National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 132 - MAY 1982

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 3 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 repair and rehabilitation of existing bridges.

There are nearly 600,000 highway bridges in the United States; about three out of four were built before 1935, 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.

Some 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 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 $47 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.

Bridge designers continually attempt to improve their work through innovation. New design methods, materials, and construction techniques, developed through research, generally advance the quality of the end product; but, innovation is not usually possible without some risk, and it sometimes gives rise to new problems in maintenance, repair, and rehabilitation. For example, welded connections, used extensively in the construction of steel bridges over the past 20 years, have developed fatigue problems in some instances. Findings from NCHRP research (see NCHRP Reports 102 and 147; and Table 1(a)) were the basis for a complete revision of AASHTO's provisions for consideration of fatigue in design of steel bridge members. In other NCHRP research (see NCHRP Reports 206 and 227), methods were developed for repairing and retrofitting fatigue-susceptible welded connections. These methods have been used to rehabilitate welded steel bridge members that were designed under earlier specifications. In one particular bridge, where the recommended technique of peening was used in lieu of bolted splices at the ends of hundreds of cover plates, the cost savings exceeded $1 million.

Another area in which new questions are developing as a result of innovations in structural design involves the repair of prestressed concrete bridge members. Over the past 20 years, thousands of bridges have been built with prestressed concrete superstructures. Most of these structures are relatively new, and are performing well. Deterioration caused by environmental attack has not been a major problem to date; therefore, most engineers have only limited experience in repairing prestressed concrete. Yet, repairs are sometimes necessary. Nationwide each year, more than 100 prestressed concrete girders are damaged by impact by over-height vehicles. Concrete is crushed; reinforcement is sometimes severed; the damage is highly visible; the condition of the bridge could be unsafe; and the situation is usually urgent. In the past, the engineer, who must decide what to do under these circumstances, has not had adequate information on which to base a decision, and damaged girders that might have been repaired, in almost all cases, were removed and replaced. Guidance is now available in the form of recommendations for repair techniques developed in a recent NCHRP study (see NCHRP Report 226). With the cost of complete replacement of a damaged girder averaging about $50,000 and the cost of repairing in-place estimated at $15,000, the potential savings amount to millions of dollars annually.

It is worth noting also that this study is a good example of the benefits that can be derived from a cooperative research program. The problem of accidently damaged prestressed concrete bridge members is probably not important enough for any one highway agency to justify research on its own; but, by 52 highway agencies pooling their funds through NCHRP, a $60,000 study could result in savings of millions of dollars nationally each year.

Another active area of research in recent years has been directed at bridge deck durability, both with regard to prevention of deterioration and rehabilitation of damaged decks. The findings of a recent study (see NCHRP Synthesis of Highway Practice 86; and Table 1(b)) have been used in establishing bridge deck repair procedures that avoid costly bridge closings and detours. The study concluded that traffic can be maintained on a bridge while concrete is placed in deck repairs, overlays, widenings, or replacements.

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 118 published in February 1980.

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. James D. Cooper, Bridge Structures Group, Office of Research, HRS-11, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. 20590, 703/285-2072.

All NCHRP publications on bridge research are listed chronologically in Table 1. Some 45 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 1981.

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

Additional information may be obtained by contacting Robert J. Reilly, NCHRP Projects Engineer, at 202/334-3224.

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	$2.80	1964
4 *	Non-Chemical Methods of Snow and Ice Control on Highway Structures	6-2	Roy Jorgensen and Associates	74	3.20	1964
16 *	Protective Coatings to Prevent Deterioration of Concrete by Deicing Chemicals	6-3	Battelle Memorial Institute	21	1.60	1965
23 *	Methods for Reducing Corrosion of Reinforcing Steel	6-4	Battelle Memorial Institute	22	1.40	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	8.00	1969
74B *	Protective Coatings for Highway Structural Steel--Current Highway Practices	4-6	Steel Structures Painting Council	102	4.00	1969
80 *	Oversize-Overwieght Permit Operation on State Highways	2-10	Roy Jorgensen and Associates	120	5.20	1969
83 *	Distribution of Wheel Loads on Highway Bridges	12-2	Iowa State University	56	2.80	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	3.60	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	5.00	1970
106 *	Revibration of Retarded Concrete for Continuous Bridge Decks	18-1	University of Illinois	67	3.40	1970
109 *	Elastomeric Bearing Research	12-9	Battelle Memorial Institute	53	3.00	1970
116	Structural Analysis and Design of Pipe Culverts	15-3	Northwestern University	155	6.40	1971
141 *	Changes in Legal Vehicle Weights and Dimensions: Some Economic Effects on Highways	19-3	Wilbur Smith and Associates	184	8.40	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
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

	of Concrete Bridge Decks--Laboratory Phase		Development			
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	5.60	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

TABLE 1 (Continued)

No.	Title	Proj. No.	Research Agency	No. of Pages	Cost	Year of Publ.
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
	(b) NCHRP Synthesis of Highway Practice					
2	Bridge Approach Design and Construction Practices	20-5 Topic #2	Transportation Research Board	30	2.00	1969
4	Concrete Bridge Deck Durability	#3	Transportation Research Board	28	2.20	1970
5*	Scour at Bridge Waterways	#5	Transportation Research Board	28	2.40	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
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 Preconstruction 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 Repairs of Bridge Substructures	#10-08	Transportation Research Board	77	7.60	1981
	(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

* Out of print - Available in microfiche from the Transportation Research Board. The cost is $4.00 per publication.

TABLE 2

UNCORRECTED AGENCY FINAL REPORTS

Proj. No.	Title	Research Agency	Availability*
12-1	Deformation of Steel Beams Related to Permitted Highway Bridge Overloads	Univ. of Missouri	B
12-4	Thermal Characteristics of Highway Bridges	Southwest Research Institute	B
12-6	Prediction of Permanent Camber of Bridges	Univ. of Missouri	B
12-11/1	Waterproof Membranes 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 Evaluation of Bridge Rail Concepts	Texas A&M Univ.	B
22-2(2)	Multiple Service Level Highway Bridge Railings--Performance and Design Criteria (Phase 1)	Southwest Research Institute	B
22-2(2)	Multiple Service Level Highway Bridge Railings--Development and Evaluation of Low-Cost Railing System (Phase 2)	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 $4.00 per publication.

TABLE 3

RESEARCH IN PROGRESS

Project Number	Title	Research Agency	Completion Date
4-14	Coating Systems for Painting Old and New Structural Steel	Georgia Institute of Technology	6/30/82
10-15	Structural Strength Evaluation of Existing Reinforced Concrete Bridges	Engineering Computer Corporation	9/30/82
10-16	Assessment of Deficiencies and Preservation of Bridge Substructures Below the Waterline	Byrd, Tallamy, MacDonald & Lewis	8/15/82
10-20	Elastomeric Bearings - Design, Construction, and Materials	University of Washington	6/30/82
10-22	The Performance of Weathering Steel in Bridges	Sheladia Associates, Inc.	9/30/83
12-15(4)	Steel Bridge Members Under Variable-Amplitude, Long-Life Fatigue Loading	Lehigh University	6/30/83
12-17A	Guidelines for Evaluation and Repair of Damaged Steel Bridge Members	George O. Shanafelt & Willis B. Horn	9/30/83
12-18	Development of an Integrated Bridge Design System	Multisystems, Inc.	8/31/82
12-21/1	Evaluation of Damage and Methods of Repair for Prestressed Concrete Bridge Members	George O. Shanafelt & Willis B. Horn	7/31/84
12-22	Thermal Effects in Concrete Bridge Superstructures	Engineering Computer Corp.	5/31/83
18-2(3)	Long-Term Rehabilitation of Salt-Contaminated Bridge Decks	Lehigh University	11/01/82
20-5	Synthesis of Information Related to Highway Problems	Transportation Research Board	Variable
	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 13-11, Evaluation of Criteria for Historic Bridge Decisions		
20-7	Task 18, Editorial Revision of AASHTO Standard Specifications for Highway Bridges	Howard, Needles, Tammen & Bergendoff	12/31/82
24-1	Manual on Subsurface Investigation	Haley and Aldrich, Inc.	6/30/82

TABLE 4

PENDING RESEARCH

Project Number	Title	Funds Available	Expected Start
4-15	Corrosion Protection of Prestressing Systems in Concrete Bridges	$ 250,000	Mid 1982
Continuation of 4-15	Corrosion Protection of Prestressing Systems in Concrete Bridges	100,000	Late 1984
Continuation of 10-13	Ultrasonic Measurement of Weld Flaw Size	250,000	Mid 1982
Continuation of 10-15	Structural Strength Evaluation of Existing Reinforced Concrete Bridges	100,000	Late 1982
Continuation of 10-16	Assessment of Deficiencies and Preservation of Bridge Substructures Below the Waterline	150,000	Late 1982
Continuation of 10-20	Elastomeric Bearings - Design, Construction, and Materials	150,000	Late 1982
10-23	Removal of Lead-Based Bridge Paints	75,000	Mid 1982
Continuation of 10-23	Removal of Lead-Based Bridge Paints	55,000	Late 1983
Continuation of 12-15(4)	Steel Bridge Members Under Variable-Amplitude, Long-Life Fatigue Loading	250,000	Early 1983
Continuation of 12-17A	Guidelines for Evaluation and Repair of Damaged Steel Bridge Members	100,000	Late 1983
Continuation of 12-18	Development of an Integrated Bridge Design System	150,000	Late 1982
Continuation of 12-19	Cathodic Protection of Concrete Bridge Structures	150,000	Late 1982
Continuation of 12-21/1	Evaluation of Damage and Methods of Repair for Prestressed Concrete Bridge Members	70,000	Mid 1984
12-23	The Performance of Steel Grid Bridge Decks	100,000	Cancelled
12-24	Design of Multi-Beam Precast Bridge Superstructures	150,000	Late 1982
14-6	Evaluating Deferred Maintenance Strategies	300,000	Mid 1982
Continuation of 18-2(3)	Long-Term Rehabilitation of Salt-Contaminated Bridge Decks	70,000	Mid 1983
22-4	Performance of Longitudinal Traffic Barriers	500,000	Late 1982

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