t No. FHWA-RD-78-133

ENDING THE SERVICE LIFE OF EXISTING BRIDGES BY INCREASING THEIR LOAD CARRYING CAPACITY

June 1978

Final Report

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D. C. 20590

FOREWORD

As a result of field inspection over 140 bridges located in 5 different States, a catalogue of bridge deficiencies as related to types of structures and frequency of occurrence has been generated. The principal reasons given for bridge deficiencies included lack of proper maintenance due to insufficient maintenance funds, exposure of bridge elements to hostile environmental conditions, general wear due to usage, and poor initial design detail.

Conclusions have been reached as a result of this study regarding the use of rehabilitation techniques. Procedures have been developed to increase the load carrying capacity and to rehabilitate bridges to improve geometrics in a cost-effective manner.

Because of the magnitude of the bridge problem, it is essential that the proper decisions be reached as to how to correct these problems. This study is a start in providing some of the information that is needed by engineers responsible for maintaining the nation's bridges. Additional research is urgently needed so that the heavy expenditures that must be made over the next decade to resolve our bridge problems will be spent as prudently and as effectively as possible.

This report is being distributed to the Washington and field offices of the Federal Highway Administration, State highway departments, and interested researchers.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

Technical Report Documentation Page

1. Report No. FHWA-RD-78-133	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES BY INCREASING THEIR LOAD CARRYING CAPACITY		5. Report Date June, 1978
		6. Performing Organization Code
		8. Performing Organization Report No.
7. Author(s) Roland H. Berger		
9. Performing Organization Name and Address Byrd, Tallamy, MacDonald and Lewis, A Division of Wilbur Smith and Associates, 2921 Telestar Court, Falls Church, Virginia 22042		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FH-11-9214
12. Sponsoring Agency Name and Address Offices of Research and Development, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. 20590		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code
15. Supplementary Notes FHWA Contract Manager: Mr. Jerar Nishanian		

16. Abstract

A catalog of bridge deficiencies is developed based on the inspection of over 140 deficient bridges located in Illinois, Florida, Pennsylvania, California, and Tennessee. A classification of structure types is developed for concrete, steel and timber bridges. Deficiencies are related to the structure classification system and a hierarchy of the most common deficiencies established.

Techniques presently utilized by state highway departments to correct deficiences are described and evaluated. Several innovative techniques for increasing the load carrying capacity are also described. Utilizing these techniques, increased capacity values are developed. Cost factors are also analyzed and graphic presentations which show the relative merit of each system are presented.

Techniques for increasing load capacity include: (1) Lightweight deck systems, e.g., timber, plate, steel grid, metal; (2) changes in structural system, e.g. develop continuity in simple spans, composite action, post tensioning; (3) member strengthening techniques, e.g., epoxy attached plates, replacement members, supplemental support systems.

Techniques developed for improving geometrics include widening concepts for through girder bridges and improved clearance for through truss bridges.

The report includes examples of techniques developed as they apply to actual bridge rehabilitation projects. Details are shown illustrating these techniques.

17. Key Words Bridge Rehabilitation, Bridge Repairs, Increased Bridge Service Life, Increased Bridge Capacity, Bridge Deficiencies	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	152	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGMENT

The research study covered by this report was conducted by Byrd, Tallamy, MacDonald and Lewis, a Division of Wilbur Smith and Associates. The Principal Investigator was R. H. Berger. Others making contributions were R. Koenig, D. H. Beeson, and R. Smith who assisted in the inspection work and who also aided in the development and evaluation of various repair techniques.

The author wishes to thank the State Highway staff members in California, Tennessee, Illinois, Pennsylvania, and Florida for their cooperation in supplying data for this report and assisting the research team in conducting inspections in these states.

Special thanks are extended to Mr. Jerar Nishanian of the Federal Highway Administration who, as Project Manager, provided invaluable assistance in contacts with Federal and state highway staff members.

SUMMARY

As a result of field inspecting over 140 bridges located in five different states (Illinois, Pennsylvania, Tennessee, Florida and California), a catalogue of bridge deficiencies as related to types of structures and frequency of occurrence has been generated. This catalogue includes bridges in the short- to medium-span range 6.1m to 45.7m (20 feet to 150 feet) constructed of steel, concrete, and timber. Only fixed span bridges have been considered, although many of the multiple span bridges inspected included a movable span.

Through discussions with bridge maintenance personnel in each of the states where inspections were conducted, considerable insight into the cause of deficiencies was gained. The principal reasons given for bridge deficiencies included lack of proper maintenance due to insufficient maintenance funds, exposure of bridge elements to hostile environmental conditions, general wear due to usage, and poor initial design detail.

Techniques presently in use for increasing the load carrying capacity of existing bridges revealed several methods that have been used successfully. These include strengthening weak members by replacement or by adding additional material, and reducing the dead load through the installation of lightweight deck systems thereby increasing live load capacity. Other innovative techniques investigated included the application of exterior reinforcing plates to concrete and beams by adhesives, making a series of simple spans continuous, and adding supplemental supports to reduce span lengths or to assist in carrying live loads.

Procedures for improving geometrics that have been utilized successfully included adjustments to portal and sway frames on through trusses and widening procedures. Concepts for increasing vertical clearance by the use of thinner deck systems and by lowering floor framing systems have also been developed.

widening procedures for through girder bridges, including the placement of the floor system at the top flange, are possible in certain situations where approach grades can be adjusted several feet. Procedures for providing additional usable roadway by altering cross section geometrics can, in some cases, also be used effectively.

Additional repairs involving bearing replacement, expansion joints, abutment stabilization, concrete repairs, and other repair techniques were reviewed and a discussion of these is included with the report.

The relative merits of different techniques that can be used to increase load carrying capacity have been evaluated. A concept identified as the "Improvement Factor" has been computed to relate span length to the increase in carrying capacity as determined by flexural requirements. Relating the Factor to cost data provides a means for comparing both cost and effectiveness of various techniques.

In order to demonstrate the applicability of several techniques for rehabilitating deficient bridges, five bridges were selected for the development of rehabilitation plans. These plans are included in the Appendix of the report. Cost data for rehabilitation and for replacement of these bridges are given for comparison purposes. In four out of the five bridges for which plans were prepared, initial costs for rehabilitation are lower than replacement costs by as much as ten times based on a replacement structure of comparable length to the existing bridge.

Conclusions have been reached as a result of the study regarding the use of rehabilitation techniques. Procedures have been developed to increase the load carrying capacity and to rehabilitate bridges to improve geometrics in a cost-effective manner.

Recommendations have been made as to the need for additional research in the areas of development and evaluation of rehabilitation techniques, development of criteria for posting, and prioritization of bridge repairs.

TABLE OF CONTENTS

		Page
SUMMARY		
CHAPTER I -	INTRODUCTION	1
	STUDY OBJECTIVES	3
	RESEARCH APPROACH	3
CHAPTER II -	FIELD INSPECTIONS	5
	PROGRAM DEVELOPMENT	5
	INSPECTIONS	8
	ANALYSIS OF DATA	11
CHAPTER III -	DISCUSSION OF BRIDGE DEFICIENCIES	17
	STRUCTURAL	17
	MECHANICAL	19
	GEOMETRIC	20
	SAFETY	20
	BRIDGE DEFICIENCY CATALOGUE	21
CHAPTER IV -	COLLECTION OF REHABILITATION PROCEDURE DATA	22
	LITERATURE SEARCH	22
	TRADE ASSOCIATIONS	22
	MANUFACTURERS	23
	TRANSPORTATION AGENCIES	23
	OTHER SOURCES	24
CHAPTER V -	REHABILITATION CONCEPTS	26
	INCREASE LIVE LOAD CAPACITY	26
	IMPROVE GEOMETRICS	44
	CORRECT MECHANICAL DEFICIENCIES	49
	MISCELLANEOUS REPAIRS	52
CHAPTER VI -	REHABILITATION TECHNIQUE EVALUATION	55
	IMPROVEMENT FACTOR	55
	COST EFFECTIVENESS FACTOR	59
CHAPTER VII -	REHABILITATION TECHNIQUE DEMONSTRATION	61
	SELECTION OF BRIDGES	61
	SELECTION OF REHABILITATION TECHNIQUES	64
	PLAN DEVELOPMENT	65
	COST ANALYSIS	66

		Page
CHAPTER VIII -	CONCLUSIONS AND RECOMMENDATIONS	69
	CONCLUSIONS	69
	RECOMMENDATIONS	70
APPENDIXES		
A	Summary of Bridge Inspections in Participating States	
B	Bridge Deficiency Catalogue and Photo Log Deficiencies	
C	Listing and Description of Rehabilitation Plans Reviewed	
D	Rehabilitation Techniques	
E	Demonstration Plans for Bridge Rehabilitation	

LIST OF TABLES

Number		
1	Status of States Deficient Bridges as of September 30, 1977	2
2	Bridge Inspection Type Summary	13
3	Bridge Inspection Deficiency Summary	15
4	Comparison of National Inventory Data and Bridges Inspected in Participating States	16
5	Bridge Rehabilitation Demonstration Techniques	62
6	Cost Summary - Demonstration Bridges	68

LIST OF FIGURES

Number		Page
1	Kingpost Truss Beam Reinforcement	30
2	External Concrete Reinforcing	35
3	Supplemental Transverse Supports	38
4	Conceptual Details - Simple Span Steel Beam to Continuous	45
5	Conceptual Details - Thru Girder Deck Widening	48
6	Span-Improvement Factor - Dead Load Reduction Systems	57
7	Span-Improvement Factor - Structural Modification Systems	58

CHAPTER I

INTRODUCTION

Current estimates indicate that of the 234,000 bridges on the Federal Aid Highway System, 6,912 are structurally deficient and 26,603 are functionally obsolete. This information is taken from a recent summary of inventory reports supplied by the states to the Federal Highway Administration (FHWA). A breakdown by state is shown in Table 1.

By FHWA definition, a structurally deficient bridge is one that has been restricted to light vehicles only or closed to traffic entirely. A functionally obsolete bridge is one whose deck geometry, clearance, or approach roadway alignment can no longer safely serve the system of which it is an integral part.

These deficient bridges are used daily by millions of vehicles including cars, trucks, and commercial and school buses. In this unsafe condition, these bridges jeopardize human life, disrupt commerce, and impair economic growth.

In 1975, 1,072 fatalities were reported involving collisions with bridge elements. Each year the FHWA reports that some 150 bridges collapse, sag, or otherwise become impassable.

Replacement of these antiquated structures is extremely costly (American Road and Transportation Builders Association estimates $11.8 billion) and is unlikely to be a practical short-range solution. The alternative is to repair and rehabilitate these deficient bridges so that they can remain in service for a sufficient length of time to enable the development and implementation of realistic replacement programs.

Consequently, there is an urgent need to develop techniques for rehabilitating structures to accommodate imposed service loads. This study addresses this need.

TABLE 1. STATUS OF STATES DEFICIENT BRIDGES
AS OF SEPTEMBER 30, 1977

State	Total Number of Bridges on Federal-aid Systems	Structurally Deficient	Functionally Obsolete
ALABAMA	6,353	154	389
ALASKA	507	11	12
ARIZONA	3,999	24	125
ARKANSAS	5,134	57	706
CALIFORNIA	12,269	85	589
COLORADO	3,062	105	37
CONNECTICUT	1,509	23	52
DELAWARE	456	14	21
DIST. OF COL.	193	9	12
FLORIDA	4,788	107	664
GEORGIA	7,350	180	1,515
HAWAII	564	37	34
IDAHO	1,542	210	34
ILLINOIS	9,285	276	1,790
INDIANA	5,861	101	399
IOWA	6,808	172	895
KANSAS	9,544	523	1,391
KENTUCKY	4,635	66	1,169
LOUISIANA	4,964	85	1,900
MAINE	1,169	37	74
MARYLAND	2,338	20	191
MASSACHUSETTS	2,310	61	146
MICHIGAN	5,328	200	325
MINNESOTA	4,466	70	751
MISSISSIPPI	6,177	638	320
MISSOURI	7,558	277	335
MONTANA	2,186	29	129
NEBRASKA	4,119	395	661
NEVADA	718	32	100
NEW HAMPSHIRE	1,121	53	266
NEW JERSEY	2,259	100	105
NEW MEXICO	2,715	22	217
NEW YORK	6,639	277	933
NORTH CAROLINA	3,918	186	690
NORTH DAKOTA	1,753	166	380
OHIO	11,259	397	547
OKLAHOMA	7,222	220	358
OREGON	3,514	65	282
PENNSYLVANIA	7,949	185	723
RHODE ISLAND	503	7	26
SOUTH CAROLINA	3,997	124	259
SOUTH DAKOTA	2,674	85	1,220
TENNESSEE	6,845	263	1,130
TEXAS	23,800	51	1,360
UTAH	1,183	35	149
VERMONT	1,307	22	465
VIRGINIA	5,424	215	871
WASHINGTON	3,782	41	159
WEST VIRGINIA	2,503	172	354
WISCONSIN	5,912	207	916
WYOMING	1,839	13	256
PUERTO RICO	706	8	171
TOTAL	234,016	6,912*	26,603*

*The total number of deficient bridges used (Structurally Deficient and Functionally Obsolete) reflect the Federal Highway Administration's interpretation of the States' Inventory Data pertinent to the Special Bridge Replacement Program, and need not necessarily agree with the States' records for these two categories.

STUDY OBJECTIVES

More specifically, the objectives of this study are to develop and evaluate the effectiveness of present rehabilitation techniques and to develop new techniques for making bridge repairs, to improve geometrics, to increase load-carrying capacity, and to correct mechanical and other minor deficiencies. Additional objectives are to define and catalogue common bridge deficiencies and to develop a structural type catalogue.

RESEARCH APPROACH

To accomplish the aims of the study, a three-phase plan was developed.

- Phase I - Perform a field inspection of representative deficient bridges and develop a cataloging system for bridge types and bridge deficiencies.
- Phase II - Review rehabilitation procedures presently in use by state bridge departments and conduct a literature search to assemble a comprehensive data file on bridge rehabilitation techniques. This phase also includes the development of innovative rehabilitation techniques and an evaluation of all techniques reviewed.
- Phase III - Demonstrate those techniques judged to be most effective by developing rehabilitation plans for five selected structures.

Since the full spectrum of bridge construction is extremely broad and in a number of areas, highly specialized, it was decided to eliminate several types of structures from consideration during the study. Thus, the structures falling into a span range of 6 m to 60 m (20 feet to 200 feet) in steel, concrete and timber are included. Excluded are long span bridges, movable bridges, and other unique types of bridge construction.

It was also decided to eliminate repair and replacement systems for reinforced concrete bridge decks. This is a highly specialized area in which considerable research has already been done and other research is under way.

Similarly, the broad areas of fatigue cracking and fracture mechanics have not been considered in this study.

CHAPTER II

FIELD INSPECTIONS

PROGRAM DEVELOPMENT

Prior to conducting the bridge field inspections, a comprehensive program was developed to determine the most effective and the most efficient manner in which this phase of the work could be done.

Federal Inventory

The FHWA, with the cooperation of all of the 50 states, has conducted an inventory of bridges on the Federal-aid Highway System (FAS). This inventory data is on computer files at the FHWA in Washington, D. C.

Through the cooperation of the FHWA Bridge Division, Office of Engineering, a sorting program was developed to produce the bridge report for each bridge listed as structurally deficient or functionally obsolete, in each of the five states in which the inspections were to be conducted.

The first draft of the "National Bridge Inventory, Summary of Select Data" which contains a summary by states of deficient bridges was also made available for use by the research team. This publication contains data summarized by road system as well as by individual states.

State Participation

Five state highway departments agreed to have the research team inspect bridges under their jurisdiction. These cooperating states were Florida, California, Illinois, Tennessee and Pennsylvania.

Prior to visiting each cooperating state, contact was made through the FHWA regional field office advising the appropriate state agency of the desire of the study team to visit the state and to conduct inspections of deficient bridges.

A communique was then sent outlining the study and requesting data on deficient bridges within the state.

Response from each individual state usually included a list of structures that the state highway department felt was representative of the deficient structures within their state and would demonstrate the most commonly occurring deficiencies. Bridge locations and, in several instances, photographs and inspection reports were also included with the state's response.

Meeting with States

Following review of material received from FHWA and from the state, a preliminary meeting was held in each state capital. Attendees at these meetings included representatives from the FHWA, state agencies and the research team. The purpose of these meetings was to establish a final inspection program and to make final arrangements for conducting the field inspections.

Data previously forwarded to the research team by the state was again reviewed at these meetings for applicability to the study aims. The bridges recommended for inspection were then supplemented by additional locations to provide a suitable program.

Computer printouts of the state bridge inventory were reviewed to obtain additional candidates for inspection. Recommendations of the state bridge personnel were carefully considered. Maintenance records and structural evaluations of each candidate bridge were also reviewed and included in consideration for selecting structure locations for field inspections.

Final Inspection Program

After analyzing all of the available data and considering the discussions with the state bridge unit personnel and their recommendations, a final list of candidate bridge locations was established. These structures were then located on maps provided by the state.

Candidate bridges were subdivided into structure type classifications--first by material used in the superstructure primary support system, and then further subdivided into structural system classifications. Material classifications included concrete, steel and wood. Structural classifications included multiple beam or girder, through or deck truss, prestressed beam, through or deck girders, continuous or simple spans. Since many of the multiple span structures consisted of several different makeups in both material and structural system, a single location could appear in several categories.

Using the listing of deficient bridges provided by FHWA, supplemented with computer printout listings provided by the state, a judgment was made as to the most commonly occurring types of deficient bridges within the state. This was input to the listing of potentials already developed. The candidate locations were then given a priority rating so that the inspections would cover as closely as possible the most frequently occurring types of structural deficiency.

The final consideration was geometric location. Since the inspection team had only a limited amount of time to spend in each state due to budgeting constraints, it was desirable to keep travel time between general areas selected for inspections and between individual bridge sites to a minimum.

The final inspection plan that emerged from all of these considerations was reviewed with the state bridge personnel and minor adjustments made to eliminate local coordination problems. Arrangements were then finalized with district or regional offices of the state to provide logistic support wherever possible.

INSPECTIONS

Bridge inspections were carried out by a two-man team consisting of a senior engineer and an assistant. In many instances, the research inspection team was accompanied by a state inspector and other engineers from the state bridge unit. The project director for the FHWA was also with the research inspection team during the initial inspections in each state.

Description of Inspection

Prior to actual inspection, the inspection team reviewed reports from former inspections and records of bridge maintenance activities. The inspection was then conducted with this advanced information influencing, in many cases, the depth of inspection to be made.

Three types of inspections were conducted: detailed, sampling, and specific.

Detailed Inspection - This type of inspection consisted of a thorough look at the entire structure. The team usually had support help from the local maintenance office which supplied ladders, boats, snoopers and other equipment needed to provide access to the bridge components. The team was equipped with small hand tools and safety equipment.

Primary structural supports were inspected in detail and deficiencies noted. Concrete elements were sounded to determine their serviceability and defects noted. Deck condition, movement under live loads, joint, approaches, drainage, and other components were reviewed in detail. Substructure elements were inspected also. In many instances plumbness of piers and abutments was also checked. Bearings were inspected and position of expansion bearings under existing temperature noted.

Traffic conditions during the inspection period were observed including volume and type of vehicles utilizing the facility. Roadway alignment, vertical and horizontal clearance and approach roadway cross section geometrics, were observed and deficiencies noted.

The condition of approaches to the bridge were also recorded. These included approach pavement condition, as well as safety features--guardrail, shoulders, wingwall ends and the like.

Sophisticated equipment for determination of material properties utilized in the bridge construction, crack detectors, or chemical impregnation tests, were not utilized since this type of information could be obtained from state records or was not necessary to the aims of the study.

Sampling Inspection - Many of the structures that were inspected were too large to permit a detailed inspection of the entire bridge to be made. Furthermore, since most of the bridges in this category had numerous repetitions of similar structure makeup, there was little to be gained for the intent of the study by performing a detailed inspection of each span.

These inspections were normally conducted with personnel from the state bridge office or local maintenance office who were familiar with the bridge and who could point out specific areas where deficiencies occurred. With their assistance and having the latest inspection report of the bridge in hand, the inspection team could look at those precise locations where these deficiencies existed. These particular areas of the bridge were given a thorough inspection in a manner similar to that previously described for a "Detailed Inspection."

In addition, a random sampling of spans was inspected in detail. The number of these samplings was dependent on accessibility, types of different structural span makeup and available time. Also, the roadway approach, bridge alignment, safety condition and overall general condition of the bridge were noted.

Specific Inspection - In some instances the state bridge engineers at preliminary meetings, indicated certain unique deficiencies that they believed would be useful for the research team to see. These included cracked structural members (either steel or concrete), unique superstructure movements, bridges damaged by collision, flood damage and other deficiencies.

In addition to field inspecting deficiencies, rehabilitation procedures and repair techniques for specific bridges were also inspected. These included steel truss strengthening, truss portal and sway frame modification to increase vertical clearance, deck widening, member replacement, and others.

Existing Inspection Reports

In almost every instance, prior inspection reports for the selected bridges were made available and in many instances copies of these reports were given to the inspection team. These reports proved to be invaluable in carrying out the field work, providing familiarity with the bridge prior to the actual field visit.

The field inspections verified deficiencies already diagnosed and included in the existing reports and, in some instances, discovered new deficiencies or more advanced stages of bridge component deterioration. Where repairs had been made as a result of prior inspection, the inspectors reviewed the adequacy and the serviceability of the repair technique used.

Documentation

Report - Following each bridge inspection, a detailed report was prepared at the site utilizing portable dictating equipment. This procedure proved to be invaluable in capturing in a very efficient manner the inspection data. These reports were later typed, edited by the inspector, and added to the file which had been established for each structure.

Photographs - During the course of the inspection numerous photographs were taken to further document the inspection. These were taken using black and white film plus supplementary color photos. These photos were logged and added to the file for each bridge.

Bridge File - The file developed for each bridge location contained all data received from the state as well as the field inspection report. A typical file included: Inspection records and reports, maintenance reports of repairs, records of collision damage, inventory data as prepared for the FHWA and for state use, rating computation prepared by state bridge personnel, research team inspection report and the photos taken by the research inspection team.

Summary Report

After the completion of inspections in each participating state, a summary report of the work in that state was prepared. This report contained information on the number and the type of bridges inspected. Deficiencies observed were listed and described. Comments of state personnel pertinent to the study were captured and a listing of rehabilitation techniques used in the state developed. A state map showing the bridge locations was prepared and included with the summary report.

The summary report developed for each of the five participating states is included in Appendix A.

ANALYSIS OF DATA

The data obtained from the bridge inspection, supplemented with data obtained from participating state bridge engineers and from the FHWA was utilized to establish a bridge type classification system and a catalogue of bridge deficiencies. The data was further reviewed to establish the relative rate of occurrence for each deficiency. The overall inspection program was finally reviewed and compared with data on the Federal inventory of bridges to assess the degree of representation that the inspection program provided based on the total numbers of deficient bridges in the five participating states.

Bridge Type Catalogue

Based on the field inspection data, a classification of bridge types by material and by structural system was developed. This classification system was based on superstructure and substructure characteristics.

Each bridge that was inspected was listed on the classification matrix. This data was summarized for each state and a final summary sheet prepared. The summary lists the total number of bridges under each category that were inspected in each state and is shown in Table 2.

Bridge Deficiencies

A classification of major deficiencies was established based on data collected during the field inspections. A list of deficiencies associated with superstructure and substructure elements, geometrics and safety are included with this deficiency classification.

For each state in which bridge inspections were conducted, a chart was made up in which the major deficiencies were listed. Each bridge inspection report was then reviewed and applicable deficiencies noted on the chart. A summary was then compiled for all bridges in each particular state. As the reports were reviewed, additional deficiencies not already listed were added to the catalogue.

STRUCTURE CATAGORY

STATE	SUPERSTRUCTURE																						
	MAIN SUPPORT SYSTEM															DECK						SPAN TYPE	
	STEEL								TIMBER	REINFORCED CONCRETE						TYPE				OVERLAY			
	MULTIPLE BEAM	MULTIPLE DECK GIRDER	THRU GIRDER	TWIN GIRDER WITH FLOOR SYSTEM	DECK TRUSS	THRU TRUSS	PONY TRUSS	ARCH	MULTIPLE STRINGER	SLAB	"T" BEAMS	PRESTRESSED MULTI BEAM	POST TENSIONED MULTI BEAM	MULTIPLE BEAM - CONV. REINFORCEMENT	REINFORCED CONCRETE ARCH	REINFORCED CONCRETE	OPEN STEEL GRID	TIMBER	CORROGATED METAL	NONE	ASPHALT	MOVABLE	CONTINUOUS
FLORIDA	3	1	0	2	1	2	3	0	2	3	2	1	3	3	0	12	5	7	0	9	6	5	2
TENNESSEE	32	1	0	0	0	4	7	0	4	0	0	0	0	1	0	15	0	12	7	7	22	0	3
CALIFORNIA	2	0	0	0	1	3	1	1	6	0	6	0	0	2	0	16	2	2	0	7	12	1	1
PENNSYLVANIA	13	1	7	0	1	6	0	0	1	0	1	4	0	1	5	13	1	7	0	4	37	0	8
ILLINOIS	26	0	2	0	0	14	7	0	0	0	1	0	0	0	0	24	0	1	0	13	31	0	1
TOTAL	76	3	9	2	3	29	18	1	13	3	10	5	3	7	5	80	8	29	7	40	108	6	15

STATE	SUBSTRUCTURE																	
	ABUTMENTS						PIERS					PILE BENTS						
	TYPE											CAP			PILES			
	MASONRY	REINFORCED CONCRETE STUB	REINFORCED CONCRETE FULL HEIGHT	REINFORCED CONCRETE SPILL - THRU	TIMBER BULKHEAD	TIMBER WITH CONCRETE CAP	REINFORCED CONCRETE HAMMERHEAD	MASONRY - SOLID	REINFORCED CONCRETE WALL	R.C. RIGID FRAME - IND. FTGS.	R.C. RIGID FRAME - PEDESTAL WALL	TIMBER	REINFORCED CONCRETE	COMPOSITE TIMBER & CONCRETE	CONCRETE PRECAST	TIMBER	STEEL WITH CONCRETE PEDESTAL	STEEL H PILE
FLORIDA	2	5	5	1	0	2	1	0	2	5	1	7	3	0	3	11	0	0
TENNESSEE	5	6	5	0	3	0	1	1	4	2	2	9	5	0	0	8	0	2
CALIFORNIA	4	2	6	0	1	1	0	0	4	1	4	1	3	0	0	2	1	1
PENNSYLVANIA	10	6	19	0	1	0	5	3	7	0	3	1	1	1	0	0	0	1
ILLINOIS	2	7	14	0	0	0	2	1	3	1	0	2	10	0	0	2	0	2
TOTAL	23	26	49	1	5	3	9	5	20	9	10	20	22	1	3	23	1	6

TABLE 2 BRIDGE INSPECTION TYPE SUMMARY

A final summary was prepared listing the deficiencies and the number of bridges that were inspected on which each deficiency occurred. These are listed for each state and for the total inspection program in Table 3.

Comparison of Inspection Made With Total Bridges

A listing of bridges from the national inventory for the five participating states was prepared for all structures either structurally obsolete or geometrically deficient. This was prepared during the development of the inspection program for the project and further refined following the inspection phase to include additional structures as furnished by the individual states. The number of field inspections that was conducted for each classification of bridges was added to this list. This tabulation is shown in Table 4.

By inspection, it can readily be seen that the inspections conducted represented an excellent cross section of those bridges already classified as deficient by either FHWA records or state records.

MAJOR STRUCTURAL DEFICIENCIES — SUPERSTRUCTURE

	MAIN SUPPORT SYSTEM								
STATE	CORROSION WITH SECTION LOSS TRUSS MEMBER	CORROSION WITH SECTION LOSS-BEAMS & GIRDERS	BEARING INOPERABLE	CONNECTIONS - NON FUNCTIONAL	TIMBER DECAY - SECTION LOSS	CONC. SPALL - REBAR EXP. - SECTION LOSS	SEVERE CONCRETE CRACKING	BRACING MEMBER FAILURE	DAMAGE TO STRUCTURAL MEMBER BY COLLISION
FLORIDA	2	3	0	2	2	5	3	1	6
TENNESSEE	12	15	11	0	1	4	7	4	5
CALIFORNIA	4	1	0	0	1	7	4	0	2
PENNSYLVANIA	4	11	12	6	3	11	19	2	0
ILLINOIS	5	11	14	5	0	19	15	0	1
TOTAL	27	41	37	13	7	46	48	7	14

	DECK				
STATE	JOINTS NON OPERABLE	SEVERE CRACKING & SPALLING	DELAMINATIONS	GENERAL CONCRETE DETERIORATION	ROTTING - WEATHERING
FLORIDA	2	1	3	0	3
TENNESSEE	4	3	4	7	12
CALIFORNIA	1	8	8	4	6
PENNSYLVANIA	14	1	2	1	9
ILLINOIS	1	1	2	3	2
TOTAL	22	14	19	15	32

MAJOR STRUCTURAL DEFICIENCIES — SUBSTRUCTURE

	ABUTMENT				
STATE	SEVERE CRACKING & CONCRETE DETERIORATION	SETTLEMENT	TILTING & ROTATION	TIMBER DECAY	SCOUR
FLORIDA	3	0	6	3	0
TENNESSEE	3	2	1	0	3
CALIFORNIA	7	3	1	0	0
PENNSYLVANIA	23	0	0	0	4
ILLINOIS	8	0	0	0	0
TOTAL	44	5	8	3	7

	PIERS					
STATE	CAP BM - REBARS EXPOSED - SECTION LOSS	COLUMN DEFECTS - SECTION LOSS	SETTLEMENT	TILTING	CRACKING	SCOUR
FLORIDA	4	0	0	0	4	0
TENNESSEE	4	1	1	1	2	1
CALIFORNIA	2	1	0	0	3	2
PENNSYLVANIA	5	1	0	0	6	1
ILLINOIS	1	1	1	0	1	1
TOTAL	16	4	2	1	16	5

	BENTS						
STATE	SCOUR	CRACKING - LONGITUDINAL	CORROSION	SETTLEMENT	TILTING	PILE DEFECTS - SECTION LOSS	CAP SPALL - EXPOSED BAR
FLORIDA	3	5	2	1	1	7	2
TENNESSEE	0	1	3	0	0	3	0
CALIFORNIA	0	4	1	0	1	0	0
PENNSYLVANIA	0	0	0	0	0	0	1
ILLINOIS	0	1	0	0	0	0	1
TOTAL	3	11	6	1	2	10	4

OTHER DEFICIENCIES

	GEOMETRIC			
STATE	ROADWAY WIDTH	VERTICAL CLEARANCE	VERTICAL ALIGNMENT	HORIZONTAL ALIGNMENT
FLORIDA	24	1	1	0
TENNESSEE	1	0	0	0
CALIFORNIA	5	1	6	7
PENNSYLVANIA	8	1	0	1
ILLINOIS	10	0	0	0
TOTAL	48	3	7	8

	SAFETY		
STATE	QUALITY OF ROADWAY SURFACE	RAILING ENDS ACCIDENT PRONE	INADEQUATE RAILING
FLORIDA	7	2	6
TENNESSEE	0	0	0
CALIFORNIA	2	1	1
PENNSYLVANIA	10	2	12
ILLINOIS	0	0	4
TOTAL	19	5	23

RESTRICTION POSTING

STATE	BRIDGE POSTED - LOAD	BRIDGE POSTED - SPEED	BRIDGE POSTED - LANE RESTRICTION
FLORIDA	2	0	0
TENNESSEE	11	0	1
CALIFORNIA	1	1	1
PENNSYLVANIA	15	15	3
ILLINOIS	5	1	11
TOTAL	34	17	16

TABLE 3 BRIDGE INSPECTION DEFICIENCY SUMMARY

TABLE 4 COMPARISON OF NATIONAL INVENTORY DATA AND BRIDGES INSPECTED IN PARTICIPATING STATES

SUPERSTRUCTURE FRAMING			STRUCTURAL DEFICIENCIES	GEOMETRIC DEFICIENCIES		BRIDGES POSTED	NO. INSPECTED
MATERIAL	SYSTEM		INVENTORY RATING UNDER H20	SUBSTANDARD WIDTH	SUBSTANDARD CLEARANCE		
STEEL	TRUSS	THRU	98	177	4	137	47
		DECK	35	50	3	35	3
	BEAM OR GIRDER		163	172	11	124	99
	OTHER		58	106	39	62	11
	SUB TOTAL		354	505	57	358	160
CONCRETE	BEAM		29	184	35	22	25
	SLAB		35	93	21	5	3
	OTHER		15	112	42	13	5
	SUB TOTAL		79	389	98	40	33
TIMBER	BEAM		55	127	4	90	13
	SLAB		22	22	–	13	–
	OTHER		4	13	2	4	–
	SUB TOTAL		81	162	6	107	13
TOTAL			514	1056	161	505	206

CHAPTER III

DISCUSSION OF BRIDGE DEFICIENCIES

Bridge deficiencies evolve from a variety of situations and conditions. Basic design criteria, traffic usage, environmental factors, and other site conditions are all involved to some extent and are responsible for specific deficiencies. The most important contributor to bridge deficiencies, as reported by most of the state bridge units contacted, is the level of maintenance employed.

Based on the data collected, deficiency causes can be categorized into two broad areas: (1) those which result from the design of the facility and are thus inherent deficiencies, and (2) those which result from the use of the facility and are essentially the result of wear or aging. Deficiencies from either cause can be further subdivided into four areas: Structural, Mechanical, Geometric and Safety.

STRUCTURAL

Structural deficiencies are defined as those which affect the structure's ability to carry imposed loads. These are caused most frequently by lack of proper maintenance, poor design details, and original designs based on live loadings less than today's standards.

Steel Structures

In steel structures, paint system breakdown permits corrosion of the base metal to begin. Once started, the process accelerates as larger areas become exposed. Eventually the metal corrosion can result in section loss serious enough to have an impact on the load-carrying capacity of the member. If left uncorrected, the process will continue, resulting in the collapse of the bridge.

The corrosion process is accelerated by the use of chemical de-icing agents on the roadway when snow, laden with these chemicals comes in contact with the primary structural elements either as splash or storage. This is particularly true in through girders and trusses.

Webs of through girders can become "paper thin" and bearing stiffeners totally lost. Truss members likewise become severely corroded in critical areas.

Concrete Members

Concrete members deteriorate at a rapid rate when exposed to adverse environmental conditions. Penetration of brine solution through the unprotected concrete surface causes the reinforcing steel to oxidize and expand, ultimately leading to spalling and cracking of the concrete cover. Once the process begins, it accelerates at a rapid pace as more of the corrosive materials reach the reinforcing steel.

This process, which is very common in bridge decks, also occurs in primary structural members. Prestressed girders and mild steel reinforced concrete members deteriorate when conditions permit penetration by a corrosion-conducive solution. Observations of bridges in a number of the states visited have shown that this condition occurs as a result of salt water splash where low level bridges cross bodies of water with a high saline level or where roadway joints and drainage details permit runoff to come in contact with concrete beams and girders for prolonged periods of time.

Timber Members

Timber members, too, deteriorate as a result of general weathering when unprotected. Wet-dry cycles that occur frequently accelerate the process.

Light Designs

Many of the structures inspected which are currently an integral part of our Federal-aid highway system were not initially designed to carry the loads being imposed on them by modern traffic. These "light designs" were based on vehicle weights much less than those in present use and on load frequency rates that are only a small percentage of those now utilizing the crossings. Some of these older structures were designed for 3 or 4 lanes of H15 traffic and now carry heavier vehicle loads by restricting the traffic to one or two lanes.

These deficiencies apply to superstructure members as well as to substructure members. In addition, substructure elements can be structurally deficient because of foundation conditions. Pile deterioration, scour, and deep failures in underlying soil strata can cause significant reduction in the load-carrying capability of the bridge.

MECHANICAL

These deficiencies are defined as those which prohibit the structure from reacting in a controlled manner to environmental factors. These are primarily caused by corrosion of metal elements, the accumulation of debris and silt around bearings and joints, lateral movement of substructure units, and poor design details.

Build-up of debris around bearing areas often completely covers metal bearings. This debris is composed of bird droppings, nesting materials and other deposits that can be highly corrosive. When this material is saturated with a salt solution from roadway runoff it becomes even more corrosive. The bearings freeze as a result of this corrosion and prevent the bridge from responding to temperature changes as intended.

Pavement "shove" pressures often add to this problem. This is the result of temperature expansion and contraction in the approach roadway combined with traffic generated pavement movements. Stub abutments move longitudinally as a result of these forces and backwalls deflect and eventually crack. As a result, it is no longer possible for the bridge to function as intended without exerting loads on the structure beyond those considered by the designers.

Settlement and other lateral movements in piers can cause a similar situation. Pier rotation causes roadway joints to close and bearings to exhaust their capability to accommodate expansion. Ensuing temperature changes can then result in serious overstress in other elements of the bridge.

GEOMETRIC

These deficiencies are those that relate to the geometrics of the roadway as it approaches and traverses the bridge. Vertical and horizontal alignment, roadway width, vehicle site distance, and traffic capacity are included. In almost every instance these are inherent deficiencies that were built in as a result of the initial design.

SAFETY

Deficiencies relating to the safety of the motorist include those that jeopardize the safety of the vehicle as it passes over the structure. Many of these are geometric in nature (roadway width, clearance, etc.). Others pertain to the roadway appurtenances such as a bridge railing, approach guardrail protection, and traffic control devices.

Rideability deficiencies are those that impact on the riding quality of the crossing and are included in the safety category. Bridge deck deficiencies are the most common involving rideability. They can impair the load carrying capability of the bridge if the deck is designed as an integral part of the primary structural member such as in concrete T-beams and composite designs. Even with these designs the roadway becomes virtually impassable due to pot-holes and general deterioration of the deck before failure occurs.

Approach slab settlement can impair the structural integrity of the abutments and cause an increase in live load impact but usually has a greater effect on the safety of vehicles utilizing the facility since severe bumps and dips are created by the settlement.

Other safety deficiencies are those which occur because structure members are located in a position where they become a hazard to the motorist. End posts on through trusses, ends of through girders, pier and abutment placement close to travelled lanes are examples.

BRIDGE DEFICIENCY CATALOGUE

Deficiency data collected during the inspection phase of this study has been categorized in accordance with these discussions. This has been related to structure types to produce a bridge type deficiency catalogue. Structure type is based on the primary support system and on the various components within the structures. Deficiencies for each category are listed in accordance with the frequency in which they occur as indicated during the field inspection phase of the study. The Bridge Type and Deficiency Catalogue is included in Appendix B.

A series of photographs depicting a number of these deficiencies is also included in Appendix B. These photographs were taken during the inspection phase of the study and are part of the inspection file.

CHAPTER IV

COLLECTION OF REHABILITATION PROCEDURE DATA

The second phase of the research study involved obtaining information on techniques that have been used to rehabilitate deficient bridges and to develop concepts for new and innovative techniques. The data collection phase included a literature search, and the gathering of input from manufacturers, trade associations, and transportation agencies. Information was collected on both the national level as well as the international.

LITERATURE SEARCH

During the conduct of the literature search materials were obtained from several sources including the Transportation Research Board, the American Society of Civil Engineers, the American Institute of Steel Construction, the American Concrete Institute and the Federal Highway Administration. An extensive search was made at the U.S. Department of Transportation library as well as the BTML library and many articles containing pertinent information were gathered. These articles were then reviewed and an abstract was written of each. The abstracts were then compiled with a subject listing so that particular data could be quickly recalled when needed.

The majority of the information found during the search involved the application of rehabilitation techniques to existing bridges. Some of the information uncovered pertained to previous research that had been performed in bridge rehabilitation or other related areas.

TRADE ASSOCIATIONS

Nine trade associations who have interest in the bridge area were contacted and asked to provide information related to rehabilitation techniques including cost data and performance records. The amount of pertinent information received was minimal although what was received proved to be helpful to the study.

Those contacted were:

- American Institute of Timber Construction
- Prestressed Concrete Institute
- American Concrete Institute
- Wire Reinforcement Institute
- American Welding Society
- American Institute of Steel Construction
- Concrete Reinforcing Steel Institute
- Portland Cement Association
- American Iron and Steel Institute

Information was received on concrete repairs to spalled and cracked areas and for concrete deck repairs. Data on timber deck systems was also a valuable contribution.

MANUFACTURERS

Several manufacturers were contacted and asked to provide pertinent information regarding rehabilitation techniques, cost data and performance records. Significant material was submitted by a number of those manufacturers, in particular, in the areas of lightweight bridge deck systems, epoxy repair systems, and pile repair techniques.

TRANSPORTATION AGENCIES

Through the Federal Highway Administration regional offices, contacts were made with state highway departments soliciting their assistance in gathering information on rehabilitation techniques. In addition to the five states that participated in the inspection phase of the work, four additional states offered their assistance--West Virginia, Minnesota, Louisiana, Virginia--bringing the total of cooperating states to nine.

These nine state bridge departments submitted approximately 62 examples of rehabilitation plans that had been used. Many of these plans dealt with repairs to collision-damaged members and to deck repairs. Others dealt with strengthening techniques used for a variety of structure types and materials. Still others dealt with drainage devices, railing, roadway joints and bearing replacement. A listing of the plans furnished and description of the rehabilitation is contained in Appendix C.

During the inspection phase of the project, additional data was obtained through discussions with bridge and maintenance personnel on causes for bridge deficiencies as well as on methods for correcting these deficiences. This information, captured in memo files, was added to the data file also.

OTHER SOURCES

Sources in South Africa, England and Canada were contacted for possible input of rehabilitation techniques, performance data, etc. for use in the research project.

Dr. C. J. Fleming of the Department of Civil Engineering, University of Natal, South Africa was contacted for information regarding his work with epoxy adhesives. The Transport and Road Research Laboratory (TRRL) of the Department of the Environment of the Government of the United Kingdom also furnished material on epoxy adhesives and particularly with regard to bonded steel plate reinforcing of concrete beams.

The National Research Development Corporation of the United Kingdom and the CONENCO International Limited Company of Ontario, Canda, furnished valuable material on rehabilitation techniques. In particular, information was obtained regarding the post tensioning of concrete beams and girders and the use of flexible dams in dewatering construction sites in small streams.

CHAPTER V

REHABILITATION CONCEPTS

Procedures for major rehabilitation of defective bridges to extend service life as developed in this study have been classified under three general headings:

- Increase Live Load Capacity
- Improve Geometrics
- Correct Mechanical Deficiencies

Additional procedures used for general bridge repairs to correct minor deficiencies and to improve safety have also been developed. A summary or catalogue of rehabilitation techniques is included in Appendix D.

INCREASE LIVE LOAD CAPACITY

Four general procedures are available to increase the load carrying capacity of a bridge.

- Strengthen critical members
- Add supplemental members
- Reduce dead load
- Modify structural system

Under each of these alternatives, numerous procedures have been used successfully to increase the service life of an existing bridge. The following describes many of those procedures that were submitted by highway departments and others plus innovative techniques not formally put into practice.

Strengthen Critical Members

Strengthening deficient or critical members involves adding new material to the existing member or replacing the entire member or portion of the member with new material. In many instances, the connection is the critical part of the member. This deficiency can be corrected by adding additional connectors or by replacing the entire connection.

Steel Structures. The routine procedure for strengthening steel bridges as reported by virtually all state agencies contacted is to add cover plates to steel beams or girders or to add plates or structural shapes to steel truss members to increase the available section. Many of these details have been developed utilizing welding to attach the new material. In some cases the welding operation on the existing steel, because of the location and the particular detail employed, has had an adverse effect on the structural capacity of the member. Stress raisers that are susceptible to fatigue failures have unwittingly been incorporated in the structure through lack of attention to detail or to state-of-the-art knowledge of welding procedures and repetitious type loadings.

Material can be added successfully by welding to existing primary members providing that the design and details are developed in accordance with current specifications, including those dealing with fatigue characteristics. An additional requirement that must be determined is the weldability of the material used in the existing member.

Several other concepts were reviewed for strengthening steel bridge members. Post tensioning truss tension members has been done effectively. Cables are strung along the truss member and attached to the end of the member or to the connecting pin. Turnbucks are introduced to provide tensioning, or jacking arrangements are developed. The compression stresses thus induced or the resulting reduction in tensile stress in the member permit the member to carry additional live load.

A similar procedure can be utilized on lower chords of trusses to provide added carrying capacity. In this instance, cables are attached to end bearing points and then tensioned.

This same procedure can be adapted to beams and girders. By tensioning strands that are connected to the ends of the tension flange, compression stress can be induced in the girder flange or existing tension stresses can be reduced. In either case, additional live load capacity is developed.

These procedures can be developed to aid in carrying live load only or to reduce dead load distress thereby producing additional live load capacity. If it is desired to aid live load capacity only, the tensioning cables are merely drawn up snug under dead load. Live loads then are carried jointly by the strand and the flange or truss member in tension.

If dead load reduction is required, the strands are stressed such that reverse beam or truss camber is created. By carefully monitoring this camber and the cable lengthening, an accurate evaluation of induced stresses and additional capacity can be determined.

Minnesota has developed plans to strengthen a steel beam span supporting a timber floor (Bridge No. 3699 T.H. 212/Stream) utilizing this principle. They reported that live load deflections were reduced approximately 35% compared to the original structure as monitored under test loading conditions. They also reported that the system was much less costly in both labor and materials than other procedures which they considered for strengthening bridges of this type.

In situations where underclearance permits, the strengthening of either a stringer or a floor beam by adding a kingpost truss system provides an excellent means for increasing live load capacity. The procedure requires the installation of a truss with one or more posts on the bottom flange of the member.

Threaded end connections are provided so that proper tension can be induced into the system. A conceptual detail of this is shown in Figure 1. A typical application is given with the rehabilitation demonstrated in Chapter VII.

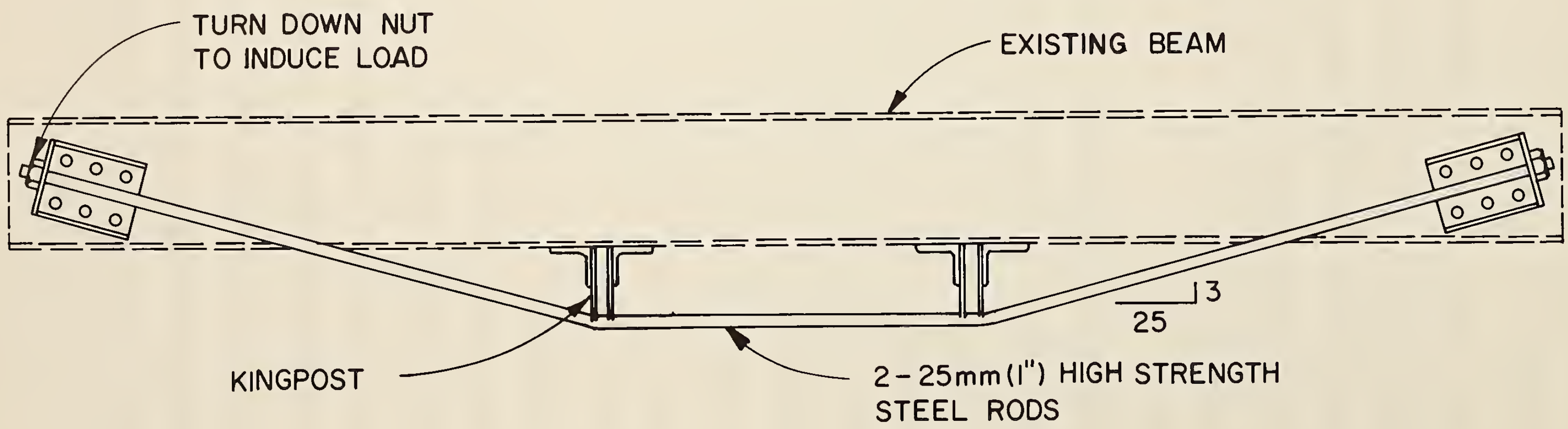
Various degrees of additional carrying capacity can be achieved by changing the geometrics of the truss and by adjusting the tension induced in the bottom chord. The installation must be carefully monitored during construction by controlling the number of turns of the connecting nuts and by measuring the deflection induced in the original member.

Concrete Structures. Concrete members are strengthened by adding external reinforcing, by external post tensioning, or by a combination of these.

External Steel Reinforcing plates can be attached in several ways to existing concrete members to increase capacity. Plates can be added to the beam flange for added flexural capacity and to the web for added shear capacity.

Connection of the plates to the concrete can be made by bolting with expansion type anchors or by epoxy adhesives. In adding shear plates, attachment can be made by drilling through the concrete member and bolting, or with epoxy adhesives.

Attachment by epoxy adhesives is a relatively new procedure but has been used successfully in the United Kingdom and other countries for bridge rehabilitation. The procedure used includes first cleaning the concrete surface and the steel surface by sandblasting. An epoxy adhesive is then applied to both surfaces and the steel plate pressed into contact with the concrete beam. Temporary scaffolding and wedging is required to provide the needed pressure (about 9.6 daPa, 2 psf) to insure contact. Following cure, the temporary shoring is removed. The plates should be kept relatively thin (0.6 cm., ¼" or less) to insure sufficient



KINGPOST TRUSS BEAM REINFORCEMENT

FIGURE 1

flexibility to compensate for irregularities in the existing beam. Plates can be added in several layers if greater thickness is needed.

Additional research is now under way to determine the long range performance of this technique. Of prime concern is the performance of epoxy adhesives under varying climatic conditions and the effect of long-term sustained loadings.

Dr. C. J. Fleming of the Department of Civil Engineering, University of Natal, South Africa has done considerable work in the use of adhesives for bonding in bridge design and construction. In his paper entitled "Polymers as Structural Adhesives With Particular Reference to the Strengthening of Existing Structures" he discusses some of the results of current research and testing programs.

Tests have been conducted on simply supported concrete beams with an approximate span of 2.5 m. (8 ft.). Two spans were loaded with both bending moment and shear forces. Other spans were loaded with two point load concentrations equally spaced from the supports to provide a central flexural zone under uniform bending and no shear. Plates were glued to the sides of the shear spans to increased shear strength and to the underside in the flexural zone to give increased bending strength.

The results of the tests in which bending steel only was glued to the underside were easily interpreted since no tensile reinforcing was cast into the concrete beam and all stresses were therefore carried by the exterior plates. The tensile stress in the steel at ultimate load was approximately 190 MPa (27.5 ksi), considerably below the yield stress of the steel. Failure occurred because of limiting bond and shear stresses in planes parallel to the steel, probably beginning in the shear zone as no shear stresses were present in the flexural zone of the beam.

Dr. Fleming concludes "These tests indicated that full tensile capacity of glued reinforcement could be developed, provided the thickness of steel was chosen so as not to exceed the bond and shear capacities of the concrete. In strengthening, the tests indicated that the full tensile capacity of glued reinforcement would be developed, provided the thickness of steel was chosen so as not to exceed the bond and shear capacities of the concrete. In strengthening structures, this is unlikely to be a severe handicap in regions of positive bending moment where the shear and bond stresses are unlikely to be high, but would be of greater concern in continuous beams at regions of negative bending moment which would be accompanied by high shears."

In the United Kingdom, additional work on attachment of reinforcing plates with epoxy adhesives has been done. A report prepared by A. K. Irwin for the Transportation and Road Research Laboratory (TRRL) of the Department of the Environment entitled "TRRL Supplementary Report 160 U C" discusses the results of testing programs carried out in the United Kingdom. In this report two reinforced concrete beams were tested, one with external steel plates epoxy-bonded to the tension flange and one without external reinforcement. Both specimens had internal mild steel reinforcing. Results show that crack widths were reduced by 50% in the externally reinforced beam, equivalent to doubling the limit state of serviceability (the serviceability load being the load at which cracking becomes unacceptable). The ultimate moment was 18 percent greater in the externally reinforced beam than in the non-externally reinforced beam.

The unplated beam failed by horizontal splitting in the concrete compression zone in the area of maximum moment. Examination of the plated beam showed that failure occurred through the concrete.

Mr. Irwin pointed out several practical problems some of which are the subjects of continuing investigations:

- At discontinuity points due to butt or lap joints between plates, high local stresses in the concrete and adhesive layers may be produced.
- Plate thickness may be limited by soffit curvatures and handling constraints.
- Progressive failure of the bond may begin at a crack bridged by the steel plate, when loading is increased.
- Resin bond strength may be affected by:
    - a) cyclic loadings (traffic or wind) applied during curing,
    - b) long-term creep of the structure, and
    - c) the plate and resin resistance to the bridge environment.

The technique of reinforcing concrete beams with steel plates attached with epoxy adhesive has been successfully used on a number of bridges. Notable among these is the work done on the interchange bridges at Swanley, Kent in the United Kingdom. These bridges are continuous three-span with reinforced concrete decks. Cracks had formed in the soffit and a design check found that the bridges were deficient in bending at the bottom fibers of the end span and in the top fibers over the piers. Plates were successfully bonded to the soffits in the positive moment areas and to the top of decks over piers. This work was completed in 1977. The bridges will be monitored to substantiate the effectiveness of the technique.

An example of this technique is included with the rehabilitation demonstrations discussed in Chapter VII.

External Post Tensioning. Several schemes for post tensioning substandard concrete members were reviewed. These included adding steel rods connected to the concrete members by brackets attached with expansion bolts or with bolts passing through the member. The rods were tensioned either by tightening end nuts or by incorporating a turnbuckle as part of the tensioning rods. A typical application of this procedure used to strengthen the cantilever portion of a hammerhead pier is shown in Figure 2. An example of an actual application of the technique is included with the rehabilitation demonstrations in Chapter VI.

Post tensioning strands can be added to simple span concrete members and attached at bearing points where stress transfer will occur. These strands should be placed in protective conduits or additional concrete should be cast around the strands for protection.

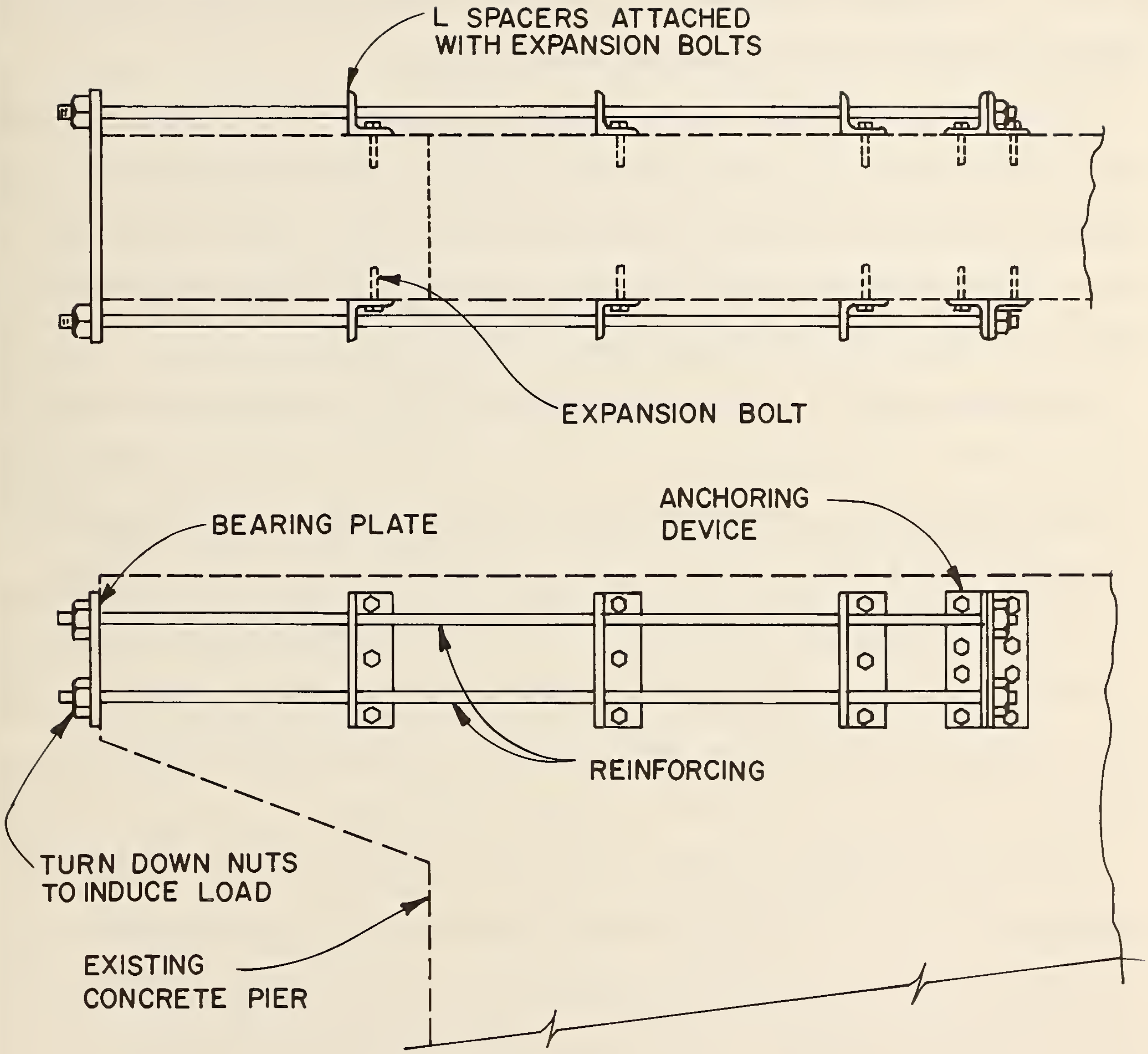
Timber Structures. Strengthening timber members is most easily done by adding external reinforcing. This normally consists of steel plates or shapes attached to the substandard member with bolts or lag screws, thus forming a composite steel/timber member. This procedure is exhibited in Chapter VII.

Post tensioning procedures already discussed for steel members can also be utilized for timber members.

Add Supplemental or Replacement Members

Adding additional members is a technique used routinely in strengthening bridges. Structurally inadequate floor systems on truss and girder bridges can be rehabilitated by erecting additional members between the existing stringers to provide necessary overall capacity. On girder bridges, additional floor beams can also be added to improve capacity.

Concrete beam and girder bridges can be strengthened by adding steel beams or precast concrete beams between or adjacent to the existing concrete sections. Timber bridges likewise can be strengthened by adding additional primary steel members.



EXTERNAL CONCRETE REINFORCING

FIGURE 2

Critical members that are defective can be replaced. This is frequently done in situations where collision damage to a key member has weakened the bridge. End posts of through or pony type trusses are recurring examples. Concrete or steel fascia stringers in overpass structures are also frequently damaged by oversized vehicles and must be replaced.

Truss member replacement requires careful analysis and development of step-by-step procedures. Shoring must be developed to insure the integrity of the structure during the replacement operation. If this is not feasible, then an alternate support system must be developed utilizing post tensioning cables or other such devices to carry temporary loads.

Adding new stringer or floor beam members will often require the removal and replacement of at least a portion of the bridge deck. However, procedures have been developed to eliminate this need. These procedures utilize supplemental supports jacked into place from below the structure. By drilling through the deck and pressure grouting, any void that exists between the top of the supplemental support and the underside of the deck can be filled. Lifting cables threaded through the same holes drilled through the deck can also be utilized for lifting the supplemental supports into place.

<u>Crutch and Pony Bents</u>. Crutch bents can be installed to carry the load of a defective pile. This procedure consists of adding a pile on either side of the defective pile in a transverse direction to the pile bent. A needle beam is installed to transfer the pile cap load to the piles. Piles can be driven through openings cut in the deck if necessary.

Pony bents are used to help carry the load of an entire bent. A cluster of piles can be driven beyond the bridge face to support a needle beam placed parallel to the defective bent. An alternative to this procedure is to drive piles through openings cut in the deck which in turn support the needle beam.

Supplemental Truss Supports. In some cases, it is feasible and practical to add additional supports to a through truss bridge. By placing these supports under the first interior panel point, the truss span is reduced significantly. Instead of a simple span system, the result is a continuous system.

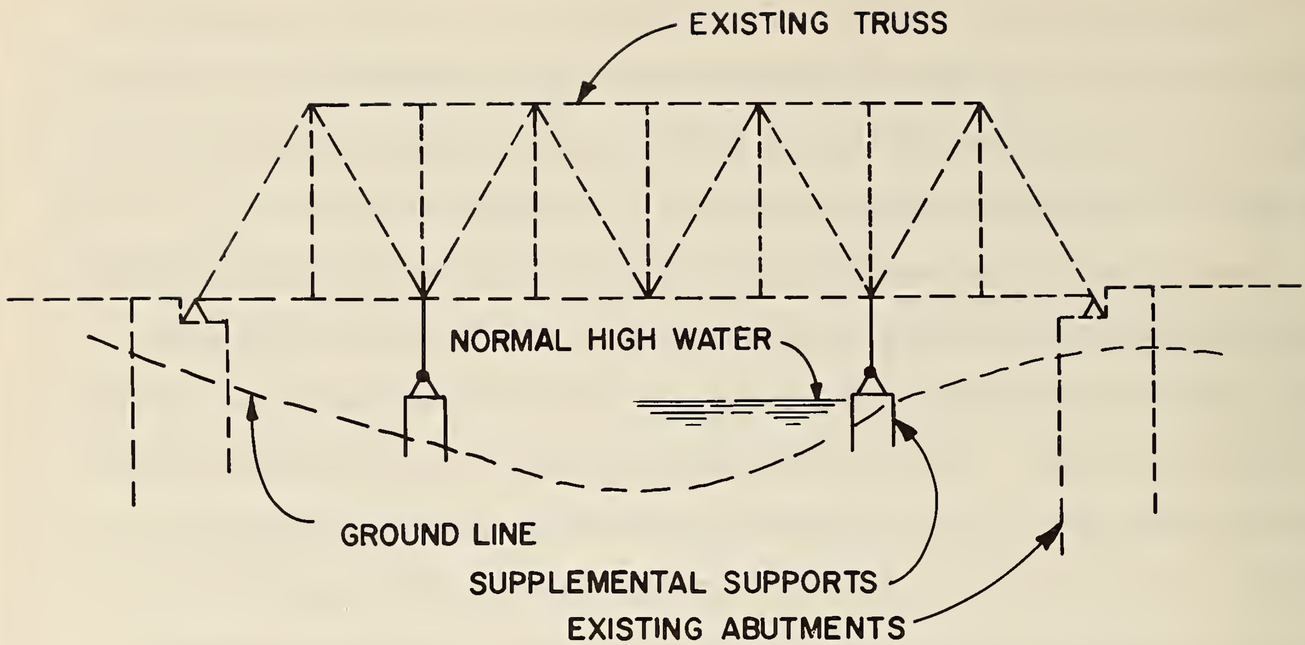
Support bents pin-connected to the truss panel points provides the needed vertical support without changing the expansion characteristics of the span. These supports can be economically designed to carry only the vertical component of induced live load. This procedure requires a detailed construction schedule which includes provision for adjusting the bent to achieve the desired load transfer. Stress levels of individual truss members must be checked for compliance with code under the altered structural system. A schematic detail is shown in Figure 3.

Supplemental Transverse Support. Where clearance and other geometric requirements permit, additional load carrying capacity can be developed by adding supplemental transverse floor beams under existing stringers which in turn are supported by supplemental girders on the outside of the existing framing system. This concept is particularly applicable where widening is required together with strengthening.

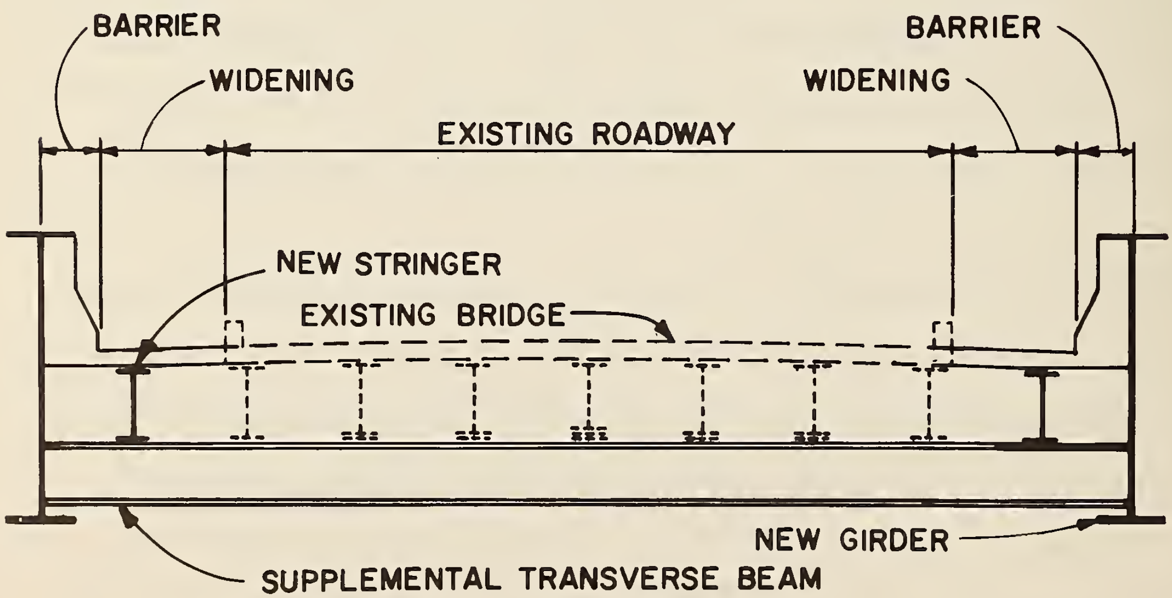
Details must be developed to adequately effect load transfer from existing stringers to the transverse floor beams. The system is useful in carrying the additional dead load and live load created by the widening plus a portion of the live load imposed on the existing stringers. A schematic detail is shown in Figure 3.

Reduce Dead Load

Dead load reduction can most easily be accomplished by removing the existing deck and providing a lighter weight substitute. A number of deck systems have been developed to provide a lightweight yet structurally adequate system. The most common of these are:



SUPPLEMENTAL TRUSS SUPPORTS



SUPPLEMENTAL TRANSVERSE SUPPORTS

FIGURE 3

- Open steel grid
- Concrete filled steel grid
- Corrugated metal
- Laminated timber
- Metal plate (Orthotropic)

Examples of several lightweight deck applications are included with the rehabilitation demonstration plans in Chapter VI.

Steel Grid. Open steel grid flooring is available in a variety of configurations from several manufacturers. It can be filled with concrete or can be left open. In the usual type of installation, the grating is welded to the top flange of the stringers. Intermediary plates or bars may be necessary to adjust for roadway crown.

A major disadvantage of open grid flooring is that it can become slippery when wet or ice-covered. Serrated top bars or welded studs provide greater skid resistance but do not eliminate the problem entirely. The open grid has the advantage of permitting snow and rain to pass through the structure, thereby eliminating the need for bridge drainage and the use of snow and ice control chemicals on the bridge.

Details should be developed that eliminate pockets over the main support members that could collect debris and cause corrosion in these members. Care should also be taken in selecting the proper grating design. Several states reported that welded details often fail due to impact and fatigue. Riveted grates reportedly provide a more reliable deck but are not as readily available.

Concrete-filled floor grating has the advantage of improving skid resistance and reducing the impact that is a primary cause of fatigue failures in the internal connections. The disadvantage is the added weight as compared to the open grid and subsequent reduction in live load capacity of the bridge. Also, it is necessary to provide and maintain an adequate deck drainage system and to employ chemicals for snow and ice control.

Corrugated Metal. Corrugated metal sheets for the deck support with an asphalt wearing surface has been used in the past and is becoming increasingly popular. Installations have shown that the system can be design to withstand modern design loading. Length of service can be increased by properly designing the drainage system to remove surface runoff and by providing adequate protection against corrosion for the metal sheets. This system has been used successfully in a number of the states visited during the inspection phase of the study. Reports indicate that the performance is consistent with expectations.

When replacing a concrete deck with this system, it will usually be necessary to add lightweight supplemental support beams between the existing stringers in order to reduce the effective deck span. On multiple stringer bridges, these can be framed to floor beams placed between existing stringers or to existing diaphragms. On truss bridges and other structures with similar floor systems, these beams can be framed to existing floor beams.

Timber. Glued-laminated timber bridge decking is a relatively new concept. This provides some reduction in dead load as compared to a concrete deck but live load distribution factors as defined in the AASHTO Bridge Specifications increase, resulting in little or no betterment especially for shorter length spans. It does provide advantages from a maintenance point of view since it is less susceptible to chemicals used in snow and ice control. It is important to provide details for fastening the panels to stringer supports that will not be conducive to insect infestation and resulting deterioration. The joint between panels must also be carefully detailed to provide shear transfer and to provide a proper seal. Clamping devices that do not require drilling or nailing are preferred to drilling and bolting.

The State of Virginia has constructed several laminated decks on an experimental basis. Initial indications are that these decks are performing in a satisfactory manner. The department has now prepared standard drawings for the design and installation of timber decks in anticipation of continued use.

Metal Decking. Steel plate decking as a replacement for deteriorated concrete provides significant weight reduction. This system can also provide additional carrying capacity for the primary members if designed to act compositely with the primary member. Ribs or supplemental lightweight flooring must be included with the decking to provide adequate roadway support. Adhesion between the steel plate and asphalt wearing surface is a potential maintenance problem, but through careful attention to specifications and with proper construction techniques, this problem can be greatly reduced.

Other Methods. In some instances it is possible to reduce the dead load carried by a bridge by eliminating certain features of the roadway cross section. Concrete parapets can be replaced by lightweight railing. Heavy concrete sidewalks are often much heavier than required to satisfy the structural requirements and can be replaced with lighter weight sections that still comply with the desired cross section geometrics. Curbs and median barriers can also be replaced with lighter sections.

Wearing surfaces added to bridge decks to improve riding quality can build up over the years to depths that reduce significantly the live load carrying capacity of the bridge. This can be removed and replaced with a minimum thickness wearing surface that will reduce dead load and, if coupled with a waterproofing system, will protect the structural integrity of the deck.

Modify Structural System

The structural system in a bridge can be modified in a number of ways to provide additional capacity to support live loads. Two such concepts determined by the study to have merit are composite action and beam continuity.

Composite Action. This procedure involves the modifications needed to change an existing beam or girder system to a composite system wherein the beam and the deck act together in resisting live loads. Composite action is provided through suitable shear connection between the beam and roadway deck. The most common device used to provide the required horizontal shear resistance is the welded stud.

The rehabilitation procedure includes removing the deteriorated concrete deck, welding shear connectors to the top flanges of the steel beam, and casting a new deck slab. In situations where the deck slab is sound and does not need to be replaced, holes can be drilled through the slab from the roadway to the steel support for welding the studs. Epoxy grout is then placed in the void between the slab and the stud.

Another process now in the experimental stage at the University of Georgia, provides shear resistance by pressure injecting epoxy adhesive into the void between the steel flange and the underside of the concrete slab. This is injected through drilled holes in the deck. Early test data indicate that this can become an effective and economical method for developing shear resistance. Construction specifications and testing procedures must be further developed, however, before this method can be used with the necessary reliability.

Composite action can also be effectively developed between steel deck plates and steel beams or stringers (orthotropic). This concept has been used frequently for new construction but also has application in rehabilitation projects. This provides additional carrying capacity through joint beam/deck action, plus provides for additional live load capacity by reducing the dead load of the roadway deck. This procedure has already been discussed under dead load reduction concepts.

Composite action between deck and stringers can also be employed in timber construction. Laminated deck panels properly attached to timber supports to develop the required horizontal shear strength can act jointly in the longitudinal direction to support superimposed dead and live loads. This technique has been demonstrated as being effective through research conducted by the University of Colorado. Results are contained in a report entitled "Composite Action in Glulam Timber Bridge Systems" by J. D. Pault, et al, June 1977.

Beam Continuity. This procedure is employed to change a series of simple beam spans to a continuous system. Through the interaction between spans, additional load-carrying capacity is obtained. The procedure is applicable to steel, timber or concrete beams.

In addition to providing increased live load capacity, this system also reduces future maintenance requirements since it eliminates a roadway joint and one set of bearings at each pier, both of which are constant maintenance problems as reported by all state bridge departments participating in the study.

The procedure consists of first removing a portion of the deck over the pier. If the deck is to be replaced, the entire existing deck is removed. A splice is then installed between adjacent beams which must be designed to transmit moment as well as shear. Existing bearings are removed and a new stiffener and bearing assembly erected. The deck is then replaced, completing the operation.

For concrete structures, the procedure is similar except that constructing the splice to transfer negative moment is more difficult. Also, the negative moment transferred through the splice that must be taken by the adjacent beams will usually require some modification to the beams themselves since concrete beams are normally not symmetrical and are not homogeneous.

Details for a steel multiple stringer bridge are shown in conceptual form in Figure 4. An application to an actual bridge is included with Chapter VII.

A concept was reviewed wherein beam and abutment continuity was developed to produce additional live load capacity in the positive moment area. This procedure requires the development of a rigid connection between the abutment and stringers. For rehabilitation work, this is difficult to achieve in a manner that will produce the necessary degree of reliability. In addition, the stresses induced in the abutment must be accommodated which can require reconstruction of the abutment or major modifications.

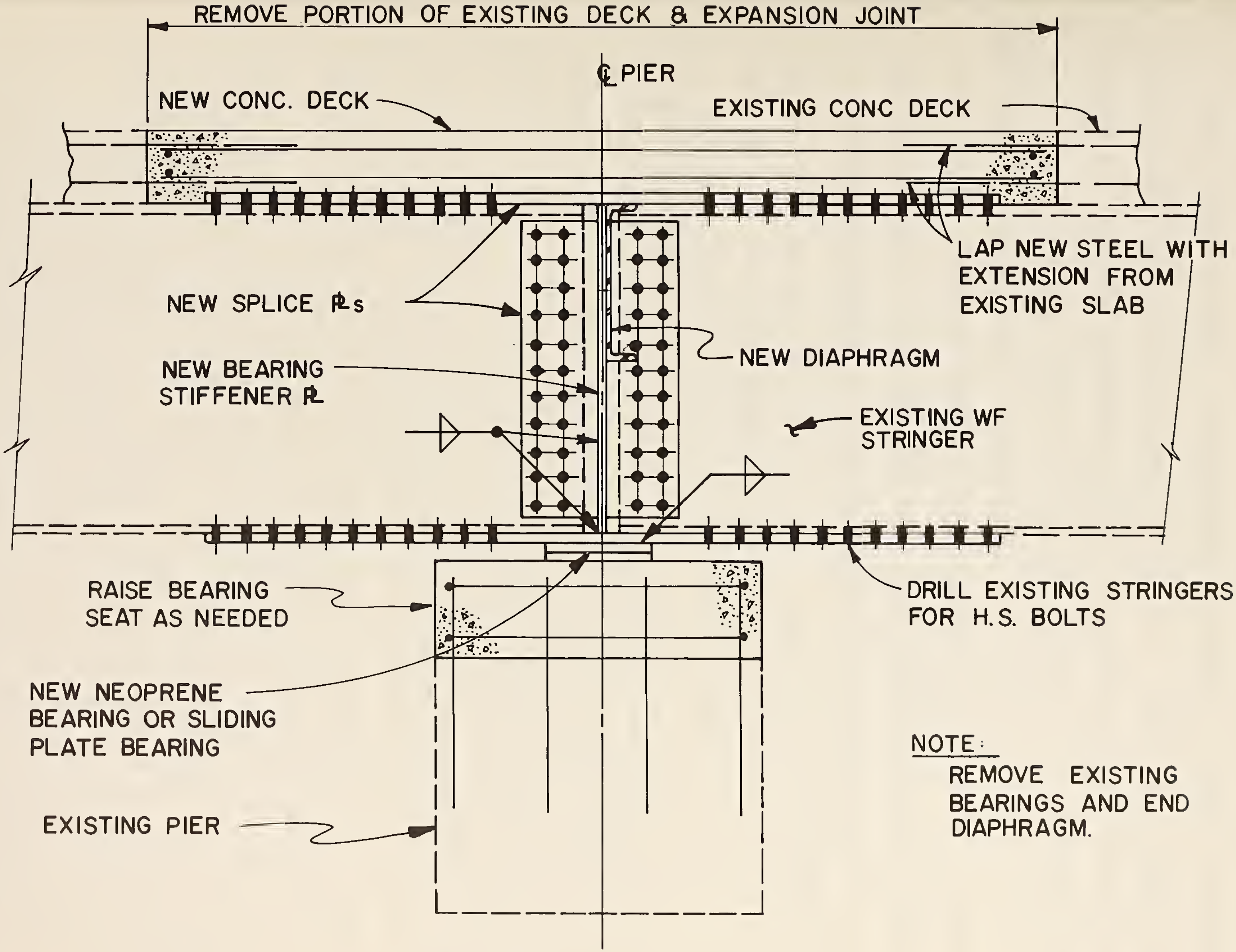
IMPROVE GEOMETRICS

Bridges that are geometrically deficient can be rehabilitated by the following methods:

- Increase vertical clearance
- Widen usable roadway
- Improve alignment

Increase Vertical Clearance

Inadequate vertical clearance is a common geometric deficiency in through truss type bridges as evidenced during the field inspection phase of the study. Additional clearance can be provided by reducing the depth of portal frames and by either eliminating or reducing the depth of sway frames. The resulting bracing system must be analyzed and proper modifications designed to transmit imposed loads. Several examples of the procedure were submitted by state bridge departments for review. Utilizing this material, details were developed for portal frame modification for one of the bridge rehabilitation demonstrations included in Chapter VII.



NOTE:
REMOVE EXISTING BEARINGS AND END DIAPHRAGM.

CONCEPTUAL DETAILS

SIMPLE SPAN STEEL BEAM TO CONTINUOUS

FIGURE 4

In certain cases it may be possible to lower the floor system on through truss bridges and thereby increase vertical clearance. Where stringers bear on the top flange of floor beams, the roadway can be lowered by framing the stringers to the floor beams keeping the top of stringer and the top of floor beam in the same plane. This concept has particular merit where the existing stringers are inadequate and need to be replaced. In this situation, the stringers can be replaced with connections detailed to frame into the existing floor beams. Approach grades must be adjusted to meet the lower profile. An example of this procedure is also included with the rehabilitation of a through truss bridge discussed in Chapter VII.

There are certain unique situations where it may be practical to lower the entire floor system on a through truss by lowering the floor beam connection at the truss panel point. This will require almost complete dismantling of the floor system, refabrication of the floor beam connections to the truss, and re-erecting the bridge superstructure. Approach grades in this situation must also be adjusted to meet the lower bridge profile.

Often it is desirable to replace a concrete deck with a lightweight floor system to increase live load capacity as previously discussed. This will usually produce as a side effect a lower bridge profile due to the thinner deck, thus providing greater clearance on through truss type structures.

Improved vertical clearance on grade-separation structures can be achieved by lowering the lower roadway, providing this can be done without undermining or otherwise jeopardizing pier or abutment footings. This procedure may require adjustment to drainage facilities and other appurtenances such as barriers, concrete curbs and guardrail. It lends itself readily to construction while maintaining traffic since one roadway at a time can be lowered on dual roadway facilities, or one lane at a time on single roadways.

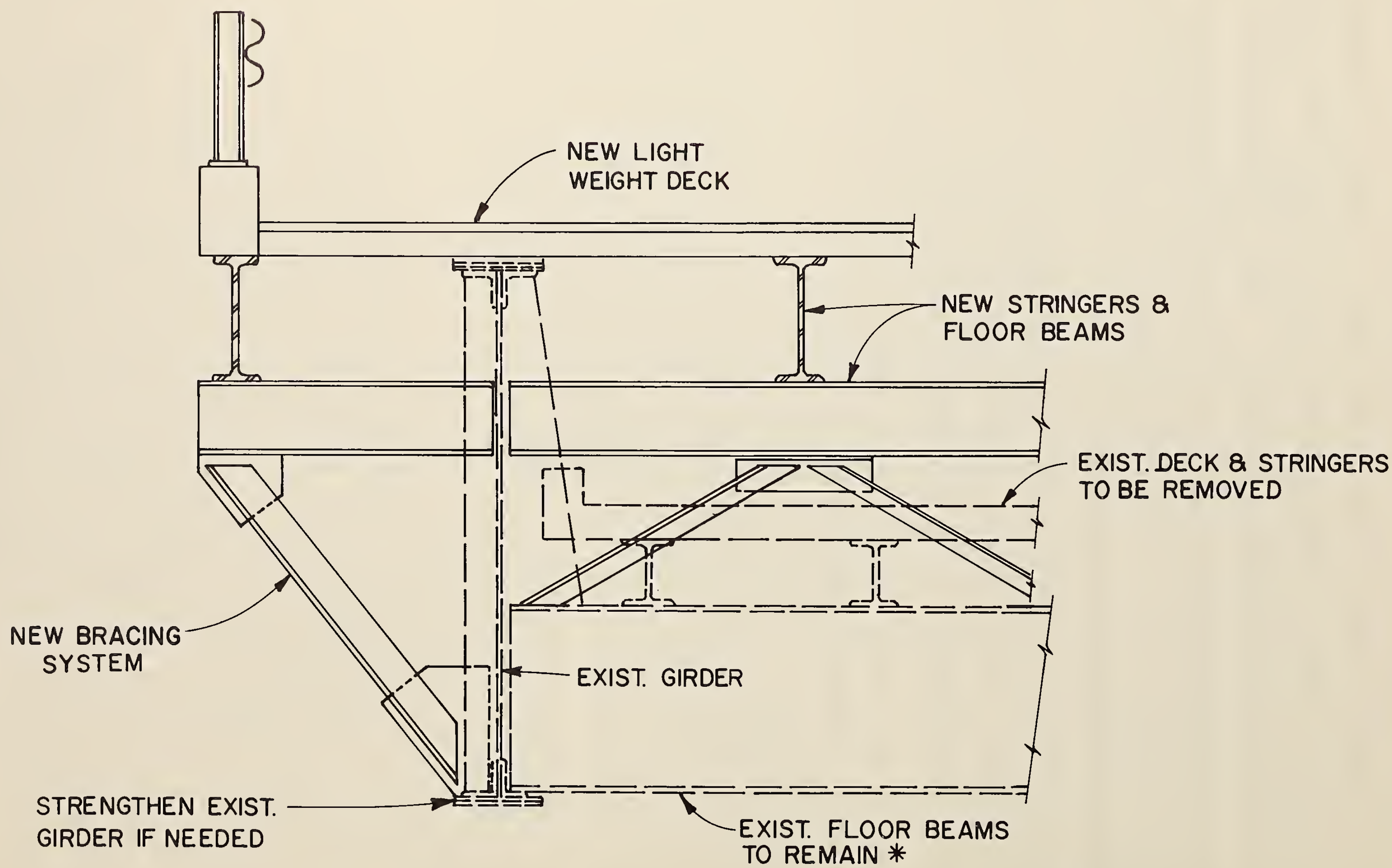
It is possible, although ordinarily more costly, to raise the superstructure and adjust the vertical alignment of the overpass roadway. This requires adding to the height of the abutments and piers. These elements must be analyzed to insure that they are capable of absorbing the increased loads imposed by the added height. If not adequate, structural modifications must be included with the rehabilitation plans.

A third alternative involves rebuilding the superstructure to obtain added vertical clearance. Where approach roadways cannot be adjusted, a thinner or through type superstructure can be constructed to develop greater vertical clearance. If the approach roadway can be adjusted then the superstructure can be reconstructed at a higher elevation.

Widen Usable Roadway

On multiple girder or multiple beam bridges of either concrete or steel construction, it is a routine process to widen the roadway. Parapets and sidewalks must be removed, piers and abutments extended, new stringers added and a new deck and curb installed. Control of traffic during construction of the new deck is necessary to insure that excessive deflection and vibration from heavy vehicles are controlled.

Through girder bridges and through truss bridges are more difficult to widen. Short of removing the entire superstructure and replacing with a new one, it is impracticable to consider widening a through truss bridge and in most instances, a pony truss bridge. Providing site conditions will permit adjustments in grade of several feet, it can be practical to widen a through girder bridge by moving the floor system to the top flange of the girder and constructing a wider deck. The main girders may require strengthening. However, this can be minimized by utilizing a lightweight deck in conjunction with the rehabilitation. A conceptual cross section of this is shown in Figure 5.



CONCEPTUAL DETAILS
THRU GIRDER DECK WIDENING

* NOTE:
CAN BE REPLACED WITH LIGHTER WEIGHT STRUT IF DEAD LOAD REDUCTION IS NEEDED.

FIGURE 5

Numerous examples of bridge widening plans were submitted by the states for review. Several examples of widening techniques are included with the rehabilitation demonstrations in Chapter VII. These have been developed based on the review of examples submitted which were refined and modified.

Improve Alignment

In many instances and especially on stream crossings, the approach roadway alignment will contain abrupt turns immediately adjacent to the bridge. Alignments of this nature are extremely difficult, if not impossible, to correct due to environmental restrictions and the need to obtain additional right-of-way.

Minor adjustments in horizontal alignment may be possible to improve safety. Each location must be reviewed and analyzed in light of the characteristics unique to that location.

Vertical alignment can be significantly improved in many instances. Abrupt crest verticals approaching the bridge can be lengthened to provide a smoother and safer transition. Site distance on crest verticals can also be improved by lengthening vertical curves or adjusting grades. These improvements can be made, in many instances, within existing right-of-way limitations.

Major modifications to alignment on the bridge proper are normally not possible. It can be practical to include vertical adjustments to improve geometrics as part of an overall bridge rehabilitation project. Deck replacement and widening projects afford the opportunity to improve roadway cross section geometrics and to make minor improvements in vertical alignment.

CORRECT MECHANICAL DEFICIENCIES

Concepts have also been reviewed and developed for correcting mechanical bridge deficiencies. These repairs are primarily those associated with those elements that permit the bridge to respond to movements. Also included are those repairs that will prevent undesirable movements occurring in fixed elements of the bridge.

Expansion Devices

For bearings, expansion joints, hangers, wind tongues and similar expansion devices, the usual rehabilitation technique reported by the participating states is to replace the defective item or to clean the existing device and adjust it to the proper position. Vertical and longitudinal jacking of the superstructure is an integral part of this work. With careful planning, this work can be done without traffic interruption.

Replacement elements should be designed to minimize future maintenance problems. Elastomeric type bearings should be used whenever possible in lieu of metal plate bearings. Most of the plans received from state bridge departments included elastomeric design where replacement bearings were necessary.

Replacement of roadway expansion joints is often required when rehabilitating the structure to correct mechanical deficiencies. Replacement joints should be watertight if possible. When open joints must be used, provision for drainage collection should be included to prevent pavement wash from reaching bearings or hangers beneath the joint. Scuppers located as close as practical to the open joint with drainage troughs under the joint provide an effective method for controlling runoff in these areas. The steel components of replacement joints should be galvanized or constructed of weathering steel to control corrosion.

In situations where pavement shove, rotation of supports or other movements have caused the expansion devices to become jammed, it may be necessary to rebuild the abutment backwall or to remove a portion of the longitudinal member adjacent to the backwall in order to provide sufficient gap for movement. If the abutment is not stabilized, the same problem will reoccur.

Abutment Stabilization

Procedures have been developed for stabilizing abutments against longitudinal movements. Tiebacks can be installed, anchoring the abutment to deadmen or utilizing soil or rock anchors. Devices should be included in the details to distribute the tieback load over the abutments. These can be bearing plates or waler type beams. A tieback procedure included with a rehabilitation demonstration plan is discussed in Chapter VI.

Settlement is more difficult and costly to correct. Underpinning of abutments will prevent continued settlement activity. Settlement caused by excess vertical forces acting on the abutment can be reduced by providing supplemental support for the approach slab. This can be achieved by constructing a pile bent at the rear face of the backwall to support the approach slab. Pile bents can also be constructed in front of the abutment to aid in supporting the bridge superstructure. Soil stabilization procedures also aid in preventing additional settlement.

Where lateral soil pressures are the cause for an unstabilized condition, a cutoff structure can be constructed to resist lateral forces. Sheet piling driven behind the abutment is an effective technique.

Proper drainage can often be effective in correcting abutment stabilization problems. Reducing hydrostatic pressures behind backwalls, preventing saturation of supporting soil strata, and preventing erosion in front of abutments can greatly reduce, if not eliminate, stabilization problems and should be included as an integral part of rehabilitation procedures to improve substructure stabilization.

Pier Stabilization

Pier settlement and leaning can cause major deficiencies to occur in other bridge elements. As in abutments, underpinning and soil stablization procedures can be used to minimize vertical settlement and footing rotation. Also, proper attention to surface as well as subsurface drainage can aid significantly in eliminating pier stabilization problems.

MISCELLANEOUS REPAIRS

There are many repairs that should be included in the rehabilitation of a deficient bridge that do not relate directly to the load carrying capacity of the bridge. However, if these deficiencies are not repaired, they can result, indirectly, in a reduction in load carrying capacity.

Drainage

An ineffective bridge deck drainage system is a major cause of deterioration in many bridge elements. Rehabilitation should include replacement with an adequate drainage system. Special attention should be given to details that will prevent deck wash from reaching bearings, superstructure members, piers, and abutments. Scuppers must be properly spaced to accommodate surface runoff and should be large enough to minimize clogging from roadway deposits. Proper provision must be included for maintenance cleaning of downspouts and collection pipes. Discharge points should be detailed to prevent erosion. Consideration should be given to galvanizing all parts of the drainage system or using weathering steel.

Bridge Decks

Deck repairs vary from full deck replacement to patching of isolated areas. Deck replacement should include adequate protection of reinforcing steel to prevent corrosion and subsequent concrete deterioration. State-of-the-art indicates that this can best be provided by coating the reinforcing bars with an epoxy sealant or by constructing a high density concrete overlay on the structural slab. Cathodic protection systems are under development and appear to be promising.

On existing decks that require repair but not replacement, the rehabilitation should include a sealing system which will prevent or at least reduce the further buildup of chlorides in the deck. A procedure to reduce the chloride content in the existing deck should be considered with the rehabilitation program. An example procedure is the electro-removal as used by the Kansas DOT.

Barriers

Replacement of inadequate bridge railing, alternation of parapet and railing ends where these face oncoming traffic, protection with attenuators at ends of through girders or through trusses, in gore areas on structures, or in front of piers within the recovery zone (9m, 30 feet from pavement edge) are all measures that should be considered in bridge rehabilitation plans.

Adequate protection for pedestrian traffic should also be provided. Redirectional barriers provided between the sidewalk or bikeway and the roadway can be effective in providing safety for pedestrians as well as for vehicles.

Piles

In addition to those techniques already described to replace defective piles in bridge pile bents, other techniques not involving replacement are available. Pile splices can be made wherein a new section of the pile is inserted and spliced after removal of the unsound portion. Jacketing of defective pile areas with concrete collars can often be done to effect repair. Numerous examples of these techniques were received from state bridge agencies as well as private suppliers and contractors for review during the study.

Concrete Repairs

Pressure grouting, gunniting, epoxy seals and others have been developed for repairing cracks and spalls in concrete surfaces. These repairs are primarily cosmetic but protect the bridge member by preventing moisture from penetrating the concrete surface and corroding reinforcement.

Procedures have been developed and used successfully to apply these mortar materials to horizontal faces and to vertical faces. The American Concrete Institute (ACI) has compiled a manual on concrete repair which is now under review prior to publication. The draft was reviewed by the research team and promises to provide an excellent guideline for concrete repairs when finally published.

The rehabilitation demonstration plans discussed in Chapter VII include techniques for spall and crack repairs.

CHAPTER VI

REHABILITATION TECHNIQUE EVALUATION

In order to arrive at decisions as to how a bridge should be rehabilitated, it is necessary to develop accurate cost data for the available options. This follows the development of feasible techniques that can be considered.

To assist in this decision-making process, two concepts have been developed during this study. These are the development of "Improvement Factor" and "Cost Effectiveness Factor." These factors are intended to serve as a guideline for the selection of a given technique for increasing bridge service life.

IMPROVEMENT FACTOR

The benefit of many techniques for increasing the load carrying capacity of a structure varies with the span length. Dead load reduction techniques, structural system changes, and adding supplemental supports all have a varying degree of benefit dependent, among other things, on span length.

The "Improvement Factor" concept relates the degree of improvement to span length. The factor is defined as the percentage of improvement in flexural capacity between a particular rehabilitation technique and a conventional design.

For this study, factors were developed for a number of rehabilitation techniques involving dead load reduction and structural system changes.

Dead Load Reduction

Five concepts, already described, that include reduction in roadway deck dead load were analyzed. Flexural requirements were determined for a 15m (50 ft.) and a 27m (90 ft.) simple span with stringers spaced at 2.1m (7 ft.) center to center. These include steel plate decking, corrugated metal decking, open steel grid deck, concrete filled steel grid and laminated timber. AASHTO specifications were used with a live load of HS20-44. Requirements for a comparable stringer span arrangement were determined using steel stringers and a concrete deck. Live load distribution factors were used as established by AASHTO.

The net change in flexural requirements between the base system and the one employing the dead load reduction technique established the amount of improvement that could be achieved. The percentage increase or decrease was designated as the "Improvement Factor."

A reduction in dead load will always result in an increase in available capacity for live load. However, the system employed to reduce the dead load can result in different live load distribution factors. The combined effect of dead load reduction and distribution change can result in a negative impact, hence the Improvement Factor can be positive or negative.

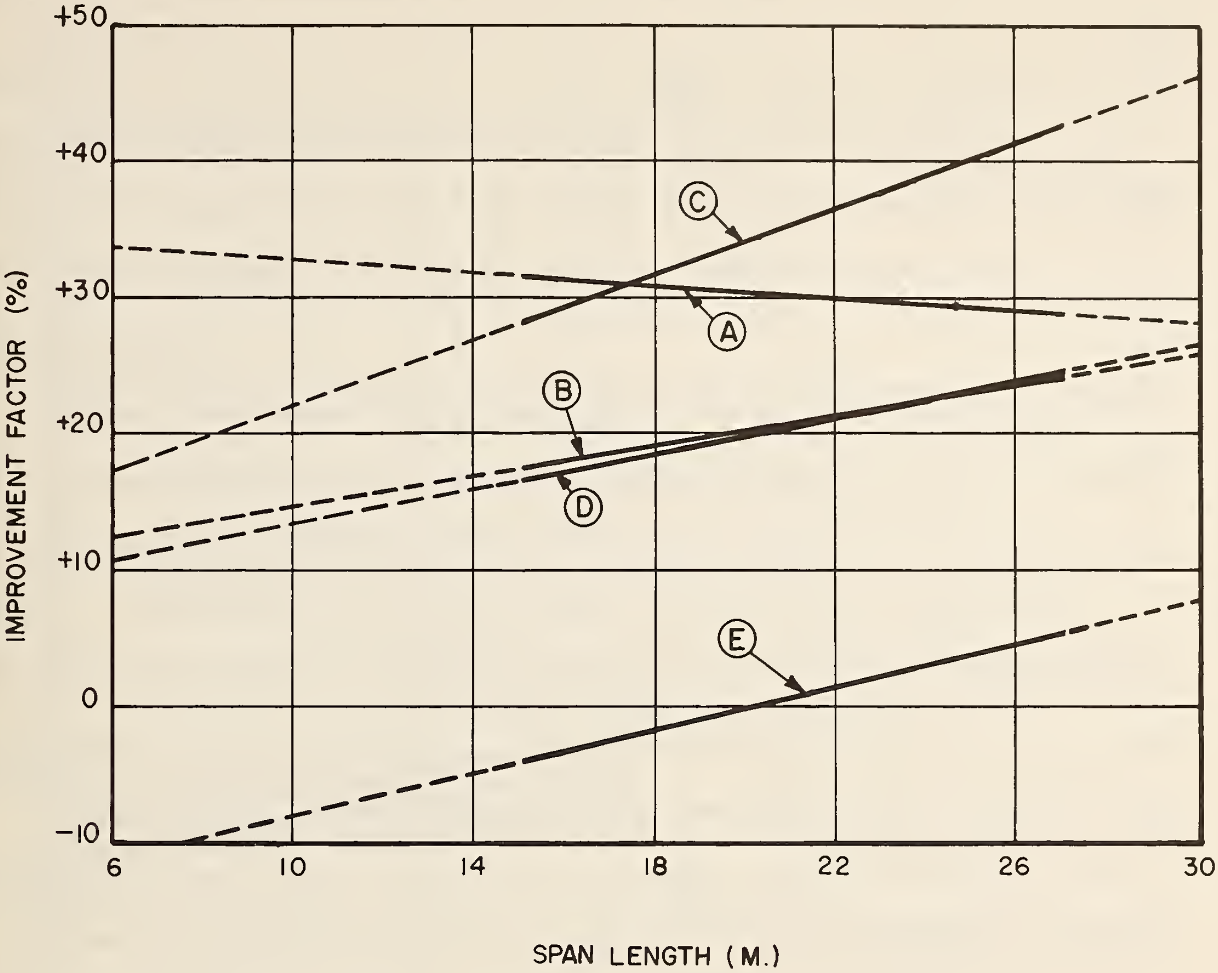
A graphic presentation of the results of this analysis is shown in Figure 6. It should be noted that only two points on each curve were computed. A straight line extrapolation was used to extend the curves as indicated. If more points were determined these curves would undoubtedly be curvilinear. However, for the purpose of comparing one technique to another, this is not significant.

Structural Modifications

In a manner similar to that described for dead load reduction procedures, "Improvement Factors" were determined for concepts involving changes to the structural system, the strengthening of support elements and for adding supplemental supports. Details for each of these systems were described earlier. A graphic presentation of the systems evaluated is shown in Figure 7.

Composite Action

Factors were determined for composite action by comparing fiber stresses developed for a non-composite design with those resulting from composite design.



COST PER SQ. M.	
A	$ 410
B	$ 270
C	$ 290
D	$ 310
E	$ 310

CONVERSION FACTOR
1 M. = 3,28 FT.

A. STEEL PLATE W/ASPHALT WEARING SURFACE SUPPLEMENTAL DECK SUPPORT SYSTEM.

B. CORRUGATED METAL W/ASPHALT WEARING SURFACE SUPPLEMENTAL DECK SUPPORT SYSTEM.

C. OPEN STEEL GRID.

D. CONCRETE FILLED STEEL GRID.

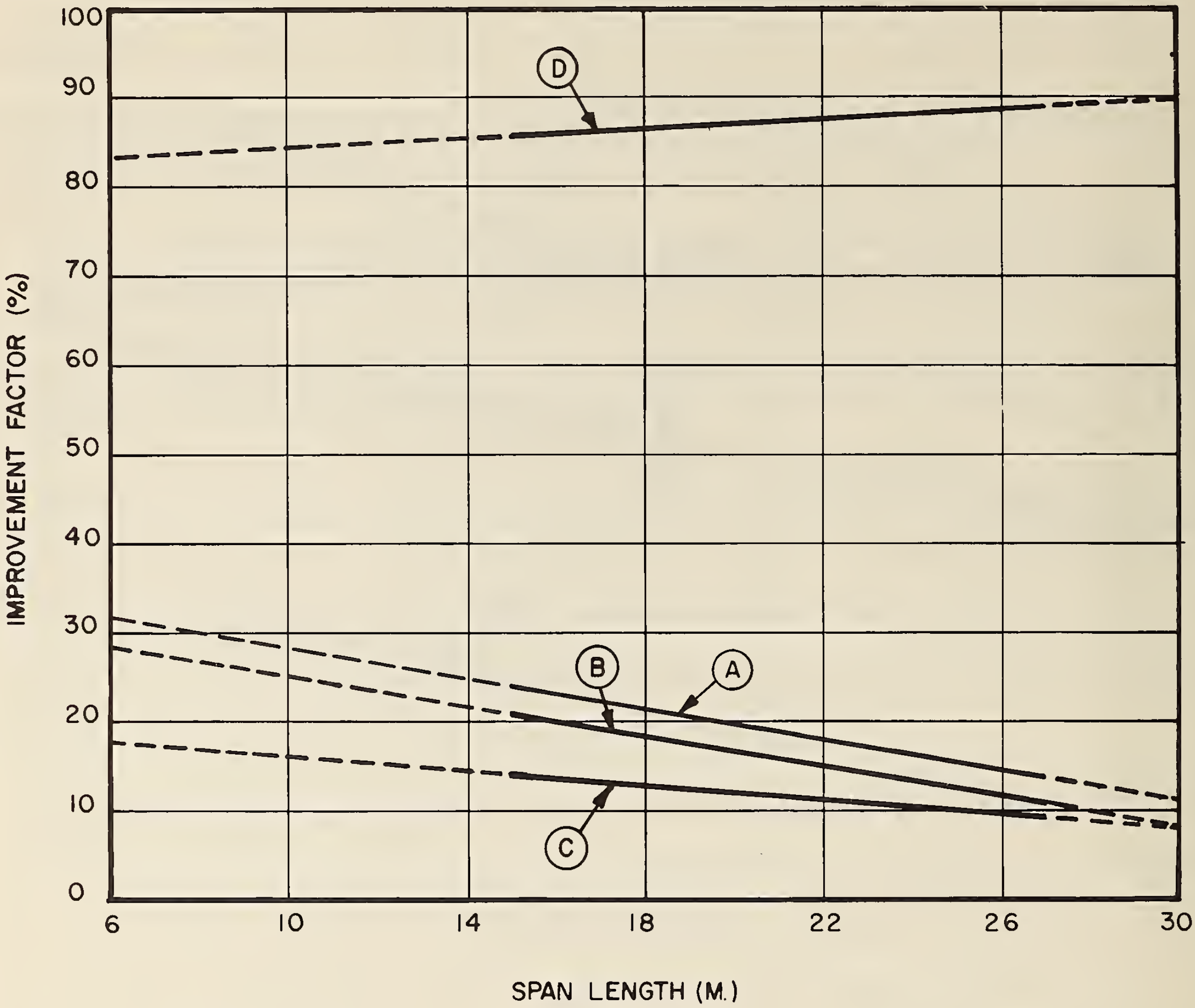
E. LAMINATED TIMBER

NOTE: DASHED LINES REPRESENT EXTRAPOLATED VALUES OF THE CURVES.

SPAN-IMPROVEMENT FACTOR

DEAD LOAD REDUCTION SYSTEMS

FIGURE 6



COST PER SQ. M.	
A	$ 50
B	$ 195
C	$ 175
D	$ 420

CONVERSION FACTOR
1 M. = 3.28 FT.

A. KINGPOST TRUSS MODIFICATION.

B. COMPOSITE ACTION - STEEL BEAM/ CONCRETE DECK.

C. CONTINUOUS MULTIPLE STEEL BEAM OR GIRDER.

D. SUPPLEMENTAL FULL DEPTH STRINGERS W/ LIGHT WEIGHT DECK.

NOTE: DASHED LINES REPRESENT EXTRAPOLATED VALUES OF THE CURVES.

SPAN-IMPROVEMENT FACTOR STRUCTURAL MODIFICATION SYSTEMS

FIGURE 7

Span length and beam spacing used are the same as for the development of Improvement Factors for other concepts. For each span investigated, the beam section was determined for non-composite action. This same section was then used for composite action with an 8-inch concrete slab.

Span Continuity

Factors were determined for span continuity by computing the positive moment requirements for a simple span steel beam system. The positive moment was then computed assuming a series of continuous spans for live load and impact. A comparison of these two values yields the Improvement Factor. This was done for the same spans and beam spacing as used for other concepts.

Supplemental Stringer Supports

Supports added between existing beams or stringers were evaluated and compared with the flexural requirements for the system without these additional members. This concept included the use of a lightweight deck with the supplemental supports. Again, a simple span multiple steel beam with non-composite concrete slab was used as the basis for comparison.

Kingpost Truss

Analysis for the development of Improvement Factors for a kingpost truss system was based on an assumed geometric condition for a single post system. Two 2.5 cm (1 inch) diameter rods were also assumed to induce a controlled negative moment into the beam. The flexural requirements with this induced moment were then compared with a conventional beam requirement to obtain the Improvement Factor.

COST EFFECTIVENESS FACTOR

For each concept for which an improvement factor has been developed, costs for implementation were estimated. These costs were based on 1978 dollar values and average costs developed from information obtained in the Washington, D. C. area. A summary of these estimated costs is shown in Figures 6 and 7.

By dividing the Improvement Factor by the estimated unit cost a Cost Effectiveness Factor can be determined. The higher the value of this factor the greater the cost effectiveness for a given situation. For example, comparing the cost effectiveness of modifying a 25m (82 feet) span by either utilizing an open grid deck or a corrugated metal deck with an asphalt wearing surface, indicates that the open grid deck provides a factor of 0.138(40 ÷ 290) and the corrugated metal deck provides a factor of 0.085(23 ÷ 270). Therefore, the open grid deck will provide the most cost effective technique.

Each of the concepts for which data was developed has other factors that must be considered in addition to initial cost before a final determination of the technique to be used is made. These include both maintenance and operational considerations as well as long term cost benefit analysis. Safety aspects must also be a prime consideration in the selection of rehabilitation techniques.

CHAPTER VII

REHABILITATION TECHNIQUE DEMONSTRATION

In the third phase of the study, detailed plans and specifications were developed for five bridges in order to demonstrate those rehabilitation techniques that have already been used effectively as well as other new concepts. Cost data was also developed for each. Plans for these bridges are included in Appendix E of this report. An outline of the rehabilitation procedures used and particular bridges utilized is given in Table 5.

SELECTION OF BRIDGES

The bridges considered for the rehabilitation demonstration were selected from those inspected during the initial phase of the study. In order to cover a broad range of common bridge types it was decided to rehabilitate at least one steel bridge, a concrete bridge and a timber bridge. Additional steel bridges were added to this list in order to demonstrate specific rehabilitation techniques.

The inspection files were reviewed and bridges that evidenced the desired deficiency and structure type listed. This process yielded several candidate bridges for each structure type.

The state in which the candidate bridges are located was contacted and record plans requested. In many instances, detail plans were not available but sketches were furnished and inspection reports yielded additional details.

With this information in hand, the five bridges to be used in the demonstration were selected. The basis for final selection included available details, simplicity of structural design and known deficiency.

TABLE 5 - BRIDGE REHABILITATION DEMONSTRATION TECHNIQUES

Type	Identification	Rehabilitation Techniques
Concrete "T-Beam" Simple Span	California 6-80	• Strengthen primary members by adding steel reinforcing plates attached with epoxy or bolts. • Install new deck joints. • Strengthen pier cap with external reinforcing. • Repair cracks and spalls. • Replace Bridge Railing.
Steel Multiple Beam Simple Span	Tennessee 44-135-9.37	• Widen roadway by adding longitudinal beams. • Increase load carrying capacity by adding supplemental stringers and by replacing concrete deck with lightweight corrugated metal/asphalt surface deck. • Widen existing pier cap to take additional stringer load. Post tension precast or cast-in-place cap addition. • Widen abutment.
Steel Multiple Beam Simple Span	Illinois 039-0027	• Widen roadway by adjusting cross section geometry. • Increase load carrying capacity by making spans continuous and by replacing concrete deck with open grid steel decking. • Stabilize abutments by installing tiebacks. • Adjust bearings. • Install new roadway expansion joints. • Improve safety by adding re-directional barriers.

Table 5 (continued)

Type	Identification	Rehabilitation Techniques
Timber Multiple Beam Simple Span	Tennessee 9-8255-1.08	• Widen roadway by extending pile bents and adding additional stringers. • Replace deck with laminated timber panel decking. • Stabilize and widen abutment by adding steel piling and concrete cap. • Improve safety by adding guardrail. • Increase capacity by making deck act compositely with stringers.
Steel Thru Truss Simple	Tennessee 21-4428.01	• Increase load carrying capacity by replacing existing deck with open grid steel decking. • Strengthen floor beams by adding kingpost truss to bottom flange. • Increase vertical clearance by lowering floor system and by modifying portal frame.

SELECTION OF REHABILITATION TECHNIQUES

Rehabilitation techniques were selected to demonstrate corrective procedures for frequently occurring deficiencies and to show those corrective procedures considered by the research team to be the most effective.

General concepts of rehabilitation that were selected to be included with the demonstration plans were:

- Increase Load Carrying Capacity
- Improve Geometrics
- Miscellaneous Repairs

In order to illustrate as many procedures for rehabilitation as possible, bridge deficiencies that actually occur as evidenced by the inspection reports were addressed as well as a number of assumed deficiencies. No distinction was made in the plans between real and assumed bridge deficiencies.

Increase Load Carrying Capacity

Techniques selected included those that reduce dead load through the installation of various types of lightweight decking. Changes in structural system involving provision for continuity and composite action were also selected. Finally, those techniques that strengthened existing members or added supplemental members were included.

Improve Geometrics

Bridge widening to accommodate greater traffic demands was noted to be a frequently occurring requirement in bridge rehabilitation. Widening usable roadway was also thought to be desirable to improve overall safety. Several techniques were therefore included with the demonstration plans to accommodate widening. These included adding additional longitudinal beams as well as obtaining additional deck area by modifying cross section geometrics.

Substandard vertical clearance on through truss bridges was also a frequently occurring deficiency as reported by all states participating in the study. Techniques for increasing clearance were included with the demonstration plans.

Miscellaneous Repairs

Techniques for repairing other bridge deficiencies were also included. These techniques were developed for commonly occurring deficiencies including abutment stabilization, bearing replacement and adjustment, roadway joint replacement, approach slab construction, and repairs for concrete cracking and spalling.

Repairs to concrete bridge decks have not been included with the rehabilitation plans. This subject has not been addressed during the study other than cursory comments regarding the need for a system to protect the deck and to prevent corrosion of the reinforcing steel.

PLAN DEVELOPMENT

The plans have been developed to show methods of rehabilitation for specific bridges and to correct actual deficiencies. As previously stated, additional deficiencies were assumed in order to demonstrate other repair techniques. The plans are therefore not intended to be utilized in a construction repair program for any of the five bridges included with the study.

The development of details has been done to a degree necessary to clearly define the procedure being demonstrated. In many instances, additional dimensions and details would be needed for actual construction.

Structural computations to support the technique demonstrated were carried to the degree necessary to assure that the technique would provide a satisfactory solution. As with the geometrics and detailing, additional computations would be necessary to support an actual rehabilitation design.

COST ANALYSIS

Cost data for rehabilitation and for replacement structures was obtained from several sources including manufacturers, state bridge offices, published cost data in periodicals and reports, and other in-house sources. All cost data is for the Washington, D. C. area, escalated to mid-year 1978.

Replacement Structure

For cost comparison purposes, replacement structures were assumed to have a total length equal to the existing bridge length. Usable roadway width was assumed to be 8.5m (28 feet) minimum with a 0.3048m (1-foot) curb on each side. Where the rehabilitated bridge had a roadway width greater than 8.5m (28 feet), the replacement structure estimate was based on the width of the rehabilitated roadway plus 0.6096 (2 feet) for curbs.

For uniformity, the replacement structure was assumed to be prestressed concrete with a reinforced concrete deck. The assumed numbe of spans was based on a span range of 18.3m (60 feet) to 27.4m (90 feet). Replacement structure costs were determined by applying unit cost to square feet of deck area in the new bridges.

Rehabilitated Structure

Construction costs have been estimated for the rehabilitation of each of the five bridges used to demonstrate rehabilitation techniques. Estimates were based on actual quantity takeoffs from the rehabilitation plans. Costs were based on unit price estimates or on an analysis of time and materials required to perform the work.

Cost Comparison

Comparing cost for rehabilitating each structure with the cost of replacing indicated that in every case except one, rehabilitation was less costly than replacement. This comparison of initial cost should not be construed to indicate that rehabilitation is the most cost effective course of action that should be followed. Other factors including assumptions made in developing replacement cost must also be considered. For each location a detailed analysis must be made that addresses the unique characteristics of each particular location including such items as:

- Long term cost including maintenance, amortization, and salvage
- Level of service provided to meet traffic demands
- Environmental constraints on constructing a replacement facility
- Availability of funds
- Delays caused by permit requirements and other issues

Of particular consequence is the initial cost figure quoted for replacement which was based on a bridge with the identical length as the existing, and a minimum cross section. In most instances in actual practice, the replacement structure will be required by geometric standards to be wider, and by hydraulic design to be longer and likely higher than the existing bridge. These can add substantially to the replacement structure cost.

A summary of cost data and other information regarding the bridges used for the demonstration of rehabilitation techniques is given in Table 6.

TABLE 6 - COST SUMMARY - DEMONSTRATION BRIDGES

Bridge Identification	Existing Bridge			Rehabilitated Bridge		Replacement Bridge		
	Type	Span(s)	Usable Roadway Width	Usable Roadway Width	Estimated Const. Cost	Span(s)	Roadway Width	Estimated Const. Cost
California 6-80	Concrete T-Beam	3 @ 30'	21'-6"	21'-6"	$ 10,000	1 @ 90"	28'-0"	$108,000
Tennessee 44-135-9.37	Steel Multiple Beam	2 @ 45'-0" 1 @ 55'-0" 1 @ 22'-0"	18'-0"	26'-0"	$151,000	2 @ 82'-6"	28'-0"	$198,000
Illinois 039-0027	Steel Multiple Beam	4 @ 40'-0" 1 @ 47'-0"	24'-0"	34'-0"	$327,000	3 @ 69'-0"	34'-0"	$304,000
Tennessee 9-8255-108	Timber Multiple Beam	6 @ 21'-0"	23'-0"	30'-0"	$101,500	2 @ 63'-0"	30'-0"	$164,000
Tennessee 21-4428-01	Steel Thru Truss	1 @ 120'	18'-0"	18'-0"	$ 81,500	2 @ 60'-0"	28'-0"	$144,000

Metric Conversion:

1' = 0.3048m

1" = 0.0254m

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

During the inspection phase of the study, over 140 bridges in five states were reviewed in the field. These inspections verified the need for a major undertaking to be made to correct existing serious situations.

The general condition of bridges in the states where inspections were conducted varied considerably from state to state. This was due, in part, to the degree of maintenance that bridges have received which varied among the states visited. Also, the frequency and type of inspection and bridge evaluations varied. Primary reasons reportedly were budgetary constraints that limited bridge maintenance and inspection programs.

While some of the states with colder climates which relied heavily on snow and ice control chemicals to maintain winter traffic had a greater bridge deficiency problem than others, some southern states had much the same problem in coastal areas with low level bridges. Salt contamination was equally damaging whether applied to the surface of the bridge or to the underside of the bridge. This was probably the most significant single contributor to bridge deterioration.

Rehabilitation techniques utilized in the nine states submitting materials were in many instances similar. There were, however, some concepts that had been developed for specific bridges that were unique.

Steel deck grid decking has had only limited use and there were considerable differences of opinion in the performance characteristics of the material. Metal plate decking has also had limited use but can be a cost-effective procedure for increasing capacity.

It was determined that geometric modification could be made in a cost-effective manner to improve safety and traffic capacity. With the exception of widening a through truss bridge, all other types of structures could be widened economically.

The demonstration plans developed for five bridge locations provide a detailed illustration of many of the techniques determined by the study to be effective in extending service life. Cost data for these is also furnished but must be incorporated with other equally important input data before a decision can be made to rehabilitate or to replace a given defective bridge.

While each bridge rehabilitation project has unique features, it was determined there are general concepts that can be compared and evaluated to determine the most practical technique to be used. Because of these unique features, there is always a need for creative thinking and the development of innovative procedures in bridge rehabilitation projects. New products and techniques are constantly being developed that could permit more efficient and longer lasting repairs to be made.

RECOMMENDATIONS

Because of the magnitude of the bridge problem as evidenced during the inspection phase of the project and further demonstrated in the federal inventory records, it is essential that the proper decisions be reached as to how to correct these problems. It is, therefore, recommended that additional research be conducted in the bridge rehabilitation area to aid in the decision-making process as well as to provide guidelines in the selection of materials and techniques to be used in the rehabilitation of deficient bridges.

Specifically, it is recommended that additional research should be conducted in the following areas:

- Develop new techniques for strengthening deficient bridges (continuation of Phase II of this project).
- Investigate the effectiveness of exterior reinforcing bonded to concrete members with adhesives and develop criteria for implementing the technique.
- Develop criteria for uniform posting of bridges found to be deficient.
- Develop parameters for prioritizing bridge repairs.
- Establish guidelines and procedures for deciding between rehabilitation and replacement.
- Review existing criteria for minimum acceptable bridge geometrics and develop guidelines for geometrics as related to volume and type of roadway usage.
- Evaluate lightweight deck system design criteria and long term performance.
- Expand concepts developed for "Improvement Factor" to include other techniques.

The deficiencies outlined and discussed in this report include many that are encountered in fixed spans ranging in length from short to medium. Development of rehabilitation procedures has covered many of these deficiencies although in some instances has been cursory and conceptual only. The ideas and suggestions as presented are intended to provide the basis for further development for application to a specific situation.

This study is a start in providing some of the information that is needed by engineers responsible for maintaining the nation's bridges. Additional research, some of which is defined above, is urgently needed so that the heavy expenditures that must be made over the next decade to resolve our bridge problems will be spent as prudently and as effectively as possible.

BIBLIOGRAPHY

Abbott, W. B., "Design and Construction of a Segmental Bridge," Public Works, pp. 44-46, July 1976.

"Baltimore Saves Old Arches with Epoxy Grout," Engineering News-Record, p. 15, July 29, 1976.

Bender, Brice, "Provisions for Possible Reconstruction of Decks on Segmental Box Girder Bridges," P.C.I. Journal, Vol. 22, No. 4, pp. 80-84, July/Aug. 1977.

Berger, R. H., and Beeson, D. H., "New Life for a Condemned Bridge," Public Works, April, 1975.

"Bridge Bearings," NCHRP Synthesis of Highway Practice 41, 62 pp., 1977.

"Bridge Inspection," Organization for Economic Cooperation and Development, Road Research Group, Paris, France, 133 pp. 1976.

"Bridge Inspector's Training Manual 70," U. S. Department of Transportation, Federal Highway Administration, Washington, D. C., Corrected Reprint 1971.

"Bridge Under Repair - but Open to Traffic," Welding Design and Fabrication, pp. 82-84, November 1976.

"Bridges, Blankets and Beads," AASHTO Quarterly, pp. 15-16, January 1977.

Byrd, Tallamy, MacDonald and Lewis, "Bridge Maintenance and Rehabilitation Program 1972-1982," for New York State Thruway Authority, May 1972.

"Dense Concrete Cuts Bridge Repair Bill," Engineering News-Record, pp. 93-95, April 14, 1977.

Evers, R. C., "Dense Mastic Surfacing of the Indian River Bridge, Port Carling, Ontario, 1975," Trinidad Lake Asphalt 3, pp. 9-13, January 1977.

Fleming, C. J., and King, G. E. M., "The Development of Structural Adhesives for Three Original Uses in South Africa," Bulletin Rilem No. 37, pp. 241-251, December 1967.

"40-year Old Bridge Deck Endurses," Highway Builder, p. 16, February 1977.

"Fresh Approach Used to Repair Bridge Deck," Public Works, pp. 46-47, January 1976.

"Glulam Bridge Systems Plans and Details," The American Institute of Timber Construction, 1975.

Godfrey, K. A., Jr., "Bridge Decks," Civil Engineering, pp. 60-65, August 1975.

Heins, Conrad P., University of Maryland, and Fout, William S. and Wilkison, Raymond T., Frederick County Roads Board, Frederick, Maryland, "Replacement or Repair of Old Truss Bridges."

"Hinged Cofferdams Save Time on Bridge Repair," Engineering News-Record, p. 14, September 4, 1975.

"Interim Specifications Bridges 1975," American Association of State Highway and Transportation Officials, Washington, D. C., 100 pp. 1975.

"Interim Specifications Bridges 1976," American Association of State Highway and Transportation Officials, Washington, D. C. 38 pp. 1976.

Irwin. C.A.K., "The Strengthening of Concrete Beams by Bonded Steel Plates," TRRL Supplementary Report 160UC, Department of the Environment, Transport and Road Research Laboratory, 8 pp. 1975.

"Manual for Maintenance Inspection of Bridges 1974," American Association of State Highway and Transportation Officials, Washington, D. C., 85 pp., 1974.

"Modules Used to Rebuild Bridge Deck," Engineering News-Record, p. 12, November 4, 1976.

"New Composite Deck Upgrades Old Bridge," Brochure, Two Ways to Build New Life Into Old Bridges, Nelson Stud Welding Division of Gregory Industries, Inc., no date.

"Open-Grid Decking Material 'Recycles' Old Bridges," Rural and Urban Roads, pp. 54-55, March 1976.

Packman, I. B., "Determining the Where and Why of Bridge Deterioration," Public Works, March 1972.

Pault, J.D., Gutkowski, R.M., Goodman, J.R., Bodig, J., "Composite Action in Glulam Timber Bridge Systems," Structural Research Report No. 17, Colorado State University, June 1977.

"Recording and Coding Guide for the Structure Inventory and Appraisal of the Nations Bridges," U.S. Department of Transportation, Federal Highway Administration, Washington, D. C., 31 pp., July 1972.

Reemsnyder, H. E., "Fatigue Life Extension of Riveted Connections," ASCE Proceedings, pp. 2591-2608, December 1975.

"Regular Spread Places Gussaphalt Bridge Deck," Roads and Streets, pp. 27-28, August 1975.

Scott, J. C., "'Assembly-Line' Deck Speeds Bridge Renovation," Better Roads, November 11, 1975.

"Standard Specifications for Highway Bridges," American Association of State Highway Officials, Washington, D. C., 469 pp., 1973.

"Steel Grid Decks 'Reclaim' Bridges in West Virginia," Ohio Contractor, p. 35, July 1974.

"Steel Grids Rejuvenate Old Bridge," Construction Advisor, pp. 18-19, May 1974.

Stratton, F. W., Alexander, Roger and Nolting, William, "Cracked Structural Concrete Repair Through Epoxy Injection and Rebar Insertion," 1977 Interim Report, Planning and Development Department, Kansas DOT, 42 pp., May 1977.

Taylor, P., "Overnight Repairs Keep Bridge Traffic on the Go," American City and County, pp. 29-31, July 1976.

"The Iowa Method of Concrete Bridge Deck Overlay Saves a Major Span," Constructioneer, p. 28, April 11, 1977.

"Vital Railway Bridge Saved," Brochure, SOILTECH, The Soils Technology Department of Raymond International Inc., pp. 8-9, No date.

Watson, Stewart C., "Some Refinements in Expansion Joint Systems," T.R.B. Record No. 535, pp. 51-51,1975.

Weeks, Kenneth R., Engineers, "Contract Documents for Bridge Street Bridge Renovation, Hampton, Virginia," City of Hampton Project No. 75-024, May 19, 1975.

Welsh, Joseph P., "Utilization of Synthetic Fabrics As Concrete Forms," paper presented at International Symposium on New Horizons in Construction Materials, Lehigh Uni rsity, November 1976.

Wiswell, G. C., Jr., "Underwater Repair and Protection of Piling and Foundations," presented at PILETALK Seminar, sponsored by Associated Pile and Fitting Corporation, March 19, 1976.

APPENDIX A Summary of Bridge Inspections In Participating States

Contract DOT-FH-11-9214

Extending the Service Life of Existing Bridges

Summary Report
PENNSYLVANIA FIELD INSPECTION

On June 1, 1977 members of the BTML inspection team met with representatives of the Pennsylvania Department of Transportation in Harrisburg, Pennsylvania to discuss the FHWA research project and identify those districts in the state which have the greatest number of candidate bridges for rehabilitation. Consideration was given to the number and type of bridges requiring rehabilitation in each district in an effort to choose districts with bridges representative of the deficiencies experienced statewide. Of the 12 Pennsylvania districts, those chosen for week-long field inspections were: Districts 5, 6 and 11 with headquarters in Allentown, St. David's and Pittsburgh, repsectively. These three districts offered the widest coverage of bridge types as well as deficiencies.

During the meeting in Harrisburg, bridge rehabilitation procedures were discussed with Mr. B. F. Kotalik, Chief Bridge Engineer, Mr. H. P. Koretsky, Bridge Engineer (Prestressed Concrete Structures) and Messrs. S. R. Simco, K. C. Patel, and N. Wood, Bridge Engineers. In addition to the discussion concerning rehabilitation techniques, Mr. Koretsky furnished locations of defective prestressed concrete bridges in each of the three districts. Construction tolerances and quality control of prestressed concrete were discussed as they relate to current deficiencies.

On June 7 and 8 meetings were held in Districts 6 and 5 respectively. In District 6, Mr. Paul Peterson, District Bridge Engineer, P. Ressler and B. Wager furnished lists of deficient bridges and their locations for the field tour the following week. Mr. Ronald Tirpak, District 5 Bridge Engineer, provided a similar list of bridges requiring rehabilitation in his district. In both districts, copies of the latest available bridge inspection reports were obtained to be included in the field inspection files.

During the week from June 13 through June 17, 18 bridges were inspected in District 6:

5 reinforced concrete arch bridges
3 steel through truss bridges
2 steel through girder bridges
3 steel I-beam stringer bridges
2 prestressed concrete multi-beam bridges
2 reinforced concrete T-beam bridges
1 reinforced concrete frame bridge

During the week from June 20 through June 24, 15 bridges were inspected in District 5:

3 steel through girder bridges
3 steel through truss bridges
5 steel I-beam stringer bridges
1 steel deck truss bridge
1 reinforced concrete arch bridge
1 reinforced concrete T-beam bridge
1 prestressed concrete multi-beam bridge

On July 5, 1977 the BTML inspection team met with Mr. Nalin Udani, District 11 Bridge Engineer, to plan and review the field inspection tour in District 11. Following that meeting, in which bridge rehabilitation techniques were also discussed, on July 6, 7, and 8, seven bridges were inspected in District 11:

3 steel I-beam stringer bridges
2 steel through girder bridges
1 steel deck girder bridge
1 prestressed concrete multi-beam bridge

For each bridge, a visual inspection was made of the bridge's major load-carrying elements and supporting structures, i.e., approaches, approach spans, and earth embankments, etc. Black and white photographs and color slides were taken to document the condition of the structures. Narrative reports were prepared for each bridge describing type of bridge, geometric configuration of the structure and its approach roadways, condition of major load-carrying elements and rehabilitation techniques which may have been used. The narrative report, photographs, slides and copies of the latest inspection report furnished by the district are included in a file prepared for each bridge inspected.

Many of the deficiencies observed in Pennsylvania were similar to those in bridges of other states. Among them are:

1. Many of the bridges inspected were more than 50 years old; most were geometrically deficient, that is, narrow roadways, insufficient vertical and horizontal clearances and poor approach alignments resulting in inadequate sight distances.

2. Deterioration in conventionally reinforced concrete structures appeared to be caused primarily by the elements, free-thaw cycles and the corrosive effects of de-icing salts. In these structures, typically, concrete cover over reinforcing bars had spalled off exposing the rebars to water. In these cases the reinforcement was severely corroded and scaling resulting in section loss.

3. Likewise, steel structures exposed to the weather have experienced severe corrosion and section loss. In many instances the webs of steel I beams have corroded through and the flange cross sections have been seriously reduced.

4. Poor deck drainage contributes significantly to the deterioration of both concrete and steel bridges. Many bridges did not have a drainage system to remove water (many times containing corrosive salts) from the deck surface. In some cases runoff is deposited directly on the load-carrying elements; in others, scuppers are completely filled with debris and inoperable.

5. Many bridges have poor decks which in some cases adds significantly to the impact to load carrying elements.

6. Some exposed timber elements, both treated and untreated, have experienced decay.

7. Many substructures, especially on older pin-connected truss bridges, are constructed of stone. In these, typically mortar joints between stones had deteriorated and undermining at the base was prevalent in many.

8. Bearings and deck joints in concrete and steel bridges in many cases require rehabilitation. Bearings are frozen by corrosion prohibiting movement for temperature expansion and contraction. Deck joints in some cases were filled with debris and/or overlayed with asphalt, likewise prohibiting necessary movement.

9. Vehicle impact on structural members, particularly steel trusses, has impaired the load-carrying capacity of many bridges. Impact is also very noticeable in approach roadway and bridge guard rails.

10. Settlement of earth fills at bridge approaches and the undermining of supporting structures due to settlement and/or stream scour were also deficiencies of several bridges.

11. In prestressed concrete multibeam bridges, particularly, prestressing wire strands in some cases are exposed and some are severed. Poor quality control resulting in insufficient concrete cover over the strands seems to be the cause of this condition.

12. Cracking in reinforced concrete arch bridges seems to be a reoccurring problem in this type of structure.

Rehabilitation techniques which have been placed in effect in Pennsylvania include:

1. On concrete decks which are replaced, the top slab reinforcement is epoxy-coated.

2. In lieu of Transflex or Wabolflex deck joints in replaced deck slabs, PENNDOT is specifying metal "tooth-type" joints with a drainage collection system beneath the joints.

3. A steel open grid deck has been used on some steel through truss bridges.

4. In some cases a protective reinforced concrete "collar" has been placed around stone substructures.

5. Cracks in reinforced concrete, and in particular arch bridges, have been sealed with epoxy. Epoxy mortar patching has been used in spalled areas.

6. In some cases decayed timber bents have been replaced in kind or with steel or concrete substructures.

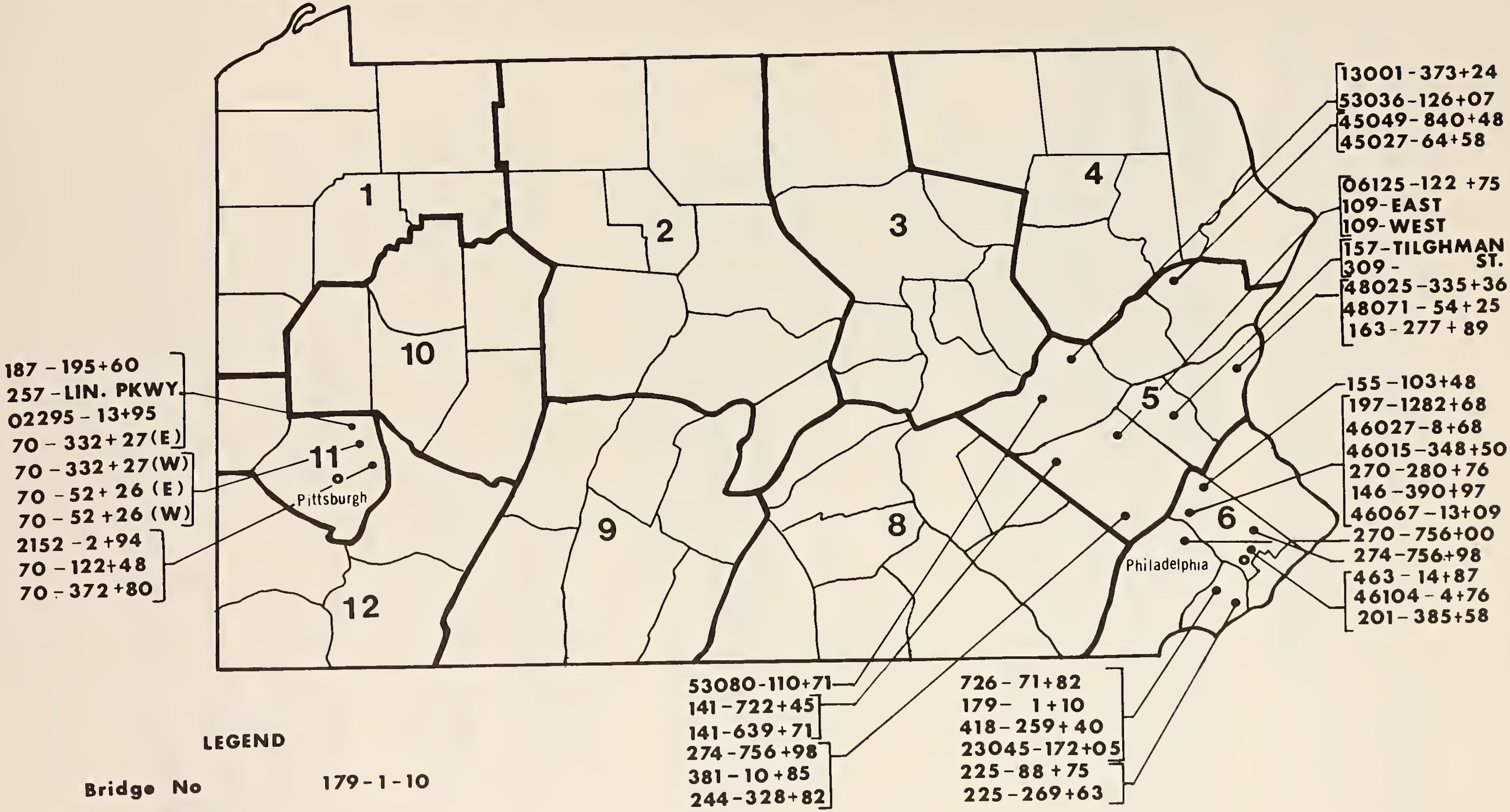
7. Effort has been made to repair defective prestressed box beams in place with an epoxy mortar mixture covering.

8. Gunnite has been used to restore cover on concrete structures and provide cover for stone substructures.

It should be noted, however, that in the June 1 meeting in Harrisburg, it was reported that PENNDOT has not developed any particularly unique rehabilitation techniques and that due to lack of funds routine maintenance was not performed on bridges in the state.

Due to the cooperation received from PENNDOT officials, 40 bridges were inspected during the Pennsylvania inspection tour. Information obtained has added significantly to the research.

PENNSYLVANIA INSPECTION TOUR



LEGEND

Bridge No	179-1-10
Bridge Location	•
City	∘
County Line	———
D.O.T. District No.	5
D.O.T. District Line	——— (heavy)

SUMMARY REPORT
FLORIDA FIELD INSPECTION

The inspection team met with Florida DOT personnel in Tallahassee on February 28 to plan the inspection tour. Existing bridge files, inspection reports and computer printouts were reviewed and an inspection tour developed that would cover most types of defective bridges within a reasonable geographic distribution. A total of 19 bridges were inspected ranging from very small single span bridges to multi-span high-level bridges several miles in length. A map showing the approximate locations of the structures is attached.

Following is a breakdown of the bridges inspected.

District 1 - Tampa Area - 8 Bridges

2 - Timber
1 - Multiple Concrete Beam
1 - Multiple Steel Beam
1 - Post Tensioned Concrete Beam Approach Span and Multiple Steel Deck Girder Main Span
1 - Post Tensioned Concrete Beam Approach Span and Steel Deck Girder and Steel Truss Main Span
1 - Post Tensioned Concrete Beam Approach Span and Steel Double Leaf Bascule Span
1 - Multiple Concrete Beam Approach Span and Steel Double Leaf Bascule Span

District 2 - Tallahassee Area - 1 Bridge

Multiple Concrete Beam Approach Span and Steel Truss Main Span

District 3 - Tallahassee Area - 2 Bridges

2 - Multiple Steel Beam--Timber Deck

District 4 - Ft. Pierce-Palm Beach Area - 8 Bridges

4 - Precast Concrete Slab
1 - Timber
1 - Steel Pony Truss
1 - Multiple Concrete Beam Approach Span and Steel Single Leaf Bascule Main Span
1 - Timber Approach Span and Steel Pony Truss Main Swing Span

Detailed inspections were conducted of each of these structures. The inspection team was assisted by Florida DOT inspectors who also furnished facilities for obtaining access to the structures over larger bodies of water. Arrangements were also made by Florida DOT to open movable spans to facilitate inspection. Copies of existing inspection reports for each of these bridges were obtained along with computer data developed to establish load limits.

A comprehensive narrative report has been prepared for each structure. This report is supplemented by numerous photographs.

The major deficiencies in these bridges can be summarized as follows:

1. <u>Concrete elements</u>

   Spalling, re-bar exposure and loss of structural capacity. Due primarily to salt spray from sea water.

2. <u>Timber Elements</u>

   Weathering, marine borers, rotting. Loss of structural section of piles at water line from wetting-drying cycle. Rotting of beams and bulkheads.

3. <u>Steel Elements</u>

   Serious corrosion in structural members resulting in loss of section due primarily to lack of preventative maintenance. Deterioration of bearing assemblies for similar reasons. Serious corrosion from salt water splash on movable spans. Corrosion of pile tips exposed due to scour.

Rehabilitation techniques predominantly used by the state include:

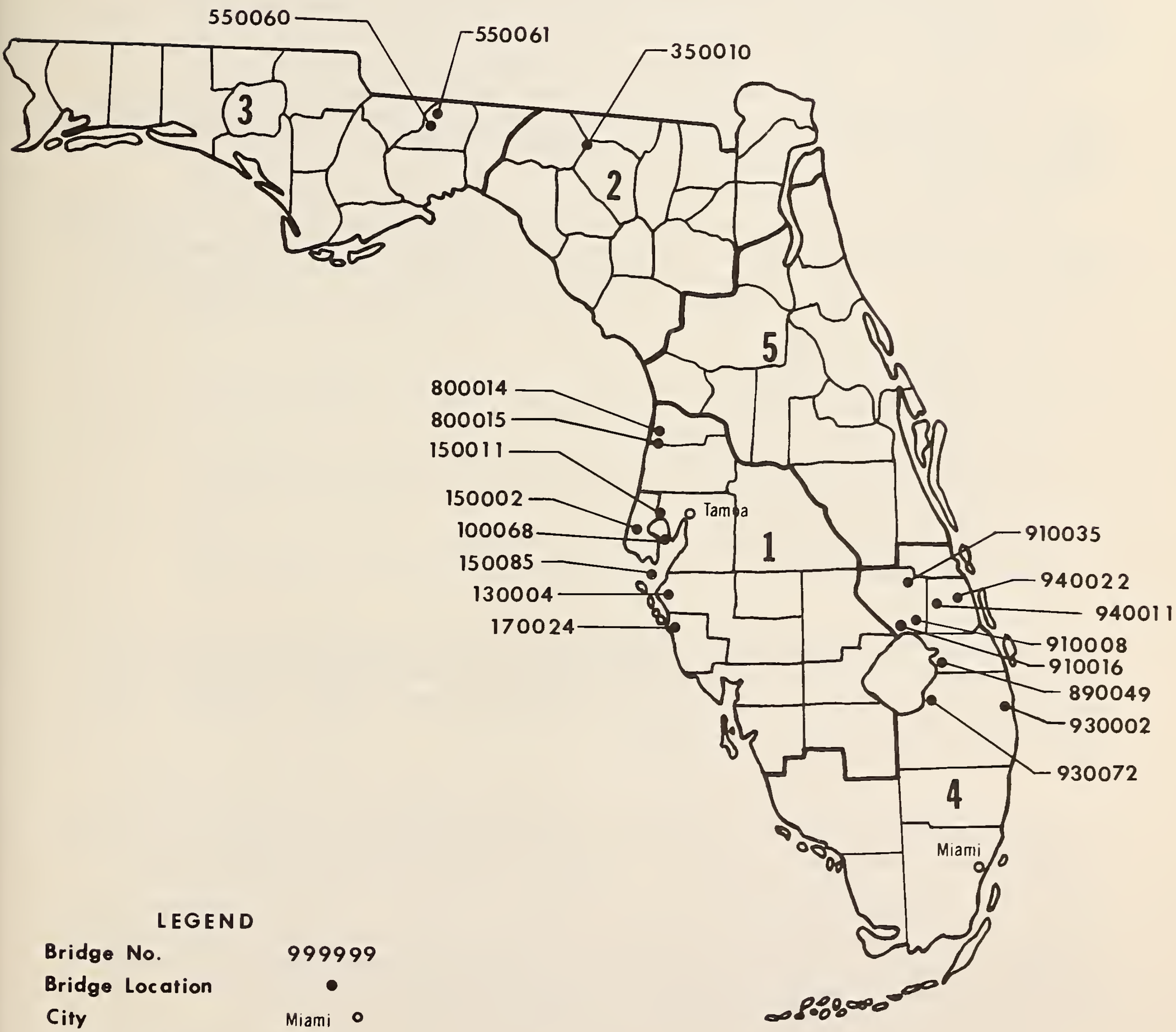
1. Erection of crutch bents to replace defective piles.
2. Addition of pony bents to increase capacity of support bents.
3. Gunnite spalled pier caps and post tension to replace loss in re-bar strength.
4. Epoxy inject cracks in concrete members.
5. Reinforce steel members by addition of material attached by welding.
6. Jacket corroded steel piles and deteriorated concrete piles.
7. Add new bents at mid-point of span to reduce span length by 50%.
8. Epoxy seal of concrete members susceptible to salt water splash.

9. Replace specific structural elements (beams, slabs, piles, etc.) deteriorated beyond repair.

10. Tie back abutments with wrapped cable and dead man.

The cooperation of the Florida DOT was excellent. Because of this, the inspections were carried out in an efficient manner and the goal for the number of structures inspected (15) was exceeded.

FLORIDA INSPECTION TOUR



LEGEND

Bridge No.	999999
Bridge Location	•
City	Miami ○
County Line	———
D.O.T. District No.	1
D.O.T. District Line	▬▬▬

SUMMARY REPORT
ILLINOIS FIELD INSPECTION

On May 9, 1977 members of the BTML inspection team met with representatives of the Illinois Department of Transportation to formulate plans for the field inspection tour in Illinois. Lists of deficient bridges were obtained for each of two districts selected for week-long tours: District 4 in Peoria, Illinois and District 9 with headquarters in Carbondale Illinois. From the lists furnished representative structures for both bridge type and deficiencies were selected.

Two bridges each in Districts 1, 3, and 6 were inspected on May 9 and 10 1977. During the week of May 16 through May 20, fourteen bridges were inspected In District 4. Sixteen bridges were inspected in District 9 from May 23 through May 27.

The thirty-six bridges inspected included many bridge types. In some cases, where a single span or several spans had been replaced, there were two structure types for a single bridge. Following is a breakdown of bridge types.

8 - Concrete T-beams
8 - Steel pony truss
15 - Steel through truss
6 - Rolled beam stringers
2 - Precast adjacent box beam
1 - Concrete thru girder
1 - Concrete solid slab
1 - Multiple steel girder
1 - Steel through girder
2 - Draw spans
1 - Lift span

Detailed inspections were conducted for each structure, photographs were taken, notes and sketches recorded in field books and narrative reports describing bridge types and discussing bridge deficiencies were prepared. In addition to these reports, copies of the latest Illinois DOT Bridge Inspection Report were obtained for each bridge.

Illinois Department of Transportation bridge maintenance engineers contributed greatly to the data gathering effort in Illinois. Besides identifying bridges in Illinois to be included in field inspections, Mr. Gayle E. Lane, state bridge maintenance engineer, presented a slide review of bridge deficiencies and rehabilitation techniques used in Illinois. He furnished standards for strengthening deficient truss bridges. During the two weeks that the inspection team was in District 4 and District 9, he accompanied the team for several days identifying problem areas and commenting on measures which IDOT is developing to rehabilitate and strengthen deficient structures.

Mr. Charles Glick, District 4 Bridge Maintenance Engineer, accompanied the team throughout the week of May 16 through May 20. Because of his knowledge of the bridges in his district he contributed immeasurably to the research effort. Besides his expert testimony, Mr. Glick furnished inspection reports, District

4 Bridge Replacement Data Sheet, and a graphical representation of District 4 Bridge Replacement Statistics. In addition he gave the team a slide presentation depicting maintenance and rehabilitation on bridges in the district.

Mr. Orville Hake, District 9 Bridge Maintenance Engineer, provided assistance during the week of May 23 through May 27 by identifying candidate bridges in the district and furnishing bridge inspection reports.

Following is a partial list of deficiencies observed:

1. Perhaps the most serious problem with the bridges inspected in Illinois and in particular District 4, is deterioration of concrete due to deicing salts, water, and freeze-thaw cycles. While the problem is most evident in concrete decks of steel and concrete bridges, the deterioration occurred in most concrete substructures and the load carrying superstructure elements of concrete bridges. In numerous locations, concrete cover over reinforcing bars in T beams and girders had spalled leaving bars exposed, corroded and scaling. Pier nosings are also extremely susceptible to this condition. Numerous examples were observed where ends of piers had sheared due to exposure to the deteriorating elements, leaving bearings and superstructure supports in precarious positions. Poor deck drainage and scuppers terminating above the bottoms of stringers and beams aggravate the problem.

2. Poor bridge decks in many cases are responsible for increased impact loads to superstructures elements, accelerating their deterioration.

3. Vehicle impact and damage from oversized loads is a serious problem in Illinois as it is in other states visited.

4. Clogged and inoperable deck joints and expansion bearings frozen by corrosion contributed to the poor condition of many bridges.

5. Numerous instances were observed where earth retaining structures have moved and rotated causing distress in bridge superstructures.

6. In a few cases, racking of the bridge on its bearings has occurred; the bridge superstructure has rotated in a horizontal plane about a point near the center of the bridge.

7. Timber elements of many bridges have rotted.

Rehabilitation techniques observed in Illinois include:

1. Strengthening through and pony trusses by replacing and/or adding section to existing truss members appeared to be a fairly common practice.

2. When bridge decks on steel truss bridges are replaced, shear studs are added to the stringers and floor beams and coverplates are added to increase the capacity of the floor system.

3. Replacing deck joints and bridge bearings on steel truss bridges has relieved stresses occurring in structures in which movement, primarily due to temperature and earth fills, has been prevented.

Similarly pavement relief joints in bridge approach slabs have allowed movement to take place without distressing the bridge superstructure.

4. In bridges where supersturctures are replaced, substructures have been salvaged to provide support for new bridge superstructures. Common practice is to replace through trusses with adjacent prestressed box beams. Abutments are widened with a hammerhead cap, existing piers are widened and reused, and new piers are added as necessary.

5. Gunnite has been used to restore concrete cover to deteriorated concrete bridge piers, abutments and girders. This technique, while apparently successful in some applications, is suspect because water is sometimes retained between the gunnite and the old concrete surface accelerating deterioration of reinforcement bars due to corrosion.

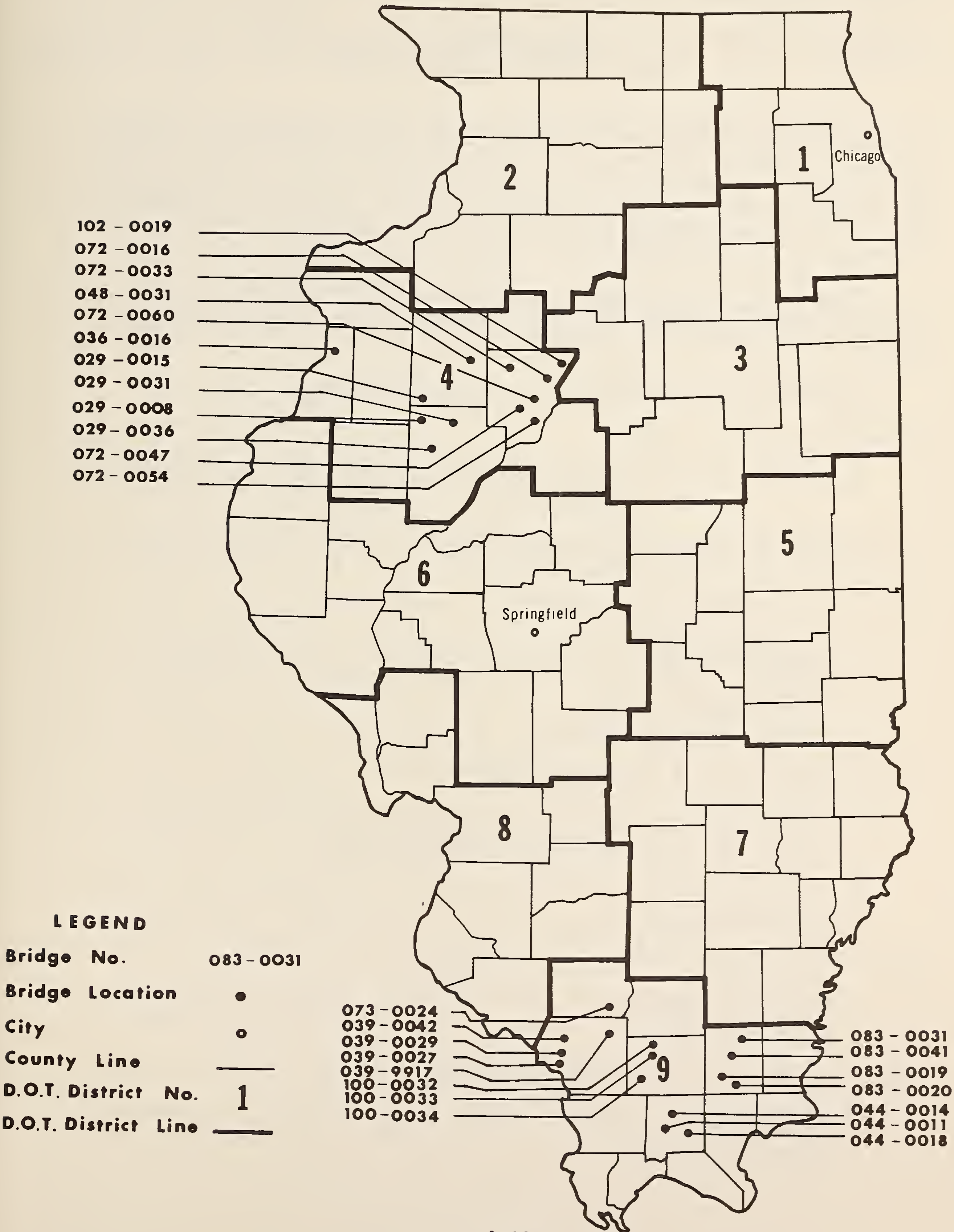
6. On many bridges, scuppers have been extended to a line below the bottom of the superstructure, thus eliminating brine deposits directly on stringers and girders.

7. In one instance the nosings on concrete piers are banded with steel plates presumably to maintain the integrity of the concrete cap.

8. Sections of deteriorated concrete deck have been replaced particularly at bridge edges and deck joints.

Exposure to many bridge types and deficiencies along with the expert testimony of Illinois DOT bridge maintenance engineers contributed greatly to the success of the Illinois inspection tour. Information obtained in Illinois adds significantly to the research.

ILLINOIS INSPECTION TOUR



Contract No. DOT-FH-11-9214
Extending the Service Life of Existing Bridges

SUMMARY REPORT
CALIFORNIA FIELD INSPECTION

The inspection team met with California DOT personnel at Sacramento, California on March 14th and 15th to review reports of deficient bridges and to plan the inspection tour. Arrangements were made to have department personnel meet the team at various locations throughout the state to assist with the inspections and to provide equipment needed to reach the various parts of the structures.

A total of 20 bridges were inspected. Included were steel, timber, and concrete structures of varying size and configuration. A map is attached, showing the location of these bridges.

Following is a breakdown of the bridges inspected:

Sacramento Area - 2 bridges

District 10 -- 1 - Steel through truss swing span--steel and timber approach spans

District 1 -- 1 - Concrete T-beam

Redding Area - District 2 - 6 Bridges

1 - Concrete T-beam
2 - Timber stringer
1 - Steel through truss
1-- Steel deck truss
1 - Steel rigid frame girder

Santa Cruz Area - District 4 - 6 Bridges

1 - Steel pony truss with timber approach spans
1 - Steel deck arch with timber approach spans
2 - Concrete slab
1 - Concrete T-beam
1 - Concrete girder

San Luis Obispo Area - District 5 - 3 Bridges

1 - Steel through truss
2 - Timber stringer

Santa Barbara Area - District 5 - 3 Bridges

1 - Steel arch
2 - Concrete T-beam

Detailed inspections were made of each of these bridges. A narrative report was made for each location in which the structure type is described and deficiencies discussed. This report is documented with photographs illustrating the various deficiencies encountered. This on-site report is supplemented by a copy of the inspection report obtained from the California Department of Transportation.

The major deficiencies encountered in the bridge inspection are summarized as follows:

Concrete Elements

Summarizing deficiencies observed during the inspection:

1. Concrete deterioration and exposure of reinforcing steel is the most recurring problem. This is caused by weathering and aging, poor quality of initial construction, exposure to brine water and stream water.

   Much of the deterioration caused by brine water is directly related to poor deck drainage.

2. Corrosion of steel bridge elements due to old and partially ineffective paint system.

3. Weathering and rotting of timber bridge components caused by exposure to the elements and by varying stream surface elevations.

4. Substructure settlement and eroding approach embankments.

5. Collision by vehicles damaging bridge components, particularly steel superstructure truss members.

6. Present service loads exceeding design loads.

7. Joints and bearings inoperable due to corrosion and debris buildup.

8. Substandard horizontal and vertical alignments, narrow widths and insufficient vertical clearances.

Rehabilitation techniques observed include:

1. Timber piling replaced with concrete jacket in concrete pedestals or with steel "H" piling.

2. Supplemental supports to shorten spans or to support undermined bridge foundations.

3. Mortar-filled bags placed to stabilize embankments.

4. Remove knee braces at portal frames and replace with shallow frame to increase vertical clearance.

5. Whaler beams and tiebacks at abutments to resist longitudinal movement.

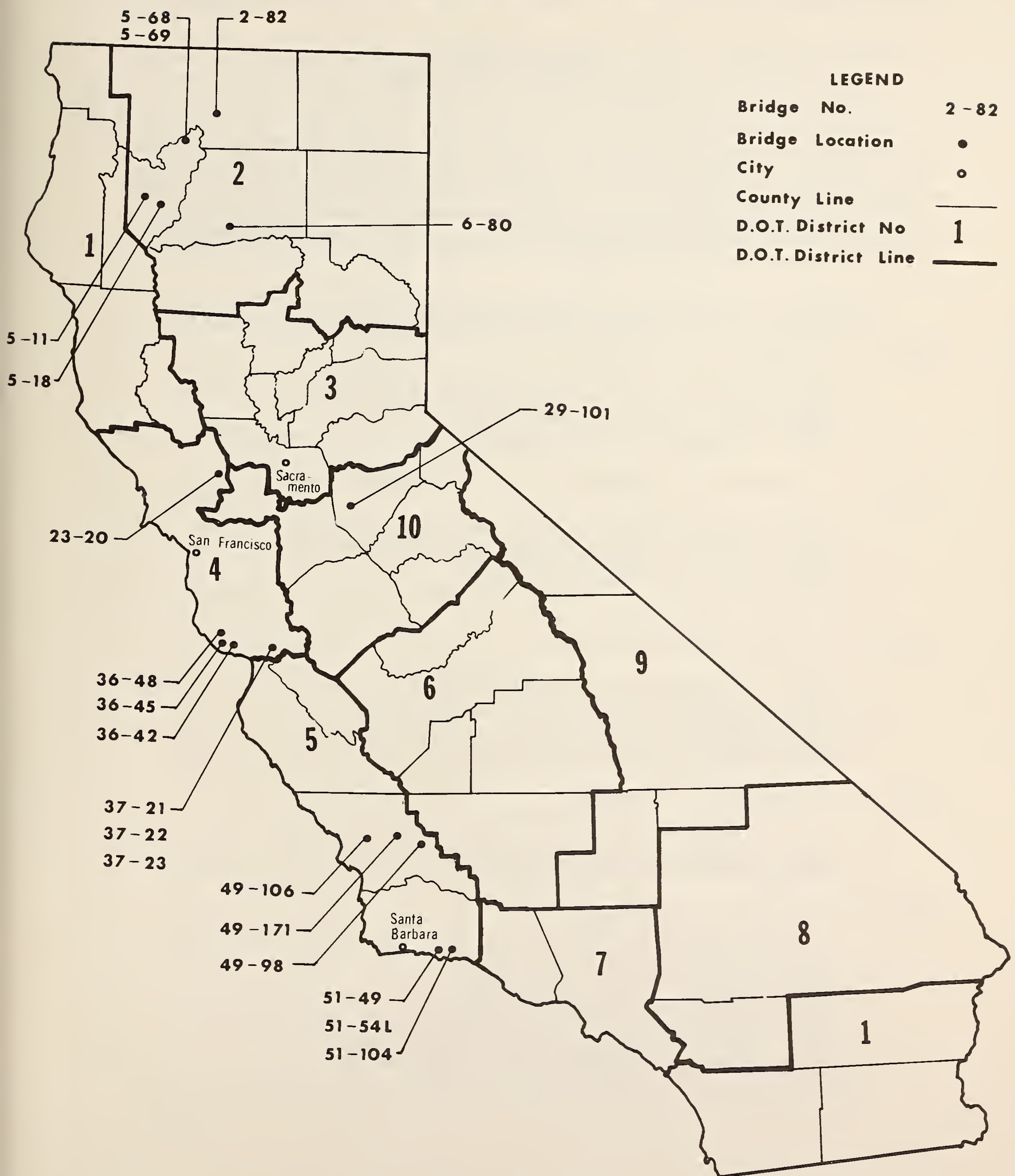
6. Add scuppers to facilitate surface drainage collection.

7. Bridge widening by extending substructures and adding additional stringers.

Through the efforts and assistance of personnel with the California Department of Transportation, the inspection tour proceeded smoothly without incident. Valuable support was furnished by providing ladders and other equipment. Department personnel escorted the inspection team to bridge sites and contributed important facts pertaining to the condition of the bridges.

The California inspection tour added to the research effort in that a representative sampling of various types of bridges which illustrated structural deficiencies and operational inadequacies of structures throughout the state were inspected. The variety of bridge types and problems encountered are typical of California and other western states.

CALIFORNIA INSPECTION TOUR



SUMMARY REPORT
TENNESSEE FIELD INSPECTION

The inspection team met with Tennessee DOT personnel in Nashville on Monday April 11, 1977 to coordinate the bridge inspection tour. Existing bridge inspection report records and printout files were reviewed and an itinerary developed to review a typical sampling of deficient structures in the state. Twenty-four bridges were inspected. A map is attached showing the location of these bridges.

Following is a listing of the bridges inspected:

Region 3 - Nashville - 4 Bridges

- 2 - Steel pony truss with concrete decks
- 1 - Steel pony truss with timber deck
- 1 - Steel through truss with timber deck

Region 1 - Knoxville - 4 Bridges

- 1 - Steel Multiple I-beam stringer with concrete deck
- 1 - Steel Multiple I-beam stringer with timber deck
- 1 - Steel pony truss with timber deck
- 1 - Concrete girder

Region 1 - Johnson City - 6 Bridges

- 2 - Steel through truss with concrete decks
- 2 - Timber Multiple stringer with timber decks
- 1 - Steel Multiple I-beam stringer with timber deck
- 1 - Steel pony truss with concrete deck

Region 2 - Cookeville - 3 Bridges

- 2 - Steel Multiple I-beam stringer with concrete deck
- 1 - Steel through truss with metal deck

Region 4 - Jackson - 7 Bridges

- 2 - Timber stringer with timber decks
- 1 - Steel pony truss with timber deck
- 1 - Steel pony truss with metal deck
- 1 - Steel through truss with concrete deck
- 1 - Steel Multiple I-beam stringer concrete deck
- 1 - Steel Multiple girder bridge with timber deck

Detailed field inspections were conducted for each of these structures. Photographs were taken and narrative reports prepared to document the condition of each bridge.

Tennessee DOT personnel assisted the efforts of the inspection team by accompanying them to bridge sites and furnishing ladders and boats where needed. Bridge inspection reports and printout data were provided by the Tennessee DOT. The assistance furnished by Tennessee DOT proved invaluable to the data gathering effort.

Summarizing various deficiencies found at the Tennessee bridge sites:

1. Corrosion of metal elements related to poor bridge drainage and lack of paint.

2. Overloading light structural design. At many locations heavily loaded vehicles crossed posted bridges at the time of inspection.

3. Weathering of timber elements especially in superstructures and rotting in substructures.

4. Concrete deterioration with cracking and spalling.

5. Joints and bearings rendered inoperable from corrosion or debris.

6. Trusses damaged due to collision from vehicles

7. Settlement of substructures and stream scour.

8. Exposure of steel piles with resulting corrosion.

Rehabilitation techniques used in Tennessee include:

1. Replacement of timber decking and deteriorated timber stringers. Timber stringers which could be reused were turned over, the former top now being the bottom.

2. Replace with metal decking and asphalt wearing course.

3. Add new superstructures with wider roadway to existing substructures or to widened substructures.

4. Widen truss bridges by adding floor beams, widening the substructures, adding stringers, and placing new floor beams.

5. Increase load capacity of trusses by welding steel sections to truss members and/or shortening spans by intermediate bents.

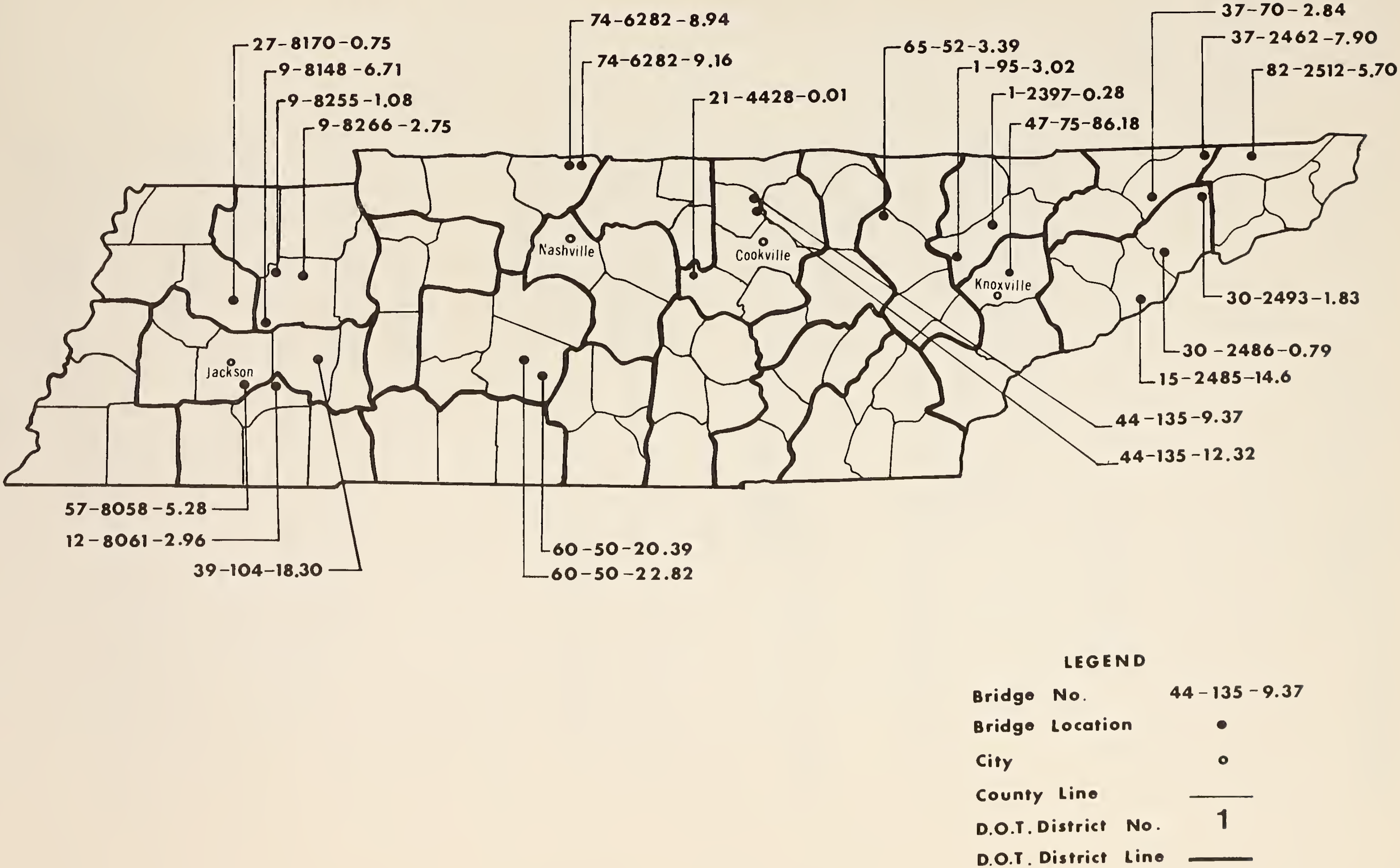
6. In one instance, steel angles with a plate attached were bolted to the bottoms of reinforced concrete girders to transfer bearing stresses from the concrete girders to the steel angles and plate.

7. Timber blocks placed below stringers to transfer reactions to floor beams where clip angle connections have failed.

8. Crib walls placed at end bents to retain approach fills and prevent undermining of bridge substructures.

In conclusion, it is felt that the Tennessee bridge inspection tour added significantly to the research. A variety of deficiencies were viewed in many different types of bridges. The structural inadequacies and functional problems of Tennessee's bridges are typical of those found throughout the rest of the southeast and perhaps the nation. Data gathered in Tennessee will contribute to the basis of information obtained in the inspection phase of the research upon which rehabilitation techniques will be developed during later phases in the project.

TENNESSEE INSPECTION TOUR



APPENDIX B Bridge Deficiency Catalogue and Photo Log of Deficiencies

BRIDGE TYPE AND DEFICIENCY CATALOGUE

SUPERSTRUCTURE

I. PRIMARY SUPPORT SYSTEM

A. Steel

1. Multiple Beam or Girder (Simple or Continuous Span).

   Paint deterioration.
   Flange and/or web corrosion.
   Bearings inoperable.
   Collision damage fascia stringers.
   Stiffener and other detail corrosion.

2. Thru Girder or Twin Deck Girder (Simple or Continuous Span).

   Paint deterioration.
   Flange and/or web corrosion.
   Bearings inoperable.
   Connections, stiffener and miscellaneous detail corrosion.
   Bracing member corrosion and damage.
   Collision damage - Girder, kneebraces.

3. Deck Truss, Thru Truss, Pony Truss (Simple Span).

   Paint deterioration.
   Flange and/or web corrosion - Stringers and floor beams.
   Bearings inoperable.
   Truss member corrosion - Section loss.
   Collision damage - Portal, truss member, sway frame.
   Bracing member corrosion, failure.
   Connection corrosion.

B. Concrete

1. Slab (Simple or Continuous Span).

   Surface delamination.
   Surface spall--Rebar exposure and corrosion.

2. Multiple Beam and T Beam (Simple or Continuous Spans).

   Web cracks.
   Surface spall - Rebar exposure and corrosion.
   Collision damage.
   Bearings inoperable.

3. Prestressed or Post Tensioned Beams (Simple or Continuous Spans).

   Surface spall - Tendon exposure.
   Web and flange cracks.
   Bearings inoperable.

C. Timber

1. Multiple Stringer (Simple or Continuous Spans).

Timber rot, surface weathering and splits.
Bearings inoperable.

II. DECKS

A. Reinforced Concrete

Wearing Surface Breakdown.
Delamination.
Surface Spall and Cracks.
Joints Inoperable.

B. Open Grid Steel

Connection Failure.
Corrosion.

C. Corrugated Metal

Wearing Surface Breakdown.
Protective Coating Deterioration.
Corrosion.

D. Timber

Wearing Surface Breakdown.
Weathering - splits, cracks and rot.
Failure of Connections to Support Members.
Joints Inoperable.

SUBSTRUCTURE

I. ABUTMENTS

A. Masonry

Mortar Deterioration.
Bearing Seat Deterioration.
Scour.

B. Concrete, Stub/Spill Thru

Cracking and Surface Spall.
Bearing Seat Deterioration.
Settlement and/or Rotation.
Back wall Failure.
Erosion - Scour.

C. Concrete, Full Height

Cracking and Surface Spall
Bearing Seat Deterioration.
Settlement and/or Rotation.
Backwall Failure.
Erosion/Scour.

D. Timber - Bulkhead

Decay - Rot
Insect Infestation.

II. PIERS

A. Reinforced Concrete - Hammerhead Solid Wall

Cracks
Bearing Seat Deterioration.
Pier Nose Deterioration.
Settlement and/or tilting.
Scour.

B. Reinforced Concrete - Rigid Frame

Cap Bm. Spall - Rebar exposure and corrosion.
Cracking in Cap.
Bearing Seat Deterioration.
Column Concrete Deterioration.
Settlement and/or Tilting.

C. Masonry

Mortar Deterioration
Erosion/Scour.

III. BENTS

A. Timber Piles & Cap

Pile Decay - Rot
Cap Weathering - Splits, cracks.
Insect Infestation - Marine borers.
Scour.

B. Concrete Pile & Cap

Longitudinal Cracks in Pile.
Bearing Seat Deterioration.
Pile Spall - Rebar exposure and corrosion.
Cap Spall - Rebar exposure and corrosion.
Collision Damage.
Scour.

C. Steel H Pile - Concrete Cap

Pile Corrosion - Section loss.
Cap Spall - Rebar exposure and corrosion.
Bearing Seat Deterioration.
Scour.

MISCELLANEOUS

A. Drainage

Inadequate Deck Drainage (Number and/or size of scuppers).
Drainage Discharge on Primary Members.
Snow and Ice Storage in Contact with Primary Members.
Leaking Deck Joints.
Control Erosion at Discharge Point.

B. Geometrics

Inadequate Roadway Width.
Inadequate Vertical Clearance.
Approach Alignment Poor.

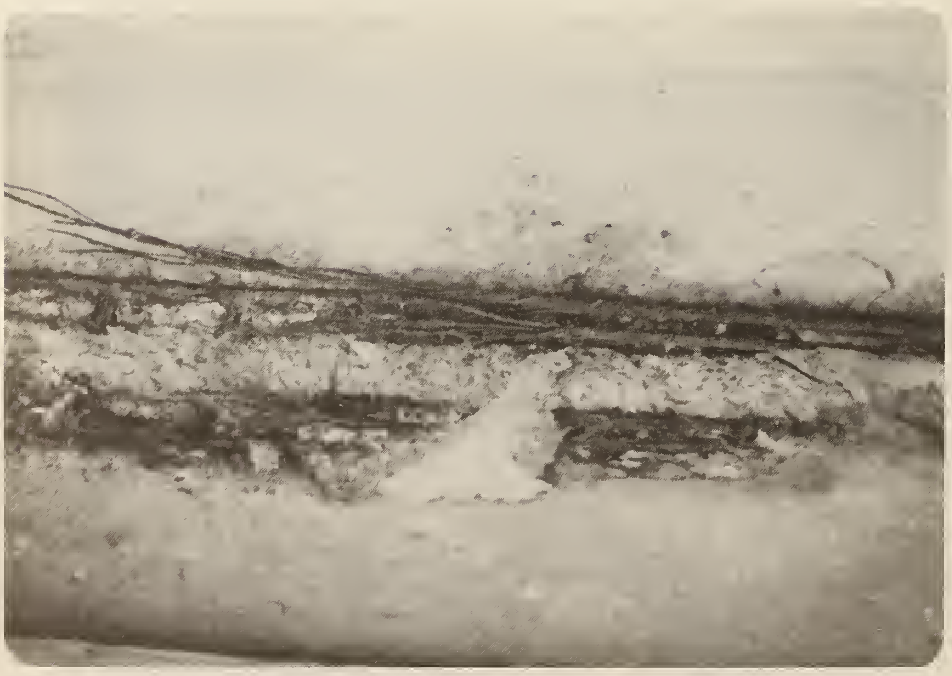
C. Safety

Inadequate Railing.
Alignment - Site distance.
Roadway Surface Deterioration.

Steel Girder Bearing
Severe Rocker Lean

Steel Lateral Bracing
Severed Member

Timber Deck
Timber Deterioration



Prestressed Concrete Beam
Concrete Spall-Broken Strands

Concrete Pile Deterioration
(Note "Crutch Bent" installed to replace pile)

Concrete Pier Cap
Exposed Re-bars and deteriorated concrete

Concrete T-beam
Exposed Re-bar and Concrete deterioration

Concrete Beam
Cracked Web at Bearing

Steel Multiple Beam Bridge
Flange and Web Corrosion

Steel Bracing
Gusset Plate Corrosion

Steel Guardrail
Inadequate

Inadequate Roadway Width
2-lane Approaches, 1-lane Bridge

Concrete Pile
Longitudinal Cracks

Solid Wall Concrete Pier
Bearing Seat Deterioration

Timber Pile Cap
Cap Weathering-Splits, Cracks

Solid Wall Concrete Pier
Pier Nose Deterioration

Timber Pile
Decay - Rot

Timber Abutment Bulkhead
Decay - Rot

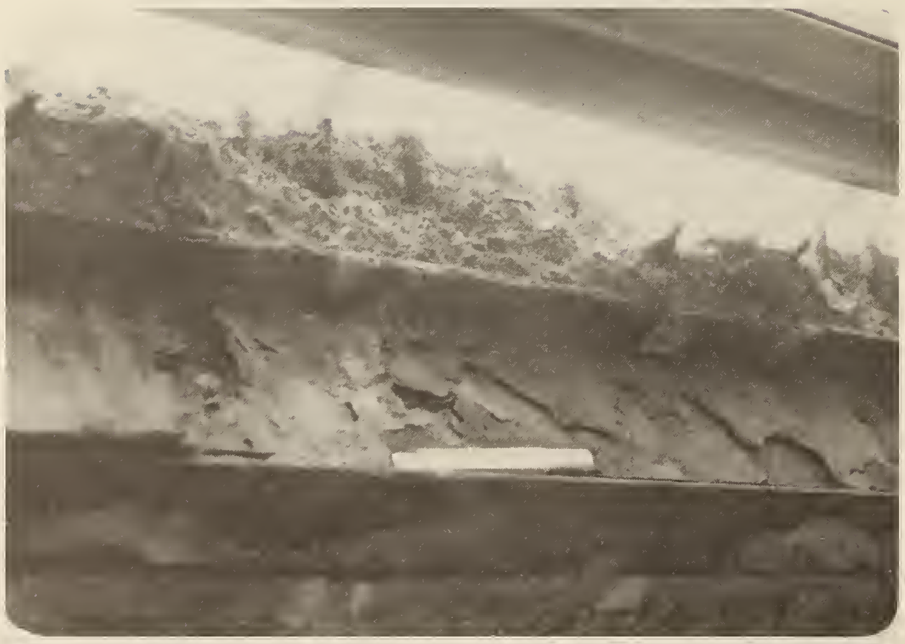
Masonry Abutment
Mortar Deterioration

Full Height Concrete Abutment
Cracking and Surface Spall

Steel Thru Truss
Collision Damage - Portal

Concrete Stub Abutment
Cracking and Surface Spall

Masonry Abutment
Bearing Seat Deterioration



Steel Truss
Fascia Stringer Corrosion - Flange and Web

Deck Joint - Open
Steel Floor System Exposed to Surface Runoff

Scupper
Drainage Discharge on Primary Members

Concrete Slab Bridge
Surface Spall-Rebar Exposure and Corrosion

Reinforced Concrete Deck
Wearing Surface Breakdown

APPENDIX C Listing and Description of Rehabilitation Plans Reviewed

WEST VIRGINIA

1. Middleway Bridge (02-51-9.34)

   Repair A - Abutment Repairs
   Repair B - New Concrete Deck

2. 6th Street Bridge (06-52-0.06)

   New Navigation Lights Installation

3. Coon Creek Bridge (20-33-3.48)

   Repair A - Floorbeam Strengthening
   Repair B - Column Eccentricity Reduction
   Repair C - New Pile, Cap Beam Abutment

4. Rita Bridge (23-10/4-0.01)

   Repair A - New Steel Grid Deck Installation
   Repair B - Repair Deteriorated Girder Flange
   Repair C - Floorbeam Strengthening
   Repair D - Tension Chord Strengthening
   Repair E - Floorbeam Deterioration Repair
   Repair F - Scoured Abutment Repair

5. Newhall Arch No. 1 (24-16-6.46)

   Repair A - Widening of Bridge
   Repair B - Widening of Abutments

6. Watson Bridge (25-250-6.26)

   Scoured Pier Repair

7. Edgarton Bridge (30-49-0.00)

   Repair A - Concrete Patching
   Repair B - Concrete Deck Replacement
   Repair C - Parapet Wall and Sidewalk Installation

8. Tamcliff Bridge (30-80-7.00)

   Repair A - Diagonal Strengthening with Loop Bars
   Repair B - Floorbeam and Stringer Strengthening

9. Verner Bridge (30-8-11.00)

   Repair A - New Drain Details
   Repair B - Sealed Expansion Dam Installation

10. Ayers Bridge (43-16-3.59)

Repair A - Compression Member Strengthening
Repair B - Sealed Expansion Dam Installation

11. Bull Creek Bridge (37-2-0.00)

Repair A - Lower Chord Protective Cover Plates
Repair B - Stringer Strengthening
Repair C - Compression Member Strengthening
Repair D - New Lower Chord Installation
Repair E - Raise Portal Clearance
Repair F - Diagonal Strengthening
Repair G - Raise Sway Bracing Clearance
Repair H - Sealed Expansion Dam Installation
Repair I - Drain Installation

12. Thomas Creek Bridge (38-28-13.98)

Bridge Replacement with Reinforced Concrete Box Culvert

13. Bowden Truss (742-5/12-432)

Repair A - Diaphragm Installation
Repair B - Diagonal Strengthening with Loop Bars
Repair C - Timber Deck Installation

14. Mill Race Bridge (47-219-8.44)

Repair A - Bridge Widening
Repair B - Sidewalk Installation

15. Williamstown - Marietta Bridge (54-14-26.84)

Abutment Strengthening

MINNESOTA

1. Bridge No. 5357 (High Bridge in St. Paul) T.H. 49 over Mississippi.

This bridge was built in 1889 and is 2860 feet long, inspection in 1977 revealed cracking and deterioration of floor beam, stringer connecting angles and truss members to the extent that the bridge was ordered closed.

Repairs were made to these members as follows:

a. Floor beams were repaired by plating over deteriorated areas.

b. Stringer connections were replaced with new angle seats and web connector angles.

c. Truss members were repaired by either total replacement or reinforcement of deteriorated areas.

With the completion of all major repairs plus sandblasting and painting of members with minor deterioration, the High Bridge was opened to traffic with a load restriction of 3 tons.

2. Bridge No. 3758 - T.H. 6 over Stream

A new concrete slab span was placed over the present concrete slab span to increase the load carrying capacity of the bridge. The new slab span was designed to support its weight plus HS20 live load and impact.

3. Bridge No. 4320 - T.H. 63

Truss was strengthened by the addition of angles to the diagonals.

4. Bridge No. 4905 - T.H. 169

A steel beam span bridge was strengthened by the addition of intermediate I-beams.

5. Bridge No. 4181 and 4182 - T.H. 15

A steel beam span bridge was strengthened by adding structural channels to each side of interior beams.

6. Bridge No. 5003 - T.H. 169

A steel beam span was temporarily reinforced by the addition of a pile bent.

7. Bridge No. 3699 - T.H. 212/Stream

A steel beam span was reinforced with steel cables that were tensioned under a timber floor beam support at the center of span.

8. Bridge No. 9800 - T.H. 56 over Mississippi River

A crack was discovered in one of the main girders, 118 feet out on the 362-foot main span. This crack extended through most of the web and the entire bottom flange. Repair consisted of jacking from top of deck and splicing over fractured area.

9. Bridge No. 9586 - T.H. 10EB over T.H. 35W

The fixed hinge on one side of a suspended span was found to be cracking and deteriorating on this concrete box girder bridge. The suspended span was jacked from top of the deck at ends and from bottom of box girder at 2 interior points. Concrete was recast above and below the fixed hinges and new elastomeric bearing pads were added. Traffic was permitted over while repairs were carried out.

10. Bridge No. 4588 - T.H. 60/Mississippi

Floor beams and stringers were repaired by the addition of angles and plates.

11. Bridge No. 9320 - T.H. 90/Mississippi River

A crack in a girder was repaired with splice plates.

VIRGINIA

1. Chapawamsic Creek Bridge (Proj. 1689-13)

    A. Widening

2. Appomattox River Bridge

    A. Slab replacement and strengthening

3. Peak Creek Bridge

    A. Repairs to concrete beams, pier caps and beam bearings

4. Rte. 1 over S.C.L. R.R.

    A. Repair of concrete spalls in bents

    B. Slab Repair

5. Piscataway Creek Bridge (Proj. 0017-028-019)

    A. Eliminating existing vertical curve and placing structure on 0.66% gradient

    B. Replacing existing substructure, eliminating 6 bents

    C. Widening roadway from 23' to 28' clear

    D. Removing existing fender system

    E. Constructing temporary bridge

6. Occoquan Creek Bridge (Proj. 1629-09)

    A. Pier Replacement

7. Bush River Bridge (Rte. 460)

    A. Repair concrete cracks in abutment using epoxy

    B. Repair of spalls and of end beam cracks.

8. A standard for bridges with steel beams and Glu-lam floor

9. A standard for steel beam bridges with wooden floors.

10. Standard Plan for fastening wooden plank floor to steel beams.

11. Bridge over Eastern Branch Elizabeth River (Proj. 0013-075-101)

    A. Existing concrete piles covered by concrete jacket

12. Nottoway River Bridge

    A. End Post reinforcement using 10"x10" timber

13. Carvins Creek Bridge (Proj. No. 0011-080-701-M600)

    A. Jacked bridge at center of span to relieve D.L. stress before welding cover plates to beams.

14. Reed Creek Bridge

    A. Truss strengthening (Member $U.L_2$)

    B. New bearing plates

15. Bridges over Pound River

    A. Jack trusses at one abutment, build new bridge seat and replace rollers

16. Bridge over SCL RR (Rte. 32)

    A. Relocating all spans; somehow all 3 spans had shifted slightly and were not in exact alignment with one another

    B. Placing shear keys

    C. Sealing joints between spans

    D. Repairing spalls

17. Bridge over Virginia Railway (Now N&W) - Rte. 29

    A. Basically same as #16 above.

18. Vaughn Bridge

    A. Repairs to Portals and End Posts

    B. Repairs to Bents

    C. Repairs to truss bracing and floor system

19. Little River Bridge (Rte. 1)

    A. Repair to top of pier

20. Meherrin River Bridge (Proj. 1840-01)

    A. Repair of cracked beam ends and concrete pier stems

21. Pagan River Bridge (Rte. No. 10)

    A. Abutment Strengthening to prevent further settling

    B. Building up of abutment seat

22. Rte. 687 Bridge over Rte. 64

    A. Pier bent repair

23. Corrotoman River Bridge (Rte. 600)

    A. Abutment repairs

24. Wolf Creek Bridge

    A. Portals and Knee brace repairs

25. Nottoway River Bridge Repairs (Proj. 0046-012-0916)

    A. Cast new pier seats

    B. Replace one span

    C. Install stud shear connectors

26. Bridge over New Market Creek (Proj. 0258-114-102, B601)

    A. Widening of 2 spans

27. Hoskins Creek Bridge (Rte. 17 & 360)

    A. Repositioning spans, repairing abutment wings.

    B. Replacing masonry plates

SOUTH CAROLINA

1. Rocky Creek Bridge (No. 12.470) Received from our Columbia Office

    A. Widening by extending pier caps with reinforced concrete; includes driving new piles

ILLINOIS

1. Pekin lift span over Illinois River
   - A. Floorbeam reinforcement by placing new W. 24x76's under existing floorbeams
2. Structure #100-0033 over Pond Creek
   - A. Strengthening of truss members and stringers
   - B. Painting of structural steel
   - C. Paving
3. Structure #100-0032 over Big Muddy River
   - A. Strengthening of floorbeams by welding cover plates (involves removing sections of concrete slab to gain access to top flanges.)

TENNESSEE

1. Overhead Crossing over L & N Railroad (Br. No. 19-1-10.66)
   A. Abutment Repair

2. Repair Details for Portals and Knee Brace 1976 (No bridge name or number shown)

3. Bridge over Watauga River (Bridge No. 90-34-23.04)
   A. Truss Repairs and cleaning and painting

4. Bridge over Sycamore Creek (Bridge No. 11-112-4.79)
   A. Truss Repairs and cleaning and painting

5. Bridge No. 53-40-364.36, I-40 over state Route 95.
   A. Structural Steel repairs

6. Bridge No. 47-9-1003 SR 9 over Holston River
   A. Repair of pin connections, bearings and expansion joint of truss.
   B. Repave

7. Bridge No. 82-2373-7.90, South Fork Holston River
   A. Structural Steel repair.
   B. Pier Bent foundation repairs

8. I-40 Bridge over Tennessee River (Bridge No. 03-40-134.71)
   A. Install anchor bolts
   B. Repaint steel
   C. Pneumatic Concrete Repairs

CALIFORNIA

1. Butte Street Overcrossing (Bridge No. 6-136)

   A. Repair of Concrete Slab and Girder

2. Gannon Slough Bridge (No. 4-24L)

   A. Repair of spalled concrete by air-blown mortar.

3. Arch Road Overcrossing (Bridge No. 29-153)

   A. Girder Replacement

   B. Painting

4. Outlet Creek Bridge (Bridge No. 10-233)

   A. Deck Rehabilitation - using asphalt concrete.

5. San Luis Obispo Creek Bridge (Contract No. 05-221744)

   A. Waterway slope protection using sacked concrete.

6. In San Luis Obispo County about 5 miles North of San Luis Obispo from 0.7 mile South to 0.5 mile North of Cuesta Overhead (Contract No. 05-218304).

   A. Concrete and metal median barriers

7. Lincoln Avenue Overcrossing (Contract No. 04-397694)

   A. Replace prestressed girder, deck slab, diaphragms, sidewalk railing, sidewalk and parts of bent caps.

FLORIDA

1. Bridge of Lions (78040 - 3532)
   - A. Structural Steel Repairs
   - B. Pier Footing Repairs
2. Gandy Bridge (10130 - 3526 - 010 - 74)
   - A. Concrete Pile Jackets
3. Tampa Bay Bridge (1013 - 202)
   - A. Intermediate Tower Bents
4. Lafayette Street Viaduct Bridge No. 100028 (10080 - 3516)
   - A. Spalled concrete repairs (gunite and epoxy)
   - B. Structural Steel Painting
   - C. Pavement

PENNSYLVANIA

1. Truss Bridge over Fishing Creek (LR 239-018 Sta. 87+95.00)
    A. Deck Replacement

2. Bridge over Schuylkill River (LR 1041-302 Sta. 339+65)
    A. Deck Rehabilitation

LOUISIANA

1. West Atchafalaya Floodway Crossing (8-04-41)
    a. Modification to Existing Bents.
    b. Redecking - C.I.P. Concrete
2. Dugdemona River Bridge (22-03-27)
    a. Widening and overlay
3. Bayou Terrebonne Bridge (65-04-20)
    a. Reconstruction of Bridge
4. Inner Harbor Navigation Canal Bridge (450-90-17)
    a. Protective Screen
5. Bayou Carencro Bridge, Bayou Bourbeaux Bridge and Bayou Callahan Bridge (424-01-30)
    a. Widening
6. Dry Creek Bridge (31-08-10)
    a. Widening

BRIDGE REHABILITATION TECHNIQUES

I. INCREASE LIVE LOAD CAPACITY

A. Strengthen Critical Members.

- o Add reinforcement plates to concrete beams.
- o Add cover plates to steel beams and girders.
- o Deepen through girder bridges.

B. Add Supplemental Members.

- o Bents to ratio span.
- o Add pony or crutch bents.
- o Add steel stringers to multiple beam bridges.

C. Dead Load Reduction.

- o Open grid deck.
- o Corrugated metal deck.
- o Metal Plate Deck (Orthotropic).
- o Laminated Timber Deck.

D. Structural System Modification.

- o Multiple steel beams to Kingpin Truss.
- o Non-composite to composite.
- o Simple spans to continuous.
- o Post tension steel or concrete beams.
- o Post tension truss members.
- o Abutment stringer continuity.

II. CORRECT MECHANICAL DEFICIENCIES

A. Bearings

- o Replace with neoprene type.
- o Replace in kind.
- o Clean, lubricate and adjust.

B. Deck Joints

- o Replace with sealed joints.
- o Add drainage collection system under open joints.

C. Substructure Stabilization.

- o Abutment tiebacks.
- o Replace abutment back wall-Provide pavement relief joint.
- o Soil stabilization-Pressure grout.

III. IMPROVE GEOMETRICS

A. Roadway Widening.

- o Multiple beam or girder - Add new members - Extend substructure units.
- o Deck truss or twin girders - Continue widening in combination with light weight decks.
- o Thru girders - Raise floor system to top flange and cantilever.
- o Pony truss or thru truss - New superstructure on Cantilever from existing substructure.

B. Vertical Clearance.

- o Reduce depth of portal frame on thru truss.
- o Eliminate or reduce depth of sway frame on thru truss.
- o Lower roadway on underpass.
- o Raise superstructure on overpass bridge.
- o Reduce girder depth over roadway.

IV. MISCELLANEOUS

A. Drainage.

- o Replace scuppers.
- o Add collection system.
- o Extend downspouts below structural steel.
- o Add clean out devices.

B. Concrete Repairs.

- o Crack repairs - Pressure grout.
- o Epoxy seal.
- o Concrete shell encasement around defective areas.

C. Pile Repairs.

- o Concrete jacket - timber or concrete.
- o Tip encasement - scoured piles.
- o Crutch bents
- o Change out through deck.
- o Pony bents - Piles driven beyond bridge deck.

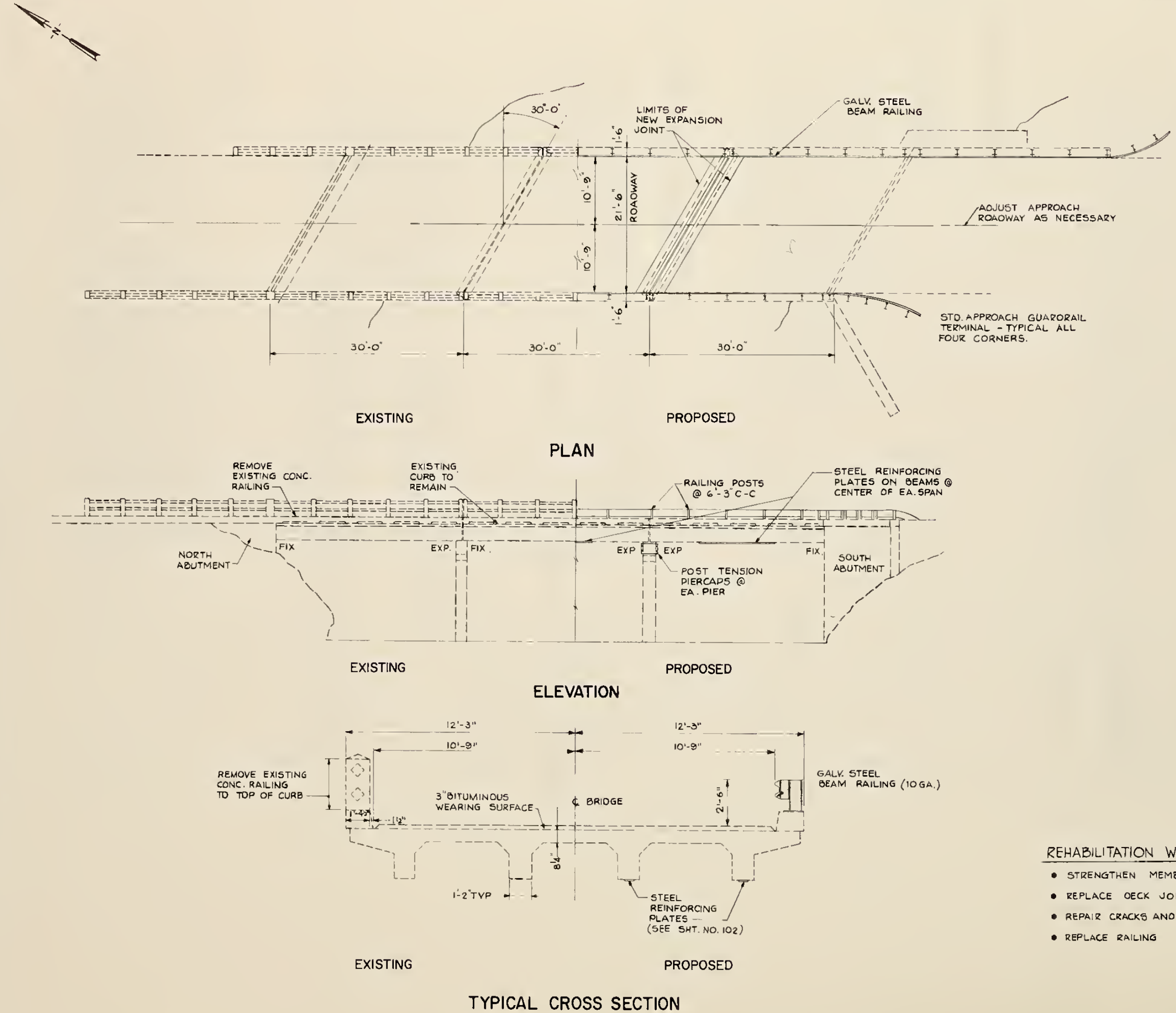
D. Safety.

- o Add redirectional crash barrier.
- o Replace substandard bridge rail.
- o Attenuater at precarious ends of truss or girders.
- o Roadway bridge deck surface repairs.

METRIC CONVERSION

Inches:	1" = 0.0254m
Feet:	1' = 0.3048m
Pounds:	1 lb. = 4.448N
Ounces	1 oz. = 0.278N
Tons:	1 T = 8,896N
Kips:	1 K = 4,448N
Sq. Ft.:	1 SF = 0.0929m^2
PSI:	1 psi = 6894.8 Pa
PSF:	1 psf = 47.88 Pa

Temperature $^{o}C = (Temp.\ ^{o}F-32)/1.8$



GENERAL NOTES

DESIGN :

- REHABILITATION SPECIFICATIONS : "SPECIFICATIONS FOR HIGHWAY BRIDGES, ELEVENTH EDITION, AASHTO 1973," AS AMENDED.
- WELDING SPECIFICATIONS : "STANDARD SPECIFICATIONS FOR WELDING OF STRUCTURAL STEEL HIGHWAY BRIDGES, AASHTO 1974"
- BRIDGE ORIGINALLY CONSTRUCTED IN 1928.
- LIVE LOAD :
  ORIGINAL DESIGN .... UNKNOWN
  EXISTING .... HS 17.3 + (INV. RATING)
  PROPOSED .... HS 20-44 (INV. RATING)

MATERIALS :

- STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 EXCEPT IN ARMOURED JOINT ASSEMBLIES WHICH SHALL CONFORM TO ASTM A588.
- EXPANSION BOLTS SHALL CONSIST OF 1/2 INCH ϕ SELF DRILLING EXPANSION ANCHORS AND SHALL CONFORM TO THE REQUIREMENTS OF FEDERAL SPECIFICATION NO. FF-S-325, GROUP III, TYPE I.
- STEEL BEAM RAILING SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M 180-70. CONNECTION BOLTS AND NUTS SHALL CONFORM TO THE REQUIREMENTS OF ASTM A307, CLASS A. BOLTS AND NUTS SHALL BE GALVANIZED IN ACCORDANCE WITH THE REQUIREMENTS OF AASHTO M 232.
- CONCRETE SHALL BE CLASS A (AE) WITH A MINIMUM 28 DAY COMPRESSIVE STRENGTH f'_c = 3,000 PSI. AIR ENTRAINING ADMIXTURES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C260. ALL EXPOSED EDGES SHALL BE CHAMFERED 3/4 INCHES.
- REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A615, GRADE 40. MINIMUM CONCRETE COVER OVER REINFORCING BARS SHALL BE 2 INCHES CLEAR.
- PAINTING OF STRUCTURAL STEEL SHALL INCLUDE ONE SHOP COAT AND TWO FIELD COATS EXCEPT FOR GALVANIZED MEMBERS OR SURFACES TO BE IN CONTACT WITH STEEL OR CONCRETE. PAINT MATERIALS SHALL BE IN CONFORMANCE WITH CURRENT AASHTO SPECIFICATIONS.
- PREFORMED ELASTOMERIC JOINT SEALER SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M220.
- ADHESIVE FOR BONDING STEEL PLATES TO CONCRETE BEAM SHALL BE A TWO COMPONENT EPOXY-RESIN SYSTEM WITH A MINIMUM SHEAR STRENGTH OF 500 PSI OVER A TEMPERATURE RANGE OF -60°F TO 180°F. SAMPLES OF THE ADHESIVE MATERIALS ALONG WITH INDEPENDENTLY CERTIFIED TEST RESULTS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.
- ADHESIVE MATERIALS FOR INJECTION REPAIR OF CONCRETE CRACKS SHALL BE A TWO COMPONENT EPOXY-RESIN SYSTEM CAPABLE OF PENETRATING AND BONDING CRACKS DOWN TO A WIDTH OF 0.003 INCHES. SAMPLES OF THE ADHESIVE MATERIALS, ALONG WITH INDEPENDENTLY CERTIFIED TEST RESULTS, SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.

CONT.-

REHABILITATION WORK:

- STRENGTHEN MEMBERS
- REPLACE DECK JOINTS
- REPAIR CRACKS AND SPALLS
- REPLACE RAILING

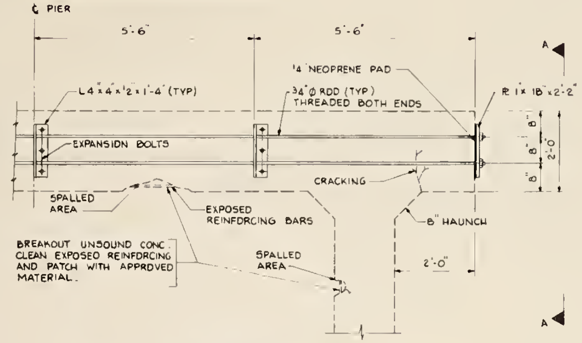
BRIDGE REHABILITATION
CONCRETE T-BEAM BRIDGE
GENERAL PLAN

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MACDONALD & LEWIS
Division of Wilbur Smith & Associates

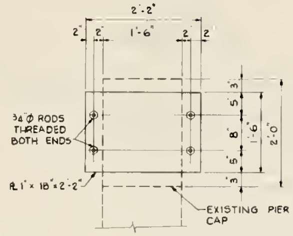
MARCH 1978

SHEET NO. 101
1 OF 2

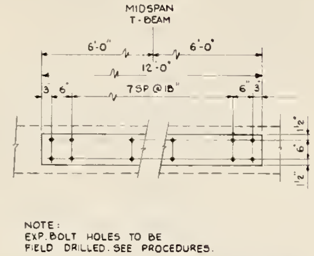


HALF ELEVATION

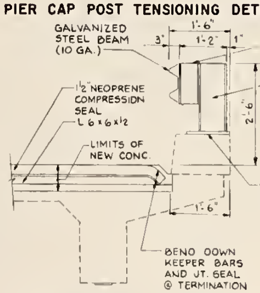
PIER CAP POST TENSIONING DETAIL



ELEVATION A A

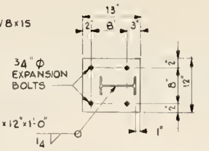


REINFORCING PLATE BOLT SPACING PLAN



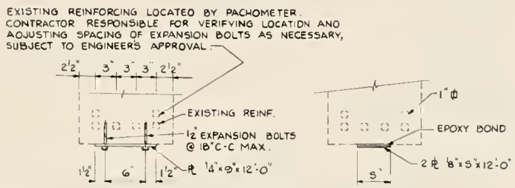
PARTIAL ELEVATION

JOINT SEAL TERMINATION DETAIL



PLAN OF ANCHOR PLATE

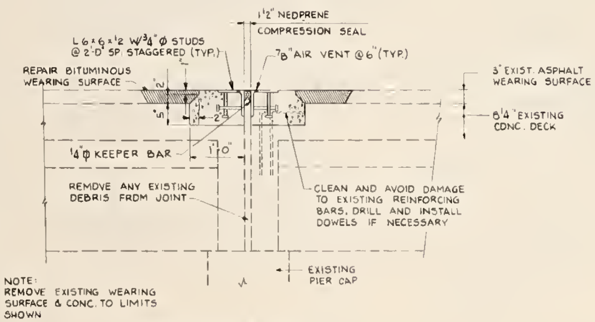
GUARDRAIL ANCHOR DETAIL



ALTERNATE EXPANSION BOLTS

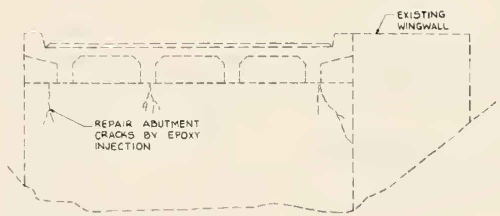
ALTERNATE EPOXY

REINFORCING PLATE DETAILS



CROSS SECTION @ PIER

EXPANSION JOINT DETAIL



ABUTMENT ELEVATION

MATERIALS (CONT.):

- MATERIALS FOR PATCHING SPALLED CONCRETE AREAS SHALL BE A TWO COMPONENT EPOXY-RESIN SYSTEM OR A NONSHRINK PORTLAND CEMENT GROUT. SAMPLES OF THE PATCHING MATERIALS ALONG WITH CERTIFIED TEST RESULTS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.
- ELASTOMERIC BEARING PADS SHALL BE IN ACCORDANCE WITH "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, AASHTO 1973, SECTION 25"
- IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO VERIFY ALL DIMENSIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING MATERIALS.

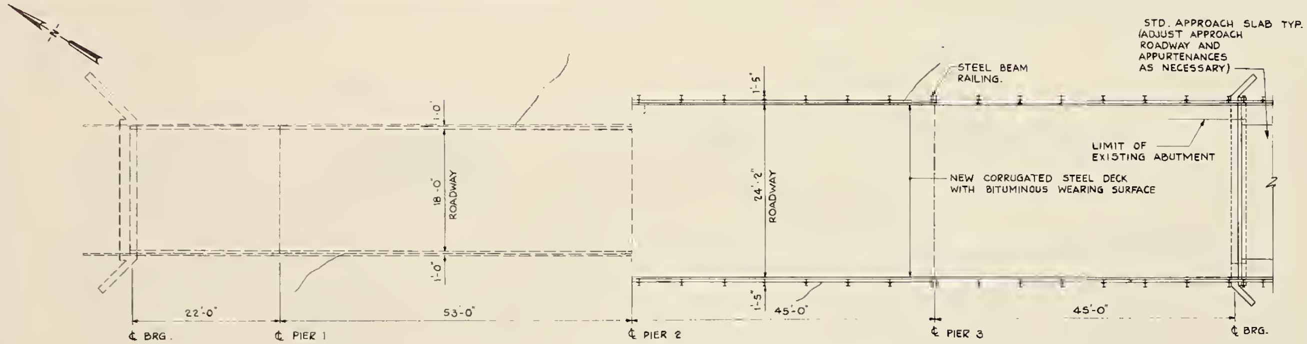
PROCEDURES:

1. CLOSE BRIDGE TO VEHICULAR TRAFFIC.
2. REMOVE EXISTING WEARING SURFACE AND CONCRETE TO THE LIMITS SHOWN AND INSTALL NEW DECK JOINTS.
3. ATTACH STEEL REINFORCING PLATES TO THE UNDERSIDE OF EACH CONCRETE BEAM. FOR THE GLUED, STEEL PLATE ALTERNATIVE, SANDBLAST THE CONCRETE CONTACT SURFACES AND STEEL PLATES WITHIN ONE HOUR OF BONDING THE PLATES TO THE CONCRETE T-BEAMS. AFTER MIXING AND APPLYING THE ADHESIVE MATERIAL TO BOTH SURFACES, WEDGE THE PLATES IN POSITION AGAINST THE BEAMS WITH A UNIFORM MINIMUM PRESSURE OF 2 PSI OR AS RECOMMENDED BY THE MANUFACTURER. MAINTAIN PRESSURE AND PROHIBIT CONSTRUCTION EQUIPMENT AS WELL AS VEHICULAR TRAFFIC FROM THE BRIDGE UNTIL THE ADHESIVE HAS CURED IN ACCORDANCE WITH THE APPROVED MANUFACTURER'S RECOMMENDATIONS.
4. PAINT EXPOSED SURFACES OF STRUCTURAL STEEL PLATES.
5. PERFORM CONCRETE SPALL REPAIR AND CONCRETE CRACK INJECTION OPERATIONS IN STRICT ACCORDANCE WITH THE APPROVED MATERIAL MANUFACTURER'S AND CURRENT ACI RECOMMENDED PROCEDURES.
6. AFTER THE CONCRETE SPALL PATCHING MATERIALS HAVE CURED, REOPEN THE BRIDGE TO TRAFFIC.
7. INSTALL PIER CAP STRENGTHENING SYSTEM. AFTER OBTAINING SNUG FIT OF ALL TENSIONING ROD NUTS, INDUCE 20 KIP LOAD IN EACH BOLT IN A MANNER APPROVED BY THE ENGINEER.
8. REMOVE EXISTING CONCRETE RAILING TO THE LIMITS SHOWN AND INSTALL STEEL BEAM RAILING.

BRIDGE REHABILITATION
CONCRETE T-BEAM BRIDGE
DETAILS

U.S Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

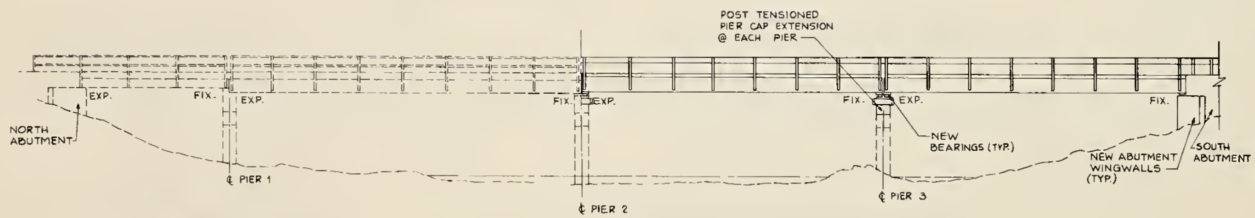
PREPARED BY	MARCH 1978
BYRD, TALLAMY, MacDONALD & LEWIS Division of Wilbur Smith & Associates	SHEET NO. 102 2 OF 2



EXISTING

PROPOSED

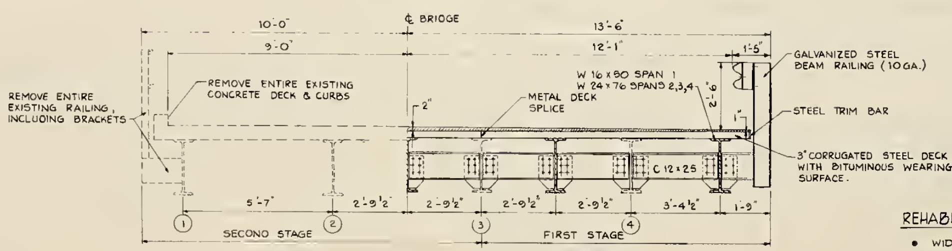
PLAN



EXISTING

PROPOSED

ELEVATION



EXISTING

PROPOSED

TYPICAL CROSS SECTION

REHABILITATION WORK:

- WIDEN BRIDGE
- POST TENSION PIER CAP EXTENTIONS
- INSTALL LIGHTWEIGHT DECK

GENERAL NOTES

DESIGN:

- REHABILITATION SPECIFICATIONS: "SPECIFICATIONS FOR HIGHWAY BRIDGES, ELEVENTH EDITION, AASHTO 1973," AS AMENDED.
- WELDING SPECIFICATIONS: "STANDARD SPECIFICATIONS FOR WELDING OF STRUCTURAL STEEL HIGHWAY BRIDGES, AASHTO 1974"
- BRIDGE ORIGINALLY CONSTRUCTED IN 1947.
- LIVE LOAD:

ORIGINAL DESIGN	UNKNOWN
EXISTING	HS 3.5 (INV. RATING)
PROPOSED	HS17.4 (INV. RATING)

MATERIALS:

- STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 EXCEPT IN ARMOURED JOINT ASSEMBLIES WHICH SHALL CONFORM TO ASTM A588.
- EXPANSION ANCHORS SHALL BE ¾ INCH Ø SELF-DRILLING ANCHORS AND SHALL CONFORM TO THE REQUIREMENTS OF FEDERAL SPECIFICATION NO. FF-S-325, GROUP III, TYPE 1.
- STEEL BEAM RAILING SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M180-70. CONNECTION BOLTS AND NUTS SHALL CONFORM TO THE REQUIREMENTS OF ASTM A307, CLASS A. BOLTS AND NUTS SHALL BE GALVANIZED IN ACCORDANCE WITH THE REQUIREMENTS OF AASHTO M232.
- CONCRETE INCLUDING PRECAST SHALL BE CLASS A (AE) WITH A MINIMUM 28 DAY COMPRESSIVE STRENGTH $f'c$ = 3,000 PSI. AIR ENTRAINING ADMIXTURES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C260. ALL EXPOSED EDGES SHALL BE CHAMFERED ¾ INCHES.
- REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A615, GRADE 40. THE MINIMUM CONCRETE COVER OVER REINFORCEMENT BARS SHALL BE 2 INCHES CLEAR.
- PAINTING OF STRUCTURAL STEEL SHALL INCLUDE ONE SHOP COAT AND TWO FIELD COATS EXCEPT FOR GALVANIZED MEMBERS OR SURFACES TO BE IN CONTACT WITH STEEL OR CONCRETE. PAINT MATERIALS SHALL BE IN CONFORMANCE WITH CURRENT AASHTO SPECIFICATIONS.
- PREFORMED ELASTOMERIC JOINT SEALER SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M220.
- ELASTOMERIC BEARING PADS SHALL BE IN ACCORDANCE WITH "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, AASHTO 1973, SECTION 25."
- POST TENSIONING STRANDS SHALL BE SEVEN WIRE STRESS RELIEVED STRANDS CONFORMING TO THE REQUIREMENTS OF ASTM A416 GRADE 270. THEY SHALL BE COATED WITH AN APPROVED RUST PREVENTATIVE, LUBRICATED AND SHEATHED.
- POST-TENSIONING ANCHORAGE COMPONENTS SHALL BE CAPABLE OF DEVELOPING THE MINIMUM GUARANTEED ULTIMATE STRENGTH OF THE STRANDS AND SHALL BE SUBJECT TO THE ENGINEER'S APPROVAL.
- CORRUGATED STEEL DECKING SHALL BE IN CONFORMANCE WITH THE REQUIREMENTS OF ASTM A570 GRADE D. ZINC COATING SHALL CONFORM TO ASTM A123 EXCEPT AT A RATE OF 2.0 OZ. PER SQUARE FOOT ON BOTH SIDES.

CONT. -

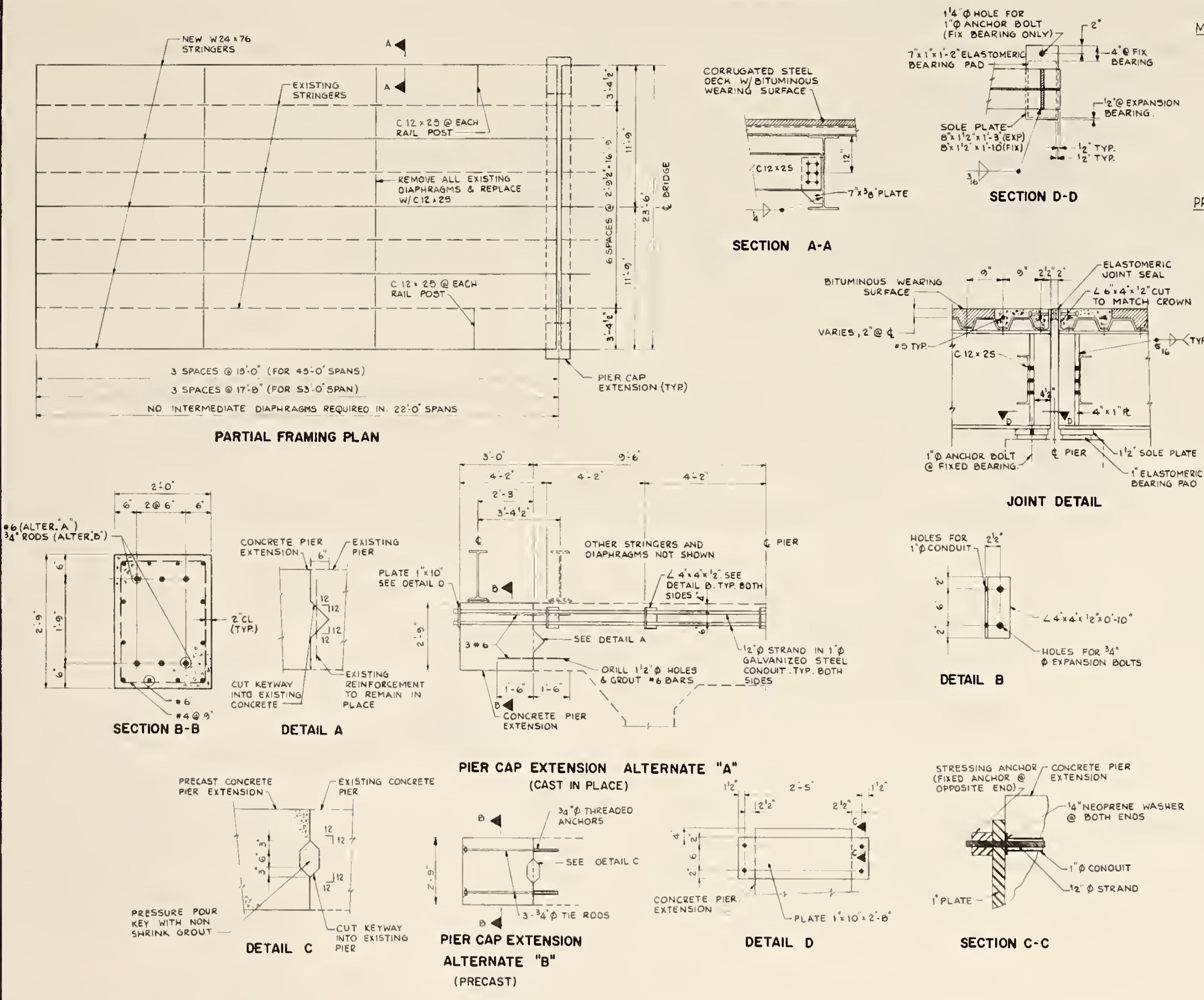
BRIDGE REHABILITATION
STEEL MULTIPLE BEAM BRIDGE
GENERAL PLAN

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MacDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

SHEET NO. 201
1 OF 3



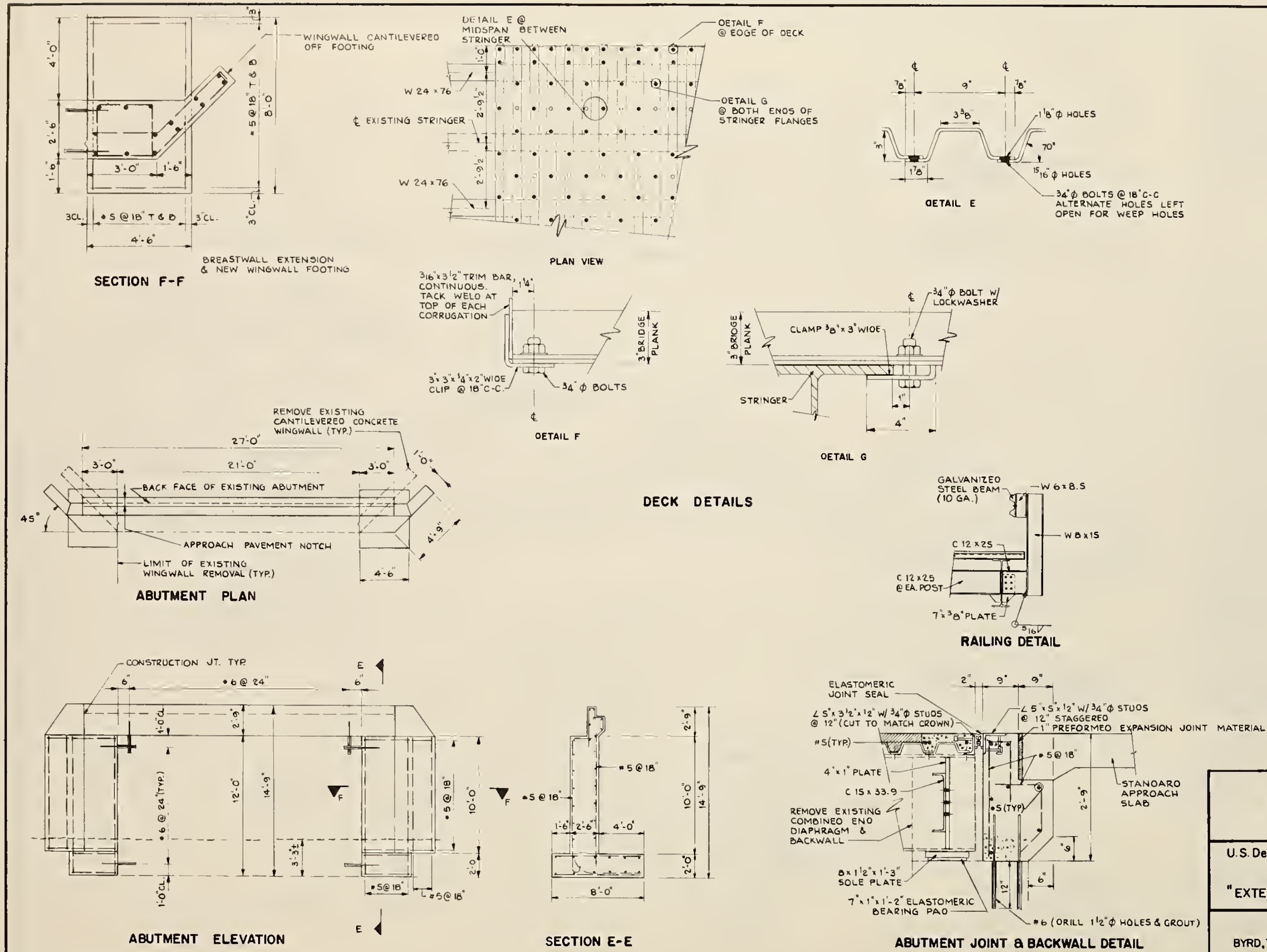
MATERIALS (CONT.):

- BITUMINOUS CONCRETE WEARING SURFACE SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF ASTM D2629 OR ASTM D1663. SPECIFIC MIX DESIGN (AND ALTERNATIVE LOCAL SPECIFICATIONS) SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.
- IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO VERIFY ALL DIMENSIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING MATERIALS.

PROCEDURES:

1. INSTALL TEMPORARY TRAFFIC BARRIERS AND MAINTAIN ONE LANE OF TRAFFIC AT ALL TIMES.
2. EXCAVATE AT ABUTMENTS AND CONSTRUCT FIRST STAGE PORTION OF ABUTMENT FOOTING AND BREASTWALL EXTENSIONS, BACKWALLS AND WINGWALLS.
3. CONSTRUCT CONCRETE PIER CAP EXTENSIONS AT BOTH ENDS OF EACH PIER, USING EITHER THE PRECAST OR CAST-IN-PLACE ALTERNATIVES AS SHOWN. POST-TENSIONING AND KEYWAY GROUTING SHALL BE IN ACCORDANCE WITH CURRENT PCI RECOMMENDATIONS.
4. REMOVE EXISTING RAILING, CONC. DECK AND CURB FROM FIRST STAGE PORTION OF BRIDGE.
5. REMOVE EXISTING LATERAL BRACING ANGLES.
6. WELD SOLE PLATES AND BEARING STIFFENERS TO EXISTING BEAMS
7. PROVIDE SMOOTH BEARING SURFACE BY GRINDING OR PATCHING CONCRETE BEARING SEAT WHERE NECESSARY AND INSTALL ELASTOMERIC BEARING PADS.
8. ERECT NEW STRINGERS, DIAPHRAGMS AND RAILING BRACKETS.
9. INSTALL ARMOURED JOINT ASSEMBLIES AND CORRUGATED METAL DECKING IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
10. PLACE PORTLAND CEMENT CONCRETE TO THE LIMITS SHOWN AT DECK JOINTS.
11. BACKFILL AT ABUTMENTS AND REPAIR APPROACH ROADWAY.
12. INSTALL BRIDGE RAILING.
13. APPLY PRIME COAT TO THE TOP SURFACE OF THE DECKING, PLACE AND COMPACT BITUMINOUS WEARING SURFACE.
14. ADJUST TRAFFIC BARRIERS, SWITCH TRAFFIC TO OPPOSITE SIDE OF BRIDGE AND REPEAT STEPS 2 THROUGH 13 FOR SECOND (STAGE 2) PORTION OF BRIDGE.
15. INSTALL CONTINUOUS ELASTOMERIC JOINT SEALS IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDED PROCEDURES.
16. REMOVE TRAFFIC BARRIERS.

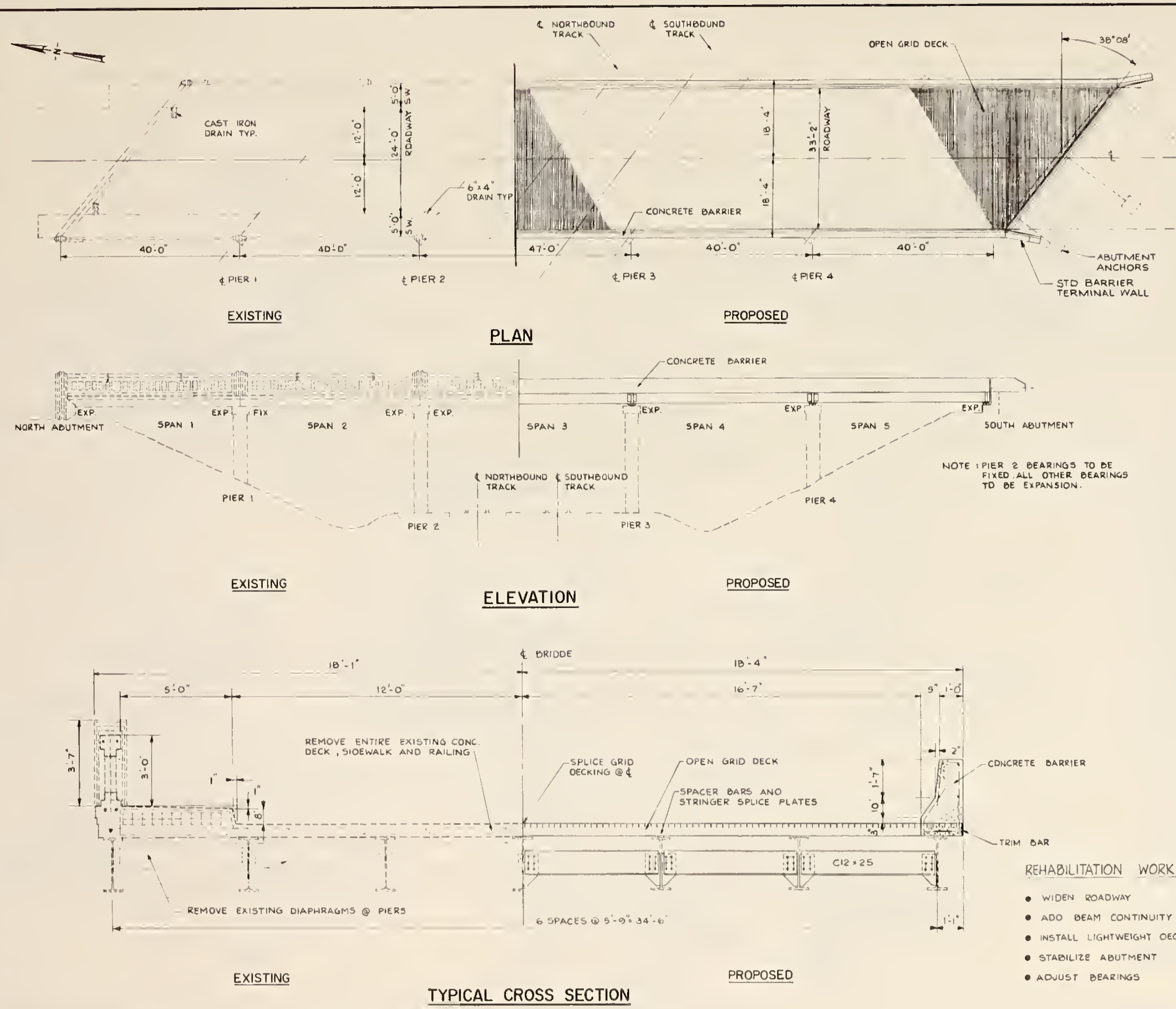
BRIDGE REHABILITATION STEEL MULTIPLE BEAM BRIDGE DETAILS	
U.S. Dept. of Transportation - Federal Highway Administration RESEARCH PROJECT NO. DOT-FH-11-9214 "EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"	
PREPARED BY BYRD, TALLAMY, MacDONALD & LEWIS Division of Wilbur Smith & Associates	MARCH 1978
	SHEET NO 202 2 OF 3



BRIDGE REHABILITATION
STEEL MULTIPLE BEAM BRIDGE
DETAILS

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY BYRD, TALLAMY, MacDONALD & LEWIS Division of Wilbur Smith & Associates	MARCH 1978 SHEET NO. 203 3 OF 3



REHABILITATION WORK:

- WIDEN ROADWAY
- ADD BEAM CONTINUITY
- INSTALL LIGHTWEIGHT DECK
- STABILIZE ABUTMENT
- ADJUST BEARINGS

GENERAL NOTES

DESIGN:

- REHABILITATION SPECIFICATIONS: SPECIFICATIONS FOR HIGHWAY BRIDGES, ELEVENTH EDITION, AASHTO 1973 AS AMENDED.
- WELDING SPECIFICATIONS: "STANDARD SPECIFICATIONS FOR WELDING OF STRUCTURAL STEEL HIGHWAY BRIDGES, AASHTO 1974."
- BRIDGE ORIGINALLY CONSTRUCTED IN 1928.
- LIVE LOAD:
  - ORIGINAL DESIGN .... UNKNOWN
  - EXISTING .... HS 17.3 + (INV. RATING)
  - PROPOSED .... HS 20-44 (INV RATING)

MATERIALS:

- STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 EXCEPT IN ARMOURED JOINT ASSEMBLIES WHICH SHALL CONFORM TO ASTM A588
- STEEL GRID DECKING SHALL CONFORM TO THE REQUIREMENTS OF THE CURRENT AASHTO "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES". PRIOR TO FABRICATION, COMPLETE SHOP AND ASSEMBLY DETAILS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL
- CONCRETE FILL FOR GRID DECKING SHALL BE CLASS C (AE). CONCRETE FOR ABUTMENT TIE-BACK DEADMEN SHALL BE CLASS B. ALL OTHER CONCRETE SHALL BE CLASS A (AE). AIR ENTRAINING ADMIXTURES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C260. ALL EXPOSED EDGES SHALL BE CHAMFERED 3/4 INCHES.
- REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A615, GRADE 40. THE MINIMUM CONCRETE COVER OVER REINFORCEMENT BARS SHALL BE 2 INCHES CLEAR
- PAINTING OF STRUCTURAL STEEL SHALL INCLUDE ONE SHOP COAT AND TWO FIELD COATS EXCEPT FOR GALVANIZED MEMBERS OR SURFACES TO BE IN CONTACT WITH STEEL OR CONCRETE. PAINT MATERIALS SHALL BE IN CONFORMANCE WITH CURRENT AASHTO SPECIFICATIONS.
- PREFORMED ELASTOMERIC JOINT SEALER SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M220.
- ELASTOMERIC BEARING PADS SHALL BE IN ACCORDANCE WITH "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, AASHTO 1973," SECTION 25.
- IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO VERIFY ALL DIMENSIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING MATERIALS.

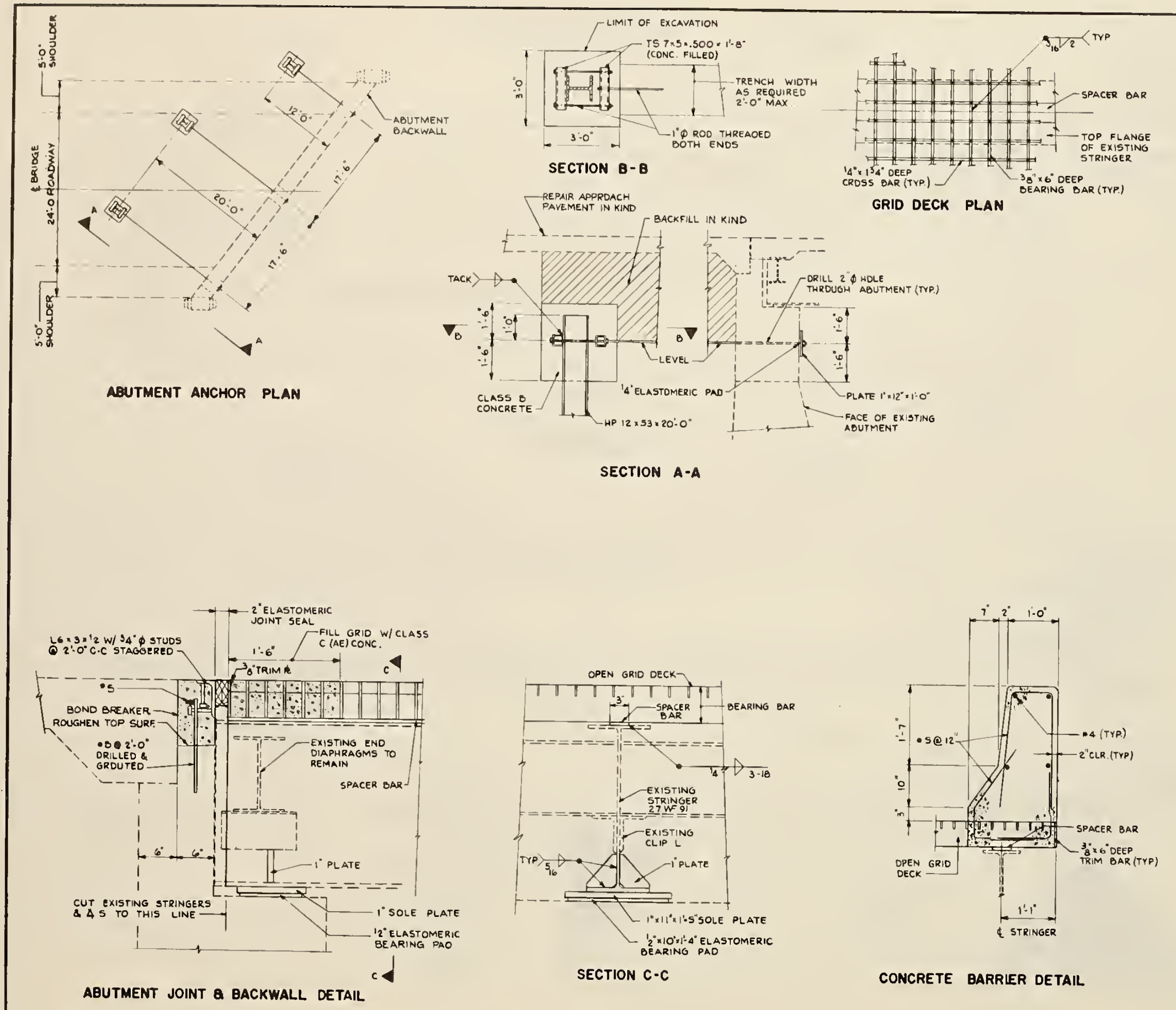
BRIDGE REHABILITATION
STEEL MULTIPLE BEAM BRIDGE
GENERAL PLAN

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MacDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

SHEET NO. 301
1 OF 3



PROCEDURES:

1. INSTALL TEMPORARY TRAFFIC BARRIERS AND MAINTAIN ONE LANE OF TRAFFIC AT ALL TIMES.
2. DRILL HOLES THROUGH ABUTMENT, EXCAVATE, DRIVE PILING, INSTALL TIE BACK RODS AND ASSEMBLIES FOR THE FIRST STAGE PORTION OF THE ABUTMENTS.
3. PLACE AND CURE ANCHOR CONCRETE, BACKFILL AND REPAIR APPROACH PAVEMENT IN KIND.
4. REMOVE THE FIRST STAGE PORTION OF THE EXISTING CONCRETE, DECK, SIDEWALK AND RAIL.
5. FLAME CUT END OF STRINGERS TO THE LIMITS SHOWN AND INSTALL BEARING STIFFENERS.
6. REMOVE TOP PORTION OF ABUTMENT BACKWALLS, DRILL AND GROUT DOWELS, INSTALL ARMOURED JOINT ASSEMBLIES, PLACE AND CURE BACKWALL CONCRETE.
7. REMOVE EXISTING DIAPHRAGMS AND CONNECTIONS AT PIERS. INSTALL NEW DIAPHRAGMS AS SHOWN
8. SPLICE STRINGERS AND INSTALL BEARING STIFFENERS @ PIERS.
9. INSTALL SPACER BARS ON THE TOP FLANGE OF THE STRINGERS.
10. INSTALL OPEN GRID IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
11. FILL GRID DECKING WITH CLASS C(AE) CONCRETE TO THE LIMITS SHOWN AND CONSTRUCT THE BARRIER WITH CLASS A (AE) CONCRETE.
12. ADJUST TEMPORARY TRAFFIC BARRIERS AND REPEAT STEPS 2 THROUGH 11 FOR SECOND STAGE PORTION OF BRIDGE.
13. AFTER INSTALLING ALL ANCHOR ASSEMBLIES AND OBTAINING SNUG FIT ON ALL NUTS, TENSION THE RODS TO 30K EACH IN A MANNER APPROVED BY THE ENGINEER
14. SPLICE GRID DECKING @ ℄.
15. JACK UP STRINGERS, REMOVE EXISTING BEARINGS, INSTALL NEW SOLE PLATES AND ELASTOMERIC BEARING PADS. DRILL AND GROUT ANCHOR BOLTS FOR FIXED BEARINGS AT PIER NO. 2.
16. APPLY FIELD COATS OF PAINT TO ALL EXPOSED STRUCTURAL STEEL. CLEAN AND SPOT PAINT EXISTING STRUCTURAL STEEL AS DIRECTED BY THE ENGINEER AND IN ACCORDANCE WITH CURRENT AASHTO RECOMMENDATIONS.
17. INSTALL CONTINUOUS ELASTOMERIC JOINT SEALS IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
18. ADJUST APPROACH ROADWAYS AS NECESSARY.
19. REMOVE TEMPORARY TRAFFIC BARRIERS.

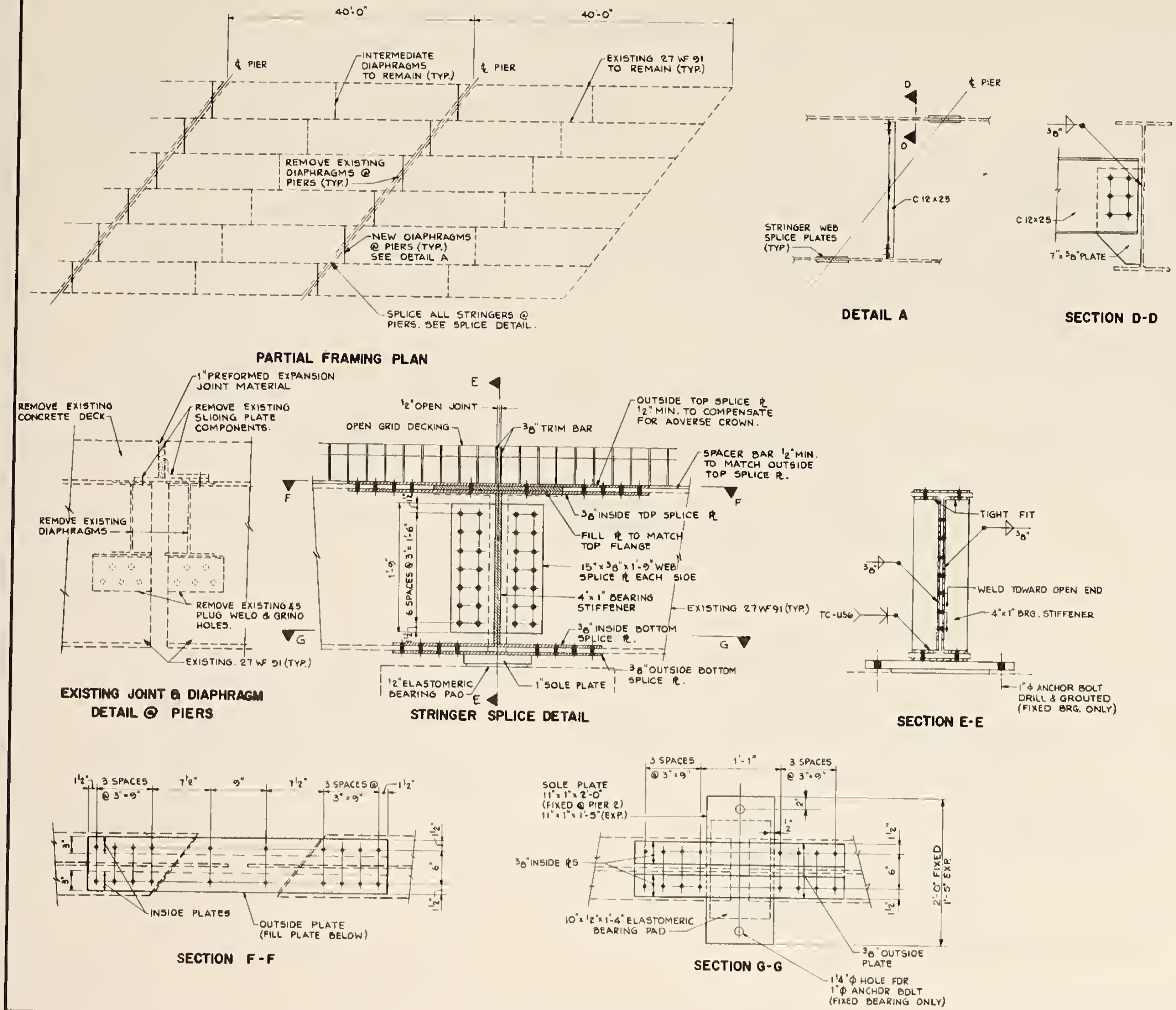
BRIDGE REHABILITATION
STEEL MULTIPLE BEAM BRIDGE
DETAILS

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MacDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

SHEET NO. 302
2 OF 3



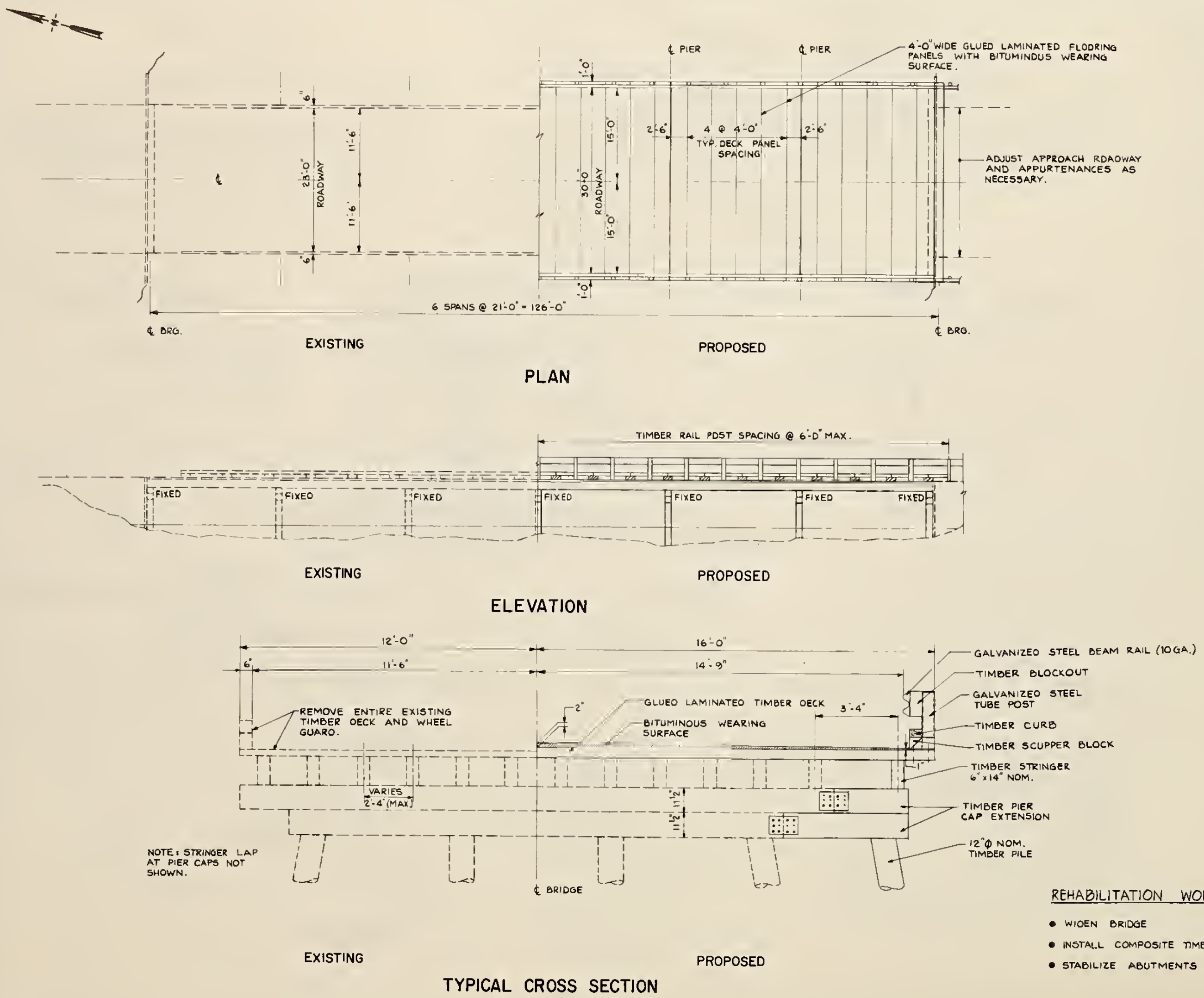
BRIDGE REHABILITATION
STEEL MULTIPLE BEAM BRIDGE
DETAILS

U.S. Dept of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MACDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

SHEET NO. 303
3 OF 3



GENERAL NOTES

DESIGN:

- REHABILITATION SPECIFICATIONS : "SPECIFICATIONS FOR HIGHWAY BRIDGES , ELEVENTH EDITION , AASHTO 1973", AS AMENDED.
- DATE OF ORIGINAL CONSTRUCTION : UNKNOWN
- LIVE LOAD :
  ORIGINAL DESIGN..........UNKNOWN
  EXISTING..........HS 12.8 (INV. RATING)
  PROPOSED..........HS 20-44 (INV. RATING)

MATERIALS:

- STRUCTURAL TIMBER AND PILING SHALL BE SELECT STRUCTURAL DOUGLAS FIR AND SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M168. PRESERVATIVE TREATMENT SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF AASHTO M133.
- GLUED LAMINATED TIMBER DECKING SHALL CONFORM TO THE REQUIREMENTS OF U.S. COMMERCIAL STANDARD CS 253-63.
- STRUCTURAL STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A36.
- STEEL BEAM RAILING SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M180. CONNECTION BOLTS AND NUTS SHALL CONFORM TO THE REQUIREMENTS OF ASTM A307, CLASS A. BOLTS AND NUTS SHALL BE GALVANIZED IN ACCORDANCE WITH THE REQUIREMENTS OF AASHTO M232.
- CONCRETE SHALL BE CLASS A (AE) WITH A MINIMUM 28 DAY COMPRESSIVE STRENGTH f'c = 3,000 PSI. AIR ENTRAINING ADMIXTURES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C260. ALL EXPOSED EDGES SHALL BE CHAMFERED 3/4 INCHES.
- REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A615, GRADE 40. THE MINIMUM CONCRETE COVER OVER REINFORCEMENT BARS SHALL BE 2 INCHES CLEAR.
- BITUMINOUS CONCRETE WEARING SURFACE SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF ASTM D2629 OR D1663. SPECIFIC MIX DESIGN (AND ALTERNATIVE LOCALLY DEVELOPED SPECIFICATIONS) SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.
- PREFORMED EXPANSION JOINT FILLER SHALL CONFORM TO THE REQUIREMENTS OF ASTM D1751 OR D1752.
- STEEL SHEET PILING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A328.
- IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO VERIFY ALL DIMENSIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING MATERIALS.

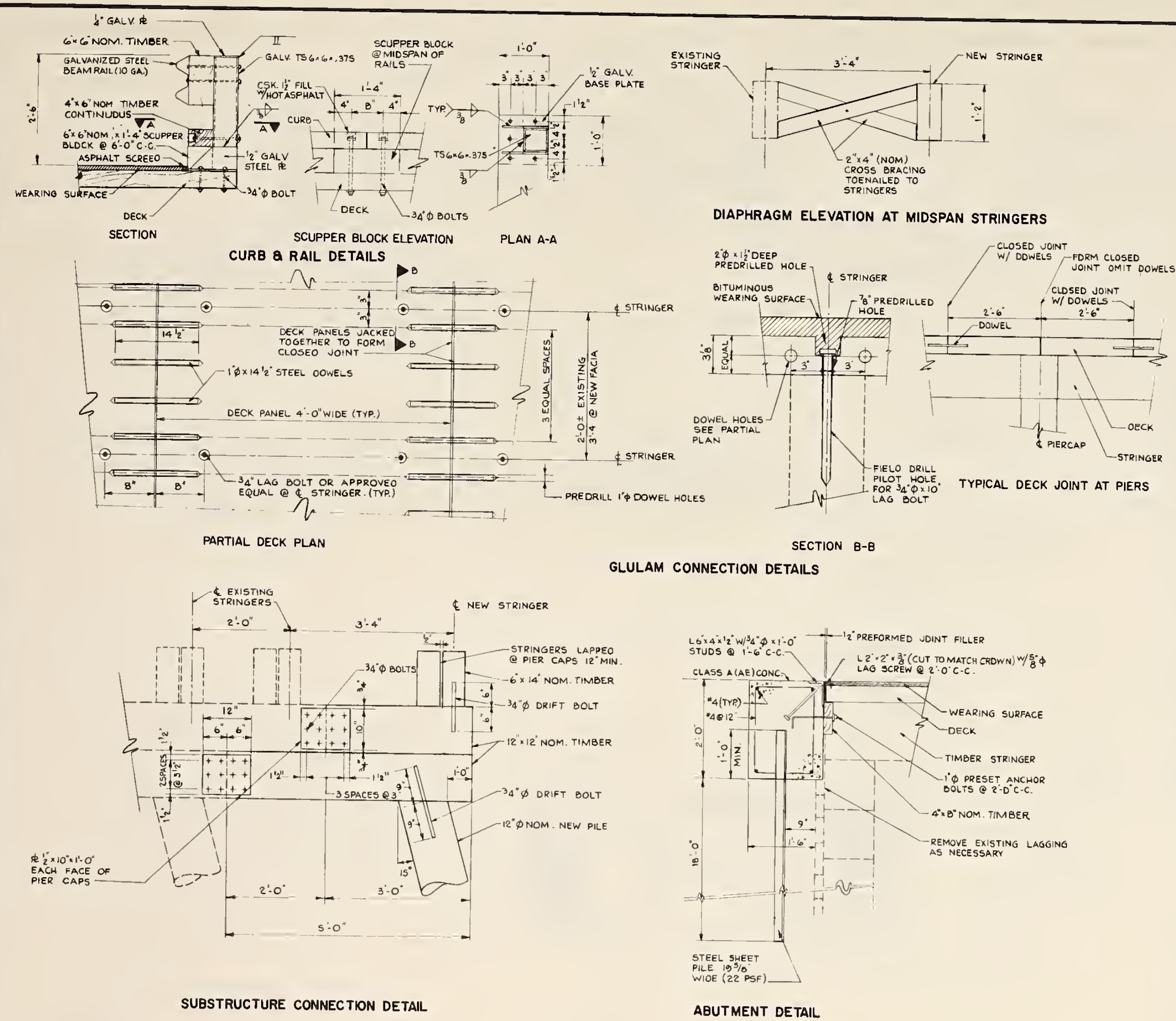
REHABILITATION WORK:

- WIDEN BRIDGE
- INSTALL COMPOSITE TIMBER DECK
- STABILIZE ABUTMENTS

BRIDGE REHABILITATION
TIMBER MULTIPLE BEAM BRIDGE
GENERAL PLAN

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY BYRD, TALLAMY, MacDONALD & LEWIS Division of Wilbur Smith & Associates	MARCH 1978 SHEET NO. 401 1 OF 2



PROCEDURES :

1. CLOSE BRIDGE TO VEHICULAR TRAFFIC.
2. REMOVE ENTIRE EXISTING TIMBER DECK.
3. DRIVE TIMBER PILING AND CONSTRUCT TIMBER PIER CAP EXTENSIONS.
4. INSTALL NEW TIMBER FACIA STRINGERS AND CROSS BRACING.
5. EXCAVATE AT ABUTMENTS, DRIVE SHEET PILING AND POUR CONCRETE CAP.
6. INSTALL GLUED LAMINATED TIMBER (GLULAM) DECKING.
7. CONSTRUCT RAILING AND TIMBER CURBING.
8. INSTALL DECK JOINT ANGLES AT ABUTMENTS AND PLACE BITUMINOUS WEARING SURFACE.
9. REPAIR AND ADJUST APPROACH ROADWAY AND APPURTENANCES AS NECESSARY.
10. REOPEN BRIDGE TO VEHICULAR TRAFFIC.

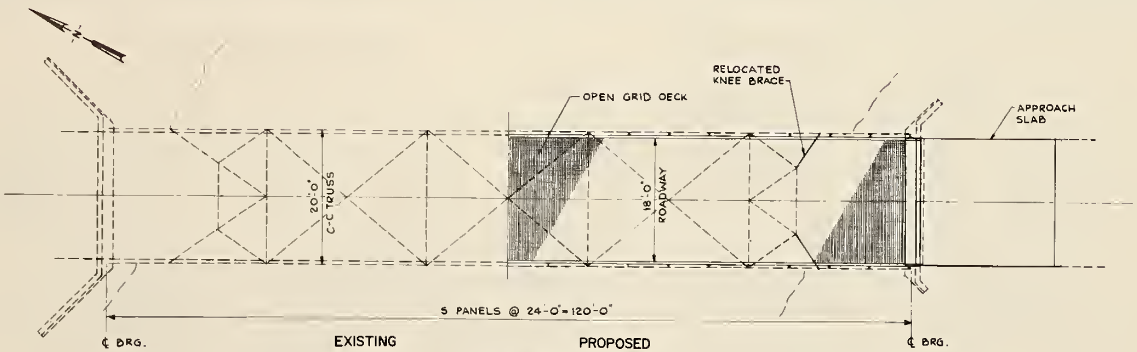
BRIDGE REHABILITATION
TIMBER MULTIPLE BEAM BRIDGE
DETAILS

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

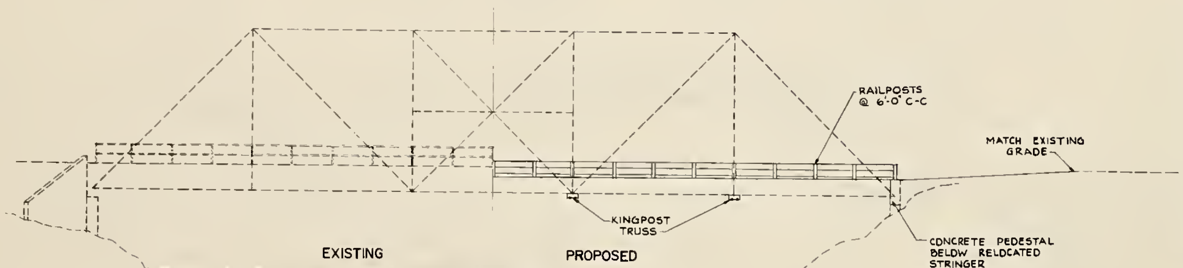
PREPARED BY
BYRD, TALLAMY, MacDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

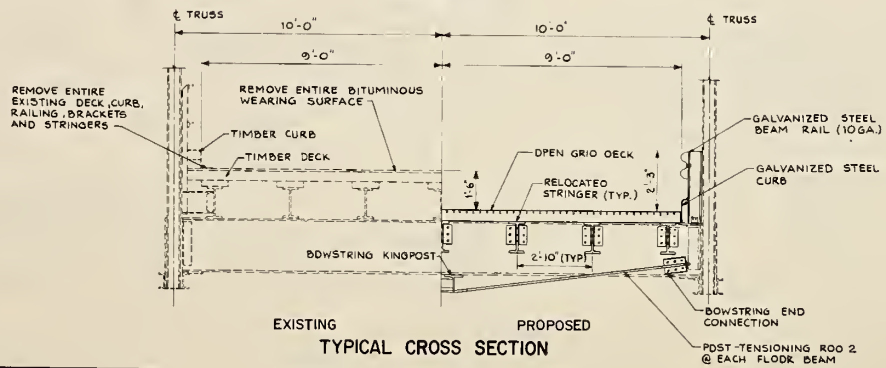
SHEET NO. 402
2 OF 2



PLAN



ELEVATION



TYPICAL CROSS SECTION

GENERAL NOTES

DESIGN:

- REHABILITATION SPECIFICATIONS: "SPECIFICATIONS FOR HIGHWAY BRIDGES, ELEVENTH EDITION, AASHTO 1973," AS AMENDED.
- WELDING SPECIFICATIONS: "STANDARD SPECIFICATIONS FOR WELDING OF STRUCTURAL STEEL HIGHWAY BRIDGES, AASHTO 1974."
- BRIDGE ORIGINALLY CONSTRUCTED IN 1931.
- LIVE LOAD:
  - ORIGINAL DESIGN .... 2 TEN TON TRUCKS WITH $\frac{50}{L+125}$ IMPACT.
  - EXISTING .... HS 18.0 (INV. RATING)
  - PROPOSED .... HS 20-44 (INV. RATING)

MATERIALS

- STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 EXCEPT FOR STEEL GRID DECKING AND ARMOURED JOINT ASSEMBLIES WHICH SHALL CONFORM TO ASTM A588. ALL FASTENERS SHALL BE 7/8" φ H.S. BOLTS UNLESS NOTED OTHERWISE.
- STEEL GRID DECKING SHALL CONFORM TO THE REQUIREMENTS OF THE CURRENT AASHTO "STANDARD SPECIFICATION FOR HIGHWAY BRIDGES". PRIOR TO FABRICATION, THE CONTRACTOR SHALL SUBMIT COMPLETE SHOP AND ASSEMBLY DETAILS TO THE ENGINEER FOR APPROVAL.
- CONCRETE FILL FOR GRID DECKING SHALL BE CLASS C(AE). ALL OTHER CONCRETE SHALL BE CLASS A (AE). MINIMUM 28 DAY COMPRESSIVE STRENGTH f'_c = 3000 PSI. AIR ENTRAINING ADMIXTURES SHALL CONFORM TO THE REQUIREMENTS OF ASTM C260. ALL EXPOSED EDGES SHALL BE CHAMFERED 3/4 INCHES.
- REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A 615, GRADE 40. THE MINIMUM CONCRETE COVER OVER REINFORCMENT BARS SHALL BE 2 INCHES CLEAR.
- PAINTING OF STRUCTURAL STEEL SHALL INCLUDE ONE SHOP COAT AND TWO FIELD COATS EXCEPT FOR GALVANIZED MEMBERS OR SURFACES TO BE IN CONTACT WITH STEEL OR CONCRETE. PAINT MATERIALS SHALL BE IN CONFORMANCE WITH CURRENT AASHTO SPECIFICATIONS.
- PREFORMED ELASTOMERIC JOINT SEALER SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M220.
- ELASTOMERIC BEARING PADS SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE CURRENT AASHTO "STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES".
- IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO VERIFY ALL DIMENSIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING MATERIALS.
- PREFORMED EXPANSION JOINT FILLER SHALL CONFORM TO THE REQUIREMENTS OF ASTM D1752.
- STEEL BEAM RAILING SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M180-70. CONNECTION BOLTS AND NUTS SHALL CONFORM TO THE REQUIREMENTS OF ASTM A307, CLASS A. BOLTS AND NUTS SHALL BE GALVANIZED IN ACCORDANCE WITH THE REQUIREMENTS OF AASHTO M232.

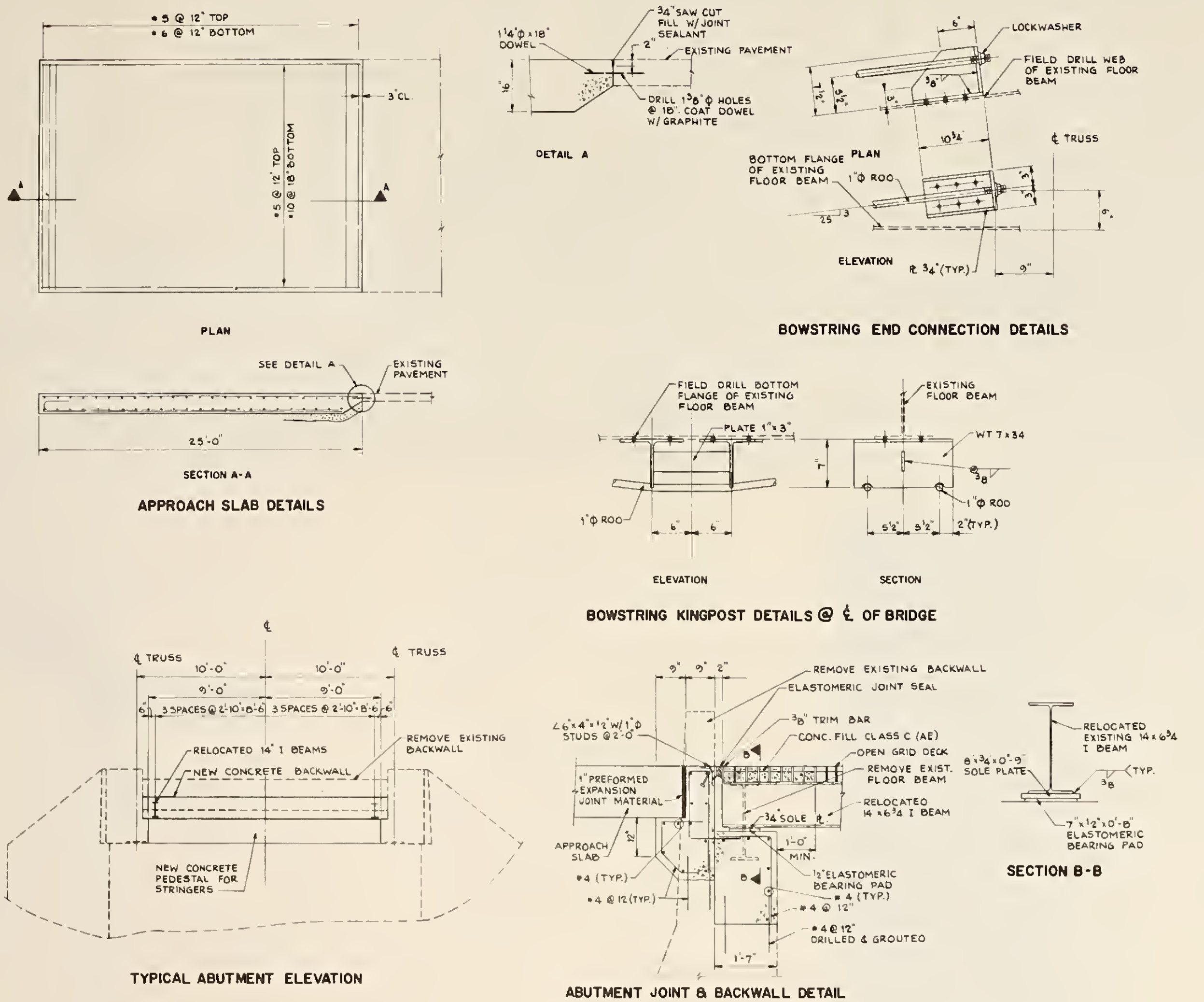
REHABILITATION WORK:

- INSTALL LIGHTWEIGHT DECK
- ADD KINGPOST TRUSSES TO FLOOR BEAMS
- INCREASE VERTICAL CLEARANCE

BRIDGE REHABILITATION
STEEL THRU TRUSS BRIDGE
GENERAL PLAN

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY BYRD, TALLAMY, MacDONALD & LEWIS Division of Wilbur Smith & Associates	MARCH 1978
	SHEET NO. 501 1 OF 3



PROCEDURES:

1 CLOSE BRIDGE TO ALL TRAFFIC.
2 REMOVE ENTIRE EXISTING BITUMINOUS WEARING SURFACE, TIMBER DECK AND CURB, AND METAL RAIL AND BRACKETS.
3 REMOVE EXISTING STRINGERS AND END FLOOR BEAMS. CONSTRUCT CONCRETE PEDESTAL FOR STRINGER BEARINGS AT ABUTMENTS.
4 FIELD CUT STRINGERS TO FIT, DRILL BOLT HOLTS AND ATTACH TO FLOOR BEAM WEBS IN LOWERED POSITION.
5 ATTACH BEARING STIFFENERS AND SOLE PLATES TO STRINGERS AT ABUTMENTS. INSTALL ELASTOMERIC BEARING PADS.
6 FIELD DRILL BOLT HOLES IN FLOOR BEAMS AND ATTACH "BOW STRING" KING POSTS AND END CONNECTIONS.
7 INSTALL POST TENSIONING RODS. AFTER OBTAINING SNUG FIT ON ALL NUTS, TENSION RODS TO 20K EACH SIMULTANEOUSLY ON BOTH SIDES OF FLOOR BEAMS IN A MANNER APPROVED BY THE ENGINEER.
8 INSTALL OPEN GRID DECKING IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATIONS.
9 FILL OPEN GRID DECKING WITH CONCRETE AT THE ABUTMENTS TO THE LIMITS SHOWN.
10 INSTALL BRACKETS, STEEL BEAM RAILING AND STEEL CURB.
11 REMOVE EXISTING ABUTMENT BACKWALLS AND RECONSTRUCT AS SHOWN WITH INTEGRAL ARMOURED JOINT ASSEMBLY.
12 REMOVE APPROACH PAVEMENT, PREPARE SUBGRADE AND CONSTRUCT APPROACH SLABS.
13 REMOVE EXISTING KNEE BRACING. FIELD CUT TO FIT AND CONNECT TO END POSTS WITH NEW GUSSET PLATES. REMOVE EXISTING UPPER GUSSET PLATES ONE AT A TIME, AND WELD BRACING TO NEW GUSSET PLATES.
14 APPLY PAINT FIELD COATS TO NEW STRUCTURAL STEEL. CLEAN AND SPOT PAINT EXISTING STRUCTURAL STEEL IN ACCORDANCE WITH CURRENT AASHTO RECOMMENDATIONS AND AS DIRECTED BY THE ENGINEER.

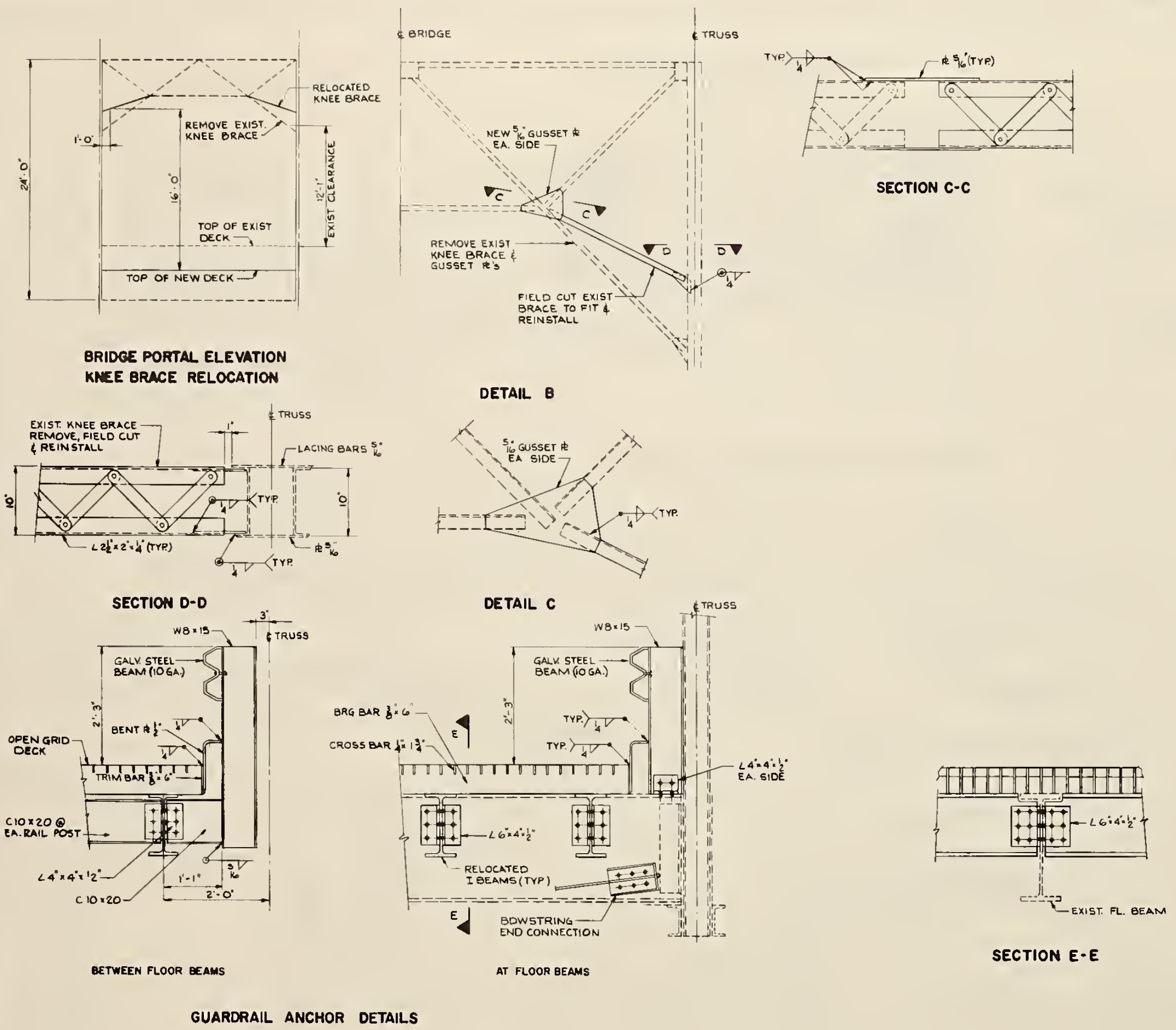
BRIDGE REHABILITATION
STEEL THRU TRUSS BRIDGE
DETAILS

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MacDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

SHEET NO. 502
2 OF 3



BRIDGE REHABILITATION
STEEL THRU TRUSS BRIDGE
DETAILS

U.S. Dept. of Transportation - Federal Highway Administration
RESEARCH PROJECT NO. DOT-FH-11-9214
"EXTENDING THE SERVICE LIFE OF EXISTING BRIDGES"

PREPARED BY
BYRD, TALLAMY, MacDONALD & LEWIS
Division of Wilbur Smith & Associates

MARCH 1978

SHEET NO. 503
3 OF 3

FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Opera tion for Safety

Safety R&D addresses problems connected wi the responsibilities of the Federal Highw Administration under the Highway Safety A and includes investigation of appropriate desi standards, roadside hardware, signing, a physical and scientific data for the formulati of improved safety regulations.

2. Reduction of Traffic Congestion ar Improved Operational Efficiency

Traffic R&D is concerned with increasing t operational efficiency of existing highways advancing technology, by improving designs f existing as well as new facilities, and by kee ing the demand-capacity relationship in bett balance through traffic management techniqu such as bus and carpool preferential treatmer motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring

ment and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

---

* The complete 7-volume official statement of the FCP available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

FHWA
R&D