NCHRP Synthesis of Highway Practice

2 *	Bridge Approach Design and Construction Practices	20-5 Topic #2	Transportation Research Board	30	*	1969
4 *	Concrete Bridge Deck Durability	#3	Transportation Research Board	28	*	1970
5*	Scour at Bridge Waterways	#5	Transportation Research Board	28	*	1970
33	Acquisition and Use of Geotechnical Information	#5-04	Transportation Research Board	40	4.00	1976
41	Bridge Bearings	#6-09	Transportation Research Board	62	4.80	1977
42	Design of Pile Foundations	#5-04	Transportation Research Board	68	4.80	1977
44	Consolidation of Concrete for Pavements, Bridge Decks, and Overlays	#7-01	Transportation Research Board	61	4.80	1977

TABLE 1 - continued

No.	Title	Proj. No.	Research Agency	No. of Pages	Cost	Year of Publ.
50	Durability of Drainage Pipe	#5-09	Transportation Research Board	37	3.60	1978
53	Precast Concrete Elements for Transportation Facilities	#8-05	Transportation Research Board	48	5.60	1978
57	Durability of Concrete Bridge Decks	#9-01	Transportation Research Board	61	6.00	1979
67	Bridge Drainage Systems	#10-06	Transportation Research Board	44	5.60	1979
68	Motor Vehicle Size and Weight Regulations, Enforcement, and Permit Organizations	#10-04	Transportation Research Board	45	$ 6.00	1980
78	Value Engineering in Precon-struction and Construction	#11-02 & 03	Transportation Research Board	23	6.40	1981
82	Criteria for Evaluation of Truck Weight Enforcement Programs	#12-02	Transportation Research Board	74	7.20	1981
86	Effects of Traffic-Induced Vibrations on Bridge-Deck Repairs	#10-21	Transportation Research Board	40	6.80	1981
88	Underwater Inspection and Re-pairs of Bridge Substructures	#10-08	Transportation Research Board	77	7.60	1981
101	Historic Bridges: Criteria for Decision Making	#13-11	Transportation Research Board	84	8.00	1983
	(c) NCHRP Research Results Digest					
14	Waterproof Expansion Joints for Bridges	12-3	Southwest Research Institute	3	1.00	1969
81	Crash Testing and Evaluation of Attenuating Bridge Railing System	22-1A	Texas A&M University	10	1.00	1976
85	Bridge Deck Repairs	12-16	Battelle Columbus Laboratory	22	1.00	1976
115	NCHRP Research on the Durability of Reinforced Concrete Bridge Components	Var.	Transportation Research Board	6	1.00	1979
141	Liability of State Highway Departments for Defects in Design, Construction, and Maintenance of Bridges	20-6	Transportation Research Board	30	3.00	1983

* Out of print - Available in microfiche from the Transportation Research Board The cost is $4.50 per publication

TABLE 2 - UNCORRECTED AGENCY FINAL REPORT

Proj. No.	Title	Research Agency	Availability*
4-14	Coating Systems for Painting Old and New Structural Steel	Georgia Institute of Technology	A & B
10-15	Structural Strength Evaluation of Existing Reinforced Concrete Brigdes	Engineering Computer Corporation	A & B
12-1	Deformation of Steel Beams Related to Permitted Highway Bridge Overloads	University of Missouri	B
12-4	Thermal Characteristics of Highway Bridges	Southwest Research Institute	B
12-6	Prediction of Permanent Camber of Bridges	University of Missouri	B
12-11/1	Waterproof Membrances for Protection of Concrete Bridge Decks	Materials R & D	A & B
12-15	Detection and Repair of Fatigue Cracking in Highway Bridges	Lehigh University	B
12-15(2)	Retrofitting Procedures for Fatigue-Damaged Full-Scale Welded Bridge Beams	Lehigh University	B
12-16	Influence of Bridge Deck Repairs on Corrosion of Reinforcing Steel	Battelle Columbus Laboratories	A & B
12-17	Evaluation of Repair Techniques for Damaged Steel Bridge Members	Battelle Columbus Laboratories	A & B
12-18	Development of an Integrated Bridge Design System (Interim)	Multisystems, Inc.	A & B
12-19	Corrosion Control and Repair of Concrete Bridge Structures (Interim)	Corrosion Eng. & Research Co.	A & B
12-19	Cathodic Protection of Concrete Bridge Structures	Corrosion Eng. & Research Co.	A & B
18-2(2)	Polymer Concrete in Highway Bridge Decks	Lehigh University	A & B
22-1	Concepts for Improved Traffic Barrier Systems	Walter W. White	B
22-1A	Testing and Evaulation of Bridge Rail Concepts	Texas A&M University	B
22-2(2)	Multiple Service Level Highway Bridge Railings--Performance and Design Criteria (Phase I)	Southwest Research Institute	B
22-2(2)	Multiple Service Level Highway Bridge Railings--Development and Evaluation of Low-Cost Railing System (Phase II)	Southwest Research Institute	B

* A: A copy of the uncorrected draft of the agency's report may be obtained on a loan basis by request to the Director, Cooperative Research Programs.
B: Available in microfiche from the Transportation Research Board. The cost is $4.50 per publication.

TABLE 3 - RESEARCH IN PROGRESS

Project Number	Title	Research Agency	Completion Date
4-15	Corrosion Protection of Prestressing Systems in Concrete Bridges	Wiss, Janney, Elstner & Assoc., Inc.	10/31/84
10-13/1	Ultrasonic Measurement of Welded Flaw Size (Phase II)	The Welding Institute	3/31/85
10-15/1	Structural Strength Evaluation of Existing Reinforced Concrete Bridges (Phase II)	Engineering Computer Corporation	9/30/85
10-20/1	Elastomeric Bearings - Design, Construction, and Materials (PHase II)	University of Washington	5/31/86
10-22	The Performance of Weathering Steel in Bridges	Sheladia Associates, Inc.	3/31/84
12-15(5)	Fatigue Behavior of Variable Loaded Bridge Details Near the Fatigue Limit	Lehigh University	8/31/87
12-17A	Guidelines for Evaluation and Reapir of Damaged Steel Bridge Members	George O. Shanafelt & Willis B. Horn	3/31/84
12-18	Development of an Integrated Bridge Design System	Multiplications, Inc.	3/31/84
12-18A	Assessment of an Integrated Bridge Design System	Engineering Computer Corporation	3/31/85
12-19B	Cathodic Protection of Concrete Bridge Structures	Wiss, Janney, Elstner & Assoc., Inc.	1/31/85
12-21/1	Evaluation of Damage and Methods of Repair for Prestressed Concrete Bridge Members (Phase II)	George O. Shanafelt & Willis B. Horn	7/31/84
12-22	Thermal Effects in Concrete Bridge Superstructures	Engineering Computer Corporation	3/31/84
12-24	Design of Multi-Beam Precast Bridge Superstructures	University of Washington	7/31/85
14-6	Evaluating Deferred Maintenance Strategies	ARE, Inc.	5/31/85
20-5	Synthesis of Information Related to Highway Problems Topic 9-12, Welding and Inspection Practices in Bridge Fabrication Topic 12-06, Shallow Foundations for Highway Structures Topic 12-11, Bridge Design to Reduce and Facilitate Maintenance and Repair Topic 13-08, Bridge Posting Practices Topic 14-22, Distribution of Wheel Loads on Highway Bridges Topic 15-02, Durability of Prestressed Concrete Highway Structures Topic 15-03, Detecting Defects and Deterioration in Highway Structures Topic 15-09, Protective Coating for Bridge Steel Topic 15-10, Prefabricated Bridge Elements and Systems Topic 15-19, Hot-Dip Galvanizing for Exposed Structural and Miscellaneous Steel	Transportation Research Board	Variable
20-7	Task 18, Editorial Revision of AASHTO Standard Specifications for Highway Bridges	Howard, Needles, Tammen & Bergendoff	6/30/84*
22-4	Performance of Longitudinal Traffic Barriers	Southwest Research Institute	6/30/85
24-1	Manual on Subsurface Investigation	Haley and Aldrich, Inc.	3/31/84

* To be published by AASHTO

TABLE 4 - PENDING RESEARCH

Project Number	Title	Funds Available	Expected Start
4-15	Corrosion Protection of Prestressing Systems in Concrete Bridges (Phase II)	100,000	Late 1984
10-20	Elastomeric Bearings - Design, Construction, and Materials (Phase III)	150,000	Early 1985
10-22	The Performance of Weathering Steel in Bridge (Phase II)	250,000	Late 1984
12-18	Development of an Integrated Bridge Design System (Phase II)	150,000	Mid 1985
12-25	Fatigue and Fracture Evaluation for Rating Steel Bridges	200,000	Mid 1984
12-26	Distribution of Wheel Loads on Highway Bridges	300,000	Late 1984
12-27	Welded Repair of Cracks in Steel Bridge Members	375,000	Mid 1984
12-28	Load Capacity of Bridges	1,000,000	Late 1984
12-29	Design of Simple-Span Precast Prestressed Girders Made Continuous	250,000	Late 1984
15-10	Development of a General Design Graphics Systems	500,000	Early 1985
20-5	Synthesis of Information Related to Highway Problems Topic 16-01, Bridge Inspection Equipment, Staffing, and Safety Topic 16-04, Microcomputer Software for Highway and Structural Engineering Topic 16-10, Bridge Expansion Devices		