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UPGRADING DEFICIENT THROUGH TRUSS BRIDGES

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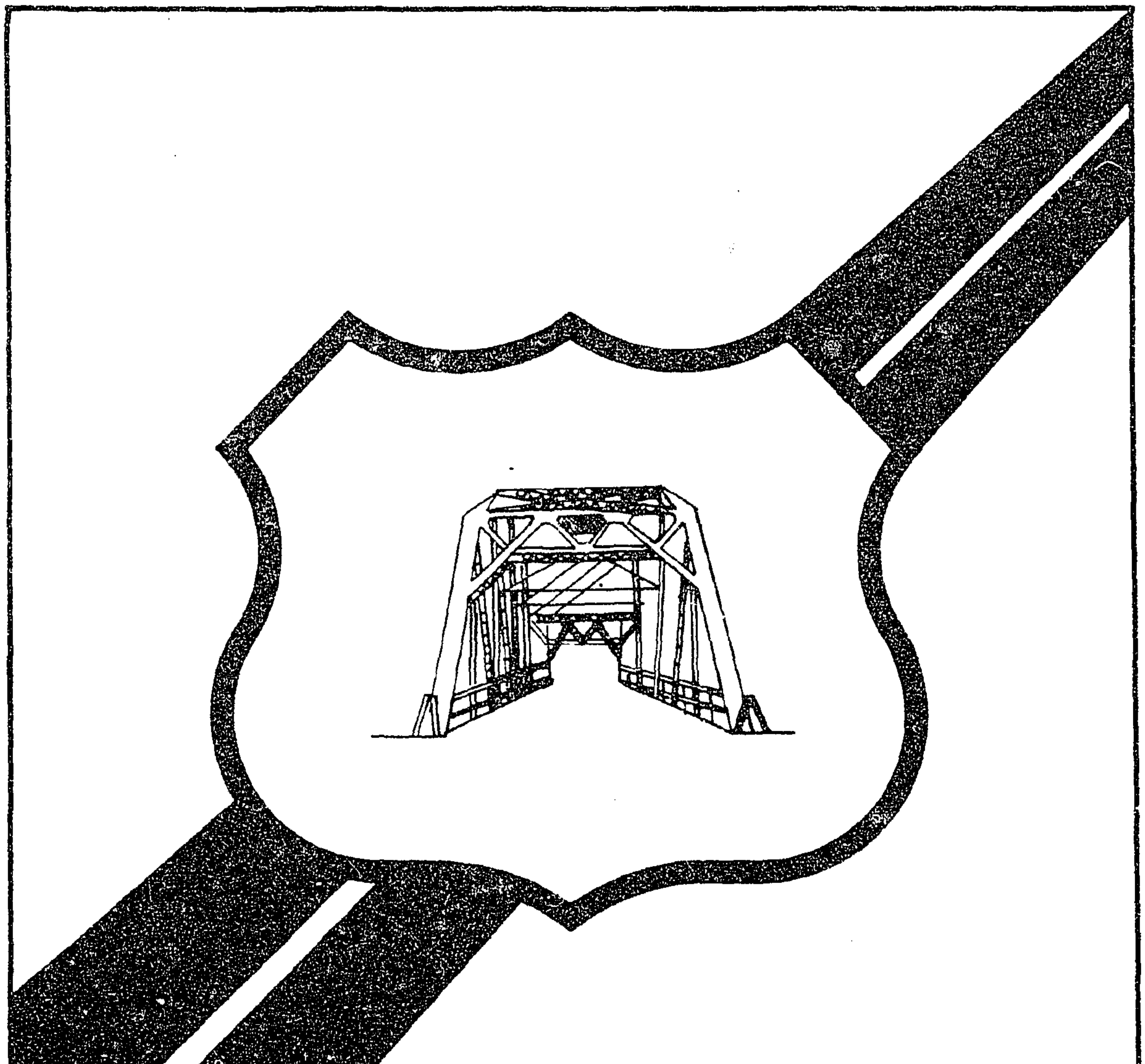

FOREWORD

Many old through truss highway bridges have experienced structural problems or have become geometrically obsolete partly because they have outlived their design life. These structures were originally designed for relatively light loading, have narrow roadways and often have seen little or no maintenance.

Research was conducted to develop alternatives to the total replacement of through truss bridges because of the large number of these structures which exist in the United States and because of the scarcity of construction funds to replace those which are deficient.

The purpose of this study is to evaluate the feasibility by comparing the cost effectiveness of rehabilitation versus total bridge replacement. Methods are presented to economically and rapidly upgrade the roadway width, vertical clearance, and load carrying capacity of geometrically inadequate and structurally unsound through truss bridges.

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NOTICE

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16. Abstract

This study consists of (a) investigation of current practices in several states to upgrade truss bridges; (b) literature search for state-of-the-art perspective; (c) evaluation of information from the FHWA bridge inventory; and (d) search for examples of truss bridge rehabilitation. The information is used to develop and evaluate various methods to rehabilitate through truss bridges.

Methods of rehabilitation are formulated, analyzed and designed to suit the most general condition of truss bridges. Several problems exist with through truss bridges; these are presented in the report.

The methods are applied to the one existing, typical bridge to demonstrate proposed methods, and to identify problems, limitations, and construction procedure as applied to actual bridges. Both specifications and drawings are included, and cost comparisons between rehabilitation and replacement are made. Recommendations for future research are given.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Bridges are an integral part of modern road networks. Over the years, many bridges, deteriorated structurally and geometrically, are now inadequate to handle present-day, increased traffic. These deficiencies have impeded movement of people and freight vital to the national economy, resulting in a significant impact on social, political and economic growth. Failures, like the Silver Bridge at Point Pleasant, West Virginia which took 46 lives, have caused increasing concern over safety of the nation's bridges, and have led to a systematic Federal Program of Bridge Inventory and Inspection to be applied to all bridges on the Federal Aid System. This program is designed to: (a) inspect and catalog present bridge conditions; (b) evaluate their load-carrying capacity; (c) determine the level of safety according to the nature of and/or geometric deficiencies; (d) determine the required rehabilitation and/or reconstruction for present use; and (e) identify a preventative maintenance program.

During the last two decades, various highway departments have realized these problems and, as a result, have undertaken projects to find suitable solutions to deficient bridge conditions. The Federal Highway Administration (FHWA) has participated in these endeavors. Many authorities believe that replacement of "old" bridges is the only alternative; however, this approach is prohibitively expensive, especially with limited available funds. In addition, priorities for replacement of these bridges might be established by political pressure rather than structural necessity.

The American Society of Civil Engineers (ASCE)[20] Task Committee on Truss Bridges pointed out that research should focus on solutions, using modern means of assessment in combination with structural analysis to remove structural or geometric deficiencies. Deficiencies must first be identified as fully as possible, and current practices for upgrading capacities of existing bridges reviewed. Cost effectiveness of current practices compared with replacement must show the relationship between the Cost Effectiveness Ratio (CER) and the length of span at the present load level as determined by American Association of State Highway and Transportation Officials (AASHTO). CER is defined as the ratio of cost of rehabilitation to cost of total replacement of the bridge.

1.2 DEFINITION OF THROUGH TRUSS BRIDGE

There are several definitions of this type of bridge. The following comprehensive definition is presented.

A bridge is usually composed of two parallel trusses or girders supporting the bridge floor or roadway. A road track may rest either directly upon the upper chords of a pair of trusses or lower chord. In the former case, it is called the deck bridge. In the latter, when it becomes desirable or necessary to reduce the vertical distance from the bottom of the truss to the top of the deck, the trusses are spread, and the deck is carried by a floor system out or near the lower-chord panel points. This type is known as a through bridge since traffic is through the bridge between the trusses, rather than on top of them. Short-span highway bridges of the through type with trusses not deep enough to permit overhead bracing are known as pony truss bridges (Fig. 1).

This definition brings out some aspects of rehabilitation, particularly restrictions. The problem is the restriction of height to make modifications in the geometry as compared to the deck type of bridge. In this report only the through truss bridge as defined here is considered for rehabilitation although methods developed will be applicable to other types. Modifications are generally sought for the structural action of trusses and their members and sometimes for the other parts of the bridge.

As will be pointed out later, modification of the deck may be necessary, and should be considered in cost comparisons of rehabilitation versus replacement of a bridge to arrive at a CER.

1.3 RESEARCH OBJECTIVES AND SCOPE OF WORK

The overall objective of this research project is a critical review of

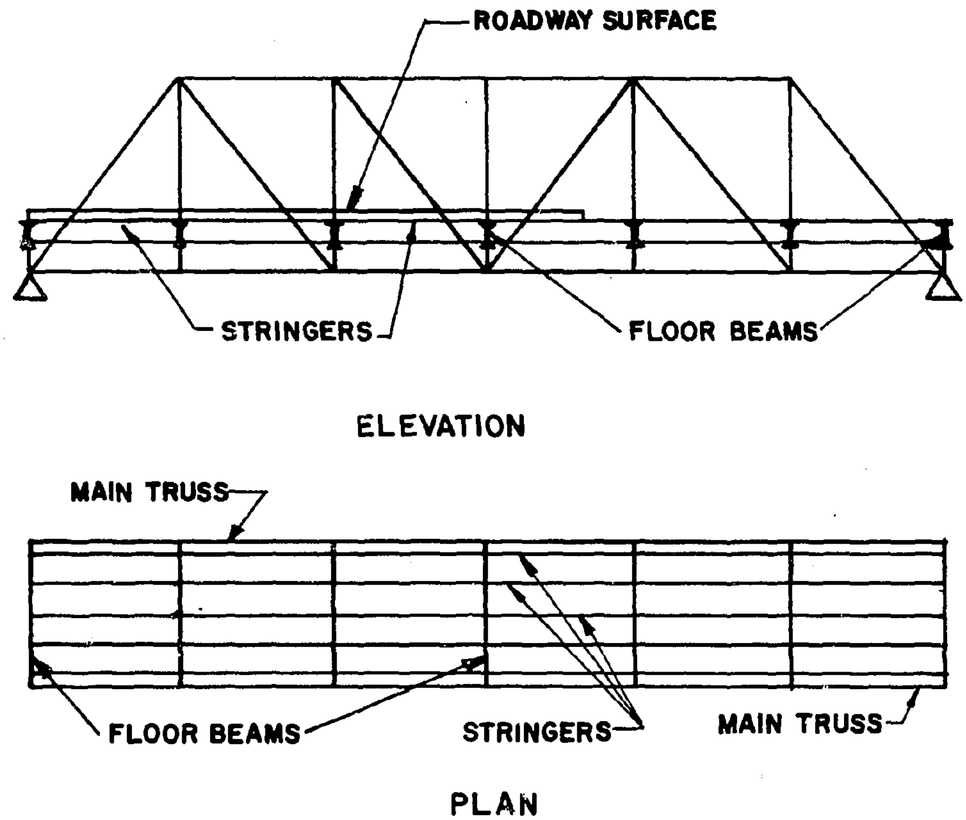


FIG. 1 DETAILS OF TYPICAL THROUGH TRUSS BRIDGE

the available literature, and elimination of practices or development of innovative methods to upgrade economically, structural and geometric deficiencies in existing through truss bridges. The entire project was divided into the following phases:

PHASE I: Establish the state-of-the-art by a review of the literature, statewide practices and various case studies reported by individuals, and definition/identification of various deficiencies.

PHASE II: Develop alternative methods to eliminate deficiencies or upgrade bridges to overcome them in order to support present loading conditions. A complete analysis and other details as required in each method are included.

PHASE III: Establish the validity of methods developed in the previous phase, by using actual examples so that limitations, construction procedure, and specifications for rehabilitation work can be evaluated. Drawings are prepared for all the methods.

Since through truss bridges exist in all types, only those used in the majority of bridges are considered. The span range considered is between 60 ft to 200 ft (18m to 60m). Rehabilitation of bridge decks is not considered, but used only for reduction of dead load or for cost estimation purposes.

CHAPTER 2: STATE-OF-THE-ART

2.1 INTRODUCTION

The state-of-the-art is the first phase of the study. A number of information sources are used to develop methods for rehabilitation or upgrading through truss bridges: (a) literature search, (b) current practices by various agencies and States, and (c) evaluation of FHWA inventory. The state-of-the-art is presented in this chapter.

2.2 TYPES OF TRUSS BRIDGES

Generally, old highway truss bridges, which are structurally deficient, have spans under 150 ft (45m) and have used the Pratt truss with parallel chords and inclined end posts extensively. The pony truss, without the top lateral system, was not used much until heavier loads and wider roadways caused the use of deeper and heavier floor beams. With deeper beams as anchor, outriggers were built from the end of the floor beams, coming up to the top chord, thus providing bracing for the top chord against buckling.

In Figs. 2 and 3, various types of bridge trusses are shown based on drawings by the Historic American Engineering Record (HAER). These are some of the types which should be anticipated in using the proposed schemes for improved load carrying capacity.

2.3 TYPES OF BRIDGE DEFICIENCIES

Deficiencies of through truss bridges can be classified as: (a) structural, (b) geometrical, due to narrowness of the bridge as well as the approach roadway and its transition, (c) mechanical, and (d) others.

Structural deficiencies occur in a variety of situations and conditions. The truss bridge is somewhat complicated, compared to a stringer (girder) bridge, not in terms of defects but their <u>critical location.</u> Since a truss

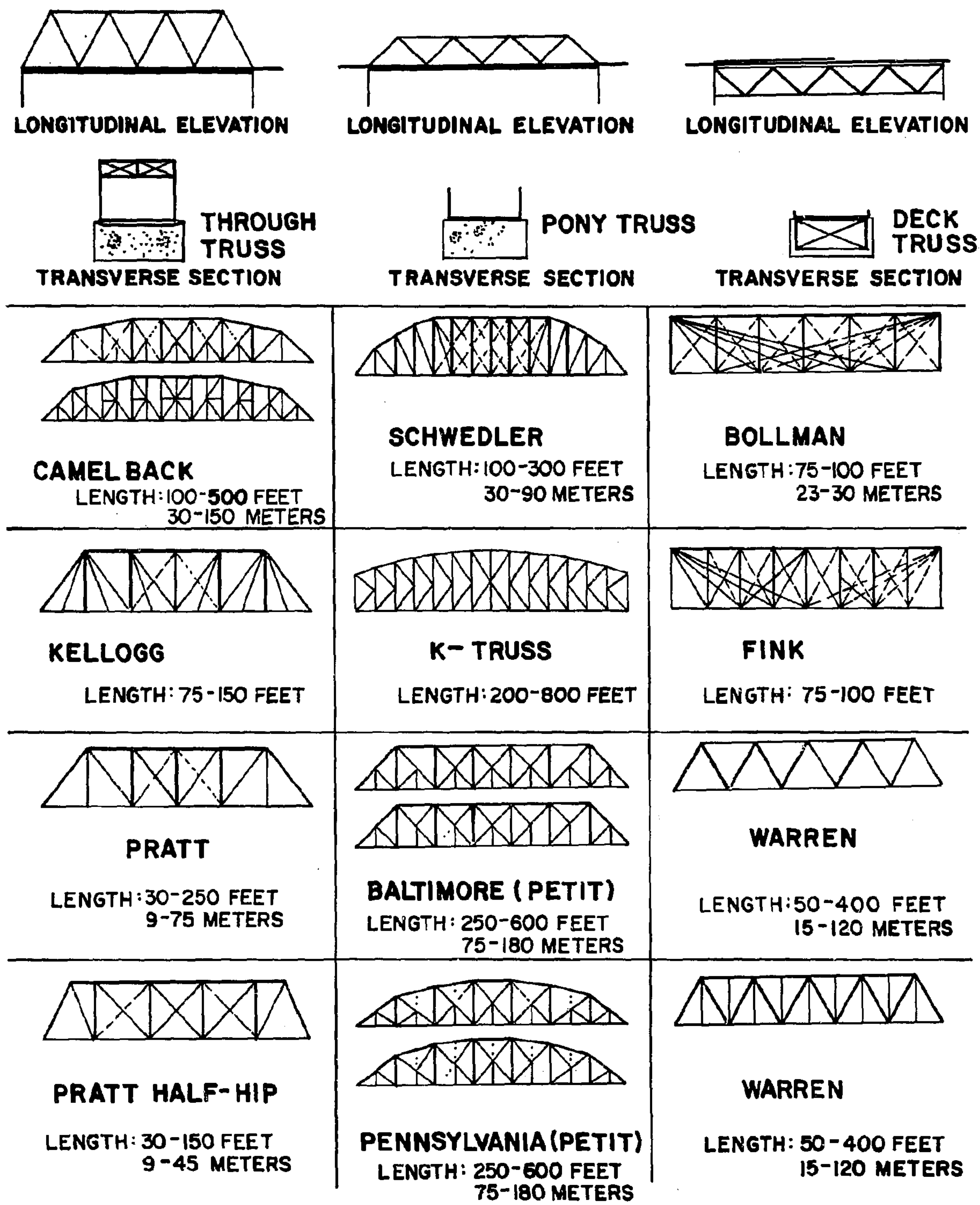


FIG. 2 TYPES OF TRUSS BRIDGES

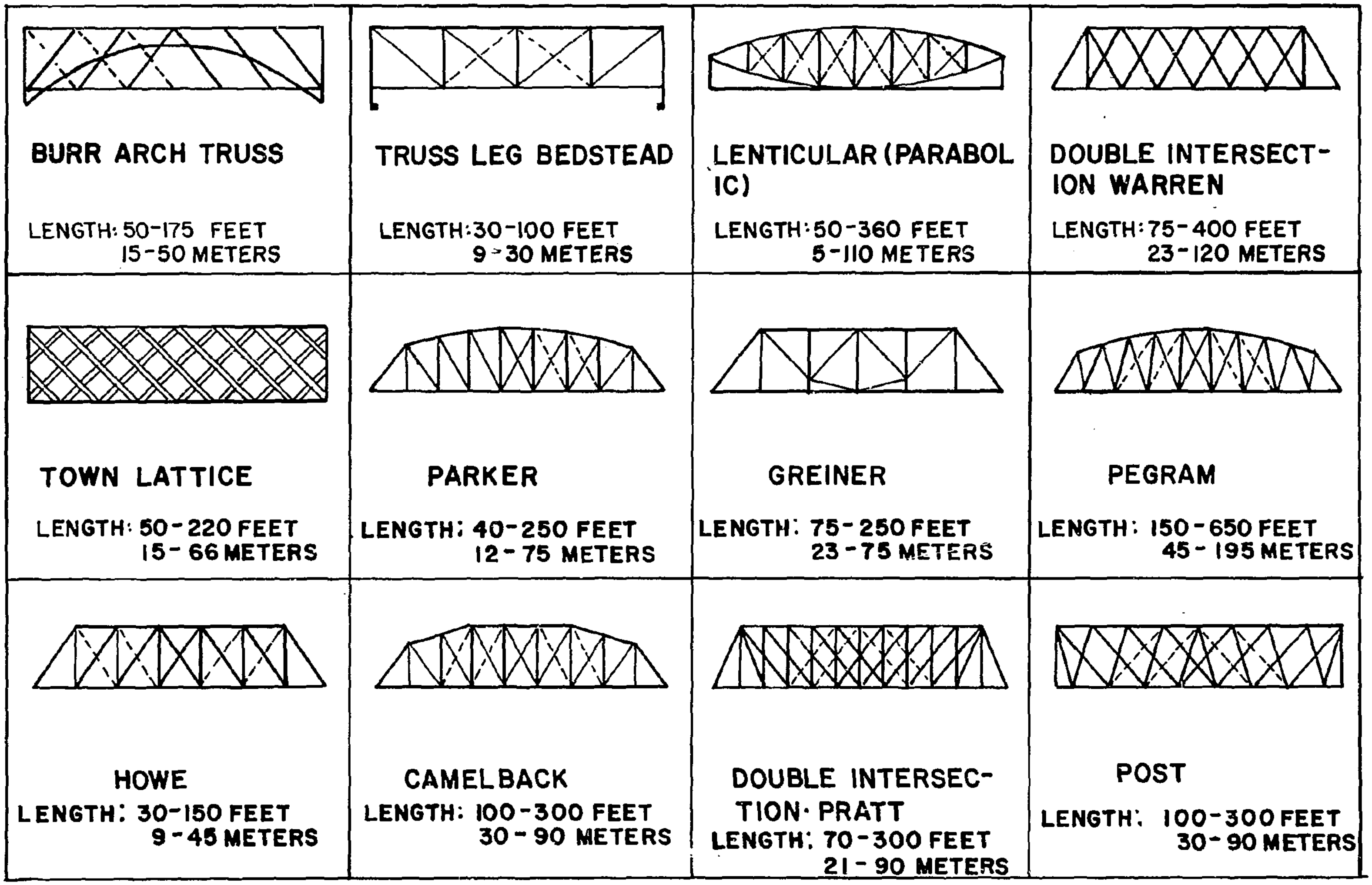


FIG. 3 TYPICAL BRIDGE TRUSS

bridge is built with a large number of members, not only must the deficient members be identified but also the overall bridge condition must be considered in an effort to find the best solution for removal of deficiencies. Connections are the next item to be checked for defects since they are often the location of distress. The bearings of a truss are also important since their loss could cause instability or even result in a failure. Distress may result from mechanical and environmental conditions or from the lower strength of materials used in the tension member of the truss construction. Thus, the material properties of the members may cause distress.

Geometric deficiencies stem from roadway widths, vertical and horizontal clearances, geometry of approach to the bridge, and traffic capacity. Many deficiencies are inherent in the initial designs. As a result, both safety and usefulness of these bridges are adversely affected.

Other deficiencies caused by environmental conditions include those which prohibit the structure from serving the designed purpose. These generally result in the corrosion of metal elements, the accumulation of debris and silt around bearings and joints, and lateral movement of the substructure units.

Debris buildup 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. Bearings freeze as a result of this corrosion, preventing 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. Under the combination of these forces, backwalls deflect and eventually crack. As a result, the bridge can no longer funtion as intended without exerting loads on the structure beyond those considered by the designers.

Settlement and 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. Subsequent temperature changes can then result in serious overstress in other elements of the bridge.

Narrowness of the bridge and approach road can be hazardous and must be taken into account in the rehabilitaton and upgrading of any bridge. In particular, an inappropriate access to a through truss may cause a collision and enough extensive damage to impair the entire bridge structure.

In a recent FHWA report[1], various deficiencies for all types of bridges are classified. Table 1 shows the number of occurrences in truss bridges found during an inspection. Another recent report[2] presents performance of a bridge, R(t) (representing "reliability"), as an exponential function:

$$R(t) = e \; \lambda \; i^{t}$$

in which,

t = number of years in service
i = function of failure mode, deficiency, and maintenance

Neither details of the above function, nor the probabilistic approach for analysis of truss bridges are necessary in this discussion. However, when considering various defects, a probabilistic approach may be used to determine the seriousness of a safety loss with respect to time caused by various factors.

2.4 LITERATURE REVIEW

There is considerable available literature in the form of research reports, committee reports and individual research papers. These are listed in the bibliography in Appendix A.

The literature may be classified into the following major categories:

(a) Individual efforts to solve actual problems of bridge deficiency.
(b) Research reports funded by a government agency or academic interest.

TABLE 1 DEFICIENCIES AND THEIR OCCURRENCE
(based on Ref. 1)

		DEFICIENCY	NUMBER OF BRIDGES
Superstructure	Main Support System	Corrosion with section loss-truss member	27
		Corrosion with section loss-beams & girders	41
		Bearing inoperable	37
		Connections, non-functional	13
		Timber decay, section loss	7
		Conc. spall--rebar exp., section loss	46
		Severe concrete cracking	48
		Bracing member failure	7
		Damage to structural member by collision	14
	Deck	Joints non-operable	22
		Severe cracking & concrete deterioration	14
		Delaminations	19
		General concrete deterioration	15
Substructure	Abutments	Severe cracking & concrete deterioration	44
		Settlement	5
		Tilting & rotation	8
		Timber decay	3
		Scour	7
	Piers	Cap BM--rebars exposed, section loss	16
		Column defects, section loss	4
		Settlement	2
		Tilting	1
		Cracking	16
		Scour	5
	Bents	Scour	3
		Cracking longitudinal	11
		Corrosion	6
		Settlement	1
		Tilting	2
		Pile defects, section loss	10
		Cap spall-exposed bar	4

TABLE 1 DEFICIENCIES AND THEIR OCCURRENCE
(based on Ref. 1)
(continued)

DEFICIENCY			NUMBER OF BRIDGES
Other Deficiencies	Geometrics	Roadway width	48
		Vertical clearance	3
		Vertical alignment	7
		Horizontal alignment	8
	Safety	Quality of roadway	19
		Railing ends accident prone	5
		Inadequate railing	23
Posted Restric-tions		Bridge posted, load	34
		Bridge posted, speed	17
		Bridge posted, lane restriction	16

(c) Reports related to maintenance and rating (load capacity) of existing bridges.

(d) Computer programs related to item (c).

Proceedings of an international conference (1981) on "Rehabilitation of Structures including Investigations"[3] include over 50 papers related to this general topic. Case studies of truss bridges indicating methods used by various authors are discussed.

Kittridge[4] suggests a method which utilizes cables as dead and live load-sharing members to effectively strengthen simple span structure. Calling it "the cable sling strengthening" method, he notes three main advantages: (a) simplicity in design and construction; (b) practicality enabling application to structures, such as a twin girder or truss superstructure; and (c) versatility for potential use in multiple-span continuous structures (Fig. 4).

A truss bridge unable to carry existing traffic may be strengthened by adding auxiliary systems, members, or piers. Additional bracing members may be provided if the unbraced length is too long. Support systems using cable and beam grillages could be added if necessary if appearance is not important. These are illustrated in Figs. 5 through 7.

A paper by Sanders, et al[5] describes the ultimate load test of a truss bridge floor system. A modified Parker-type high-truss bridge (Fig. 8), located northwest of Des Moines, Iowa, along with several of its components, was tested to failure during the summer of 1974.

Bandopadhyay[6] suggests prestressing a truss (Fig. 9), using the following principle: under full load combination of dead, live, and impact load truss members will undergo elastic deformations, say 1, 2, 3, etc. If the, member lengths are adjusted by these values at the rehabilitation stage, a cambered outline of the bridge, as shown in Fig. 9a, would result, but this would also ensure that under full load, the nominal outline of the bridge would be retained (i.e. in parallel chord truss, the chords will become flat), as shown in Fig. 9b. The truss can be prestressed only for one particular set of loadings, i.e., full load combination of dead load, live load, and impact load. In this case the two extreme conditions of loading on the truss are: (1) when the axial forces in the chord members are at a minimum (as under load only), the deformation stresses are at a maximum (Fig. 9a); and (2) when the axial forces in the chord members are at a maximum, the deformation stresses are at a minimum (Fig. 9b).

From the information gathered during the inspection and rating, a decision must be made whether or not to repair, replace, abandon, or change use. Using one study, this decision can be based on safety, economics, and appearance, using two principles in economics. The first principle can be expressed as a deferred expenditure, where the break-even point is at:

$$A = P(1+i)^n$$

Where:

A = cost whose return is to be realized

P = deferred expenditure

n = number of years repair must be deferred to return value of increased cost of later repair

i = interest rate

As an example, let:

C = cost of immediate repair

0.2C = cost of preservative treatment

1.1C = cost of later repair

Then:

$$A = 1.1C + 0.2C = 1.3C$$

$$P = C - 0.2C = 0.8C$$

And with:

$$i = 16\%$$

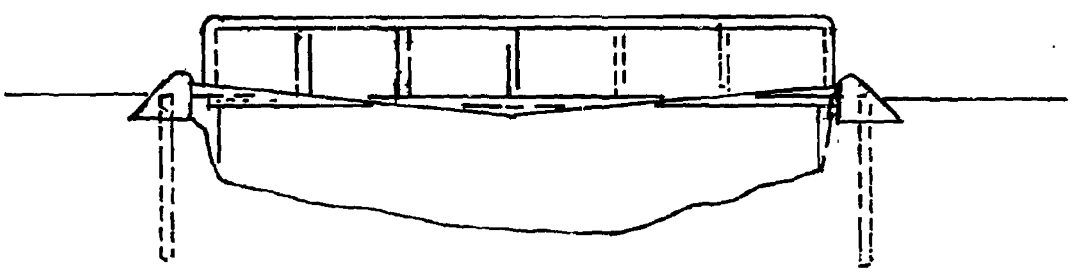
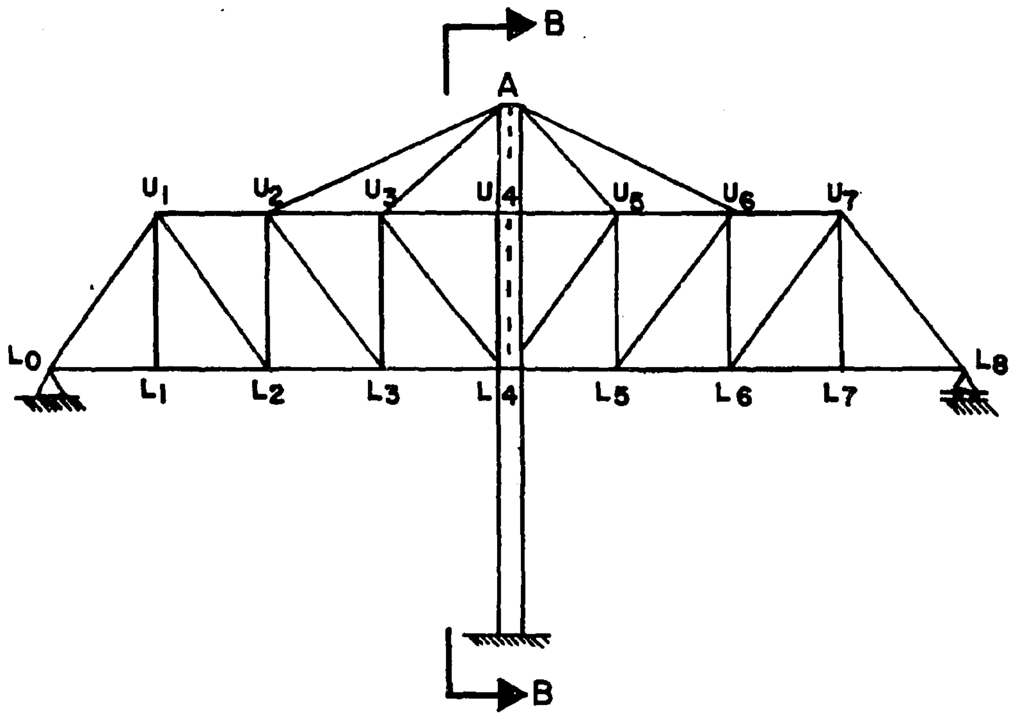
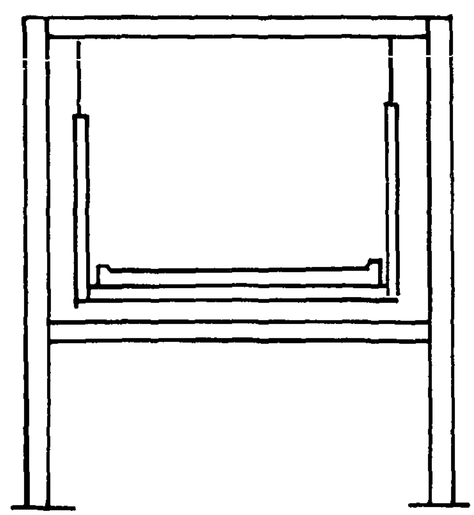


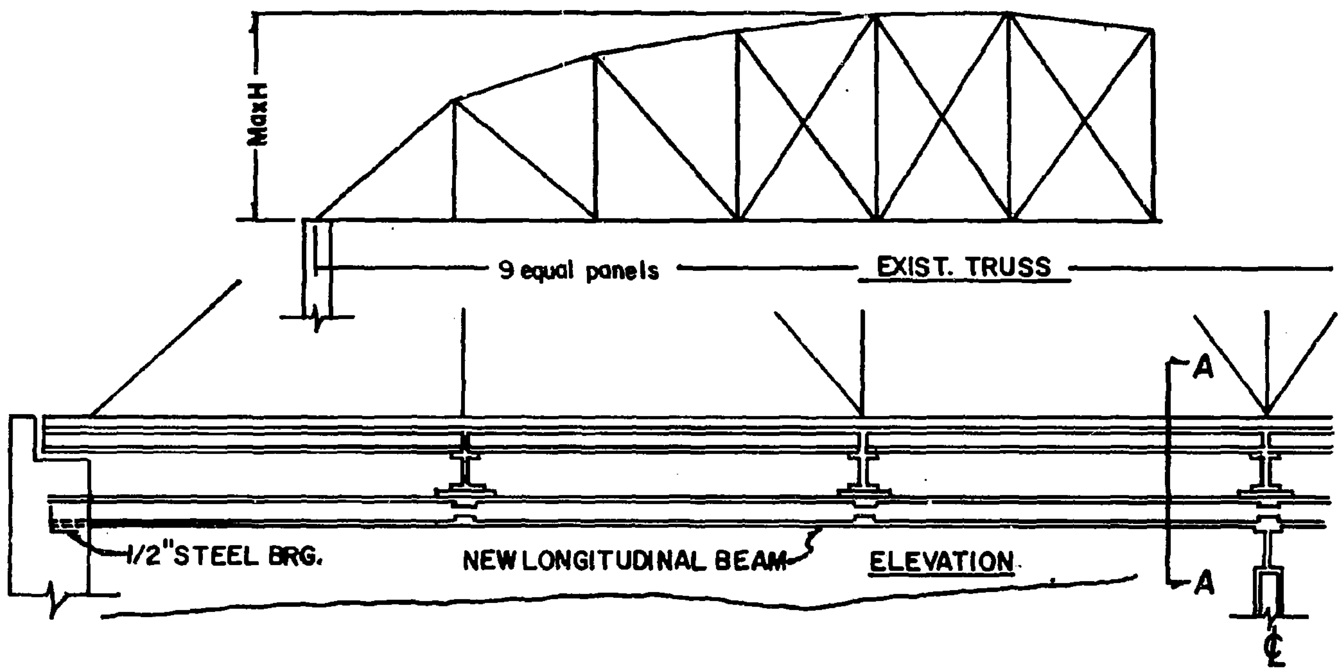
FIG. 4 ILLUSTRATION OF THE CABLE SLING METHOD





SECTION B-B

FIG. 5 CABLE-STAYED ADDITIONAL SUPPORT SYSTEM



TRUSS REPAIR

FIG. 6 BEAM GRILLAGE AND PIER ADDITIONAL SUPPORT SYSTEM

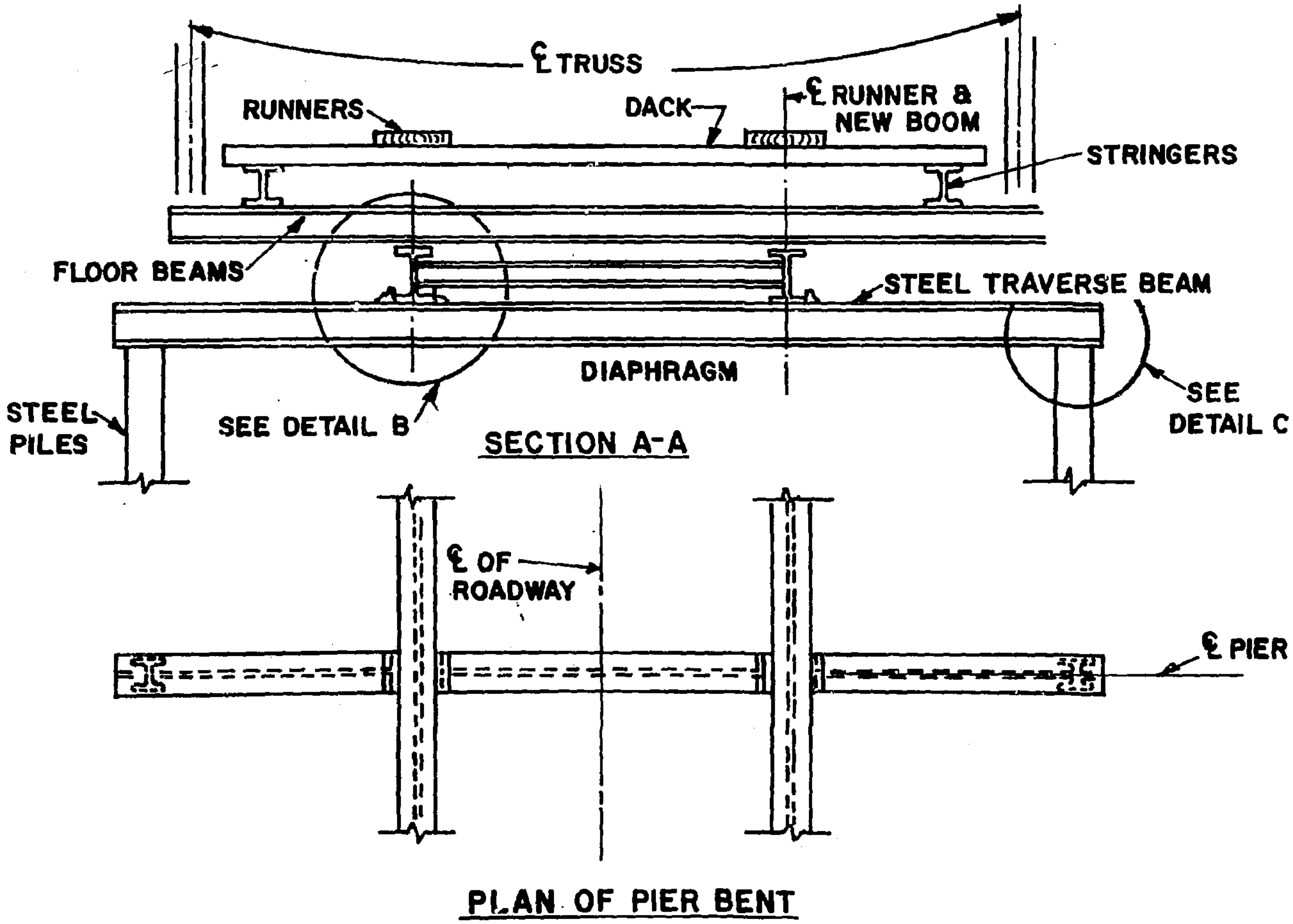


FIG. 7 BEAM GRILLAGE AND PIER ADDITIONAL SUPPORT SYSTEM

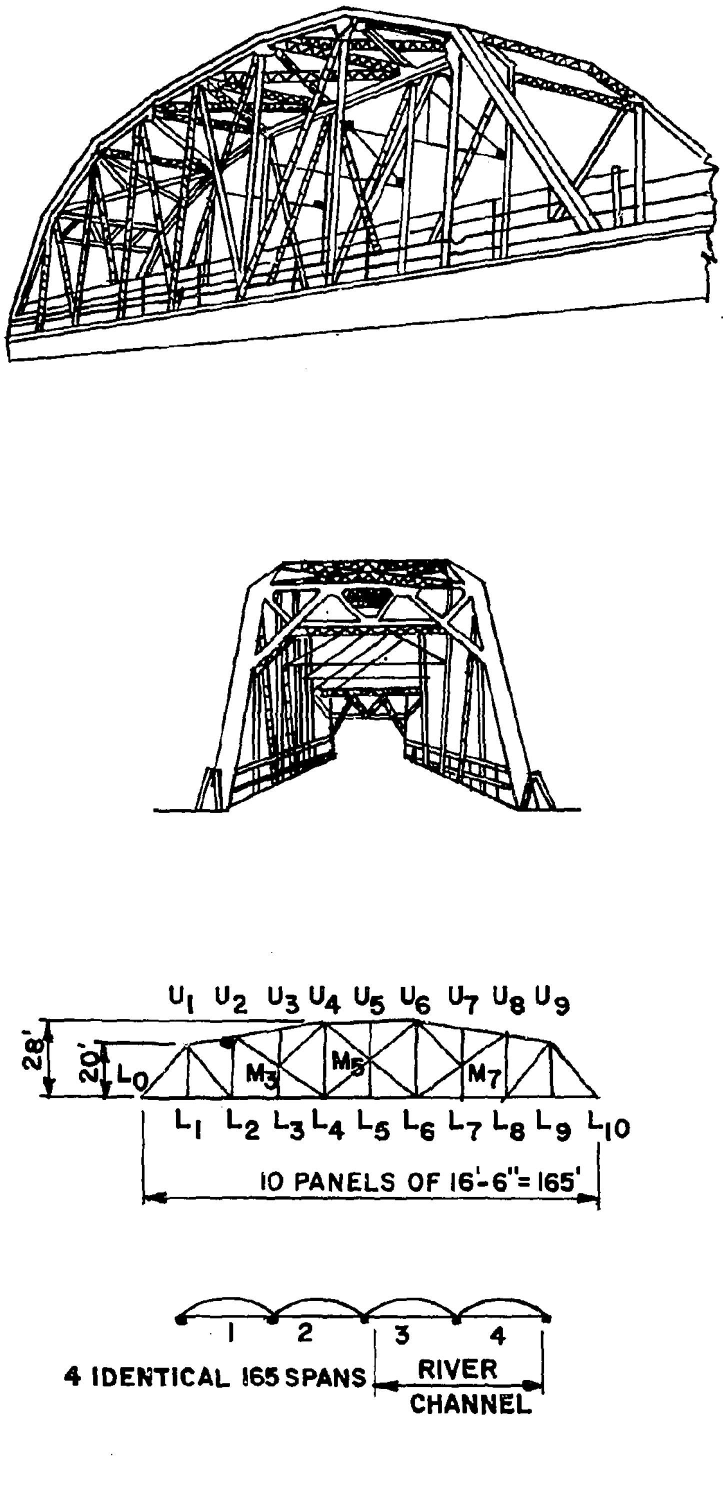
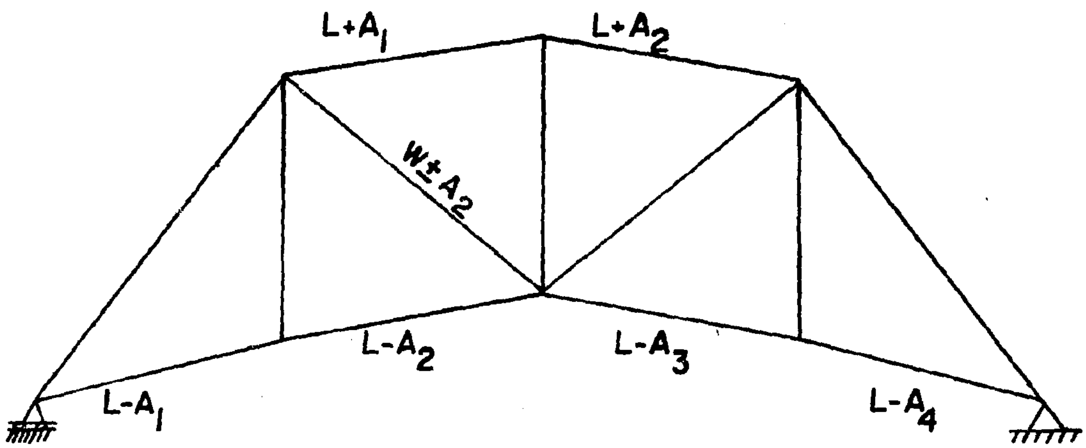
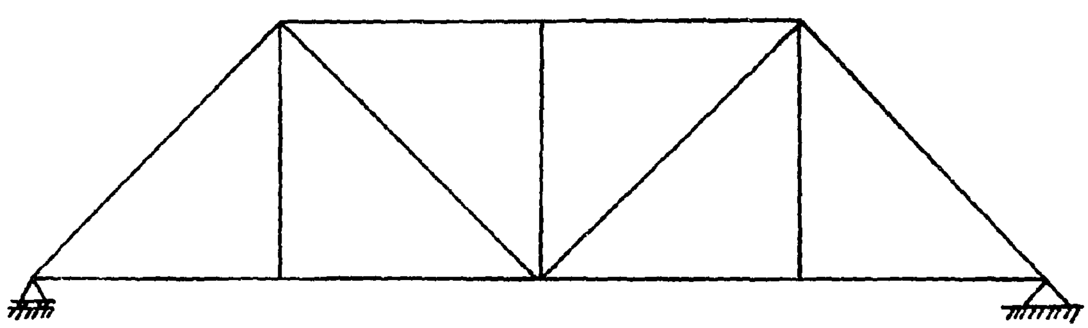


FIG. 8 DETAILS OF HUBBY BRIDGE



(a) COMBINED OUTLINE: DEAD LOAD ONLY, DEFORMATION STRESS MAXIMUM.



(b) NOMINIAL OUTLINE: FULL LOAD (DEAD LOAD AND IMPACT LOAD), DEFORMATION STRESS A MINIMUM.

FIG. 9 PRINCIPLE OF PRESTRESSING A TRUSS (BANDOPADHYAY - 1965)

Then:

$$n = \frac{\text{Log } A/P}{\text{Log } (1+i)} = 3.3 \text{ years}$$

Thus, if the preservative treatment will sustain for more than 3.3 years, it will pay to defer the repair.

Using the second principle, if repair cost is less than 50% of the replacement costs, it pays to repair; if repair costs are greater than 50% of the replacement costs, the solution should be replacement.

Bridge Rating and Analysis of Structural System (BRASS) was developed by Johnston, et al[7], in the form of a computer program. This three-part report consists of: I--System Reference Manual, II--Example Problems, and III--Programming Aids. Volume I describes the components of the system, including bridge design, structural inventory, deck design and review, structural analysis, structural loading, and girder section design and review. The system's 45 computer programs are flexible and user-oriented. The bridge design processes included in these programs adhere to uniform bridge design standards. Volume II includes test data for eight typical highway bridge loading analysis and rating problems and the solutions to these problems. The test data allow an organization to implement and initially execute the rating system without extensive data collection and modification. The output examples provide a system checkout and serve a tutorial function. Volume III, is primarily a user's manual for the developed program, BRASS.

Another program (LATBUK) was developed by Csagoly, et al[8] for lateral buckling of pony truss bridges. Although such bridges were once popular for their economy and ease of construction, the load-carrying capacity of these bridges became suspect and many were taken out of service or replaced by modern structures to accommodate the tremendous increase in the weight of commercial vehicles after World War II.

An ultimate load test, carried out on one pony truss bridge in 1969, indicates that these bridges possess an inherent strength far exceeding the value obtained by elementary structural theories. The complex problem of lateral buckling of truss compression chords, which in the past has led to oversimplified assumptions and underestimated bridge strength, was solved by a computer program based on a modified version of Bleich's method. The program was checked against experimental results, and provides bridge engineers with a better assessment of the load-carrying capacity of pony truss bridges than has been possible in the past. Since several hundred pony truss bridges exist in many parts of the country, it is economically important, especially in the present inflationary economic situation, to determine the extent to which these bridges can usefully serve their purposes.

Newlon[9] refers to the rehabilitation of (truss) bridges from the point of view of their historical significance. He developed a numerical rating system in three categories: documentation (age and builder), technology, and enviromental factors. Ideas on the rehabilitation of some old bridges, contained in this report, are applicable to the present project.

The Final Report[10] of the National Cooperative Highway Research Program (NCHRP) has identified some of the deficiencies in truss structures along with their possible solutions and limitations. These methods merely identify the solutions on a member-by-member basis rather than focus on the problem of upgrading the bridge as a whole. The compilation of such information, however, is considered useful for the second phase of this project.

Sheladia Associates (SAI) worked on two rehabilitation projects[11, 12] in the State of West Virginia, involving the inspection and development of recommendations for maintenance of truss bridge service. As in the NCHRP Report, these projects address the structural deficiencies caused by age and other factors found in the various elements of the trusses.

NCHRP National Cooperative Highway Research Program Report[13] addresses the issue of safety at narrow bridge sites and has developed a bridge safety index (BSI) for determining priorities in bridges with restricted widths.

The index combines various factors affecting geometric deficiency and assigns suitable values so that the index represents a BSI. The recommended corrective measures are based primarily on engineering judgment and the practices in Texas.

2.5 CURRENT PRACTICES

Bridge maintenance manuals by AASHTO[14], West Virginia[15], Maryland[16], and New York[17] deal with procedures to be followed for inspection and maintenance of bridges. Although actual procedures for rehabilitation are not covered, these manuals aid considerably in the task of rehabilitation or upgrading as reported in this project.

The Delaware Department of Transportation establishes priorities for rehabilitation as follows:

Priority 1 - Rehabilitation to insure safety and integrity of the structure

Priority 2 - Renovation to reduce the probability of future deterioration and maintenance.

Priority 3 - Repairs of minor items to improve appearance and functioning of the structure, and routine maintenace procedures.

The Indiana State Highway Commission and the Louisiana Department of Transportation emphasize that collisions are usually more serious than corrosion because they damage new as well as old structures, whereas corrosion damage usually involves old structures and those made up of small members or thin sections.

The Ohio Department of Transportation upgrades to the AASHTO HS-20-44 standard loading for any structure for which a repair project is proposed.

The State Highway Department of Illinois states that rehabilitation procedures depend on many factors: urgency, costs, material accessibility, density and type of traffic, age and physical condition of base material, size of project, and whether or not the work is to be accomplished by department forces or contract. The typical renovation of steel bridge structures recommends is described as including:

(1) Replacement, straightening, and/or strengthening of underdesigned or impact-damaged members.
(2) Replacement, repairing, or strengthening of deteriorated ends of beams or girders and adjacent framing systems.
(3) Renovation or replacement of inoperative bearings.
(4) Replacement or strengthening of floor systems.

The AASHTO specifications for rating and determining the capacity of existing bridges is based on weak link specification. The code allows a 125% overstress for existing members in good condition; however, it is still based on computed live load stresses. This type of rating tends to be overly conservative; it should allow for inclusion of reserves of strength by testing to determine actual live load stress conditions. This would, of course, require a thorough inspection and be allowed only in the absence of or after the repair of discontinuities, such as fatigue cracks.

2.6 FHWA BRIDGE INVENTORY ANALYSIS

Considerable information has been gathered by the Office of Engineering of the Federal Highway Administration. Numerous items associated with federally aided bridges are identified in the FHWA manual (1979)[18]. Although intended as a total history of each bridge, the data in some cases are insufficient for a complete picture. As part of this project, a number of items have been retrieved for all states on through truss bridges. Data have been tabulated for selected states in order to investigate possible trends. Procedures used in this analysis and results are presented in this section.

2.6.1 Parameters for Analysis of Inventory

The FHWA Bridge Inventory Manual includes ninety (90) data elements and a fairly thorough inventory on the present status of bridges. Elements from this inventory which may apply to through truss bridges have been selected in order to draw conclusions on average span, age, loading, condition, etc. The data elements selected are:

Item No.	Identification
1	State code
5	Inventory route
6	Features intersected
8	Structure number
24	Highway system
27	Year built
29	Average daily traffic
31	Design load
32	Approach roadway width
36	Traffic safety features
43	Structure type, through truss bridge
49	Structure length
51	Bridge roadway width, curb-to-curb
59	Superstructure
67	Structural condition
70	Safe load capacity
75	Type of work
78	Proposed roadway width
84	Cost of improvements
88	Cost of superstructure improvement

These items were run on computer by the Bridge Division of FHWA. A partial tabulation was made for Alabama, Arkansas, Arizona, Maryland and Louisiana. A typical page is shown in Table 2; other tables are on file in the Sheladia Associates, Inc., (SAI) office and not reproduced for this report. A typical summary is shown in Table 3. The parameters of age, span, width, etc. presented in Table 3 have been found useful for Phase II.

Table 2 Through Truss Bridge Data [Alabama, 1951-Present]

Structure No.	Features Intersected	Year Built	Width	Span	Av. Daily Traffic	Safe Load	Design Load	Cost of Improving	Const. Cost of Improving	Material
82330262 Y	I.C. Railroad	1952	22	128	75	4	--	165,000	95,000	Timber
22071 Y	Pan Creek	1954	20	46	45	4	--	56,000	43,000	Steel
22128 Y	Mulberry River	1958	17	287	25	5	--	484,000	285,000	Steel
24123 Z	Six Mile Creek	1962	18	121	110	4	H-10	72,000	41,000	Steel
31041 Z	Corner Creek	1959	20	112	50	2	--	163,000	90,000	Steel
36145 Y	Branch	1952	14	24	10	5	H-10	40,000	20,000	Timber
36212 Y	Branch	1951	14	30	4	5	H-10	40,000	20,000	Timber
36215 Y	Branch	1951	14	24	4	5	H-10	40,000	20,000	Timber
36291 Y	Larkin Fork Creek	1958	14	50	15	5	H-10	80,000	40,000	Timber
41085 Z	Ropes Creek	1958	16	370	100	5	--	---	---	Steel
41091 Z	Sougahatchee Creek	1960	20	254	60	5	--	---	---	Steel
64010 Z	Blackwater Creek	1965	20	126	300	4	H-10	152,000	74,000	Steel
64063 Z	Wolf Creek	1960	12	80	50	4	H-10	99,000	48,000	Steel
2390087 B	Shoal Creek	1959	36	806	126	5	HS-20	---	---	Steel

Table 3 Summary of Some Results of Inventory Analysis

(a) Compiled Data for Five States Related to Age of Bridges

PERIOD (Years)	STATES					TOTAL
	Alabama	Arkansas	Arizona	Maryland	Louisiana	
1920-1930	90	5	11	12	2	120
1931-1940	63	9	2	24	6	104
1941-1950	38	17	0	2	1	58
1951-1960	33	6	11	--	2	52
1961-1980	9	16	1	--	3	29
Total	233	53	15	38	14	353
Before 1920	119	1	20	88	3	231

(b) Summary of Various Parameters for Period 1941-1950

1941-1950	Alabama	Range	Arkansas	Range
Av. Span	89.37	20 - 212	380.01	61-1,820
Av. Width	21.37	16 - 28	23.82	18 - 28
Loading	H-10	H-10 to H-15*	H-20	H-15 to HS-20
Av. Condition	4.45	1 - 6	6.59	5 - 8
Cost of Replac.	85,605.3	20,000 - 625,000	593,059	109,000-1,440,000

*Some loading data missing.

2.7 COMBINED BRIDGE RATING PROGRAM (CBR)

In addition to information from the inventory, Mr. Avanti C. Shroff, consultant, provided information from his experience on the Combined Bridge Rating Program (CBR). This program was developed by his office, Iffland, Kavanagh and Waterbury (IKW[19]) in response to the needs of the New York Department of Transportation's (NYDOT's) local regional office (Region 10).

The program to develop a Structurally Deficient Bridge Priority List which could be utilized to provide ready information for allocation of available funds for bridge repair lists 387 bridges:

a. 242 Option 1 bridges inventoried and inspected by IKW.
b. 106 Option 3 bridges inventoried by others but inspected by IKW.
c. 39 Nassau County bridges inventoried and inspected by others.

The program computes a "weighted average" and a "rate" for each bridge using the procedures established by the New York Department of Transportation. The data base for this computation is obtained from the inventory and field inspection for each bridge. A flow chart of the main-line program, "Flow Chart-Combined Bridge Rating Program (CBR)" (Fig. 10), is useful for future government funding for bridges to be rehabilitated.

FLOW CHART

COMBINED BRIDGE RATING PROGRAM

CBR

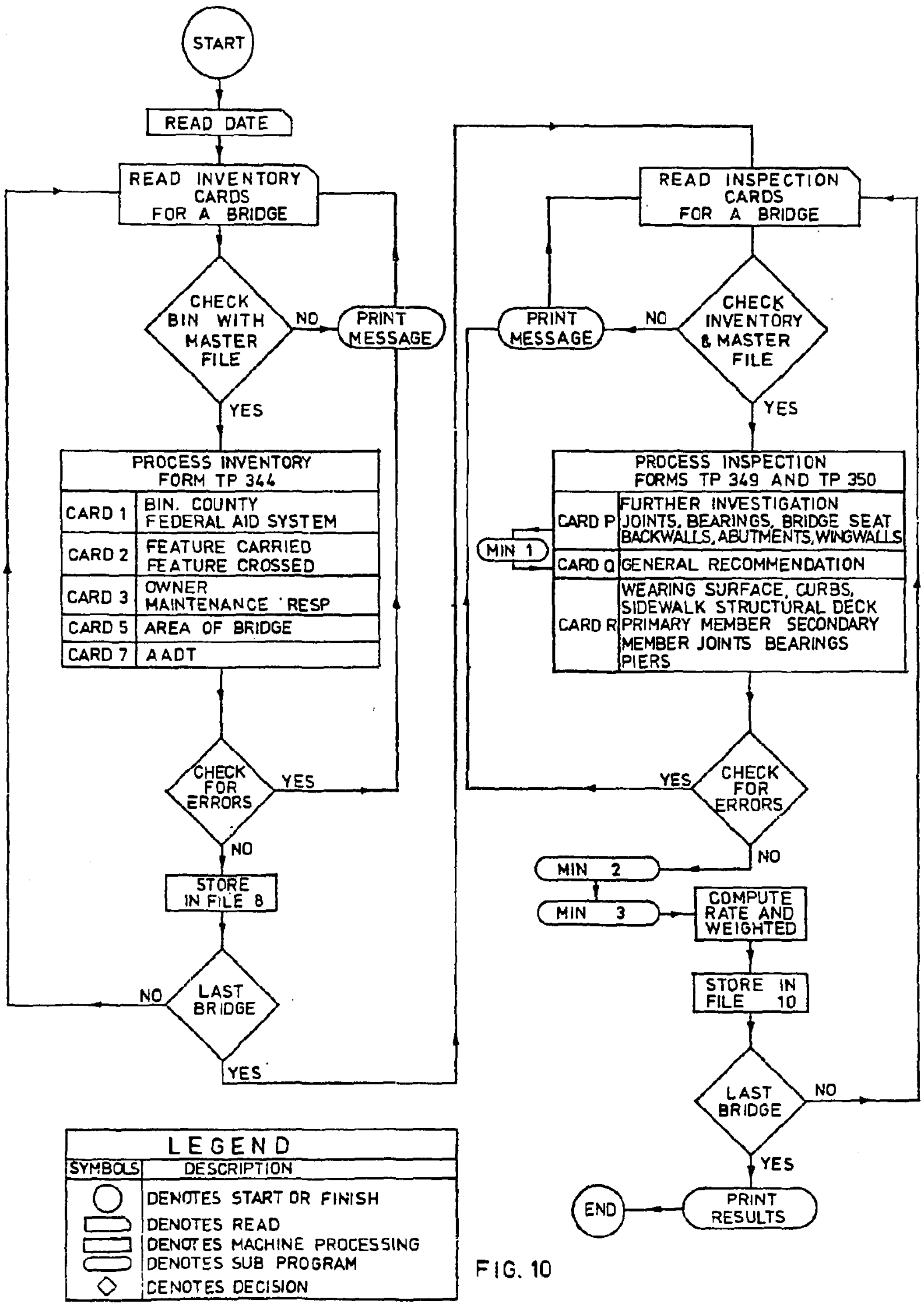


FIG. 10

CHAPTER 3: METHODS OF REHABILITATION

3.1 INTRODUCTION

Once deficiencies have been identified, the major task is to eliminate or overcome them, so that the bridge may be used for many years to come. The methods should aim at (a) increasing live load capacity, (b) improving geometry, and (c) correcting mechanical deficiencies to make bridges safe for traffic. Considering the staggering number of truss bridges having some form of deficiency, rehabilitation is the best alternative in view of astronomical replacement costs. Development of innovative and cost-effective methods to upgrade these deficient through truss bridges has therefore become a mandatory task.

3.2 STRENGTHENING OF TRUSS BRIDGES

Truss bridges are more difficult to strengthen and require much more analysis of their components, connections, and details than required for strengthening slab and girder bridges. The connections which often govern the strength of the structure are important.

Components of truss bridges, which may be deficient and need strengthening are:

a. Tension members
b. Compression members
c. Supports
d. Deck

a. Tension members: Tension members in trusses often may be reinforced by addition of adjustable bars. These may be of several types, such as, loop bars or single bars attached to a loop, or forging that fits over and bears on the pin. Care must be taken to form the portion of the bar or forging in contact with the pin so that full bearing will be secured, preferably with an attachment on one-half of the pin. When a bar of uniform section is bent around a pin, the cross-section is likely to be reduced by stretching of the bar and narrowing of the outer edge, for which allowance shall be made. When pin room is limited, bars sometimes are placed over the heads of existing eyebars. This method gives doubtful results because the edges of the eyebar heads are not finished to a true surface.

Two additional bars or members equally spaced from the center of the pin should be used to strengthen each panel except when a single bar is placed in the exact center of the pin. The resultant stresses in the pins under the revised loading condition must be investigated to insure validity of the structure.

After the new members have been installed, the entire panel should be adjusted properly to distribute dead load tension to all members. Eyebars or rods not having adjustable provisions can be adjusted in accordance with Section 8.2 of Chapter 15 of the American Railway Engineers Association (AREA) Manual[21]. Elongated eyebars may be adjusted in accordance with the same Section 8.2.

Parts of corroded bars can be replaced by first detensioning with the aid of electrothermal flexible furnaces clamped to each bar; the heating power of the furnaces is obtained by current from a standard portable welding generator. The resulting expansion from this heating will reduce tensile stress to zero in 10-15 minutes with temperature rising to a maximum of about 200°F (95°C). When new parts of each bar are fitted, the repaired member is post tensioned by straining with high tensile bars between two brackets temporarily bolted to the member on each side of the splice. Jacks are used to apply a force equivalent to the dead load stress to be transferred. Double butt straps or splice plates are drilled and bolted with high-strength bolts while the bars are held at the required stress.

Rolled or built-up sections may be effectively reinforced by addition of cover plates in the planes of the gusset plates, riveted, high-strength bolted or welded to the flange of the member, and butt welded to the gusset plates, providing the strength of the gusset plate and its connection are adequate and the existing material weldable. Care should be taken to protect against fatigue provisions at the connections of the cover plates to the gussets as well as against the possibility of cracking from an unknown type of material. Unless dead load stress in the original member is relieved, new metal so added should be effective for carrying its portion of the live load stress only.

Floor beam hangers are frequently highly stressed from a combination of bending and direct axial tension. To reduce the possibility of fatigue cracking in these highly stressed hangers, sharp edged corners or re-entrant cuts should be eliminated or modified. The use of high-strength bolts at the top connection of the floorbeam hangers to replace all rivets should also be considered to improve load transfer to the gusset plates. In the case of odd-panel bridges, the middle panel will have cross diagonals, or "counters". Variation from tension to compression causes relaxation in these counters. Addition of turnbuckles allows maintenance crews to keep constant tension in the counters. A typical end connection for pin joints, combining ease of member replacement with capacity for tension adjustment, is shown in Fig. 11.

b. Compression Members: Reinforcement of compression members requires careful investigation. Chord members of many old bridges are unsymmetrical in section and are eccentrically loaded. This condition may be corrected by an added plate and connecting the two in proper location. A small amount of metal placed in this way often will increase considerably the rating of the member.

Reinforcement of compression members requiring substantial increases in the sectional area calls for special analysis, the

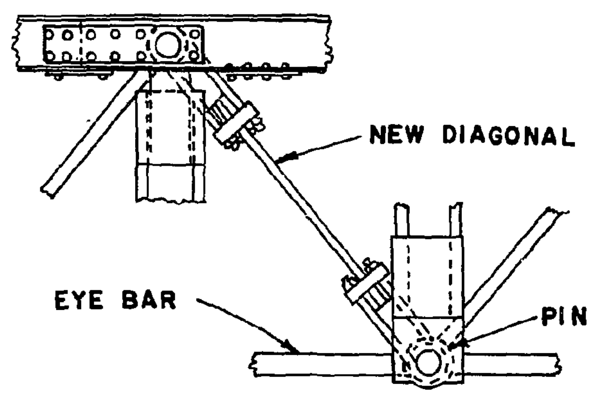


FIG. 11 REPLACEMENT DIAGONAL USED BY VIRGINIA

solution depending on the type of section, details at or near the pins, and other conditions. Metal sometimes may be added to the cover plate, usually between existing lines of rivets. This should be balanced by placing additional metal on the lower flanges, as described in the preceding paragraph. Full-length side plates may be added to the web plates of the section, between the vertical legs of the upper and lower angles, providing adequate means of transferring this stress into the connnection or adjacent member can be obtained. If the cover plate in the original design is so wide in proportion to its thickness that it has little resistance to buckling, this may be corrected by adding a cover plate connected by fasteners along the center line in addition to the fasteners through the angles. Often strengthening is solely for the purpose of reducing the slenderness ratio.

One of the difficulties encountered in reinforcing compression members is to introduce the dead load stress into the additional material. If this is not done, full value cannot be obtained from the new material. For instance, assuming that the new material gets no dead load stress, that the dead load stress in the old material is 10,000 psi (70 MPa), and that the total allowable stress is 26,000 psi (182 MPa), then the new material will be carrying only 16,000 psi (112 MPa) stress from live load only. This is the maximuxm stress to which the new metal can be worked, since any higher stress would cause overstress in the old metal. Several methods may be used to meet this condition. The one most commonly employed in heavy reinforcing members is to calculate the shortening necessary to produce the desired stress under dead load, and then drill holes in the old and new members in such position that the new members will be shortened by drifting before the sections are bolted or the rivets are driven. Although this method is used by many, others feel that it is not a good practice.

Another method is used on upper chords and end posts. It can be employed for large members with thin cover plates compared to unsupported width, bringing all the old metal into full use. Reinforcement, in this case, is in the form of a new central web with top and bottom flange angles divided into two segments, each occupying one-half of the panel length. The segments are designed to receive a wedge between their adjacent ends. The segments are placed along the member with ends bearing against the pins and the wedge. To introduce compression in the segments, the new material is first seated for proper bearing against the pins or connections by pulling the wedge up tight with a large bolt. Care must be taken to prevent or minimize bending in the pin. The wedges are then slacked off and pulled up to a snug fit, after which all wedges in one chord are drawn up simultaneously a predetermined amount to develop the desired dead load stress in the new metal. The bolts holding the wedges are left in place permanently. The flanges of the new segment are riveted or bolted to the top cover plate and to the lower lacing bars, thus making the new center segment an integral part of the chord, carrying the same stress as the old metal.

c. Supports: Under certain favorable conditions, it is possible to shorten the effective span length of a truss by installation of auxiliary piers or bents at the first or second interior panel points. However, since this converts a simple span truss to a three-span continuous truss and introduces new and different stress characteristics, a thorough analysis of the altered truss must be made. Members having insufficient capacity must be strengthened to carry the revised loading prior to installation of the new supports.

Erection of supporting falsework may be advisable as an emergency measure. However, this should not be a permanent feature because erosion may make the supports ineffective.

d. Deck: Often it is possible to replace the deck with a new deck of lighter weight, thus reducing the dead weight and increasing the capacity of the bridge. A number of deck systems have been used. Among the common ones are:

1) Open steel grid
2) Concrete filled steel grid
3) Corrugated metal
4) Laminated timber
5) Metal plate (orthotropic)

Open Steel Grid: This type of flooring is available in a variety of configurations from several manufacturers. It can be filled with concrete or left open. In the usual 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 entirely the problem. The open grid has the advantage of permitting snow and rain to pass through the structure, thereby eliminating the need for bridge drainage, and use of snow and ice control chemicals on the bridge.

Details should be developed to eliminate pockets over the main support members which could collect debris and cause corrosion. Care should be taken in selecting the proper grating design. Several States reported that welded details often fail from 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 often causes the brittle fracture and fatigue failures from repetitive loads in the internal connections. A disadvantage is added weight as compared to the open grid, and subsequent reduction in live load capacity of the bridge. It is necessary to provide and maintain adequate deck drainage system and employ chemicals for snow and ice control, and protection against corrosion of grid.

Corrugated Metal: Corrugated metal sheets for deck support with asphalt wearing surface have been used and is becoming increasingly popular. Installations have shown that the system can be designed to withstand modern design loading. Although such methods are not long-term solutions, length of service can be increased by properly designing the drainage system to remove surface runoff, and by providing adequate protection against corrosion of the metal sheets. This system has been used successfully in a number of States visited during the inspection phase of the study. Reports indicate that 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 existing stringers to reduce the effective deck span. On multiple stringer bridges, these can be framed to floor beams placed between existing stringers. On truss bridges and other structures with similar floor systems, these beams can be framed to existing floor beams.

Timber: Glue-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 improvement, especially for shorter spans. An advantage from a maintenance point of view is less susceptibilty 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 be carefully detailed to provide shear transfer and a proper seal. Clamping devices not requiring nailing are preferred to drilling and bolting.

The Virginia Department of Highways and Transportation has constructed several experimental laminated decks. Initial indications are that these decks are performing satisfactorily. The Department has now prepared standard drawings for design and installation of timber decks in anticipation of continued use.

Metal Decking: Steel plate decking, as replacement for deteriorated concrete, provides significant weight reduction. This system can provide additional carrying capacity for the primary members if designed to act compositely with such (beam) members. 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.

3.3 ASSUMPTIONS IN DEVELOPING METHODS

In this study, a number of methods of upgrading the through truss bridge have been considered, using a "basic" truss structure. The basic truss generally falls into the categories of Warren and pony trusses, as presented in the previous chapter. Therefore, methods developed were applied to practical (and available) bridges of these types. Certain assumptions have been made to establish the direction of the research:

a. Basic Loading: The statistical survey of the FHWA bridge inventory indicates that loading on existing bridges is HS-15. Thus, upgrading is considered from HS-15 to HS-20 loading as the present loading.

b. Strength of Truss: Since the designed load is HS-15, the truss was originally checked for this loading and the strength verified, based on recommended practice of the AASHTO manual (Table 4). It is further assumed that there is no "environmental" deterioration of any member. If any is found in the field, it will be accounted separately for replacement of that member.

c. Capacity of Members: In most trusses, some members are overdesigned for practical reasons, which may include uniform size of members, simplified construction, etc. The advantage of this "over design" should be taken, whenever possible, during the development of a method.

d. Use of Better Materials: Since the original construction of truss bridges, better materials have been developed with higher allowable stresses. These materials have been included in current editions of design manuals.

3.4 DEFICIENCIES AND CORRESPONDING SOLUTIONS

The main purpose of rehabilitation of defective bridges is to extend their service life under current requirements, such as HS-20 loading. The solutions are classified under these general categories:

a. Additional Live Load Capacity
b. Improvement of Geometric Efficiency
c. Correction of Mechanical Deficiencies
d. Combination of a, b, and c.

A brief discussion and possible solutions follow:

a. Additional Live Load Capacity: Four general procedures are available to increase the load-carrying capacity of a bridge: 1) Strengthen critical members, 2) add supplemental members or supports, 3) reduce dead load, 4) modify structural system.

1) Strengthen Critical Members: Strengthening deficient or critical members involves adding new material to the existing member or replacing the entire member or portion of it with new material, or reducing the stress level in

TABLE 4

ALLOWABLE STRESSES IN STRUCTURAL STEEL MEMBERS ACCORDING TO AASHTO MANUAL

		DATE BUILT - STEEL UNKNOWN				CARBON STEEL
		Prior to 1905	1905 to 1936	1936 to 1963	After 1963	
AASHTO Designation (1)						M-94(1961)
ASTM Designation (1)						A7(1967)
Minimum Tensile Strength	F	52,000	60,000			60,000
Minimum Yield Point	F	26,000	30,000	33,000	36,000	33,000
Axial tension, section. Tension in extreme fiber of rolled shapes, girders and built-up sections, subject to bending. Axial Compression, gross section; Stiffness of plate girders. Compression in splice material, gross section.	0.55F	14,000	16,000	18,000	20,000	18,000
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is: (A) Supported laterally it's full length by embedment in concrete.	0.55F	14,000	16,000	18,000	20,000	18,000
(B) Partially supported or unsupported (2) with /b not greater than...		42 14,000-3.9 $\bar{b}$	39 16,000-5.2 $\bar{b}$	38 18,000-6.3 $\bar{b}$	36 20,000-7.5 $\bar{b}$	38 14,000-6.3 $\bar{b}$
Compression in concentrically loaded columns (3) with C a = $\frac{2\ E}{F}$		148.4	138.1	131.7	126.1	131.7
$F = \frac{F}{F.S.}\left[1 - \frac{\frac{KL}{r}\ F}{4\ E}\right]$ ......when $\frac{KL}{r}$ C .... $F = \frac{2E}{F.S.\ \frac{KL}{r}} = \frac{135{,}008{,}740}{\frac{KL}{r}}$....when $\frac{KL}{r}$ C with F.S. = 2.12		12,260- 0.28 $\frac{KL}{r}$	14,150- 0.37 $\frac{KL}{r}$	15,570- 0.45 $\frac{KL}{r}$	16,980- 0.53 $\frac{KL}{r}$	15,570- 0.45 $\frac{KL}{r}$

TABLE 4
(continued)

ALLOWABLE STRESSES IN STRUCTURAL STEEL MEMBERS ACCORDING TO AASHTO MANUAL

		DATE BUILT - STEEL UNKNOWN				CARBON STEEL
		Prior to 1905	1905 to 1936	1936 to 1963	After 1963	
Shear in girder webs, gross section		8,500	9,500	11,000	12,000	11,000
Bearing on milled stiffeners and other steel parts in contact Stress in extreme fiber of pins	0.80F	20,000	24,000	26,000	29,000	26,000
Bearing on pins not subject to rotation		20,000	24,000	26,000	29,000	26,000
Bearing on pins subject to rotation (such as rockers and hinges		10,000	12,000	13,000	14,000	13,000
Shear in pins	0.40F	10,000	12,000	13,000	14,000	13,000
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners).	1.35F	70,000	81,000			81,000

(1) Number in parenthesis represents the last year these specifications were printed.
(2) = length, in inches, of unsupported flange between lateral connections, knee braces or other points of support.
b = flange width, in inches.
(3) E = modulus of elasticity of steel.
r = governing radius of gyration.
L = actual unbraced length.
K = effective length factor.

NOTE: The formulae do not apply with variable moment of inertia.

the existing member. 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. Strengthening of members depends on the material used in the truss. Different methods can be used for steel and timber trusses, as presented below:

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. Material used in the existing member must be weldable. The welding operation on existing steel, in some cases, has an adverse effect on structural capacity of the member because of location and the particular detail employed. Stress raisers susceptible to fatigue failures have unwittingly been incorporated into 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.

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.

2) Add Supplemental or Replacement Members/Supports:
   Defective critical members can be replaced. This is

frequently done when 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 integrity of the structure during the replacement operation. If this is not feasible, an alternate support system must be developed utilizing post tensioning cables or other such devices to carry loads temporarily.

In some cases, additional supports to a through truss bridge are feasible and practical. Even by placing supports at the interior panel points next to the present supports, the truss span is reduced significantly. Instead of a simple span system, the truss may be converted into a continuous system.

Support bents pin-connected to the truss panel points provide 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 adjusting the bent to achieve desired load transfer. Stress levels of individual truss members must be checked for compliance with code under the alternate structural system. A schematic detail is shown in Figure 12.

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 lightweight yet structurally adequate deck systems have been developed. This was discussed in the preceding section.

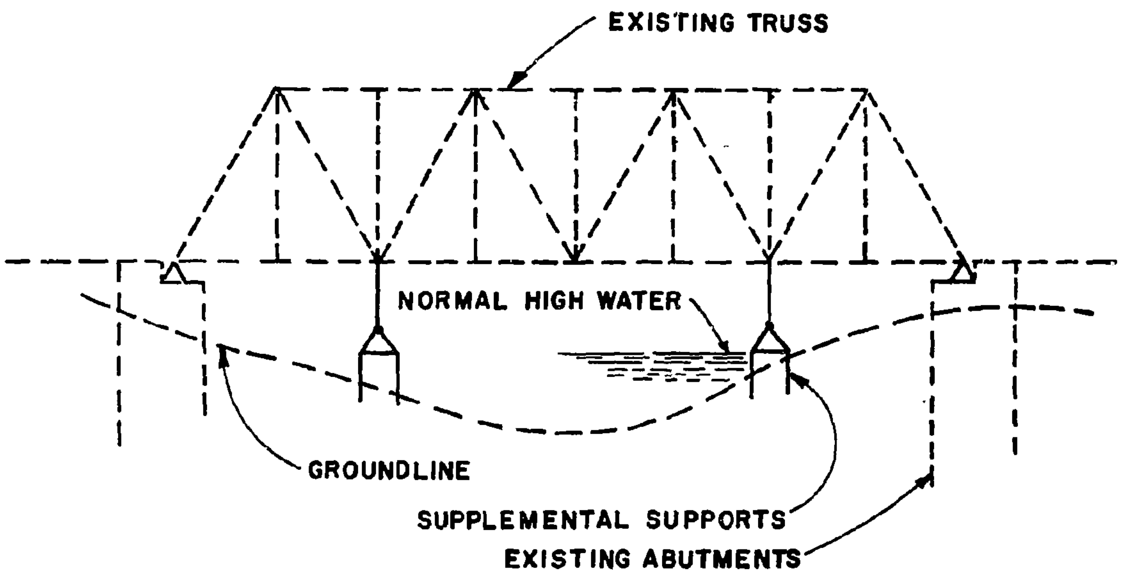


FIG.12 ADDITIONAL TRUSS SUPPORTS

4) Modify Structural System: In general, it is not possible to change the structural system in through truss bridges as may be done the with beam-girder type of bridge. Hence, this type of solution is not considered, except when new lanes are to be added to the present bridge.

b. Improvement of Geometric Efficiency: Geometrically deficient bridges can be rehabilitated by the following methods: (1) increase vertical clearance, (2) widen usable roadway, (3) improve alignment.

1) Increase Vertical Clearance: Inadequate vertical clearance is a common geometric deficiency in through truss bridges as was evident during the field inspection. Additional clearance can be provided by reducing the depth of portal frames and the depth of sway frames. The resulting bracing system must be analyzed and proper modifications designed to transmit imposed loads. In certain cases, it may be possible to lower the floor system on through truss bridges, thereby increasing vertical clearance. When 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 the stringer and the top of the floor beam in the same plane. This concept has particular merit when the existing stringers are inadequate and need replacement. In this situation, stringers can be replaced with connections detailed to frame into the existing floor beams. Approach grades should be adjusted to meet the lower profile.

Certain unique situations 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 should also be adjusted to meet the lower bridge profile.

c. Correction of Mechanical Deficiencies: Corrections of mechanical deficiencies primarily involve elements which permit the bridge to respond to movements. Examples are expansion devices, abutment stabilization, barriers, etc. These are not addressed in the methods of rehabilitation in this report.

d. Combination of Methods: Review of the methods presented in this report may seem inadequate for correction of a particular bridge deficiency. The author wishes to state explicitly that the proper solution, in most cases, can only be achieved by a suitable combination of methods.

3.5 PROPOSED METHODS

Several methods have been developed during this project based on various deficiencies in the bridge structure. They are presented in the following format:

a. Purpose
b. Details of method: (1) sketches, (2) steps, and (3) tables, and (4) results
c. Limitations (if any)
d. Construction procedure

These methods are applied to an actual truss bridge, which was inspected by the author's associates to determine the feasibility of each method, followed by the cost comparison with replacement. Both the applications and cost evaluation are presented in Chapter 4 and the drawings in Appendix D.

3.5.1 Strengthening of Compression Member

Purpose: To reduce the effective length of compression member by adding new members, as shown in Fig. 13. The analysis of structure shows that these additional members are not subjected to a large force. The reduction in the effective length increases the allowable stress in the main members. The effective length should be considered about both axes and support in the weaker direction should be provided.

Details of Method: The method is straightforward; the sketches shown in Fig. 13 explain the details.

Results: On the average, the allowable stresses can be increased by 15-20% by reducing the length to half its original length.

Limitations:

1) Only the compression members (top chord) of the truss require this method.
2) Existing connections must be checked and redesigned, if necessary, for the new design loading.
3) Although compression member capacity is increased, the tension member (bottom chord, in particular) should be checked to match the new capacity, and an additional plate may be added to strengthen it for the new design load.
4) Additional members reduce effective length in only one direction. Lateral bracing may be provided to ensure stability in that direction.

Construction Procedure: Select new vertical section, its location and connections, based on the existing top and bottom chords. Typical details are shown in Drawing No. 4.

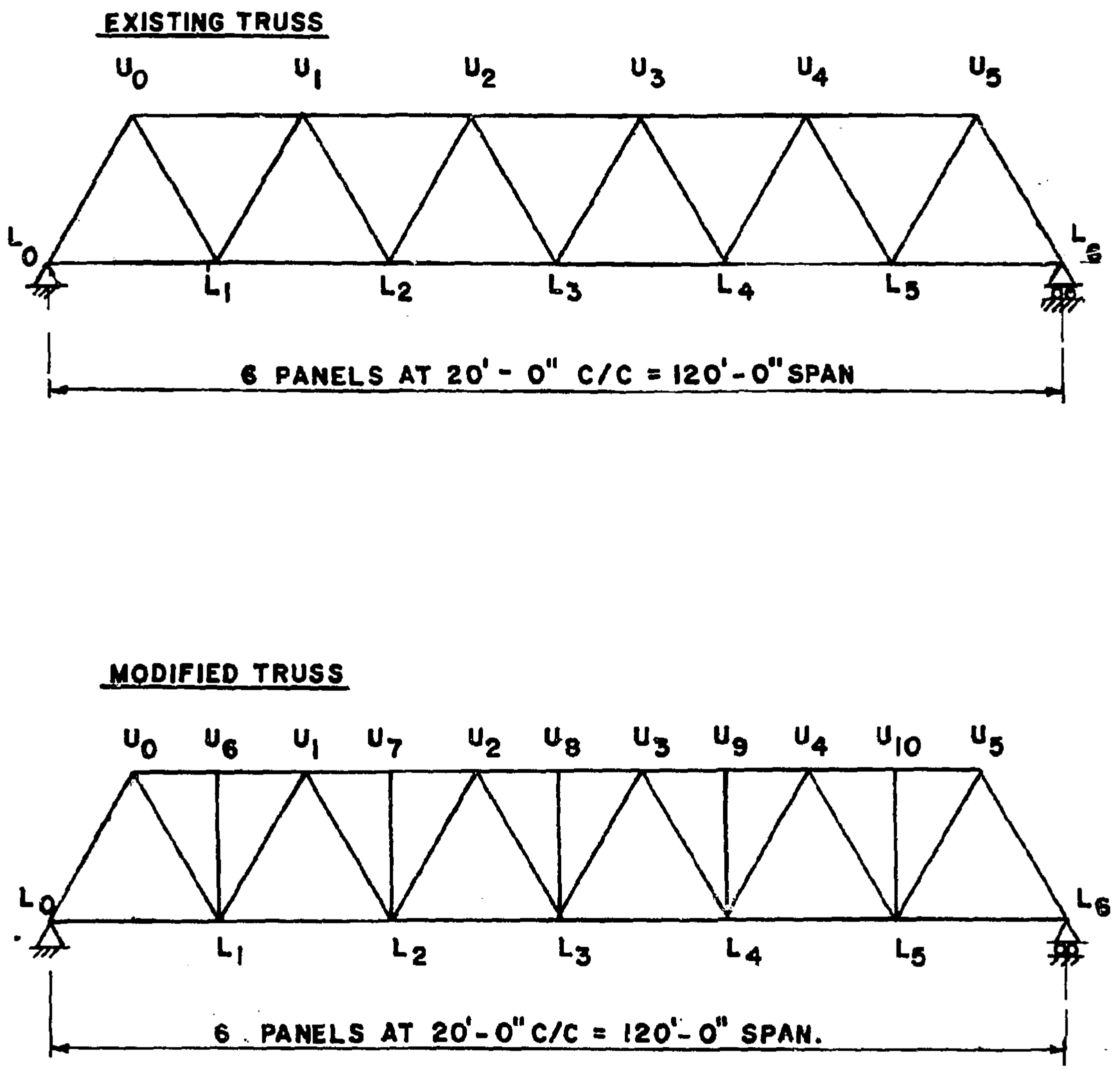


FIG. 13 STRENGTHENING OF COMPRESSION MEMBER

3.5.2 Prestressing of Bottom (Tension) Chord

Purpose: To induce the stress of opposite nature in the member, so that it can take additional load. Cables are strung along the truss member and attached to the end of the member or to the connecting pin. Alternately, king posts may be provided, as shown in this method. Turnbuckles are introduced to provide tensioning or jacking arrangements. The com- pression stresses, thus induced, result in reduction in tensile stress in the member and permit it to carry additional live loads.

Details of Method: The details of this method may vary, based on where the prop (post) is placed. The analysis, however, is based upon the tension applied to the cables and attached to this post. As is shown in the next chapter, the procedure determines the necessary force for the needed compensatory prestress in the members.

Figs. 14 (a) and (b) show the respective arrangement for either one or two posts. In the analysis, angle was varied within practical limits and values are as indicated in Table 11. Using this table, the predetermined angle can be selected which may minimize the forces in cable in a given situation of rehabilitation.

Limitations:

1) Clearly, the limitation comes from clearance under the bridge, due to height of the post(s) or vertical support(s)

2) Secondly, if there is any lost cross-section of a member, the member must be properly strengthened using other methods before applying this method.

Construction Procedure:

1) As mentioned earlier, the proper system of cable and supports must be chosen to get the minimum force required to tension the cable.

2) Select (from commercially available data) the cable to suit the force.

3) Construction details are shown in Drawing Nos. 5 and 6.

4) Select the dimensions and locations of vertical supports.

5) Proper pin arrangement is made for the connection between the cable and truss attachment points.

6) String the cable along with the turnbuckle on the attached locations.

7) Tension cable to the desired load of force and fix up the turnbuckle at that load level.

3.5.3 Method of Additional Support(s)

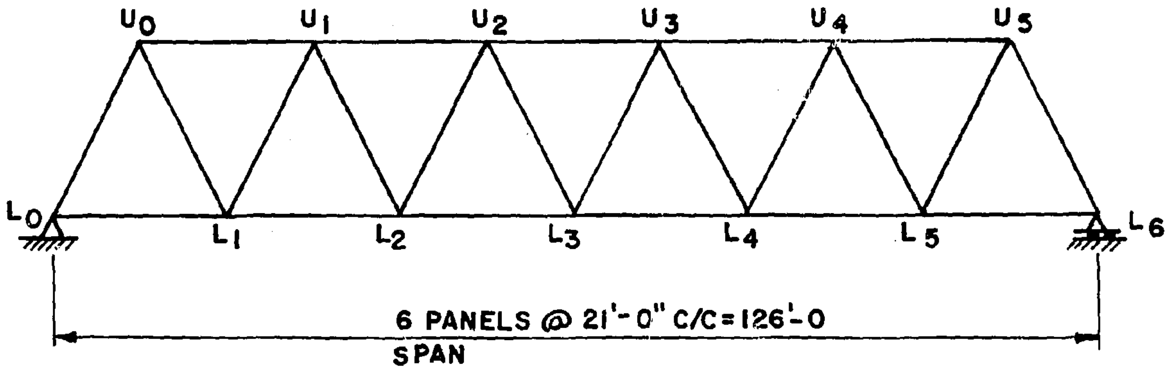
Purpose: To subdivide the truss span so that it is connected into continuous, shorter spans. In this manner, the forces in members can be reduced; conversely, for the same member, capacity can be increased from light to heavier loads.

Details of Method: Support is added at the intermediate point, preferably dividing spans equally. The truss is then analyzed for reduced span, and the forces determined. In Figs. 12 and 15, two alternates are shown for support(s), which give a clear indication of this method. The locations of supports depend on the surroundings and availability of land.

Limitations:

1) This method is limited to cases where the intermediate support is not located on a foundation too deep, such as a water crossing, but

EXISTING TRUSS



MODIFIED TRUSS

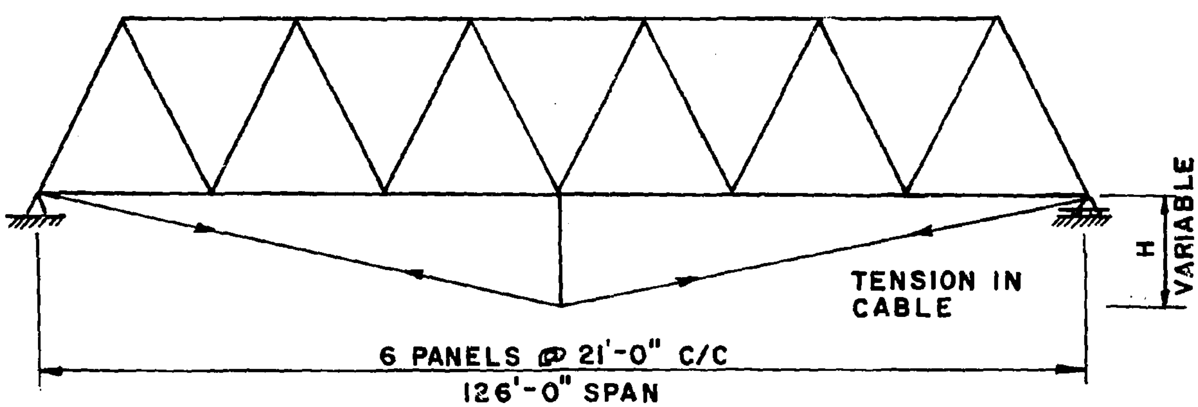
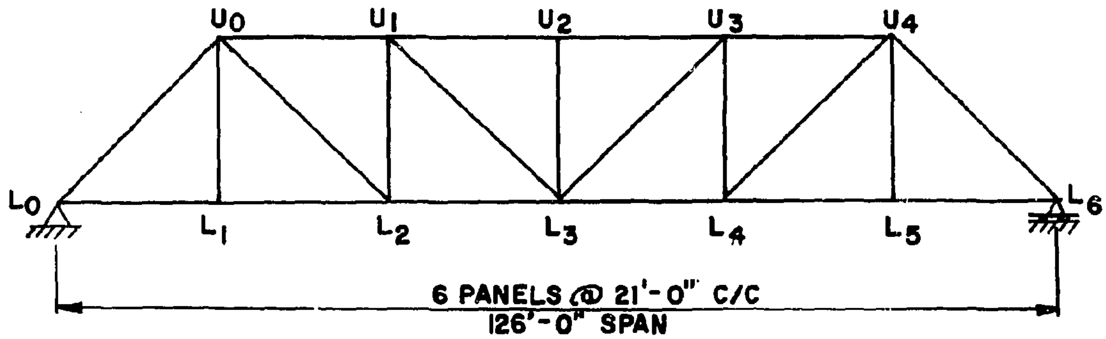


FIG.14a PRESTRESSING OF BOTTOM CHORD (SINGLE POST)

EXISTING TRUSS



MODIFIED TRUSS

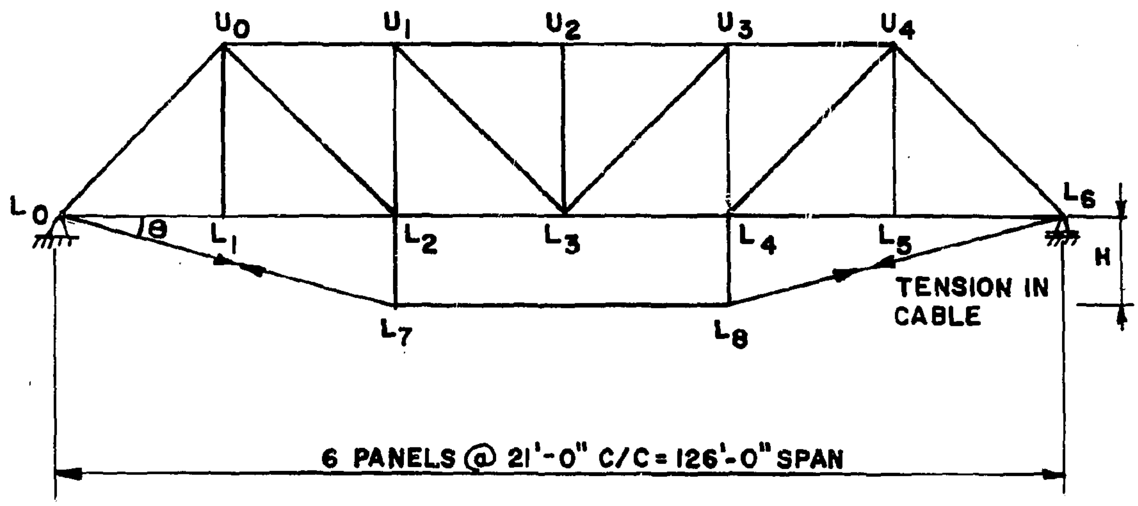


FIG.14b PRESTRESSING OF BOTTOM CHORD
(TWO POSTS)

is ideal when the bridge crosses a divided highway. Proper protection for the cross traffic should be provided without disturbance.

2) Additional support(s) may cause excessive forces in other members of truss and must be checked. If necessary, suitable strengthening must be provided as in the earlier methods.

3) Some members may experience stress reversals and must be checked.

Construction Procedure: Since the main part of this method is to install the foundation and the support(s) for the truss, details are not considered within the scope of this study. The limitations should be considered properly. Drawing No. 8 shows details of this method.

3.5.4 Shifting of Support(s)

Purpose: To increase capacity of the bridge truss by shifting (the eroded) support(s) towards the center. This method accomplishes two purposes: (1) the bridge where bearing is noticed to be a problem can be rehabilitated, and (2) the span may be reduced. This, in turn, will reduce the forces in the members as in the previous method.

Details of Method: The analysis of this method is performed as a continuous truss over supports or as a truss with overhangs. In both cases, it is advantageous to reduce the forces. The method is shown in Fig. 16. The members in the portion of overhang may cause additional deflection (or uplift) if supports are completely removed.

Limitations:

1) This method is more suitable for a truss bridge with eroded or damaged support due to some environmental or other reason.

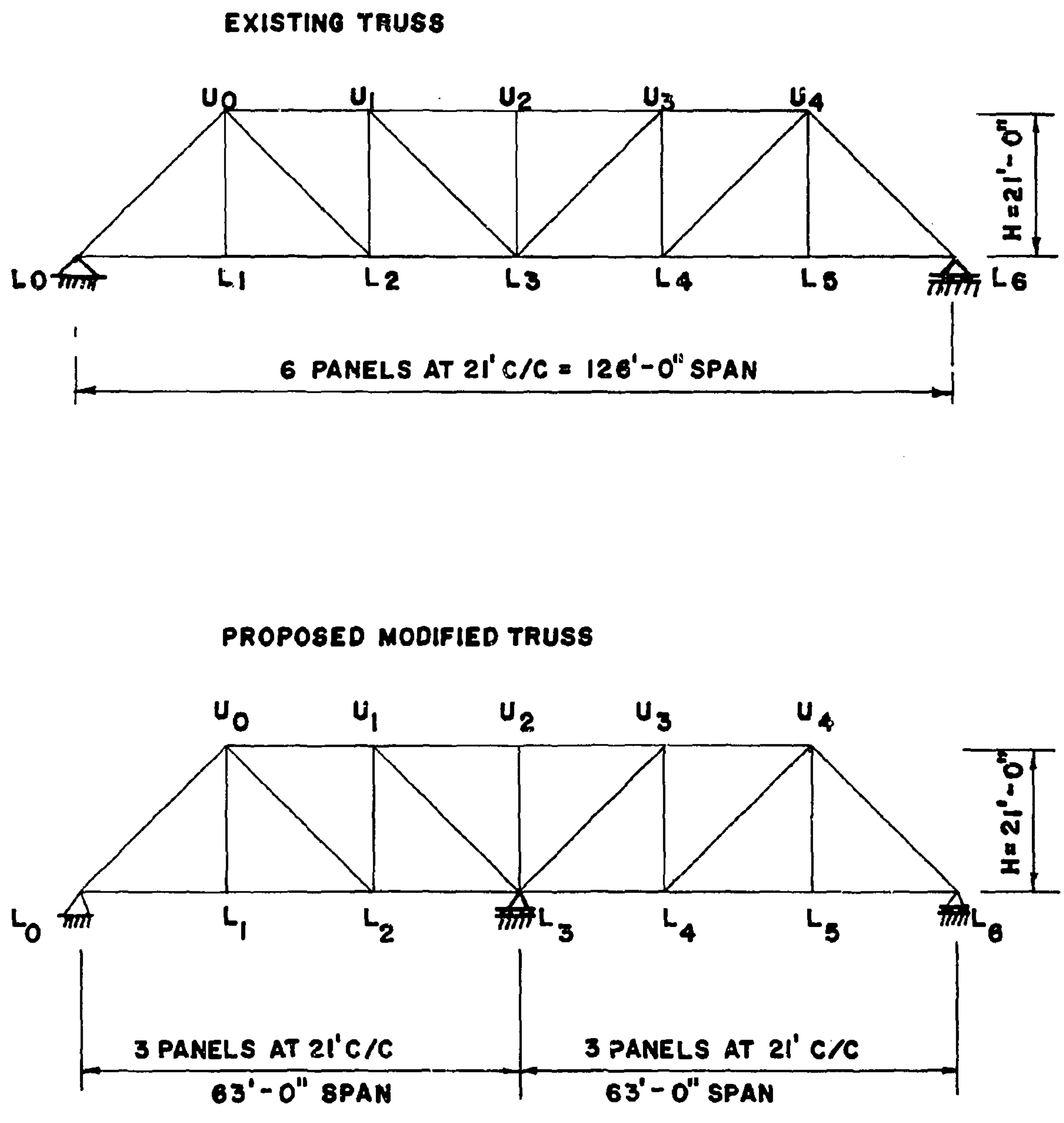


FIG. 15 ADDITION OF SUPPORT

2) Deflection (uplift) at cantilever end should be checked if the old support is completely removed; precaution must be taken to prevent this.

3) Some members may reverse stresses; they should be checked along with all the connections.

4) These new support members are not designed for truss reaction. They only support a panel loading.

Construction Procedure:

1) Intensity of traffic should be reduced to avoid added damage to the support and also during construction sequences.

2) Construct the new substructure at the deck (or support level to the truss).

3) The bearing should be achieved by jacking between the substructure and the bottom of the truss.

4) Remove jacking equipment and lower the span.

5) Check the old support for deflection of the truss at the cantilever and make suitable provision.

Details of construction are shown in Drawing No. 7.

3.5.5. Method of Subdivision:

Purpose: To subdivide several panels of the truss with longer spans. In long span trusses the unsupported length of chords and diagonals become excessive. Their lengths subjected to compression can be reduced. This will allow higher stresses in the members of reduced length, which

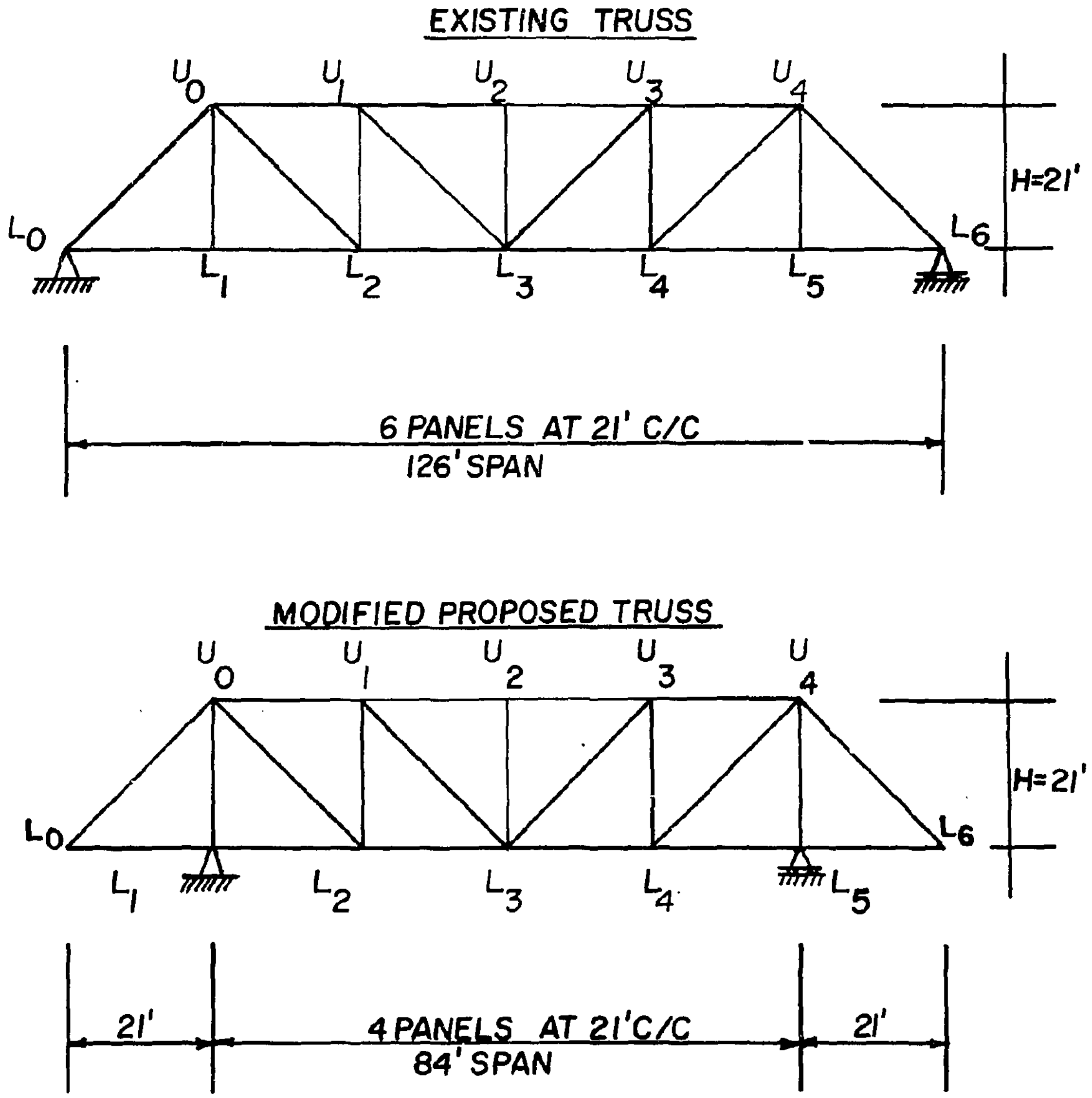


FIG. 16 SHIFTING OF SUPPORT

in turn, helps to increase load carrying capacity of the member by preventing buckling (see Section 3.5.1).

Details of Method: This method is shown and detailed in Fig. 17 (a) and (b). Newly added members are referred to as subverticals or subdiagonals and are shown both for Pratt truss and Warren truss. By this method the allowable stresses can be increased by approximately 20%.

Limitations:

1) Existing connections must be checked and redesigned, if necessary, for the new design stresses.

2) The truss members which are not being subdivided should also be checked to match the new capacity of the truss.

Construction Procedure:

1) Select the new members and connections based on existing members.

2) A typical connection detail is shown in Drawing Nos. 9 and 10.

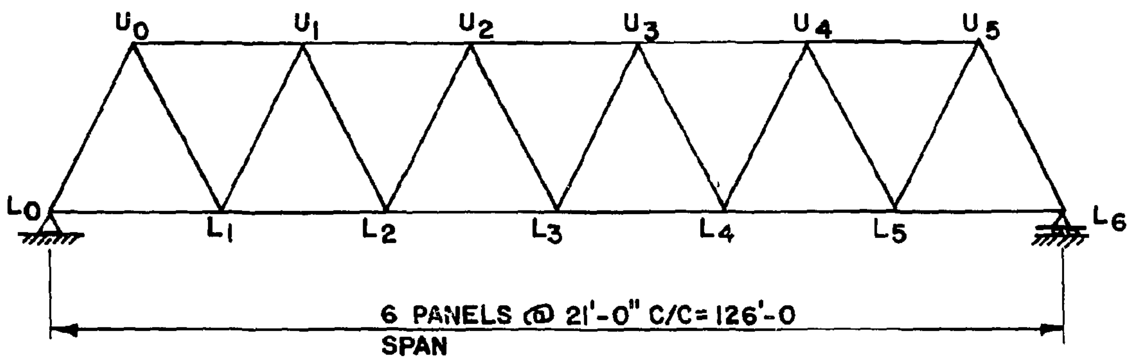
3.5.6 Increase Vertical Clearance:

Purpose: Often it is found during an inspection and maintenance program that vertical clearance is needed to allow safe movement of heavy trucks. This is done by changing the bracing system of the existing bridge.

Details of Methods: Extra vertical clearance is obtained by one of the three alternates as shown in Fig. 18. They are: (1) to replace an inclined member by a horizontal member to take the same amount of lateral force, (2) to convert bracing into a frame instead of a truss, and

METHOD OF SUBDIVISION (WARREN TRUSS)

EXISTING TRUSS



MODIFIED TRUSS

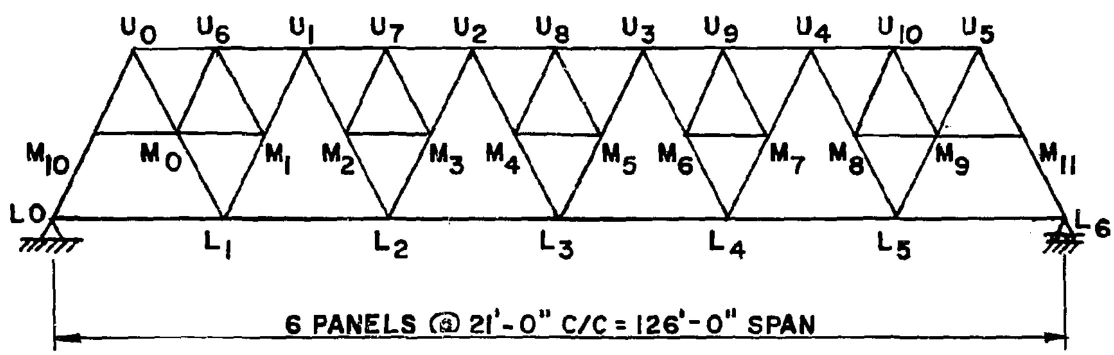
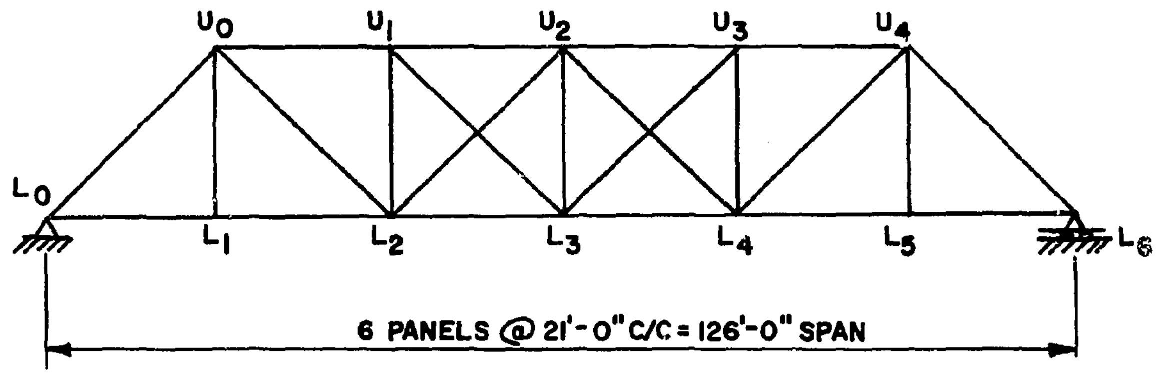


FIG. 17 a METHOD OF SUBDIVISION

METHOD OF SUBDIVISION (PRATT TRUSS)

EXISTING TRUSS



MODIFIED TRUSS

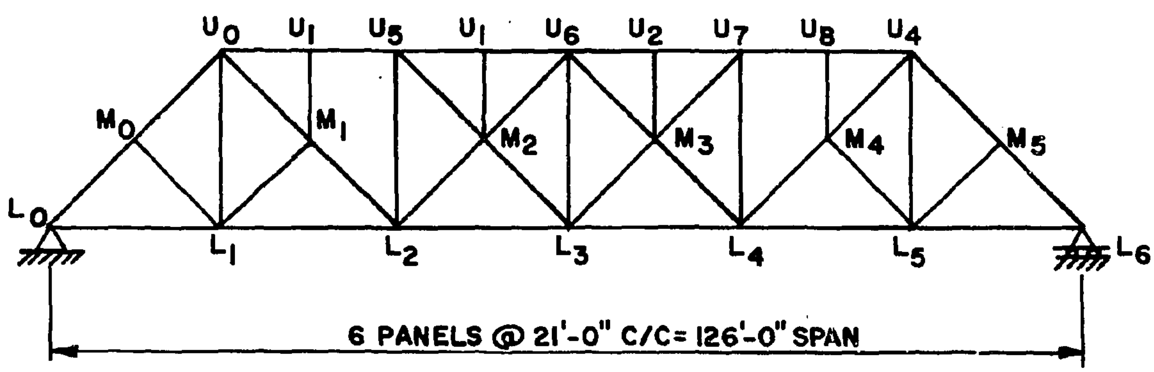


FIG. 17 b METHOD OF SUBDIVISION

(3) to raise the bottom chord of lateral bracing. The analysis in each method is performed as follows:

1) Determine lateral (and wind) forces on the truss, for which the original bracing system is analyzed and checked.

2) Using this wind loading, modify members as shown in the above figure and analyze the various alternatives.

3) Design the new system as a truss or truss-frame, as applicable.

Limitations: None

Construction Procedure:

1) Remove (dismantle) bracing from the trusses and support them on a temporary basis.

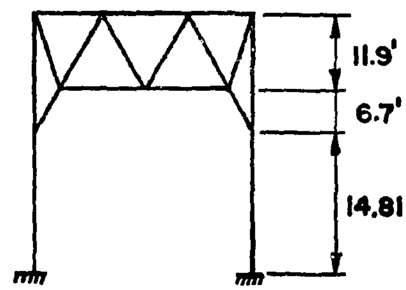
2) Reconstruct portions to be modified as shown in Fig. 18 and also in Drawing 12.

3.5.7 Additional Lane for Heavier (Truck) Traffic: (Geometric Deficiency)

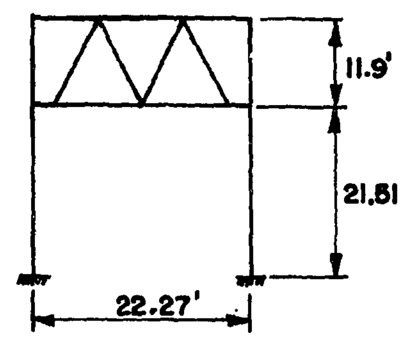
Purpose: To add lanes on each side of the two-lane bridge, converting it into a 4-lane bridge, without modifying the truss itself. Many two-lane bridges on four-lane highways cause safety problems; hence, the increase in bridge width. Alternately, an additional two-lane bridge on one side may be possible, depending on available land.

Details of Methods: In this method, a lane is added on each side of the bridge (Fig. 19), which will carry heavy traffic. The old bridge, designed for lighter loads (or traffic with less intensity), can be left for such traffic, while the additional lanes can be provided using plate girders, prestressed concrete girders or other similar methods. If the

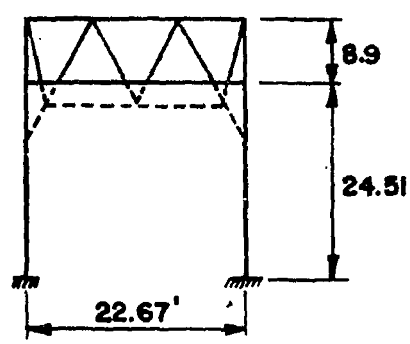
INCREASE VERTICAL CLEARANCE
EXISTING TRUSS



MODIFIED PROPOSED TRUSS



MODIFIED PROPOSED TRUSS



NOTE - - - - PORTION TO BE REMOVED

FIG. 18 INCREASE VERTICAL CLEARANCE

existing foundations are strong enough to take up the additional forces, then they will be utilized and the method will be more economical.

Limitations:

1) The main limitation to this method is the availability of adjacent land and foundation conditions.

2) Limits on weight carried on parts of the bridge must be posted.

Construction Procedure: Since this directly involves constructing a new bridge, it is not presented as part of the rehabilitation process. Some details are presented in Drawing 11.

3.5.8 Corrective Methods for Narrowness of Bridge:

Purpose: This section is introduced here to demonstrate the upgrading of a through truss bridge by eliminating the geometric deficiency. The main purpose is to provide a safe transition from a four-lane roadway to a two-lane bridge (or from wide approach to narrow passage), especially when other solutions are not possible (to widen the bridge).

Details of Method(s): Various methods are recommended based on NCHRP research. Tables 5 and 6 show details of these alternatives.

Change Approach Grades: When grade continuity is a problem, consideration should be given to major changes in grades of the approaching roadway.

Realign Roadway: When sight distance problems are apparent and traffic measures appear to fail, realignment of the bridge approach roadways may be the only acceptable alternative.

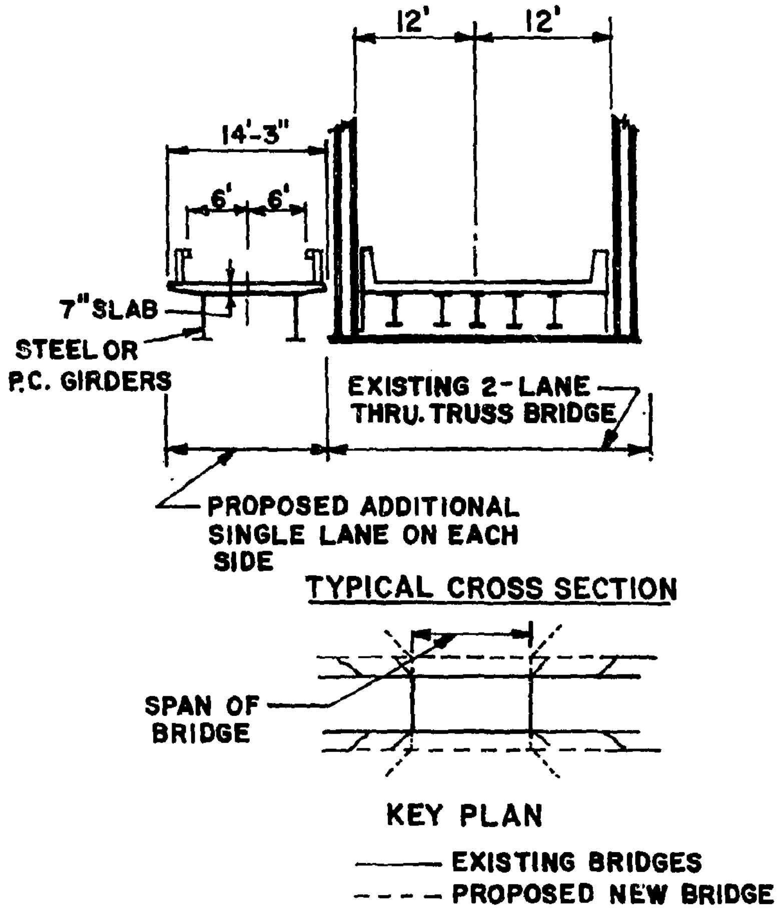


FIG. 19 ADDITIONAL LANE FOR HEAVY TRAFFIC

TABLE 5

ALTERNATE METHODS FOR THE PROBLEM OF NARROWNESS

Alternate No.	Description
1	Change approach grades
2	Realign roadway
3	Install smooth bridge rail
4	Install approach guardrail
5	Place edge lines
6	Remove centerline for one-way operation
7	Place pavement transition markings
8	Install narrow bridge sign
9	Install stop, yield, or signalization
10	Transition shoulders to bridges
11	Advisory speed signs
12	Re-route commercial vehicles
13	Environmental control
14	Approach bridge delineation

TABLE 6

APPROPRIATE ALTERNATE SOLUTIONS

To Reduce Probability of Accidents

1. Manage speed -- use treatment alternatives 8, 9, 11*
2. Change physical conditions -- use treatment alternatives 1, 2, 9, 13
3. Change visual conditions -- use treatment alternatives 2, 3, 4, 6, 7, 10, 14
4. Manage lateral position -- use treatment alternatives 2, 3, 4, 5, 6, 7, 10
5. Increase expectancy -- use treatment alternatives 2, 4, 8, 9, 10, 11, 14
6. Change traffic mix -- use treatment alternative 12

To Reduce Severity of Accidents

1. Manage speed -- use treatment alternatives 8, 9, 11
2. Change physical conditions -- use treatment alternatives 2, 3, 4, 13

* Refer to Table 5 for these alternatives

Install Approach Guardrail: Approach guardrail should be used at all restricted-width bridge locations, following the examples and standards in Highway Design and Operational Practice Related to Highway Safety [See AASHTO (1974)]. The approach guardrail serves several functions, including redirecting errant vehicles from impacting the ends of bridges. The approach rail must be correctly tied to the bridge end and/or bridge rail system.

Place Pavement Edge Markings: Edge lines are effective visual guides for the driver. They are useful in showing width continuity from the approach roadway to the structure.

Place Pavement Transition Markings: Pavement transition markings are necessary where large differences exist between the approach roadway width and the bridge width. On higher-speed highways, the single edge line may not be sufficient. In these areas, diagonal shoulder markers, rumble strips, and raised reflectors can be used effectively. Edge lines also can be used in the transition from a wide roadway approach to a restricted-width bridge.

Install Narrow Bridge Sign: When a bridge is 24 ft. (7.2 m) or less in width or when the bridge width is substantially less than the approach width, the narrow bridge sign (W5-2, Manual on Uniform Traffic Control Device (MUTCD)) should be considered. When the width is less than 20 ft. (6 m), the one-lane bridge sign (W5-3, MUTCD) should be considered. Advance warning of the situation should be given.

Install Stop, Yield Sign or Signalization: When a bridge is less than 18 to 20 ft in width (5.4 to 6 m) and there is a high proportion of commerical vehicles), appropriate signs (such as one-lane, yield, stop, and advance warning) should be installed in accordance with MUTCD requirements. When extremely high risk is involved, positive control (such as traffic-actuated signalization) should be considered.

Transition Shoulders: When gross discontinuities occur (such as when a shoulder is dropped at the bridge), the driver should be warned. This may be done by paint markings, delineators, or pavement reflectors, which should begin approximately 1000 ft (300 m) in advance of the bridge and gradually taper to the bridge. It is not suggested that the shoulder itself be tapered since the shoulder provides a necessary recovery area. Positive transition can be accomplished using these suggested measures.

Advisory Speed Signs: Appropriate advisory speed signs may be used in conjunction with warning signs at narrow bridge locations.

Reroute Commercial Vehicles: This alternative probably is not viable in most cases. However, there may be situations where through commercial traffic should be rerouted around restricted or one-lane bridge sites.

Environmental Control: Consideration should be given to the control or elimination of access, extraneous development, distracting lights, and other roadside disturbances (such as boat ramps and fishing docks) in the vicinity of restricted-width bridge sites. Excessive roadside activities are undesirable distractions to the driver.

Install Approach and Bridge Delineation: Nighttime negotiation of narrow bridges appears to be especially hazardous. Appropriate delineation of bridge approaches and the bridge railings should be provided to aid the driver. Positive nighttime delineation of width transition is also desirable.

Some of the solutions may not be the "standard practice", but their use in hazardous locations is a feasible alternative which must be considerered in solving the narrow bridge problem. The idea is to alert motorists that the bridge is either occupied by another vehicle or that the bridge is unoccupied. This concept might be applied where it is impossible for two vehicles to pass on the bridge or where such passing must be done at a crawl speed.

When sight distance or other problems prevent the driver from observing the bridge at sufficient distance to determine if it will be occupied or unoccupied when he reaches it, it is necessary to advise the driver by other means. Detectors with actuated signal equipment and even variable message signs could be used for this purpose. This is not a viable solution for all narrow bridges, but on certain important facilities it may be acceptable and even cost-effective.

CHAPTER 4: DETAILS OF METHODS OF APPLICATIONS

4.1 INTRODUCTION

Having presented the various methods, the practical use of these methods must be investigated. SAI had previously inspected one of the through truss bridges which is used as an example for rehabilitation. Presented in this chapter are the various solutions in this case using the methods discussed earlier. The bridge is approximately a 120 ft (36 m), simply supported span with all the members shown as they existed. Following the application and actual comparison of stresses and loads, cost comparisons are made and specifications and drawings prepared for the rehabilitation work.

4.2 EFFECTIVENESS OF VARIOUS METHODS

In all cases comparisons are made for forces in members in the "existting" bridge due to HS-15 loading and the "upgraded" bridge due to HS-20 loading. These forces are presented in Tables 7 through 12 for all methods. The tables present the member, its size and existing capacity in tension or compression, forces in existing truss due to HS-15, and in the modified trusses due to HS-20 loading. For each method, the dead load forces are computed both for the existing concrete deck as well as lighter deck (steel grating). Sample calculations with details are shown in Section 4.4 for each method to indicate some of the values obtained in these tables.

4.3 COST COMPARISONS

In a rehabilitation work, it is important that its cost be less than approximately 50 percent of replacement cost of the bridge to make it a cost effective solution. Although this was done originally for only one particular bridge, a range of spans between 60 and 200 ft. (18 m and 60 m) is used to compare cost of rehabilitation and replacement. These comparisons are shown in Figs. 20 through 24 for various methods discussed earlier. In these figures, the cost of reconstruction includes both construction and design costs (in 1981

TABLE 7 STRENGTHENING OF COMPRESSION MEMBER

MEMBER	MEMBER SIZE	CAPACITY OF MEMBERS (KIPS) TENSION	COMPRESSION	EXISTING TRUSS: HS-15 LOADING FORCES (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	MODIFIED TRUSS: HS-20 LOADING FORCES WITH EXIST. DECK (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	MODIFIED TRUSS: HS-20 LOADING FORCES WITH NEW DECK (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	INCREASED CAPACITY, IF ANY (KIPS)
U_oL_o	2C 10X20 1 Pl 7/16X10"	-	-188	-101.0	- 65.0	-166.0	-101.0	- 86.7	-188.0	- 86.7	- 86.7	-174.0	-
U_oL_1	-do-	226	-188	-101.0	65.0	166.0	101.0	86.7	188.0	86.7	86.7	174.0	-
U_1L_1	-do-	-	-188	- 60.5	- 50.7	-112.0	- 60.5	- 67.6	-128.0	- 51.9	- 67.6	-120.0	-
U_1L_2	-do-	226	-188	60.5	50.7	112.0	60.5	67.6	128.0	51.9	67.6	120.0	-
U_2L_2	-do-	-	-188	- 20.3	- 36.3	- 57.0	- 20.3	- 48.4	- 68.0	- 17.4	- 48.4	- 66.0	-
U_2L_3	-do-	266	-188	20.3	36.3	57.0	20.3	48.4	68.0	17.4	48.4	66.0	-
U_oU_1 U_oU_6-U_6U_1	2C 12X30 1 Pl 7/16X16"	-	-322	-101.0	- 65.0	-166.0	-101.0	- 86.7	-188.0	- 86.7	- 86.7	-174.0	342
U_1U_2 U_1U_7-U_7U_2	-do-	-	-322	-161.7	-101.4	-263.0	-161.7	-135.2	-297.0	-138.6	-135.2	-273.0	342
U_2U_3 U_2U_8-U_8U_3	-do-	-	-322	-182	-112.3	-294.0	-182.0	-149.7	-332.0	-156.0	-149.7	-306.0	342
L_oL_1	2C 12X30 1Pl 7/16X12"	275	-	50.4	32.4	83.0	50.4	43.0	93.0	43.2	43.0	83.0	-
L_1L_2	-do-	275	-	131.3	77.7	209.0	131.3	103.6	235.0	112.5	103.6	216.0	-
L_2L_3	-do-	275	-	171.85	102.6	275.0	171.85	136.8	310.0	147.3	136.8	284.0	-

NOTES: 1. Plus (+) and minus (-) indicate tension and compression respectively.

2. Additional Members are L_1U_6, L_2U_7, L_3U_8 and their size is C 10X15.3

3. Refer to Fig. 13.

TABLE 8 PRESTRESSING OF BOTTOM CHORD

MEMBER	EXISTING MEMBER SIZE	CAPACITY OF MEMBERS (KIPS)		EXISTING TRUSS: HS-15 LOADING FORCES (KIPS)			EXISTING TRUSS: HS-20 LOADING FORCES (KIPS)			ADDITIONAL CAPACITY REQUIRED	OPPOSITE FORCES IN MEMBERS DUE TO TENSION IN CABLE	MODIFIED TRUSS: HS-20 LOADING FORCES (KIPS)		
		TENSION	COMPRESSION	DEAD LOAD	LIVE LOAD	TOTAL	DEAD LOAD	LIVE LOAD	TOTAL			DEAD LOAD	LIVE LOAD	TOTAL
U_oL_o	2C 12X25 1Pl 7/16X16"	-	-258	-124	-79.8	-204	-124	-106.1	-230	- 26	26	- 98	-106.1	-204
U_oL_1	-do-	315	-283	-140	-87.8	-228	-140	-116.8	-257	- 29	36.8	-103	-116.8	-220
U_1U_2	2C 12X30 1Pl 7/16X16"	-	-320	-157.5	-97.5	-255	-157.5	-129.7	-287	- 32	36.8	-121	-129.7	-251
U_oL_1	2C 8X11.5	96	- 64	35	45.6	81	35	60.4	95	14	-	35	60.6	96
U_oL_2	2L 5X3-1/2X5/16	158	-	74.2	62.1	137	74.2	82.6	157	20	- 26	48.2	82.6	131
U_1L_2	2C 8X11.5	96	- 64	- 17.5	-31.5	- 49	- 17.5	- 41.9	- 60	11	-	- 17.5	- 41.9	- 60
U_1L_3	2L 5X3-1/2X5/16	70	-	24.85	44.65	70	24.85	59.4	85	15	-	24.85	59.4	85
U_2L_3	2C 8X11.5	96	- 64	-	-	-	-	-	-	-	-	-	-	-
L_oL_1	2L 5X3-1/2X5/16 2L 5X3-1/2X3/8	154	-	87.5	56.3	144	87.5	74.9	163	19	-149	- 61.5	74.9	13.4
L_1L_2	-do-	154	-	87.5	56.3	144	87.5	74.9	163	19	-149	- 61.5	74.9	13.4
L_2L_3	2L 5X3-1/2X5/16 2L 5X3-1/2X3/8	243	-	140	87.8	227	140	116.8	257	30	-168	- 28	116.8	89

NOTES: 1. Tension in cable L_oL_7, L_6L_8 = 132^k.

2. Additional Members are L_2L_7 and L_4L_8 and their size is C 8X11.5

3. Refer to Fig. 14.

TABLE 9 ADDITION OF SUPPORT

MEMBER	MEMBER SIZE	CAPACITY OF MEMBERS (KIPS) TENSION	COMPRESSION	EXISTING TRUSS: HS-15 LOADING FORCES (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	MODIFIED TRUSS: HS-20 LOADING FORCES WITH EXIST. DECK (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	MODIFIED TRUSS: HS-20 LOADING FORCES WITH NEW DECK (KIPS) DEAD LOAD	LIVE LOAD	TOTAL
U_oL_o	2C 12X25 1 Pl 7/16X16"	-	-258	-123.9	- 79.8	-204.0	- 36.05	- 62.6	- 98	- 30.90	- 62.6	- 94
U_oU_1	-do-	315	-283	-140	- 87.76	-228	- 15.75	- 36.80	- 53.0	- 13.50	- 36.80	- 50
U_1U_2	2C 12X30 1Pl 7/16X16"	-	-320	-149.50	- 90.26	-240	8.40	19.23	28.0	7.20	19.23	26
U_oL_1	2C 8X11.5	-	- 64	35	45.6	81	35	60.65	96	30	60.65	91
U_oL_2	2L 5X3-1/2X5/16	158	-	74.2	62.1	136	- 13.65	- 37.67	- 51	- 11.70	- 37.67	- 49
U_1L_2	2C 8X11.5	-	- 64	- 9.45	- 16.2	- 26	24.50	29.32	54	21	29.32	50
U_1L_3	2L 5X3-1/2X5/16	70	-	13.65	23.24	37	- 34.48	- 41.64	- 76	- 29.55	- 41.64	- 71
U_2L_2	2L 3X3X5/16	48	-	- 11.20	- 21.38	- 33	28.70	40.89	70	24.60	40.89	65
U_2L_3	2C 8X11.5	-	- 64	15.75	20.52	36	- 40.39	- 35.72	- 76	- 34.62	- 35.72	- 70
L_oL_1	2L 5X3-1/2X5/16 2L 5X3-1/2X3/8	154	-	87.50	56.32	144	25.55	44.40	70	21.90	44.40	66
L_1L_2	-do-	154	-	87.50	56.32	144	25.55	44.40	70	21.90	44.40	66
L_2L_3	2L 5X3-1/2X5/8 2L 5X3-1/2X5/16	243	-	148.05	87.74	236	- 4.34	- 13.57	- 18	- 3.70	- 13.57	- 17

NOTES: 1. Plus (+) and minus (-) indicate tension and compression respectively.

2. Refer to Fig. 15.

TABLE 10 SHIFTING OF SUPPORT

MEMBER	MEMBER SIZE	CAPACITY OF MEMBERS (KIPS)		EXISTING TRUSS: HS-15 LOADING FORCES (KIPS)			MODIFIED TRUSS: HS-20 LOADING FORCES WITH EXIST. DECK (KIPS)			MODIFIED TRUSS: HS-20 LOADING FORCES WITH NEW DECK (KIPS)		
		TENSION	COMPRESSION	DEAD LOAD	LIVE LOAD	TOTAL	DEAD LOAD	LIVE LOAD	TOTAL	DEAD LOAD	LIVE LOAD	TOTAL
U_oL_o	2C 12X25 1 Pl 7/16X16"	-	-258	-123.9	- 79.8	-204.0	49.49	85.75	111.0	42.42	82.75	104
U_oU_1	-do-	315	-283	-140	- 87.76	-228	- 17.50	- 62.87	- 80	- 15	- 62.87	- 78
U_1U_2	2C 12X30 1Pl 7/16X16"	-	-320	-149.50	- 90.26	-240	- 26.95	- 69.25	- 96	- 23.10	- 69.25	- 92
U_oL_1	2C 8X11.5	-	- 64	35	45.6	81	- 87.50	-102.85	-190	- 75	-102.85	-178
U_oL_2	2L 5X3-1/2X11X16	150	-	74.2	62.1	136	74.20	88.93	163	63.6	88.93	153
U_1L_2	2C 8X11.5	-	- 64	- 9.45	- 16.2	- 26	- 9.45	- 20.67	- 30.0	- 8.1	- 20.67	- 29
U_1L_3	2L 5X3-1/2X5/16	70	-	13.65	23.24	37	13.65	29.83	43	11.70	29.83	41.53
U_2L_2	2L 3X3X5/16	48	-	- 11.20	- 21.38	- 33	- 11.20	- 27.13	- 38	- 9.60	- 27.13	- 36.73
U_2L_3	2C 8X11.5	-	- 64	15.75	20.52	36	15.75	27.29	43	13.50	27.29	41
L_oL_1	2L 5X3-1/2X5/16 2L 5X3-1/2X3/8	154	-	87.50	56.32	144	- 17.55	- 60.65	- 78	- 15	- 60.65	- 76
L_1L_2	-do-	154	-	87.50	56.32	144	- 17.5	- 60.65	- 78	- 15	- 60.65	- 76
L_2L_3	2L 5X3-1/2X5/8	243	-	148.05	87.74	236	25.55	66.14	92	21.90	66.14	88

NOTES: 1. Plus (+) and minus (-) indicate tension and compression respectively.

2. Refer to Fig. 16.

TABLE 11 METHOD OF SUBDIVISION (PRATT TRUSS)

MEMBER	MEMBER SIZE	CAPACITY OF MEMBERS (KIPS) TENSION	COMPRESSION	EXISTING TRUSS: HS-15 LOADING FORCES (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	MODIFIED TRUSS: HS-20 LOADING FORCES WITH EXIST. DECK (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	MODIFIED TRUSS: HS-20 LOADING FORCES WITH NEW DECK (KIPS) DEAD LOAD	LIVE LOAD	TOTAL	INCREASED CAPACITY, IF ANY (KIPS)
U_oL_c $U_oM_o - M_oL_o$	2C 12X25 1 Pl 7/16X16"	-	-253	-123.9	- 79.8	-204	-123.9	-106.1	-230	-106.2	-106.1	-212	-295
U_oU_1 $U_oU_5 - U_5U_1$	-do-	315	-283	-140	- 87.76	-228	-140	-116.7	-257	-120	-116.7	-237	-301
U_1U_2 $U_1U_6 - U_6U_2$	2C 12X30 1 Pl 7/16X16"	-	-320	-149.5	- 90.26	-240	-149.5	-120.1	-270	-128	-120.1	-248	-342
U_oL_1	2C 8X11.5	91	- 64	35	45.6	81	35	60.7	96	30	60.7	91	-
U_oL_2 $U_oM_1 - M_1L_2$	2L 5X3-1/2X5/16	158	-	74.2	62.1	136	74.2	82.6	157	63.6	82.6	146	-
U_1L_2	2C 8X11.5	91	- 64	- 9.45	- 16.2	- 26.0	- 9.45	- 21.5	- 31	- 8.1	- 21.5	- 30	-
U_1L_3 $U_1M_2 - M_2L_3$	2L 5X3-1/2X5/16	70	-	13.65	23.24	370	13.65	30.91	45	11.70	30.91	43	-
U_2L_2	2L 3X3X5/16	48	-	- 11.20	- 21.38	- 33.0	- 11.20	- 28.44	- 40	- 9.6	- 28.44	- 38	-
U_2L_3	2C 8X11.5	91	- 64	15.75	20.52	36.0	15.75	27.29	- 43	13.5	27.29	41	-
L_oL_1	2L 5X3-1/2X5/16 2L 5X3-1/2X3/8	154	-	87.50	56.32	144.0	87.5	74.9	163	75	74.9	150	-
L_1L_2	-do-	154	-	87.50	56.32	144.0	87.5	74.9	163	75	74.9	150	-
L_2L_3	2L 5X3-1/2X5/8 2L 5X3-1/2X5/16	243	-	148.05	87.74	236.0	148.05	116.7	265	126.9	116.7	244	-

NOTES: 1. Plus (+) and minus (-) indicate tension and compression respectively.

2. Additional Members are M_oL_1, L_1M_1, M_1U_5 and M_uU_6 .

3. Refer to Fig. 17b.

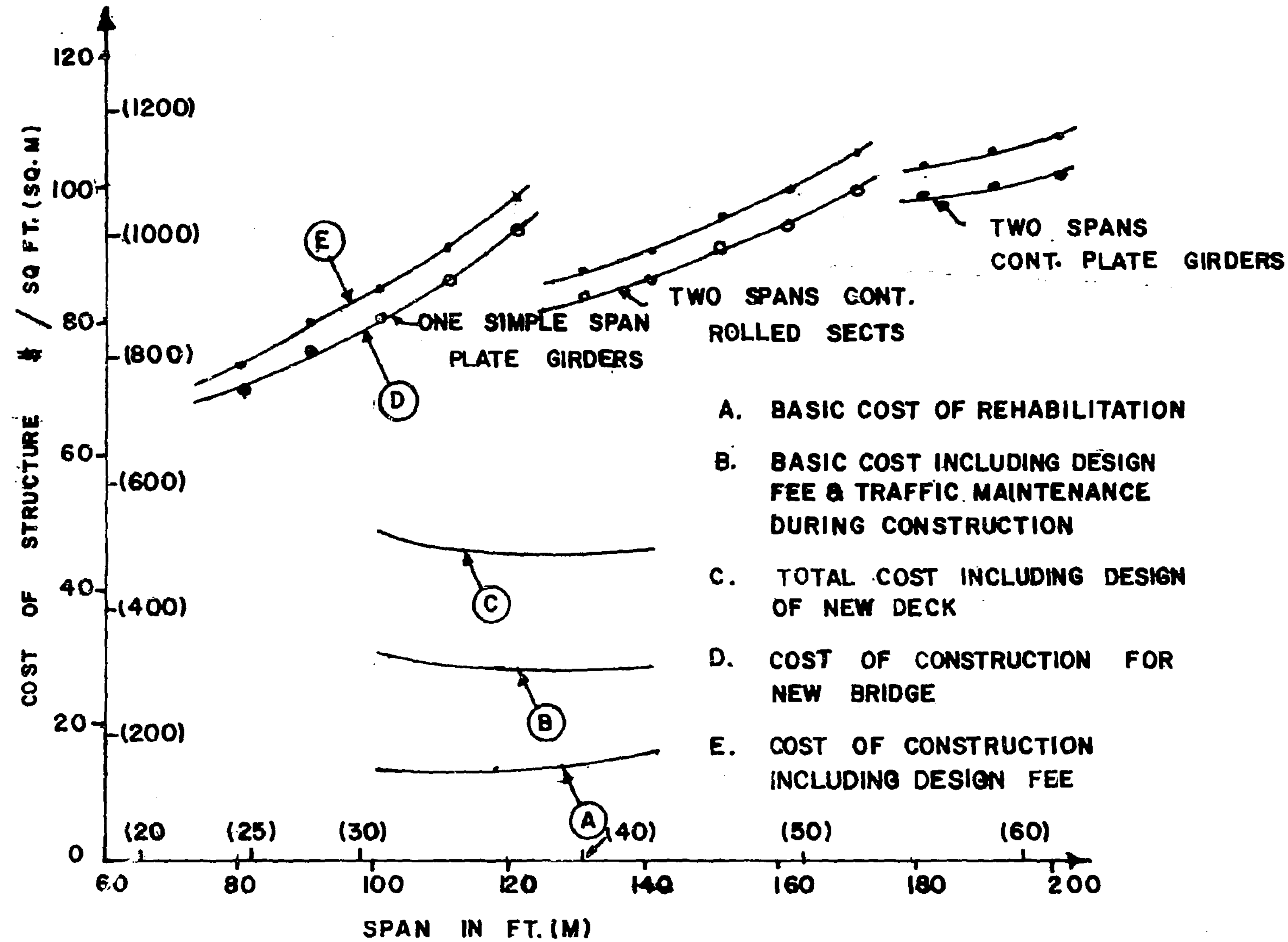


FIG. 20 COST COMPARISON - METHOD OF STRENGTHENING OF COMPRESSION MEMBER

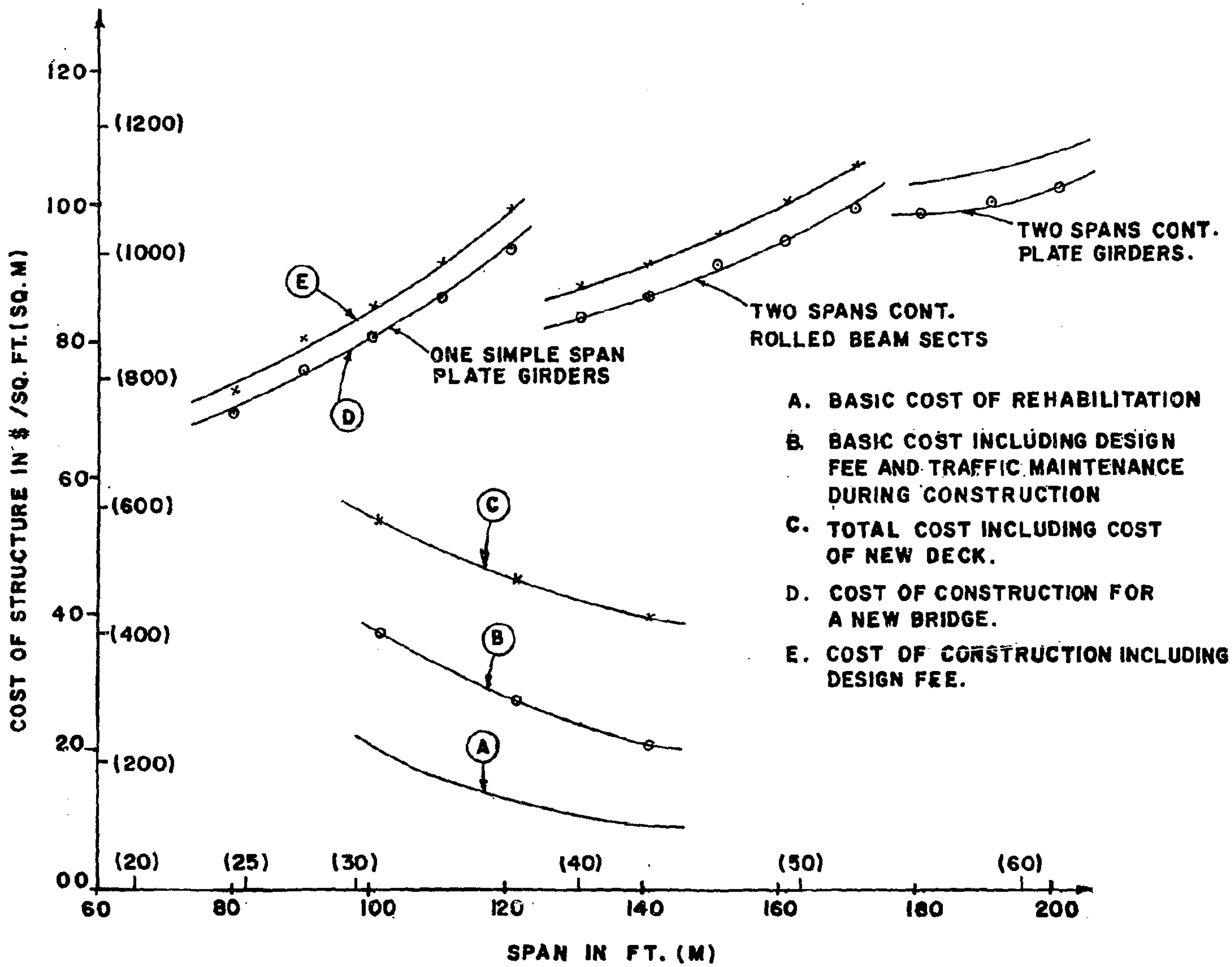


FIG. 21 COST COMPARISON - METHOD OF PRESTRESSING BOTTOM CHORD

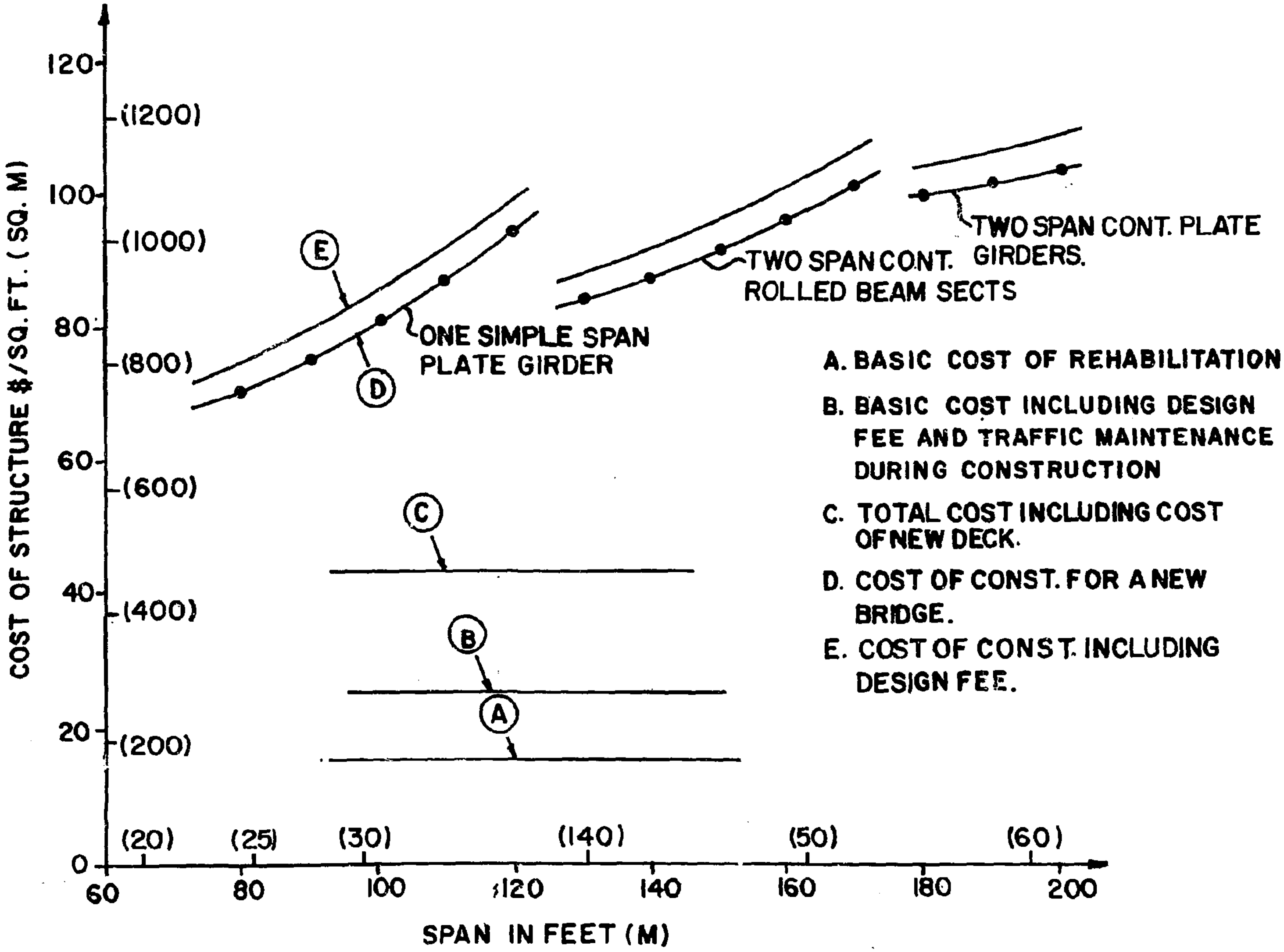


FIG. 22 COST COMPARISON - METHOD OF ADDITIONAL SUPPORTS

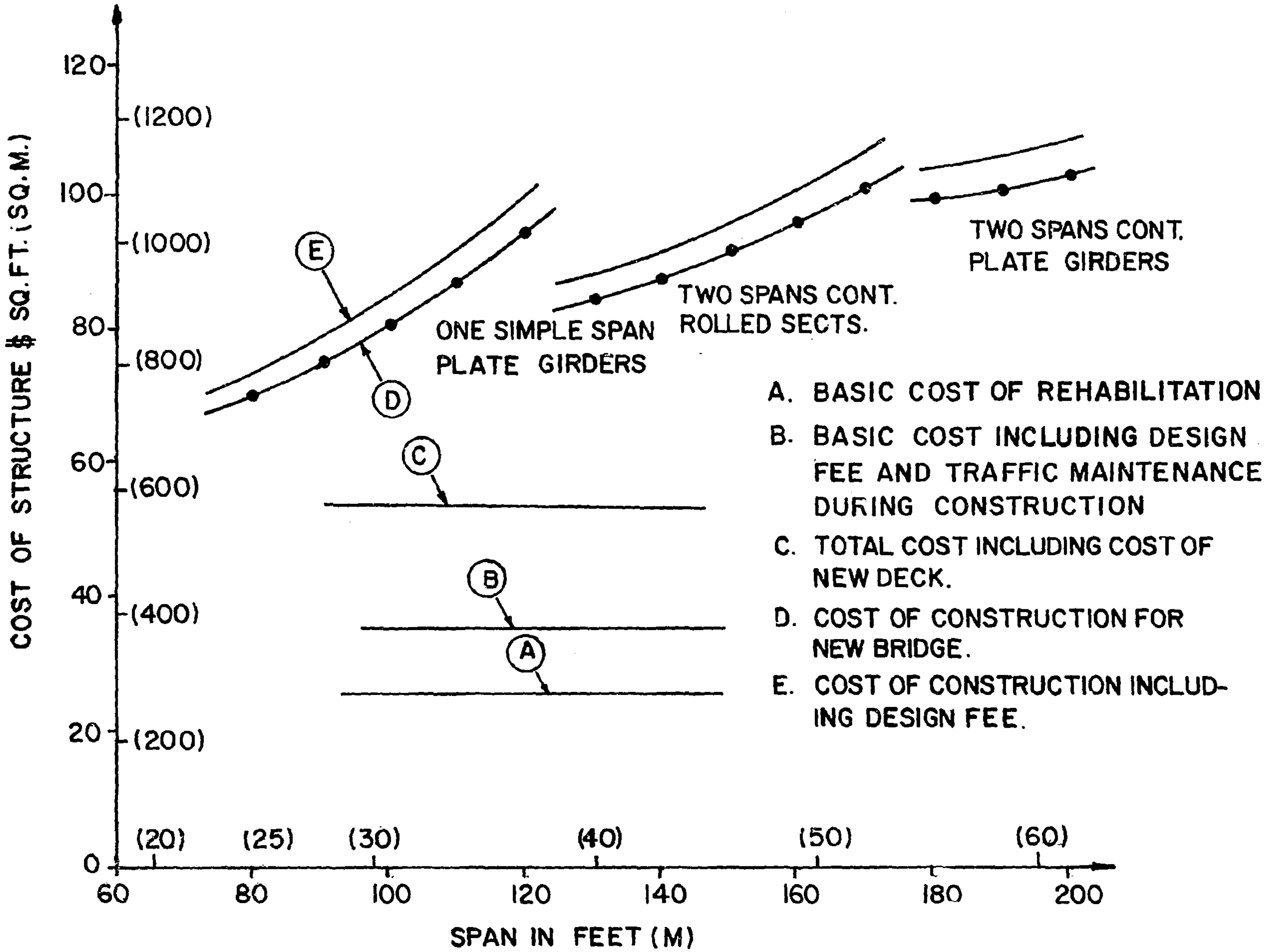


FIG. 23 COST COMPRISON - SHIFTING OF SUPPORTS

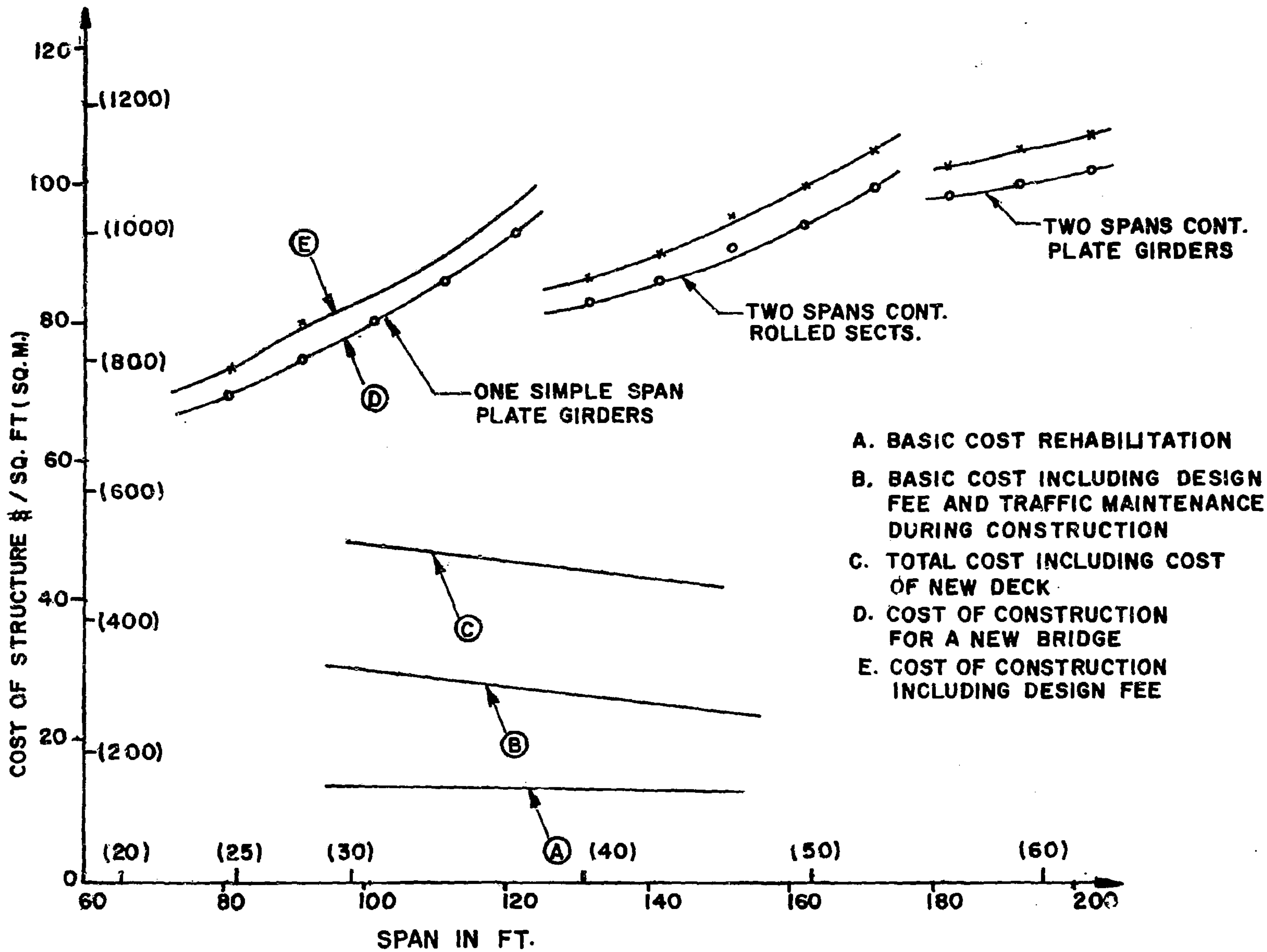


FIG. 24 COST COMPARISON-METHOD OF SUBDIVISION

Table 12 COST ANALYSIS

Method	Span	Basic Cost	Add'l Cost	Total Basic Cost	Cost of Design & Traffic Maint.	Cost of Deck Re-Placement	Total Cost of Rehab.		Cost of Replacement	
							Without Deck	With New Deck	Constr. Cost	Constr./ Design Cost
Strengthening of Compres-sion Member	100'-0"	4.5	9.0	13.5	17	18	30.5	48.5	80	84.5
	120'-0"	4.5	9.0	13.5	14	18	27.5	45.5	93	98
	140'-0"	5.5	11.0	16.5	12	18	28.5	46.5	86	90.5
Method of Prestressing	100'-0"	6.0	12.0	18.0	17	17	35	53	80	84.5
	120'-0"	4.5	9.0	13.5	14	18	27.5	45.5	93	98
	140'-0"	3.0	6.0	9.0	12	18	21	39	86	90.5
Shifting of Support	100'-0" to 140'-0"	35.0	----	35.0	10	18	45	63	80	84.5
Addition of Support	100'-0" to 140'-0"	18.0	----	18.0	10	18	36	54	80	84.5
Method of Subdivision	100'-0"	4.5	9.0	13.5	17	18	30.5	48.5	80	84.5
	120'-0"	4.5	9.0	13.5	14	18	27.5	45.5	93	98
	140'-0"	4.5	9.0	13.5	12	18	25.5	43.5	86	90.5

NOTE:
1. All costs are in dollars per sq. ft. (for conversion to $/Sq. m. multiply by 10.71).
2. Traffic maintenance cost is estimated @ $15,000 for the entire bridge.
3. Design and supervision costs estimated @ $25,000 for the entire bridge.

dollars). Discontinuity in the curves is caused by replacement of a bridge from a simple to a continuous span and from rolled sections to plate girders. The costs may vary within $\pm 10\%$, depending on location of the bridge. Costs of rehabilitation shown in these figures have been summarized in Table 12. In the case of rehabilitation, it must be noted that several components are involved, which include basic construction costs, design costs and the cost of replacement of deck with lighter deck material. Although a lightweight deck is optional, it is included in the costs, because reduction in dead weight helps to increase live load capacity of the truss. In general, it may be concluded that the methods shown in this report provide a good way to rehabilitate the through truss bridge since their costs vary between 20-60% of reconstruction costs.

4.4 SAMPLE CALCULATION AND DETAILS

Strengthening of Compression Member

Design of compression member is based mainly on its unbraced length (ratio of KL/r, which gives the allowable stress for that member). In this method, the length of member is reduced which increases the allowable stress in that member. In general, if the length of a compression number is reduced to half, its capacity increases from HS-15 to HS-20 loading without affecting the member, e.g.

Member U_2U_3 (See Fig. 13)

Initial force = 294^K (compression) .... (HS-15 loading)

Final force = 332^K (compression) .... (HS-20 loading)

Existing member size 2L - 12X30

1 Pl - 7/16X16 in.

Length = 20'-0"

Area = 24.64 in^2

r_{min} = 4.48"

$$\frac{KL}{r_{min}} = \frac{20 \times 12}{4.48} = 53.6$$

$$\text{Allowable stress} = 14150 - 0.37 \frac{KL}{r_{min}} \quad \text{(AASHTO, 1978) (Table 4)}$$

$$= 14150 - 0.37 (53.60)^2$$
$$= 13 \text{ ksi}$$

$$\text{Allowable load} = 13 \times 24.64 = 322^k > 294^k$$

Now, by subpaneling the truss, the member U_2U_3 is upgraded by reducing the length to half.

Length = 10'-0"

$$\frac{KL}{r_{min}} = \frac{10 \times 12}{4.48} = 26.78$$

$$\text{Allowable stress} = 14150 - 0.37 (26.78)^2$$

$$= 13.88 \text{ ksi}$$

$$\text{Allowable load} = 13.88 \times 24.64$$
$$= 342 \text{ k}$$
$$> 332 \text{ k (HS-20 Force)}$$

Prestressing of Bottom Chord

In the case of trusses subjected to both dead load (D.L.) and live load (L.L.) including impact, the proportion of D.L. is reasonably higher than L.L. + impact load. The member selected for prestressing already has stresses due to dead load (before the application of live load). Turnbuckles are used to induce tension in the cables, thus inducing axial forces in the truss members which are the reverse of those produced by normal loads.

If tension is applied in the cable, it would counteract the dead load stresses and subsequently reduce member forces, when unit tension is applied, e.g. to a 6'-0" high strut, the forces in critical members are:

(1) -1.268, (2) 0.279, (3) 0.197^k (See Fig. 14)

Now, for member (3), in order to increase the capacity from 204^k (HS-15 loading) to 230^k (HS-20 loading), we need to apply tension (See Fig. 14)

of $\frac{230-204}{0.197} = 132k$

Effect of 132 kips tension in the overall truss member is shown in Table 9.

Addition of Support

This method mainly reduces the span and makes the truss continuous. By doing so, overall forces in the members are reduced substantially. However, there are critical members which undergo reversal of stresses from tension to compression; these must be checked, redesigned or replaced, according to the existing condition of the bridge. Analysis is performed on a sample Pratt truss and forces for an existing truss (HS-15 loading) and a modified truss (HS-20 loading) are shown in Table 9.

Shifting of Support

Shifting the support reduces the effective span and thus the forces in the truss members. Analysis is performed for the Pratt truss with two ends as cantilever. By reducing the span in this manner, forces in the truss members are reduced significantly. Forces in the modified truss members are shown in Table 10. It may be noted from this table that the overall forces are reduced to a great extent. However, there are critical members which undergo reversal of stresses from tension to compression, and must be checked, designed or replaced according to the existing condition of the bridge.

Method of Subdivision:

In this method, the length of chords and diagonals is reduced by subdividing the truss. The basic principle is the same as the first method of sub-paneling the truss. The forces are tabulated for typical trusses for existing as well as modified conditions. The increased capacity of members which are subdivided is also shown in Tables 11 and 12.

4.5 SPECIFICATIONS

Detailed specifications are prepared for rehabilitation work of through truss bridges and presented in Appendix B of this report; brief portions are shown in drawings when appropriate. The specifications shown in Appendix B can be used for any job, depending on the extent of rehabilitation work.

4.6 DETAILED DRAWINGS

Drawings prepared in this project are included in this report. The drawings include both existing bridge drawings (redrawn) and those required for rehabilitation work by various methods, as follows:

Drawing No. 1	Existing Mullens Bridge (Pratt Truss)
Drawing No. 2	Existing Mullens Bridge (Details)
Drawing No. 3	Existing Warren Truss Bridge
Drawing No. 4	Strengthening of Compression Member
Drawing No. 5	Method of Prestressing (Warren Truss)
Drawing No. 6	Method of Prestressing (Pratt Truss)
Drawing No. 7	Shifting of Support(s)
Drawing No. 8	Addition of Support(s)
Drawing No. 9	Method of Subdivision (Warren Truss)
Drawing No. 10	Method of Subdivision (Pratt Truss)
Drawing No. 11	Additional Lane for Heavier Loading
Drawing No. 12	Increasing Vertical Clearance
Drawing No. 13	Replacement of Existing Concrete Deck

CHAPTER 5: FINDINGS OF THE STUDY

5.1 SUMMARY OF THE PROJECT

Review the state-of-the-art of through truss bridges in this project has included literature, State and other practices, and personal contacts and experiences. The literature assembled describes a number of rehabilitation cases, which have been useful in developing the innovative methods presented in this report. The practices in various States are useful in terms of actual work of repair and maintenance of these bridges and for identifying important deficiencies, thus helping to develop suitable methods for upgrading.

Deficiencies to be overcome in prolonging the service life of truss bridges are structural and geometric, and include those resulting in safety hazards from bridge narrowness. The methods developed address these deficiencies individually; however, in actual practice, a combination of two or more methods may be more applicable.

Specifications and construction drawings are developed and are also included in appropriate sections of the report.

5.2 CONCLUSIONS

1. Inventory evaluation of through truss bridges indicates that deficiencies related to age, design loading, span and materials exist in the majority of bridges at the present time.

2. Review of the literature indicates a number of methods which have been used for upgrading/rehabilitation rather than replacing bridges (the option which is substantially more costly).

3. Methods developed in this report to upgrade through truss bridges are economical. The costs (including all aspects) of rehabilitation are found to be less than 50% of replacement costs.

Since the methods are for the two most commonly used types of bridges, there may be some different cost savings.

4. Although these methods upgrade through truss bridges by overcoming specific deficiencies in particular situations, a proper, practical solution is probably a combination of two or more methods (as applicable).

5. Proper cognizance of several limitations and restrictions should be taken into account. These include properties of materials, reversal or increase of stresses in other members and so on. Weldability of (old) steel members should be checked out particularly.

5.3 RECOMMENDATION FOR FUTURE RESEARCH

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

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

1. Actual strength test on one of the bridges due for dismantling or replacement. This test will be useful in obtaining actual data some of which are assumed in this work.

2. Tests on a through truss bridge at the FHWA facilities with suitable instrumentation. The methods of rehabilitation recommended in this report should be tried out on this bridge in the laboratory so that they can be further verified.

3. Cost effectiveness as determined in this report may be verified by actual case studies, in which States and FHWA can perform the complete rehabilitation.

4. Funding may be provided to investigate methods of rehabilitation for other types of bridges.

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APPENDIX A

STEEL TRUSS REPAIR - DIAGONAL TENSILE MEMBER

DESCRIPTION:

Replacement of damaged or deteriorated diagonal tensile member on trusses having riveted or bolted connections. Replacement details for a pinned and diagonal are suggested.

LIMITATIONS:

The procedures described are limited to tensile members with riveted or bolted truss connections only. No more than one-half of the member should be removed and replaced at a time. The new diagonal must have a capacity equal to that of the member being replaced. Care must be taken to avoid damage to the members which are to be reused.

CONSTRUCTION PROCEDURE:

1. Design the new diagonal section and connections.

2. Restrict traffic to one lane on the opposite side of the bridge.

3. Cut and install the necessary wood blocking, as shown in Fig. 25.

4. Install a cable having the capacity to carry the full dead load in the diagonal plus the live load distributed from the restricted traffic.

5. Tighten the cable system.

6. If the member to be replaced is composed of angles, as shown in Section AA, Fig. 26, it should be repaired by first removing and replacing two of the angles; then removing and replacing the last two angles. The two angles removed first should be the weaker ones, or as otherwise determined by the existing condition of the diagonal member. If the member to be replaced is similar to that shown in Section BB, Fig. 26, first one channel is removed and replaced, then the other. High strength bolts are used for connecting the new diagonal members. (See Fig. 27 for suggested connection of pinned end diagonal).

7. Install the batten plates or lacing bars at the required intervals along the diagonal. Tighten the high strength bolts at all connections.

8. Remove cable slings and other temporary components and restore the bridge to normal traffic conditions.

   Note: A number of bridge design offices in the United States have developed satisfactory procedures for replacing damaged or deteriorated steel truss members. Substantial savings are

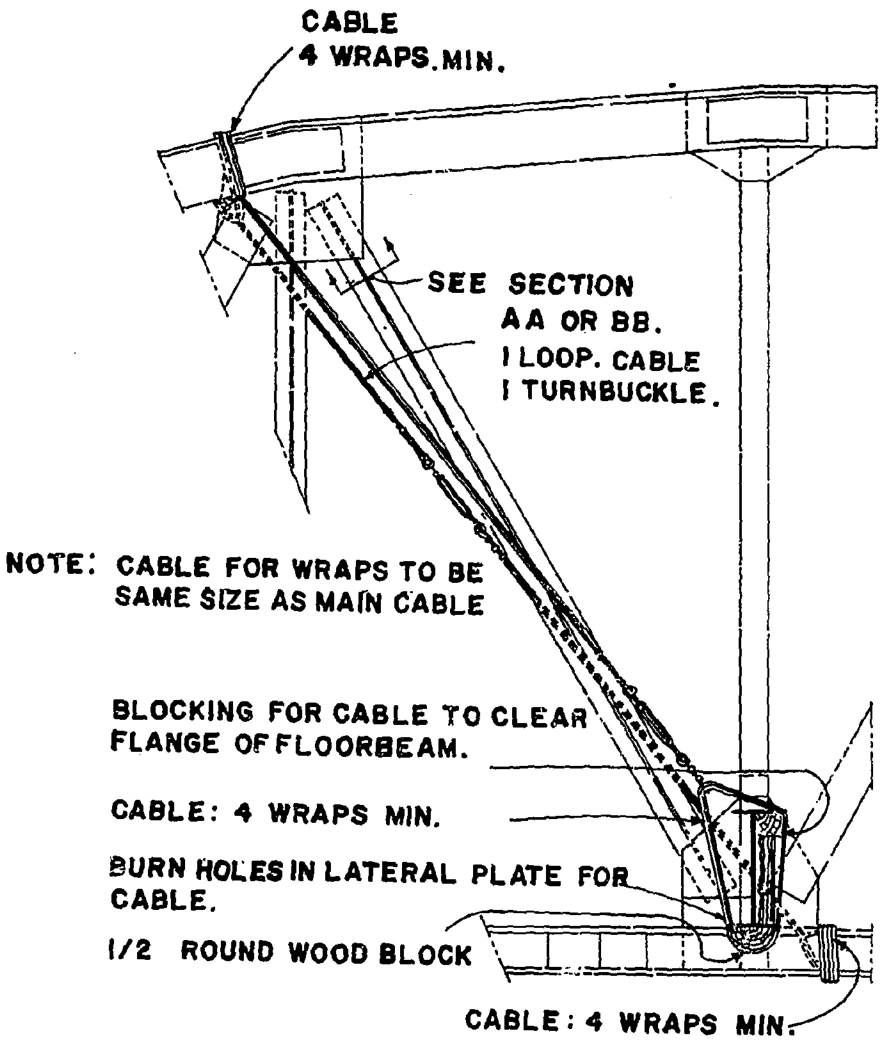
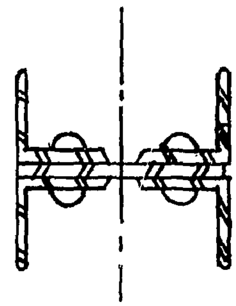
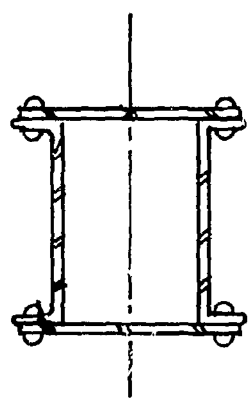


FIG. 25 TRUSS DIAGONAL REPLACEMENT
FOR RIVETED OR BOLTED CONNECTION



SECTION AA

EXISTING MEMBER COMPOSED OF FOUR ANGLES WITH BATTEN PLATES CAN BE REPLACED USING ANGLES OR ST SECTIONS WITH BATTEN PLATES.

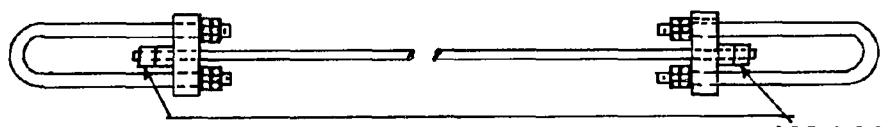


SECTION BB

EXISTING MEMBER COMPOSED OF TWO CHANNELS WITH BATTEN PLATES OR LACE BARS (USUALLY FOUND WHERE DIAGONAL MAY BE REQUIRED TO SUSTAIN COMPRESSIVE AND TENSILE FORCES) CAN SOMETIMES BE REPLACED WITH W OR HP SECTIONS WHERE CONDITIONS PERMIT.

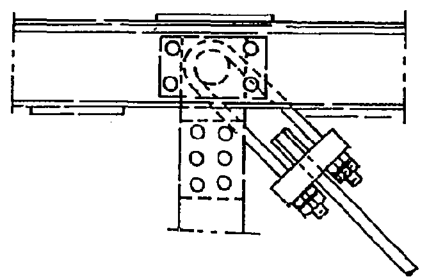
FIG. 26 TRUSS REPAIR DETAILS

NOTE: DETERIORATED DIAGONAL TENSION MEMBERS CONSISTING OF TWO EYE BARS CAN BE REPLACED BY USING RODS AS SHOWN WITH U-BOLT END CONNECTIONS. WITH NO TRAFFIC ON THE STRUCTURE, ONE OF THE DETERIORATED EYEBARS AT A TIME CAN USUALLY BE REMOVED AND REPLACED WITH THE ROD ILLUSTRATED WITHOUT THE USE OF CABLES AS SHOWN ON PAGE 3 OF 5.



ADD LOCK NUT. (TWO NUTS)
UPSET THREADED END.

NEW DIAGONAL MEMBER



CUT SLOT IN COVER PLATE TO ALLOW PLACING OF U-BOLT. WELD PLATE OVER SLOT AFTER NEW MEMBERS ARE IN PLACE.

FIG. 27 TRUSS DIAGONAL REPLACEMENT FOR PINNED END CONNECTIONS

CONSTRUCTION PROCEDURE (continued):

effected when an entire structure can be salvaged by replacement of only the subpar elements. This type of operation requires great care and a high level of engineering expertise. A note-worthy instance is in the Commonwealth of Massachusetts where, under the supervision of Mr. J. J. Aherns, Bridge Engineer, a unique procedure was developed to replace the entire lower chords of two 110-ft four-panel trusses comprising a deck truss bridge over Deerfield River at Monroe, Massachusetts. A detailed description and plans for this repair are available from the Massachusetts Department of Public Works, 100 Nashua Street, Boston, Massachusetts.

RESOURCE REQUIREMENTS:

Cable sling with turnbuckles; prefabricated steel replacement components, torch, and/or other cutting tools.

REFERENCE:

Virginia Department of Highways and Transportation

STEEL TRUSS REPAIR - VERTICAL TENSILE MEMBER

DESCRIPTION:

Replacement of damaged or deteriorated vertical tensile members on trusses having riveted or bolted connections.

LIMITATIONS:

Limited to tensile members on riveted or bolted truss connections. The new member should have a capacity equal to that of the member being replaced. Traffic should be restricted to one lane during the repair.

CONSTRUCTION PROCEDURE:

1. Design the new vertical section and connections.

2. Restrict traffic to one lane on the opposite side of the bridge.

3. Install the wood blocking and WF beam, as shown in Figs. 28 and 29, Section AA.

4. Install a cable having the capacity to carry the maximum load in the vertical member being repaired (Fig. 28).

5. Tighten the cable system to eliminate the dead load tensile force in the member being replaced.

6. If the member to be replaced is composed of angles, as shown in Section CC, Fig. 29, it can be repaired by first removing and replacing two of the angles; then removing and replacing the last two angles. The two angles removed first should be the weaker ones, or as otherwise determined by the existing condition of the vertical member. If the member to be replaced is similar to that shown in Section BB, Fig. 29, one channel is removed first and replaced, then the other. If the entire member can be safely removed, it can be replaced with other types of sections of equal strength. High strength bolts are used for connecting the new vertical members.

7. Install the batten plates or lacing bars at the required intervals along the vertical. Tighten the high strength bolts at all connections.

8. Remove cable slings and other temporary components and restore the bridge to normal traffic conditions.

RESOURCE REQUIREMENTS:

Cable sling with turnbuckles; prefabricated steel replacement components, torch, and/or other cutting tools.

REFERENCE:

Virginia Department of Highways and Transportation.

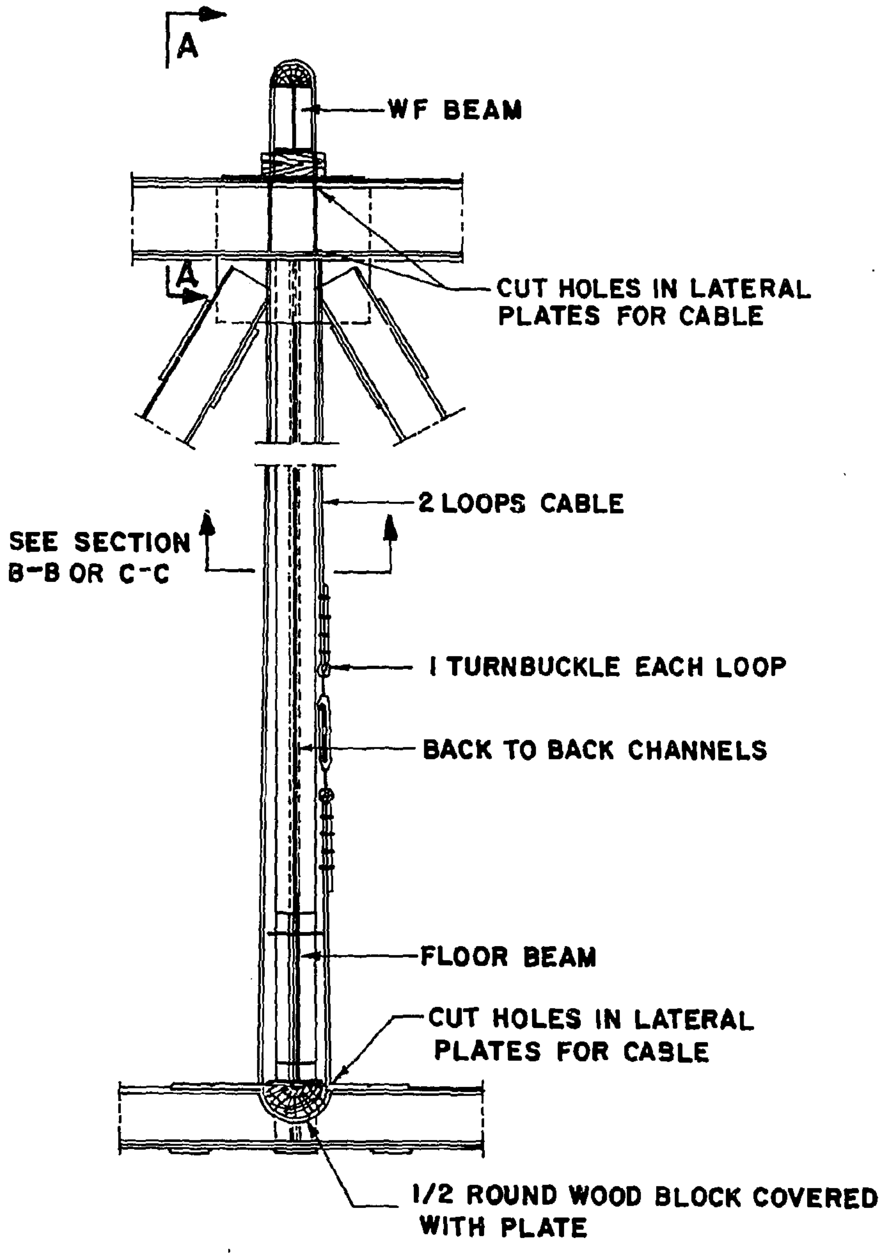


FIG. 28 VERTICAL TENSILE MEMBER REPLACEMENT FOR RIVETED OR BOLTED CONNECTIONS

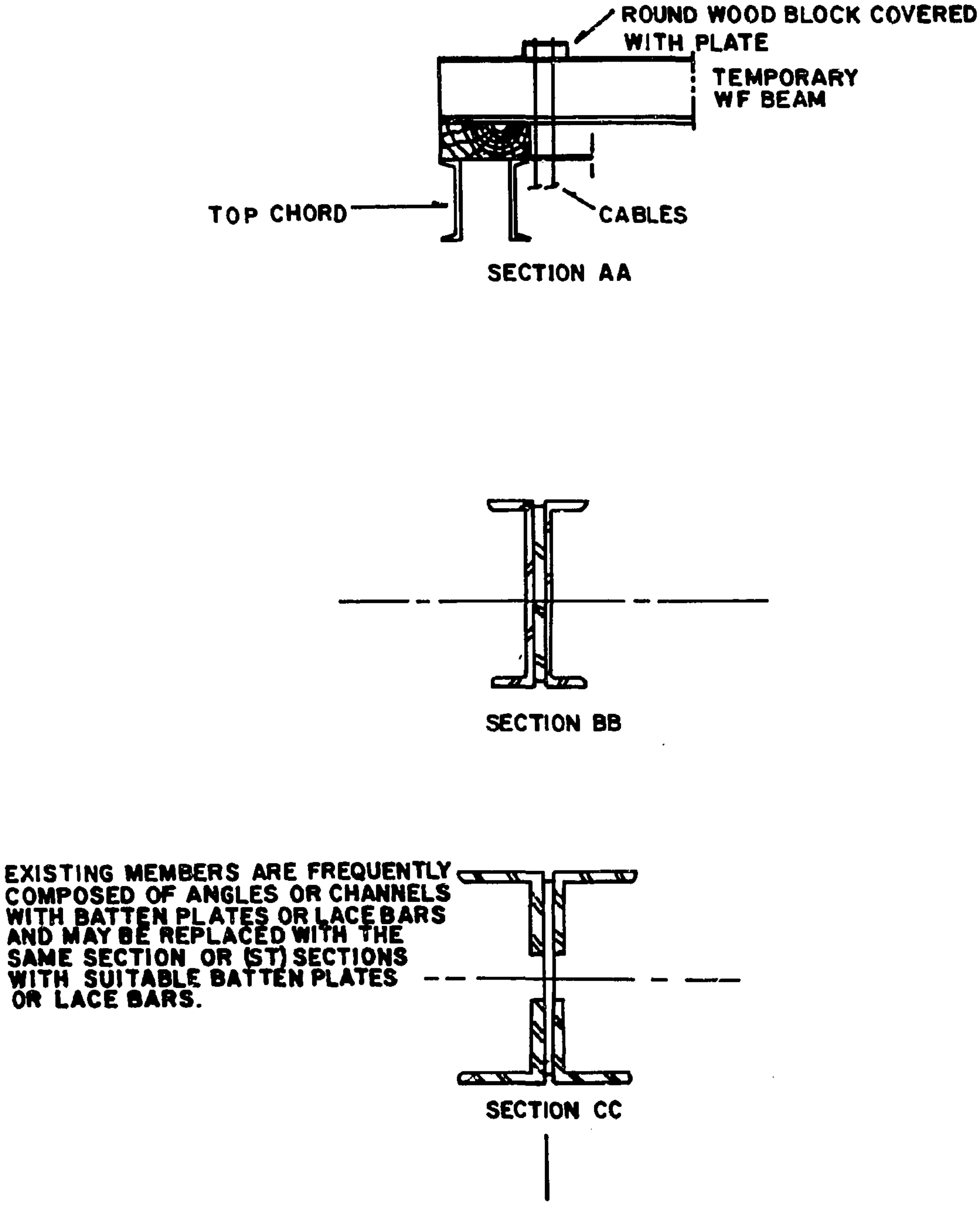


FIG. 29 TYPICAL SECTIONS OF A VERTICAL TENSILE TRUSS MEMBER

REPAIR OF DAMAGED TRUSS MEMBER

DESCRIPTION:

Splice plates are used to repair damage or deterioration in one channel of a two-channel bridge member. Procedure could be used for other built-up members as well.

LIMITATIONS:

The repair technique can be used only on built-up members which have only one of their components damaged.

CONSTRUCTION PROCEDURE:

1. Bolt a side splice plate to the damaged member, as shown in Fig. 30. Remove any rivet heads which would interfere with the splice plate if the repair is near a connection.

2. If necessary, remove old tie plates (or lacing bars) from the two channels in the area of the crack to allow placement of the bottom tie plate. Some temporary lateral bracing may be required prior to completing the repair.

3. Bolt the bottom tie plate to the member as indicated in Fig. 30.

   Note: Splice plates have been successfully attached using weldments but fatigue problems could result from welds where the structure experiences a high traffic volume. A bolted connection for the splice plate is perferable.

RESOURCE REQUIREMENTS:

Torch and/or other cutting tools; power drills; alternatively, welding equipment and a certified welder.

REFERENCE:

Texas State Department of Highways and Public Transportation.

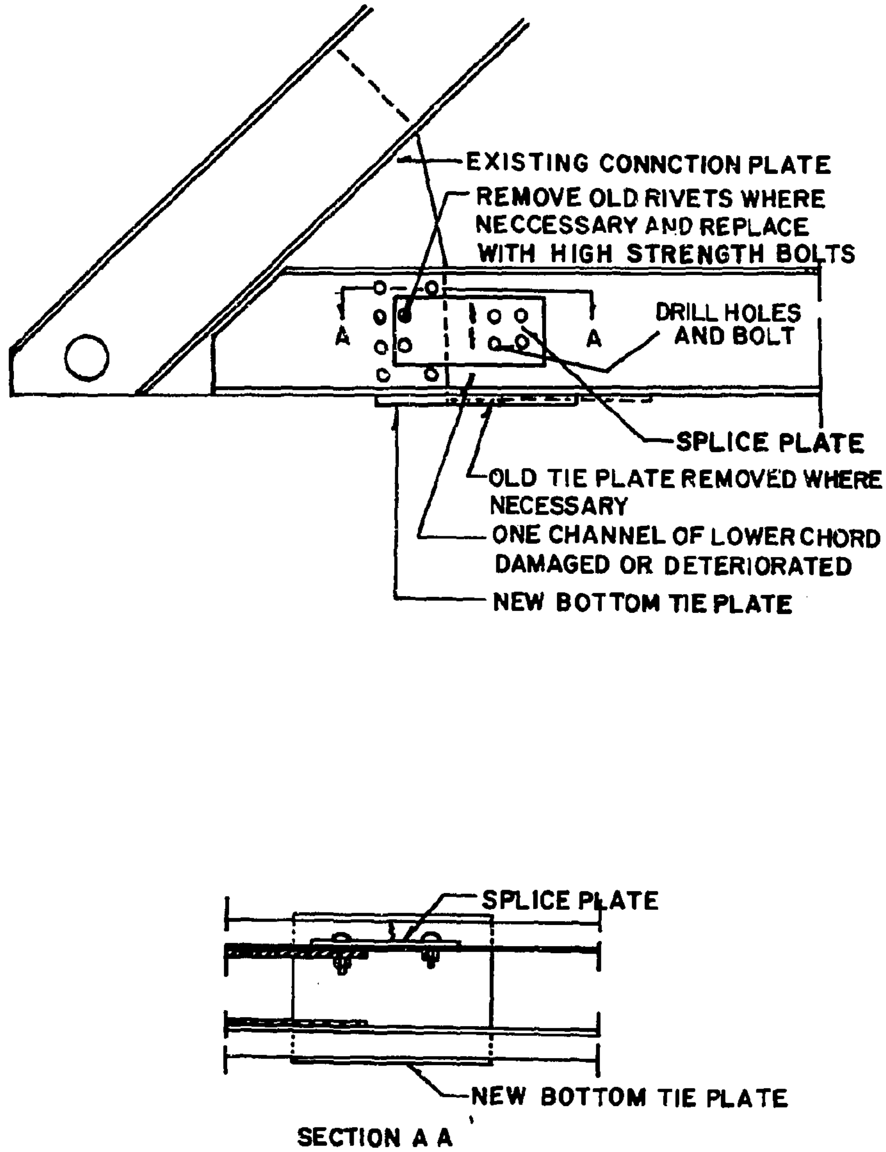


FIG. 30 REPAIR OF TYPICAL TRUSS MEMBER WHERE COMPLETE REMOVAL IS NOT REQUIRED

ADDITION OF BRIDGE RAILS TO THROUGH TRUSS

DESCRIPTION:

Bridge rails are added to existing through truss bridges in such a manner as to (1) prevent collision with truss members, (2) essentially maintain original roadway width, and (3) be independent of main structural elements of truss.

LIMITATIONS:

Bridge and supporting frame are designed for a through truss with a floor system composed of floor beams, stringers, and transverse timber floor planking. This could be adapted for a concrete roadway slab by placing the transverse channels on top of the slab and adding an asphalt or concrete overlay equal to the vertical legs (about 2 in) of the channels. The bridge rails do not meet AASHTO specifications. On very light trusses the added weight of the rails and the supporting frames may be a limitation to their use.

CONSTRUCTION PROCEDURE:

1. Select the bridge rail posts 6 to 12 ft. (224 meters) on center and between the floor beam locations (Fig. 31).

2. Remove deck timbers at the locations of the bridge rail posts and replace them with steel channels (C6x8.2) 1 ft longer than the existing deck width (Fig. 31).

3. If the stringers have wood nailing strips (as shown), attach the channels with lag bolts. If nailing strips are not used, tack weld the channels to the stringers, or use high strength bolts (Fig.31).

4. Attach bridge rail posts to channels with HS bolts through 6 x 6 angle welded to post (Fig. 31).

5. Slide lower transverse member of frame (W6x15.5) into place and attach to posts. A suggested fabrication is indicated in Fig. 31.

6. Fill the space over the channels in the timber deck with asphalt (Fig. 31).

RESOURCE REQUIREMENTS:

Staging and rigging to suit the site. Light lifting equipment is required to lift transverse steel member under roadway.

REFERENCE:

North Carolina Department of Transportation "Upgrading Safety Performance in Retrofitting Traffic Railing System," FHWA Report.

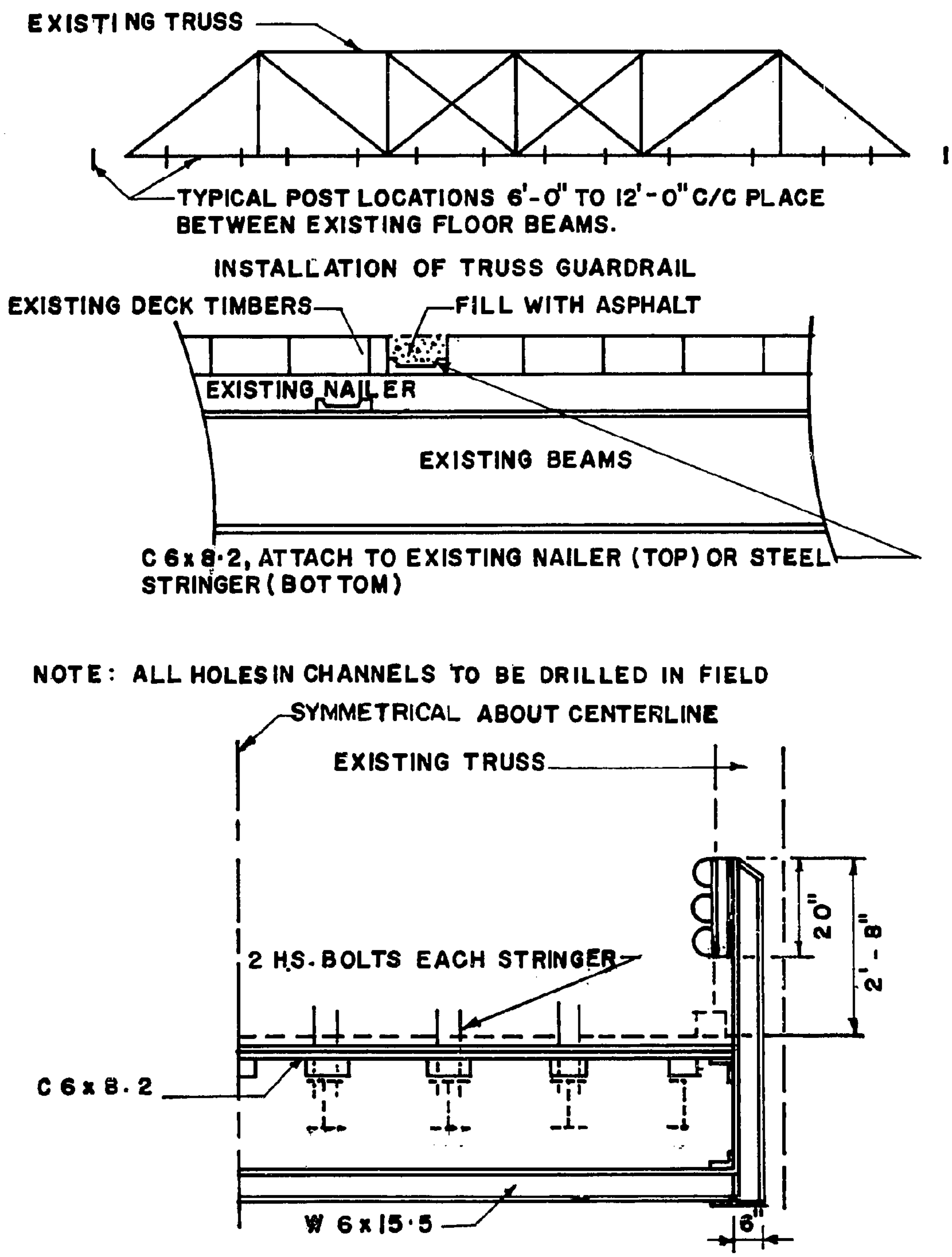


FIG. 31 ADDITION OF BRIDGE RAIL TO THROUGH TRUSS

INCREASING VERTICAL CLEARANCE OF THROUGH TRUSS BRIDGES BY MODIFYING THE PORTAL BRACING

DESCRIPTION:

Clearance on through truss bridges can be increased by rearranging the portal bracing.

LIMITATIONS:

Stresses in all members of the portal bracing should be checked for the new configuration. If existing connections are riveted, bolting is recommended for the new connections, since weldability is uncertain on many old trusses. Traffic should be limited to light loads at low speeds while the portal bracing is being modified.

CONSTRUCTION PROCEDURE:

Technique A. (Fig. 32)

1. Remove all portal bracing and install replacement members, which must be fabricated to fit between and posts.

Technique B (Fig. 32)

1. Remove lower horizontal member and cut diagonals to new length.
2. Replace horizontal member in new position and add new diagonals.

Technique C (Fig. 32)

1. Remove knee braces.

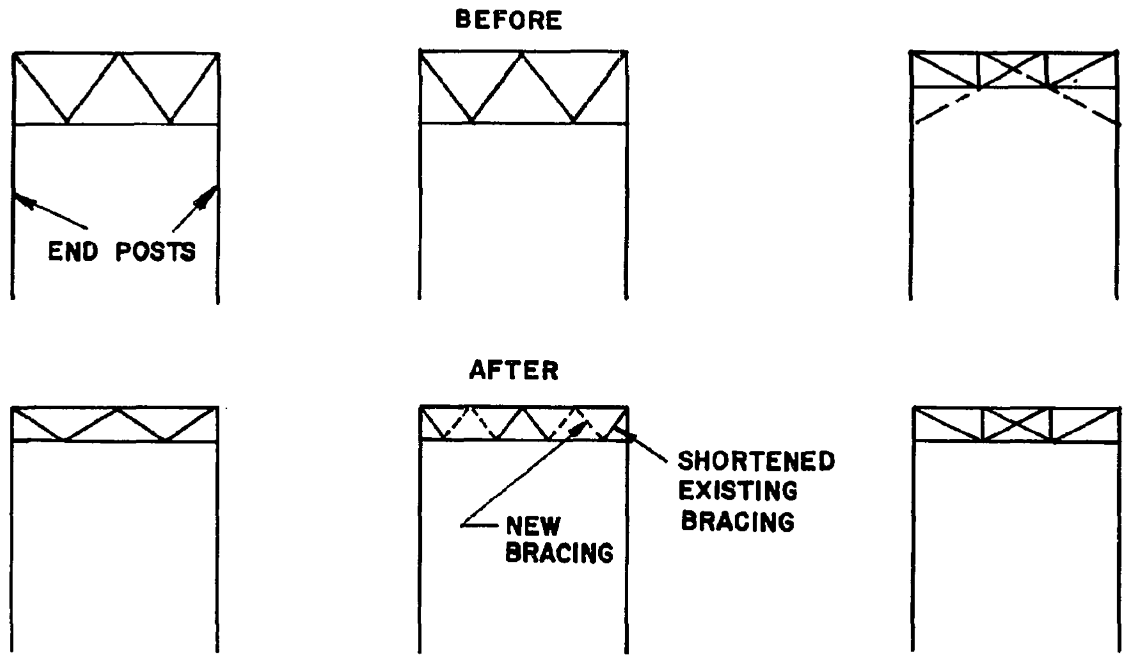
Note: The three procedures briefly described above present portal bracing modifications that have been successfully used. The new arrangements of the structural members will result in different loads in the members from the external lateral forces. The altered designs must be checked by a qualified structural engineer in each case.

RESOURCE REQUIREMENTS:

Metal cutting equipment, light lifting equipment, torque wrenches, and small hand tools.

REFERENCES:

Virginia Highway and Transportation Department
Louisiana Department of Highways
Missouri State Highway Department



(a) REMOVE ANGLE BRACING

(b) CONVERSION OF BRACING IN TO A FRAME

(C) SHORTEN THE DEPTH OF LATERAL BRACING

FIG. 32 EXAMPLES OF PORTAL MODIFICATIONS

APPENDIX B

SPECIFICATIONS FOR REHABILITATION WORK

STRUCTURAL STEEL

PART 1 GENERAL

1.1 DESCRIPTION OF WORK:

A. The extent of structural steel work is shown on the drawings.

B. Structural steel is that work defined in the American Institute of Steel Construction (AISC) "Code of Standard Practice", AASHTO Standard Specifications, and as otherwise shown on the drawings.

1.2 QUALITY ASSURANCE:

A. Codes and Standards:

1. Comply with the provisions of the following except as otherwise indicated:

   a. AISC "Code of Standard Practice for Steel Buildings and Bridges".

   b. AISC "Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings" and including the "Commentary" and Supplements thereto as issued.

   c. AISC "Specifications for Structural Joints Using ASTM A325 or A490 Bolts" approved by the Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation.

   d. American Welding Standard (AWS) D1.1 "Structural Welding Code".

   e. ASTM A6 "General Requirements for Delivery of Rolled Steel Plates, Shapes, Sheet Piling and Bars for Structural Use".

   g. AASHTO Standard Specifications for Highway Bridges.

B. Qualifications for Welding Work:

1. Quality welding processes and welding operators in accordance with AWS D1.1.

C. Source Quality Control:

1. Materials and fabrication procedures are subject to inspection and tests in the mill, shop, and field by the engineer. Such inspections and tests will not relieve the contractor of responsibility for providing materials and fabrication procedures in compliance with specified requirements.

D. Design of Members and Connections:

1. All details shown are typical: similar details apply to similar conditions, unless otherwise indicated. Verify dimensions at the site whenever possible without causing delay in the work.

E. Position all steel members and splice plates so as to place the direction of rolling parallel to the direction of stress. This provision will not apply to gusset plates in trusses, the cutting of which may require other arrangement.

1.3 SUBMITTALS:

A. Manufacturer's Data, Structural Steel:

1. Submit copy of producer's or manufacturer's specifications and installation instructions for the following products. Include laboratory test reports and other data as required to show compliance with these specifications.

a. Structural steel (each type), including certified copies of mill reports covering chemical and physical properties.

b. High-strength bolts (each type), including nuts and washers.

c. Unfinished bolts and nuts.

d. Structural steel primer paint.

e. Shrinkage-resistant grout.

B. Shop Drawings, Structural Steel:

1. Submit shop drawings including complete details and schedules for fabrication and shop assembly of members, and details, schedules, procedures and diagrams showing the sequence of erection.

2. Engineer's review of shop drawings will be for general considerations only. Compliance with requirements for

materials fabrication and erection of structural steel is the contractor's responsibility.

a. Include details of cuts, connections, camber, holes, and other pertinent data. Indicate welds by standard AWS symbols, and show size, length, and type of each weld.

b. Provide setting drawings, templates, and directions for the installation of anchor bolts and other anchorages to be installed by others.

1.4 STORAGE AND HANDLING:

A. Do not store materials on the structure in a manner that might cause destruction or damage to the members or the supporting structures. Repair or replace damaged materials or structures as directed.

PART 2 PRODUCTS

A. Rolled Steel Plates, Shapes and Bars: ASTM A709, Grade 36.

B. Structural Low-Alloy Steel: ASTM A 709 Grade 50 or 50W.

C. Cold-Formed Steel Tubing: ASTM A500, Grade B.

D. Hot-Formed Steel Tubing: ASTM A501.

E. Steel Pipe: ASTM A53, Type B or S, Grade B.

F. Carbon Steel Castings: ASTM A27, Grade 65-35, medium strength carbon steel.

G. Anchor Bolts: ASTM A307, nonheaded type unless otherwise indicated.

H. Masonry Pads under Shoes and Bearing Plates: composed of layers of eight ounce per square yard cotton duck impregnated with a high quality natural rubber compound, containing 64 plies per inch of thickness, with thickness tolerance of plus or minus five percent. Breakdown strength for compression perpendicular to the plant of lamination not less than 11,000 pounds per square inch.

I. Headed Stud Type Shear Connectors: ASTM A108, Grade 1015 or 1020, cold finished carbon steel; with dimensions complying with AISC Specifications.

J. Carbon Steel Bolts and Nuts: ASTM A307, Grade A: Hexagonal heads and nuts for all connections.

K. High-Strength Bolts and Nuts: Heavy hexagonal structural bolts, heavy hexagon nuts, and hardened washers, complying with ASTM A325.

L. Electrodes for Welding: Comply with AWS Code; where finishing is required, complete the assembly, including welding of units, before start of finishing operations.

M. Structural Steel Primer Paint: SSPC - Paint 13.

N. Structural Steel Primer Paint: Fabricator's standard.

O. Structural Steel Primer Paint: Red lead and oil; TT-P-86, Type I.

P. Structural Steel Primer Paint: Red lead-iron oxide, oil alkyd: TT-P-86, Type II.

Q. Structural Steel Primer Paint: Zinc chromate, oil-alkyd: TT-P-57, Type I.

R. Cement Grout Portland Cement (ASTM C150, Type I or Type III) and clean, uniforming graded, natural sand (ASTM C404, Size No. 2). Mix at a ratio of 1-part cement to 3-parts sand, by volume, with only the minimum amount of water required for placement and hydration.

2.1 FABRICATION:

A. Shop Fabrication and Assembly:

1. Fabricate and assemble structural assemblies in the shop to the greatest extent possible. Fabricate items of structural steel in accordance with the governing specifications and as indicated on the final shop drawings. Provide camber in structural members as shown.

2. Properly mark and match-mark materials for field assembly. Fabricate for delivery the sequence which will expedite erection and minimize field handling of materials.

3. When finishing is required, complete the assembly, including welding of units, before start of finishing operations. Provide finished surfaces of members exposed in the final structure, free of markings, burrs, and other defects.

B. Connections:

1. Weld or bolt shop connections, as indicated.

2. Bolt field connections, except where welded connections or other connections are indicated.

   a. Provide high strength threaded fasteners for all principal bolted connections, except where otherwise shown.

3. High-strength bolted construction: Install high strength threaded fasteners in accordance with AISC "Specifications for Structural Joints using ASTM A325 or A490 Bolts".

4. Welded construction: Comply with AWS Code for procedures, appearance and quality of welds, and methods used in correcting welding work.

   a. Assemble and weld built-up sections by methods which will produce true alignment of axes without warp.

5. Shear connectors: Prepare steel surfaces as recommended by the manufacturer of the shear connectors. Shop weld shear connectors, spaced as shown, to beams and girders in composite construction. Use automatic end welding of headed stud shear connectors in accordance with the manufacturer's printed instructions.

C. Holes for Other Work:

1. Provide holes required for securing other work to structural steel framing, and for the passage of other work through steel framing members, as shown on the final shop drawings. Provide threaded nuts welded to framing, and other specialty items as shown to receive other work.

2. Cut, drill, or punch holes perpendicular to metal surfaces. Do not flame cut holes or enlarge holes by burning. Drill holes in bearing plates.

2.2 SHOP PAINTING:

A. General: Shop paint all structural steel work, except those members or portions of members to be embedded in concrete or mortar. Paint embedded steel which is partially exposed on the exposed portions and the initial 2 inches of embedded areas only.

   a. Do not paint surfaces which are to be welded or high-strength bolted with friction-type connections.

   b. Do not paint surfaces, which are scheduled to receive sprayed-on fireproofing.

c. Apply two coats of paint to surfaces which are inaccessible after assembly or erection. Change color of second coat to distinguish it from the first.

B. Surface Preparation: After inspection and before shipping, clean steel work to be painted. Remove loose rust, loose mill scale, and spatter, slag or flux deposits. Clean steel in accordance with the Steel Structure Painting Council as follows:

1. SP-1 "Solvent Cleaning"
2. SP-2 "Hand Tool Cleaning"
3. SP-3 "Power Tool Cleaning"
4. SP-6 "Commercial Blast Cleaning"
5. SP-7 "Brush-off Blast Cleaning"
6. SP-10 "Near-White Blast Cleaning"

C. Painting: Immediately after surface preparation, apply structural steel primer paint in accordance with the manufacturer's instructions at a rate to provide a uniform dry film thickness and at a rate to provide a uniform dry film thickness of 2.0 mils. Use painting methods which will result in full coverage of joints, corners, edges and all exposed surfaces.

PART 3 EXECUTION

3.1 INSPECTION:

A. Examine the areas and conditions under which structural steel work is to be installed. Do not proceed with the work until unsatisfactory conditions have been corrected in an acceptable manner.

3.2 ERECTION:

A. General: Comply with the governing specifications and as herein specified.

B. Employ a Professional Engineer, registered in the jurisdiction where the work is performed, to supervise surveys during erection, as follows:

1. Check elevations of bearing surfaces.

2. Check locations of anchor bolts.

3. Ensure accuracy of erection within specified tolerances.

C. Temporary Shoring and Bracing: Provide temporary shoring and bracing members with connections of sufficient strength to bear imposed loads. Remove temporary members and connections when permanent members are in place and final connections are made.

D. Temporary Planking: Provide temporary planking and working platforms as necessary to effectively complete the work.

E. Anchor Bolts: Furnish anchor bolts and other connectors required for securing structural steel to foundations and other in-place work.

  1. Furnish templates and other devices as necessary for presetting bolts and other anchors to accurate locations.

     a. Refer to Division 3 of these specifications for anchor bolt installation requirements in concrete, and Division 4 for masonry installation.

F. Setting Bases and Bearing Plates: Clean concrete and masonry bearing surfaces of bond-reducing materials and roughen to improve bond to surfaces. Clean the bottom surface of base and bearing plates.

  1. Set loose and attached base plates and bearing plates for structural members on wedges or other adjusting devices.

  2. Tighten the anchor bolts after the supported members have been positioned and plumbed. Do not remove wedges or shims, but if protruding, cut off flush with the edge of the base or bearing plate prior to packing with grout.

  3. Pack grout solidly between bearing surfaces and bases or plates to ensure that no voids remain. Finish exposed surfaces, protect installed materials, and allow to cure in strict compliance with the manufacturer's instructions, or as otherwise required.

G. Touch-Up Painting:

  1. Immediately after erection, clean field welds, bolted connections, and abraded areas of the shop paint. Apply paint to exposed areas using the same material as used for shop painting. Apply by brush or spray to provide a minimum dry film thickness of 2.0 mils.

3.3 FIELD QUALITY CONTROL:

A. Provide access for the engineer to places where structural steel work is being fabricated or produced.

B. The engineer reserves the right, at any time before final acceptance, to reject material not complying with specified requirements.

C. Correct deficiencies in structural steel work which inspections and laboratory test reports have indicated not to be in compliance with requirements. Perform additional tests as may be necessary to reconfirm any non-compliance of the original work, and as may be necessary to show compliance of corrected work.

PART 4 MEASUREMENT AND PAYMENT

4.1 MEASUREMENT:

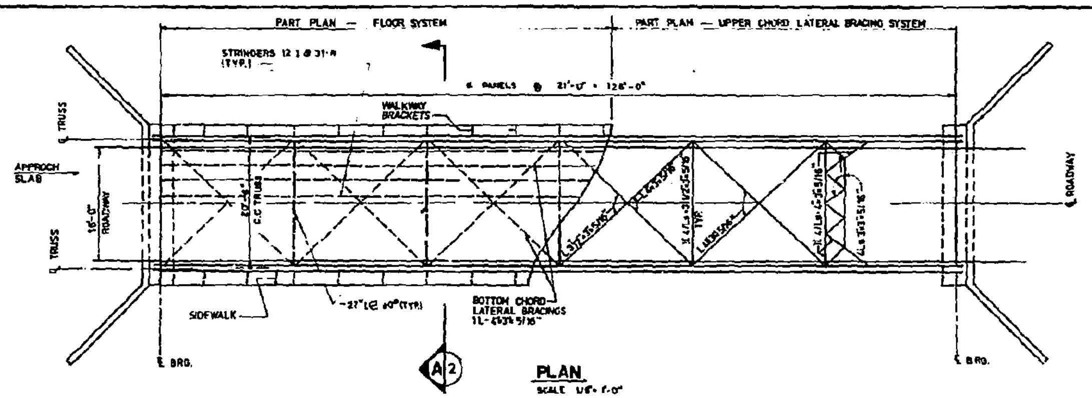
A. Only structural steel incorporated in the completed work will be measured for payment under this section. Galvanized items and shear connections will be measured separately from other structural steel.

B. Structural steel will be measured by the pound, calculated without deduction for holes under the longest dimension of 12 inches for each item, type, and grade of structural steel complete in place. For galvanized structural steel, the weight of the zinc coating will be included in the calculated weight.

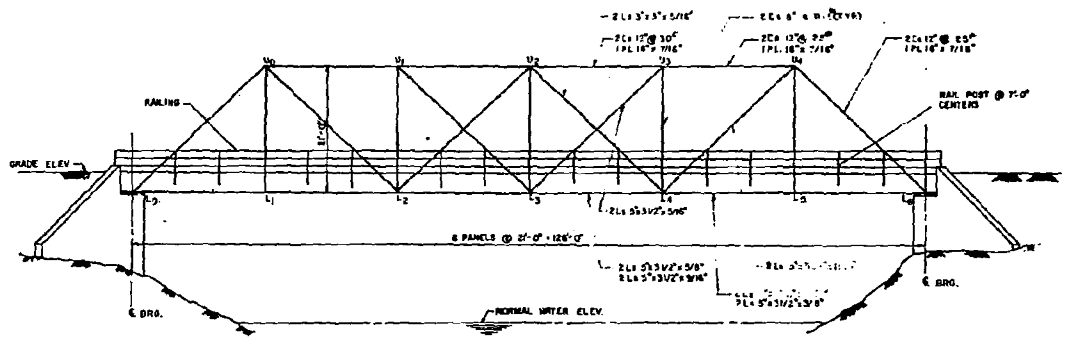
C. Shims, wedges, fasteners, metallic coating, plastomeric bearing pads, and setting bearing plates, including dry-packing, will not be separately measured for payment, but all costs in connection therewith will be considered incidental to the applicable items of structural steelwork.

4.2 PAYMENT:

A. Payment for structural steel will be made at the contract unit prices for the quantities as determined above.



PLAN
SCALE 1/8" = 1'-0"



ELEVATION
SCALE 1/8" = 1'-0"

NOTES

THE MULLENS BRIDGE ORIGINALLY CONSTRUCTED IN 1924, IN ACCORDANCE WITH STATE ROAD COMMISSION OF WEST VIRGINIA SPECIFICATION ADOPTED OCTOBER 1923. THE STRUCTURE CONSISTS OF 126'-0" SIMPLE SPAN RIVETED STEEL THROUGH TRUSS BRIDGE SUPPORTED AT BOTH END BY SKEWED CONCRETE ABUTMENT. FOR SIMPLICITY ON THIS DRAWING ABUTMENTS SHOWN ARE WITHOUT SKEW ANGLE. THE STRUCTURE HAS A 16'-0" WIDTH OF ROADWAY WITH 2, 5'-0" SIDEWALKS.

DESIGN LOADS:

- DEAD LOAD - 1755 LBS/FT. OF TRUSS
  THIS DEAD LOAD INCLUDES WEIGHT OF FUTURE WEARING SURFACE OF 25 LBS./SQ. FT. OF ROADWAY.

  SIDEWALK LIVE LOAD - 100 LBS/SQ. FT. WITH NO IMPACT.

- LIVE LOAD FOR TRUSSES - 85 LBS./SQ. FT. OF ROADWAY OR 2-15 TONS GROSS WEIGHT TRUCKS AND 63 LBS./SQ. FT. OF SIDEWALK. IMPACT FOR TRUSSES WAS USED, 15% ON ROADWAY AND 30% ON SIDEWALKS.

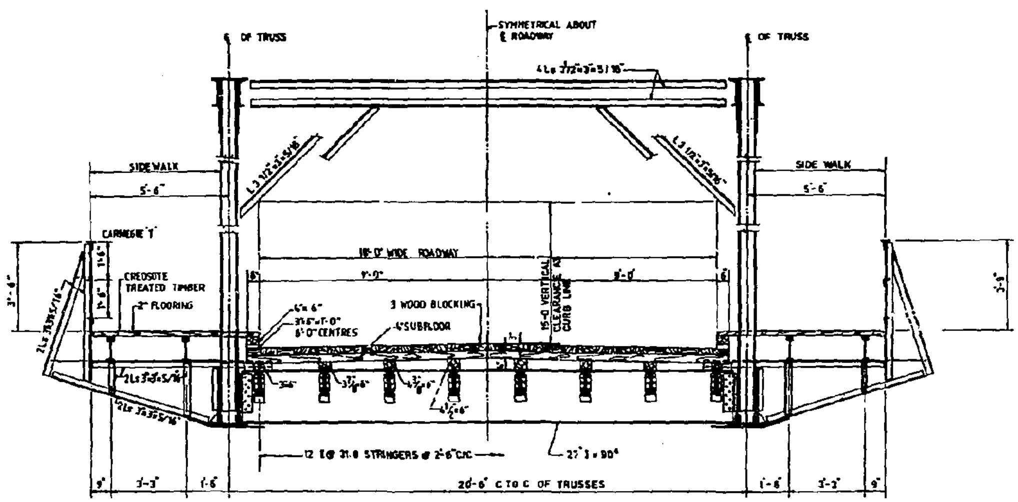
DESIGN UNIT STRESSES:

- STRUCTURAL STEEL OF 1924, F_y = 30,000 PSI, F_s = 18,000 PSI.

- FOR SECTION 'A' SEE DRAWING NO 2

PRATT TRUSS
EXISTING MULLENS BRIDGE
WEST VIRGINIA
SHEET 1 OF 2

U.S. DEPT. OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION RESEARCH PROJECT No DTFH 61-80-00096 METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES	
PREPARED BY: SHELADIA Associates, Inc. Consulting Engineers	DATE-
	DWG. NO. 1 OF 13



SECTION (A/1)
SCALE=1/2"=1'-0"

NOTE :-
THIS DRAWING IS TO BE READ IN CONJUNCTION WITH DRAWING NO. 1

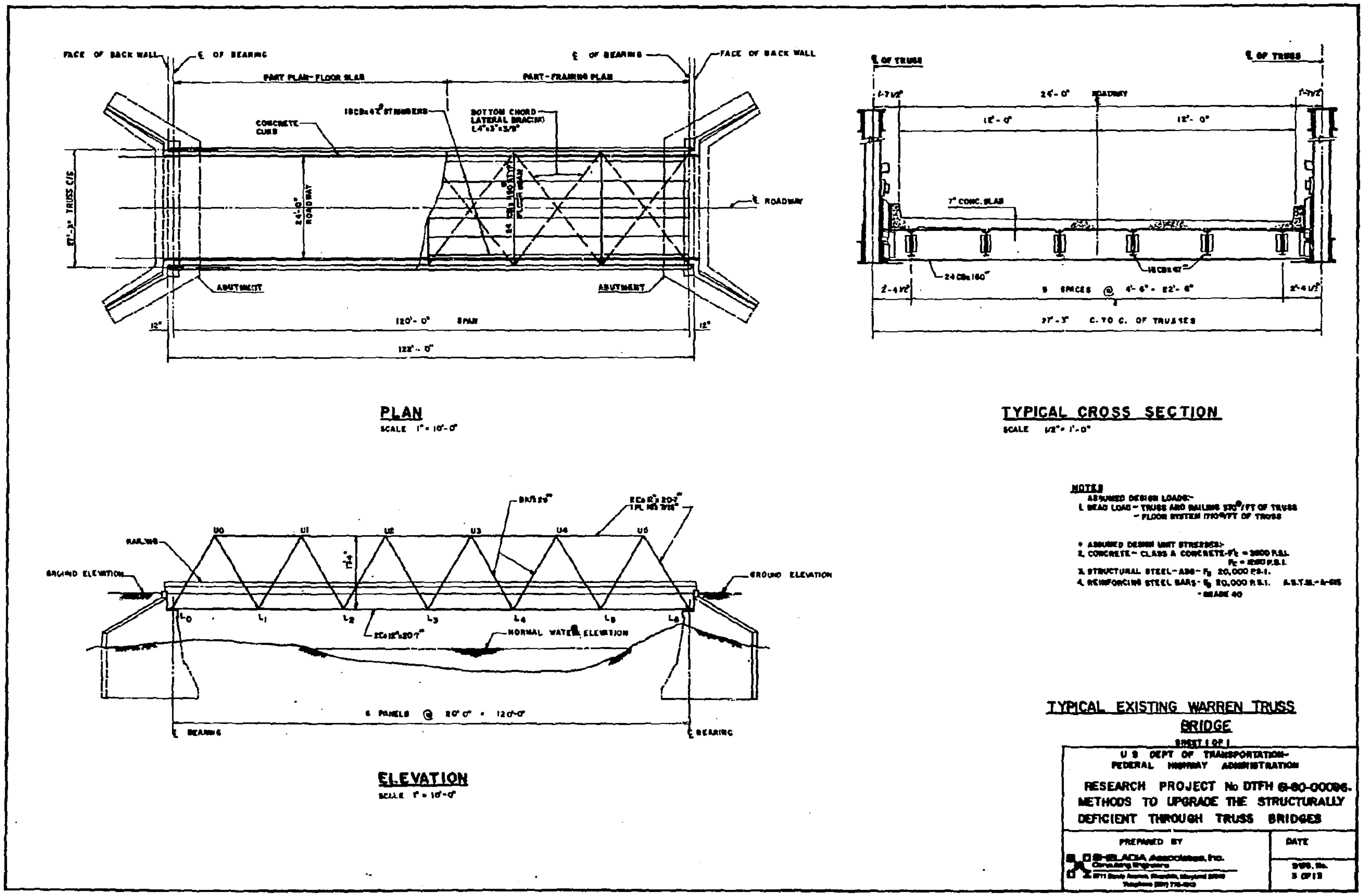
PRATT TRUSS
EXISTING MULLENS BRIDGE
WEST VIRGINIA
SHEET 2 OF 2

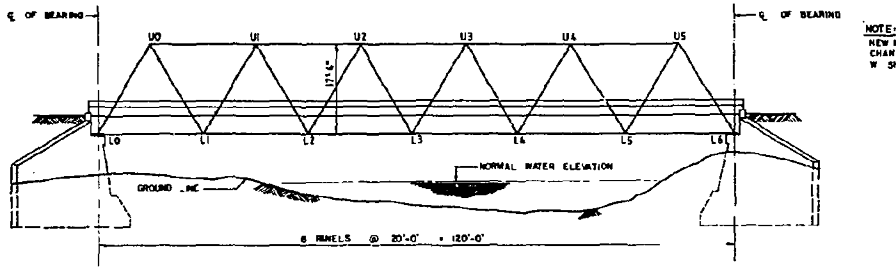
U S DEPT OF TRANSPORTATION-
FEDERAL HIGHWAY ADMINISTRATION

RESEARCH PROJECT No DTFH 61-80-00096
METHODS TO UPGRADE THE STRUCTURALLY
DEFICIENT THROUGH TRUSS BRIDGES

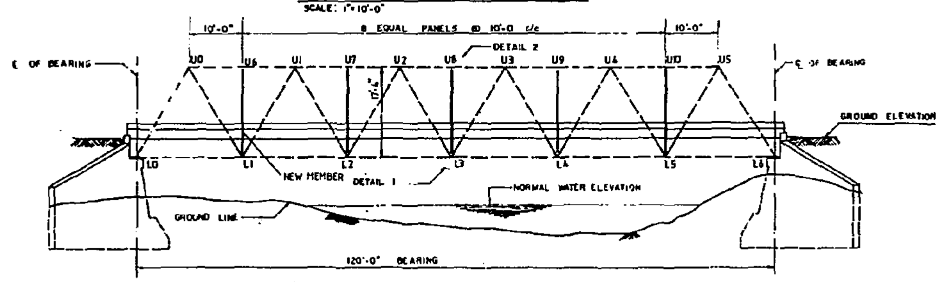
PREPARED BY
SHEALADA Associates, Inc.
Consulting Engineers

DATE
DWG. No
2 OF 13

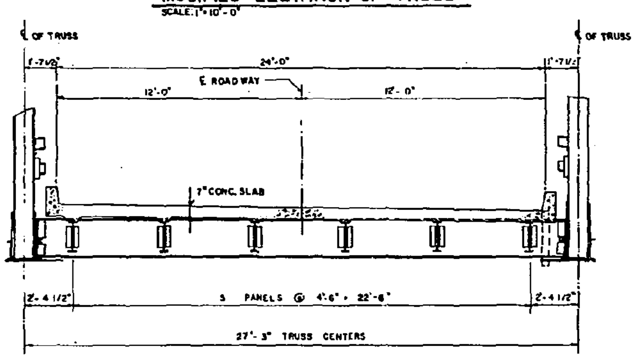

FACE OF BACK WALL
PART PLAN-FLOOR SLAB
PART-FRAMING PLAN
CONCRETE CURB
BOTTOM CHORD LATERAL BRACING
ROADWAY
ABUTMENT
120'-0" SPAN
PLAN
SCALE 1" = 10'-0"
OF TRUSS
24'-0" ROADWAY
12'-0"
7" CONC. SLAB
C. TO C. OF TRUSSES
TYPICAL CROSS SECTION
SCALE 1/2" = 1'-0"
RAILING
GROUND ELEVATION
U0
U1
U2
U3
U4
U5
NORMAL WATER ELEVATION
6 PANELS @ 20'-0" = 120'-0"
BEARING
ELEVATION
SCALE 1" = 10'-0"
NOTES
ASSUMED DESIGN LOADS:-
ASSUMED DESIGN UNIT STRESSES:-
2. CONCRETE - CLASS A CONCRETE
3. STRUCTURAL STEEL
4. REINFORCING STEEL BARS
TYPICAL EXISTING WARREN TRUSS BRIDGE
SHEET 1 OF 1
U S DEPT OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION
RESEARCH PROJECT No DTFH 61-80-00096.
METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES
PREPARED BY
DATE



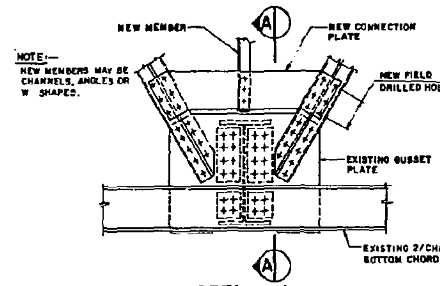
ELEVATION OF EXISTING TRUSS
SCALE: 1"= 10'-0"



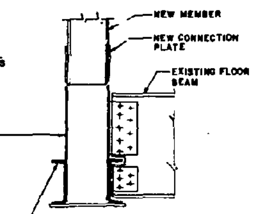
MODIFIED ELEVATION OF TRUSS
SCALE: 1"= 10'-0"



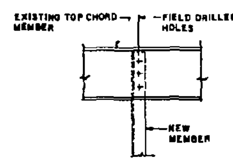
TYPICAL EXISTING CROSS SECTION
N.T.S.



DETAIL 1
SCALE: 1"= 1'-0"



SECTION A-A
SCALE: 1"= 1'-0"



DETAIL 2
SCALE: 1"= 1'-0"

GENERAL NOTES

1. SPECIFICATIONS:

THE SPECIFICATIONS FOR THE REHABILITATION SHALL CONFORM TO THE RELEVANT STATE DEPARTMENT OF HIGHWAYS AND BRIDGES STANDARD SPECIFICATIONS.

"AASHTO STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES", DATED 1977, TWELFTH EDITION INCLUDING "INTERIM SPECIFICATIONS FOR BRIDGES", DATED 1978, 1979 AND 1980 FOR DESIGN.

ANSI D 6.1-1978 MANUAL ON UNIFORM TRAFFIC CONTROL DEVICE FOR STREETS AND HIGHWAYS.

"AWS STRUCTURAL WELDING CODE", DATED 1980, WITH REVISIONS AND MODIFICATIONS OF LATEST "AASHTO STANDARD SPECIFICATIONS FOR WELDING OF STRUCTURAL STEEL HIGHWAY BRIDGES".

2. LOADING:

PROPOSED-HS20-44, WITH PROVISION FOR 2 INCH WEARING SURFACE.

3. STRUCTURAL STEEL:

STRUCTURAL STEEL SHALL CONFORM TO ASTM A-36 EXCEPT FOR STEEL GRID DECKING AND ARMOURED JOINT ASSEMBLIES WHICH SHALL CONFORM TO ASTM A-588. ALL BOLTED CONNECTIONS SHALL BE 7/8" ∅ H.S. BOLTS UNLESS OTHERWISE NOTED.

STEEL GRID DECKING SHALL CONFORM TO THE REQUIREMENTS OF THE CURRENT "AASHTO STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES". PRIOR TO FABRICATION, THE CONTRACTOR SHALL SUBMIT COMPLETE SHOP AND ASSEMBLY DETAILS TO THE ENGINEER FOR APPROVAL.

4. CONCRETE:

CONCRETE FILL FOR GRID DECKING SHALL BE CLASS C (AE). ALL OTHER CONCRETE SHALL BE CLASS A (AE). MINIMUM COMPRESSIVE STRENGTH f'_c = 4,000 PSI.

5. REINFORCING STEEL:

REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A-615, GRADE 40. OR 60

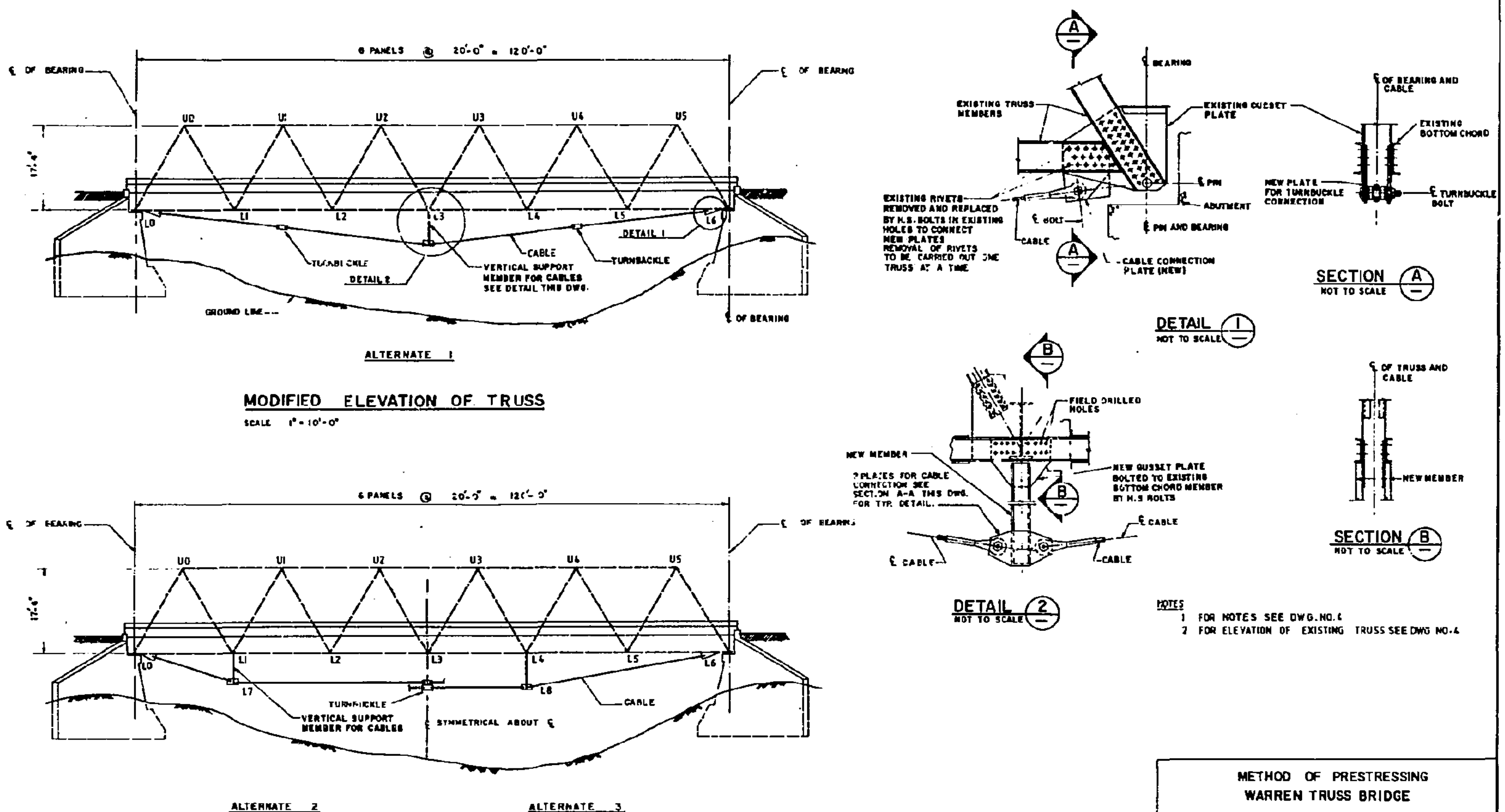
6 EXISTING CONDITIONS:

CONTRACTOR SHALL BE RESPONSIBLE TO VERIFY ALL DIMENSIONS, SIZES, LOCATIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING MATERIALS.

NOTES:—

1. ADDITIONAL LATERAL BRACING MAY BE PROVIDED AT TOP CHORDS NEW CONNECTION IF NECESSARY.
2. FOR CONSTRUCTION PROCEDURE AND LIMITATIONS REFER TO CHAPTER 3 IN THE REPORT.
3. FOR ALTERNATE FLOOR SYSTEM, REFER TO DRAWING NO. 13

LOAD REDUCTION OF COMPRESSION MEMBER WARREN TRUSS BRIDGE DETAILS	
U.S DEPT OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION	
RESEARCH PROJECT No DTFH 61-80-00096 METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES	
PREPARED BY	DATE
SHELADIA Associates, Inc. Consulting Engineers	DWG. No. 4 OF 13



NOTES
1 FOR NOTES SEE DWG. NO. 4
2 FOR ELEVATION OF EXISTING TRUSS SEE DWG NO. 4

ALTERNATE 2 ALTERNATE 3

MODIFIED ELEVATION OF TRUSS
SCALE 1" = 10'-0"

METHOD OF PRESTRESSING
WARREN TRUSS BRIDGE

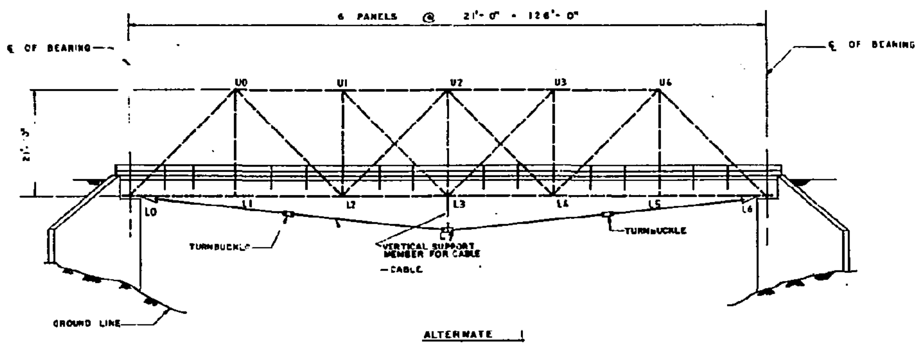
U S DEPT OF TRANSPORTATION-
FEDERAL HIGHWAY ADMINISTRATION

RESEARCH PROJECT No DTFH 61-80-00096
METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES

PREPARED BY
SHELADIA Associates, Inc.
Consulting Engineers

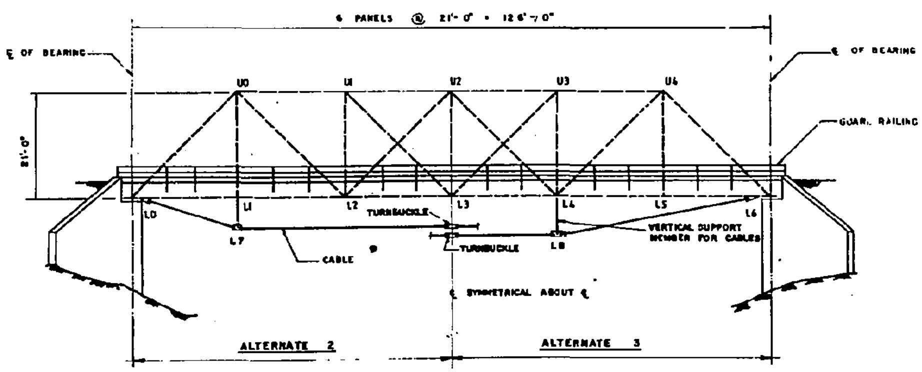
DATE

DWG No
5 OF 13



MODIFIED ELEVATION OF TRUSS

SCALE 1" = 10'-0"



MODIFIED ELEVATION OF TRUSS

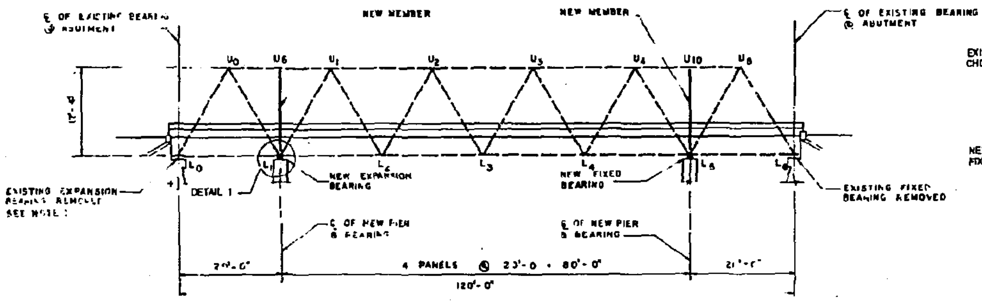
SCALE 1" = 10'-0"

NOTES

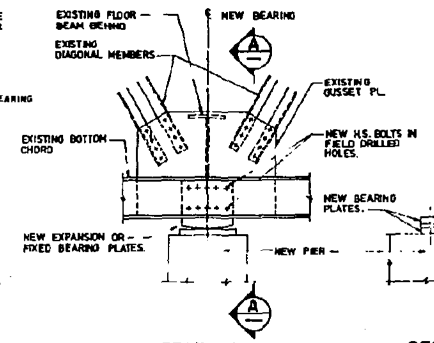
1. FOR NOTES SEE DWG. NO. 4.
2. FOR ELEVATION OF EXISTING TRUSS SEE DWG. NO. 1
3. FOR END CONNECTION OF CABLE SEE SIMILAR DETAIL ON DWG No 5. DETAIL MAY VARY DUE TO VARIATION IN TRUSS MEMBER SIZES.
4. FOR VERTICAL SUPPORT MEMBER SEE DWG. NO. 5. THE DETAIL MAY VARY DUE TO VARIATION IN TRUSS MEMBER SIZES.

METHOD OF PRESTRESSING PRATT TRUSS BRIDGE	
U.S. DEPT. OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION RESEARCH PROJECT No DTFH 61-80-00096 METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES.	
PREPARED BY SHELADIA Associates, Inc. Consulting Engineers	DATE
	DWG. No. 6 OF 13

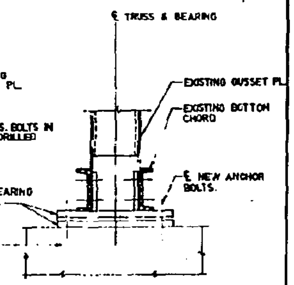
NOTE :-
NEW MEMBERS MAY BE CHANNELS, ANGLES OR W SHAPES.



MODIFIED ELEVATION OF EXISTING WARREN TRUSS



DETAIL 1
N.T.S.

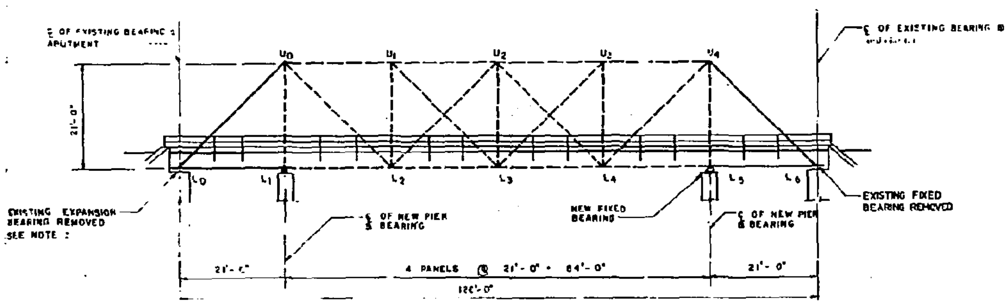


SECTION A
N.T.S.

NOTE :-
FIXED END BEARING DETAIL MAY BE SIMILAR AS SHOWN ABOVE BUT WITH FIXED BEARING SHOES.

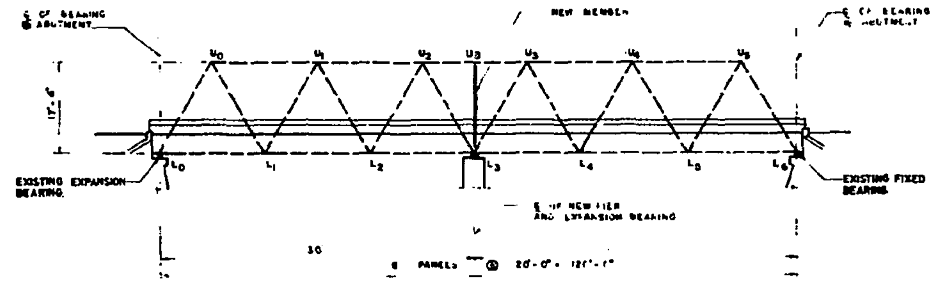
NOTES :-

1. FOR NOTES SEE DWG. NO. 4
2. FOR ELEVATION OF EXISTING TRUSSES SEE DWG. NO. 1 & 3.
3. FOR DETAILS OF NEW MEMBERS U6-L1 AND U10-L5 SEE DWG. NO. 4
4. THIS METHOD OF REHABILITATION MAY NEED STRENGTHENING OF SOME EXISTING MEMBERS.
5. ENLARGED DETAILS SHOWN MAY VARY DUE TO VARIATION IN MEMBER SIZES.
6. NEW PIER & FOUNDATIONS ARE NOT SHOWN FOR CLARITY.
7. BEARING SHOWN SHOULD BE DESIGN ACCORDING TO FINAL LOADS AND TYPE OF TRUSS.



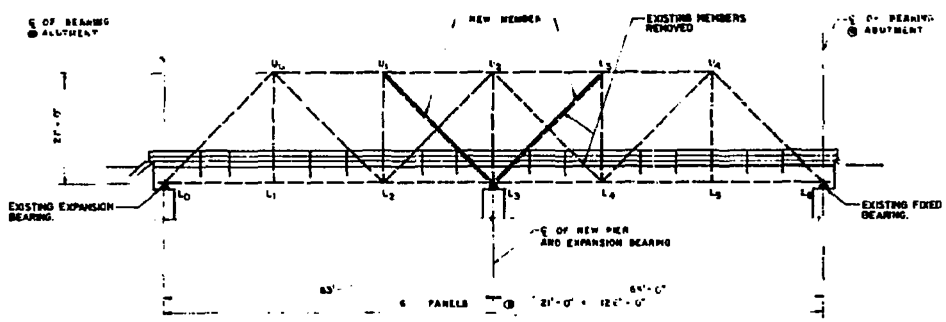
MODIFIED ELEVATION OF EXISTING PRATT TRUSS
SCALE 1" = 10'-0"

SHIFTING OF SUPPORTS WARREN AND PRATT TRUSS BRIDGES	
U S DEPT OF TRANSPORTATION- FEDERAL HIGHWAY ADMINISTRATION RESEARCH PROJECT No DTFH 61-80-00096 METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES	
PREPARED BY DSHELADIA Associates, Inc. Consulting Engineers	DATE
	DWG. No. 7 OF 13



MODIFIED ELEVATION OF EXISTING WARREN TRUSS

SCALE 1" = 10'-0"



MODIFIED ELEVATION OF EXISTING PRATT TRUSS

SCALE 1" = 10'-0"

NOTES :-

1. FOR NOTES SEE DWG. NO. 4.
2. FOR ELEVATION OF EXISTING TRUSSES SEE DWG. 1 AND 3.
3. THIS METHOD OF REHABILITATION MAY NEED STRENGTHENING OF SOME EXISTING MEMBERS.
4. NEW PIER & FOUNDATION ARE NOT SHOWN
5. FOR ENLARGED DETAIL OF BEARINGS SEE DWG. NO. 7
6. FOR DETAILS OF NEW MEMBER U3-L3 SEE DWG. NO. 6.

ADDITION OF CENTRAL SUPPORT
WARREN AND PRATT TRUSS BRIDGES

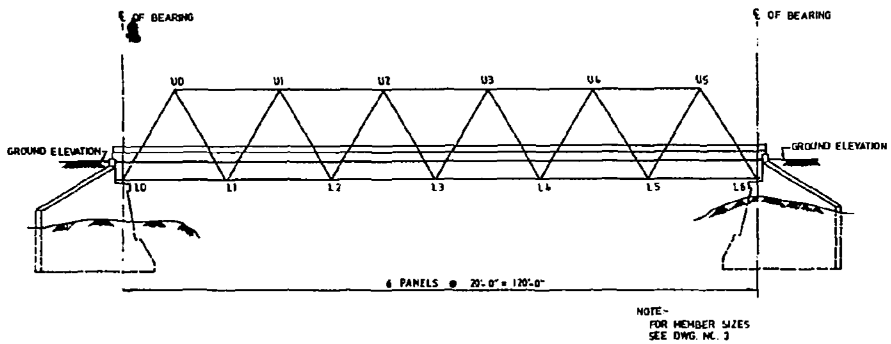
U S DEPT OF TRANSPORTATION-
FEDERAL HIGHWAY ADMINISTRATION

RESEARCH PROJECT No DTFH 61-80-00096
METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES

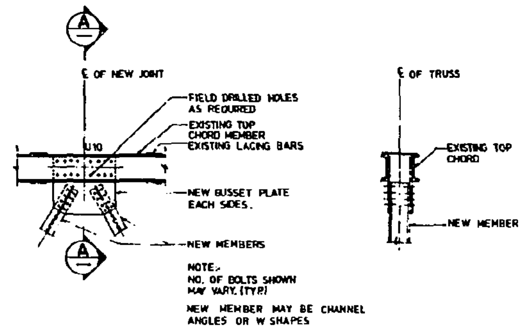
PREPARED BY
SHELADIA Associates, Inc.
Consulting Engineers

DATE

DWG NO
8 OF 13

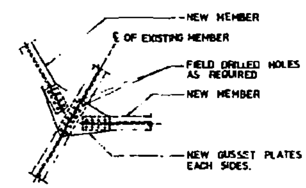


ELEVATION OF EXISTING TRUSS
SCALE 1" = 10'-0"



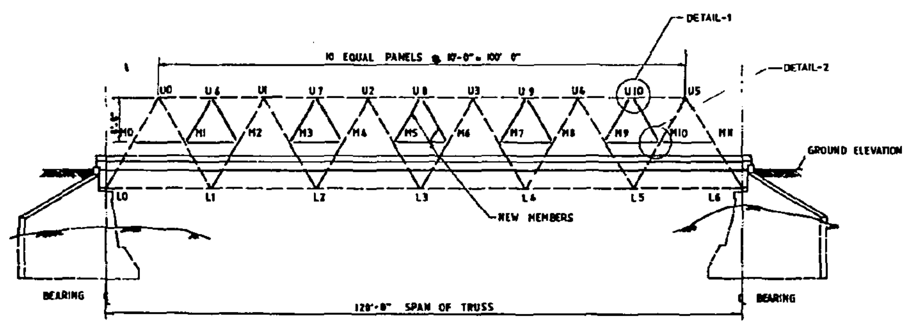
DETAIL - I
N.T.S.

SECTION (A)
N.T.S.



DETAIL - 2
N.T.S.

NOTES
1. FOR NOTES SEE DWG. NO. 4



MODIFIED ELEVATION OF TRUSS
SCALE 1" = 10'-0"

METHOD OF SUBDIVISION
WARREN TRUSS BRIDGE

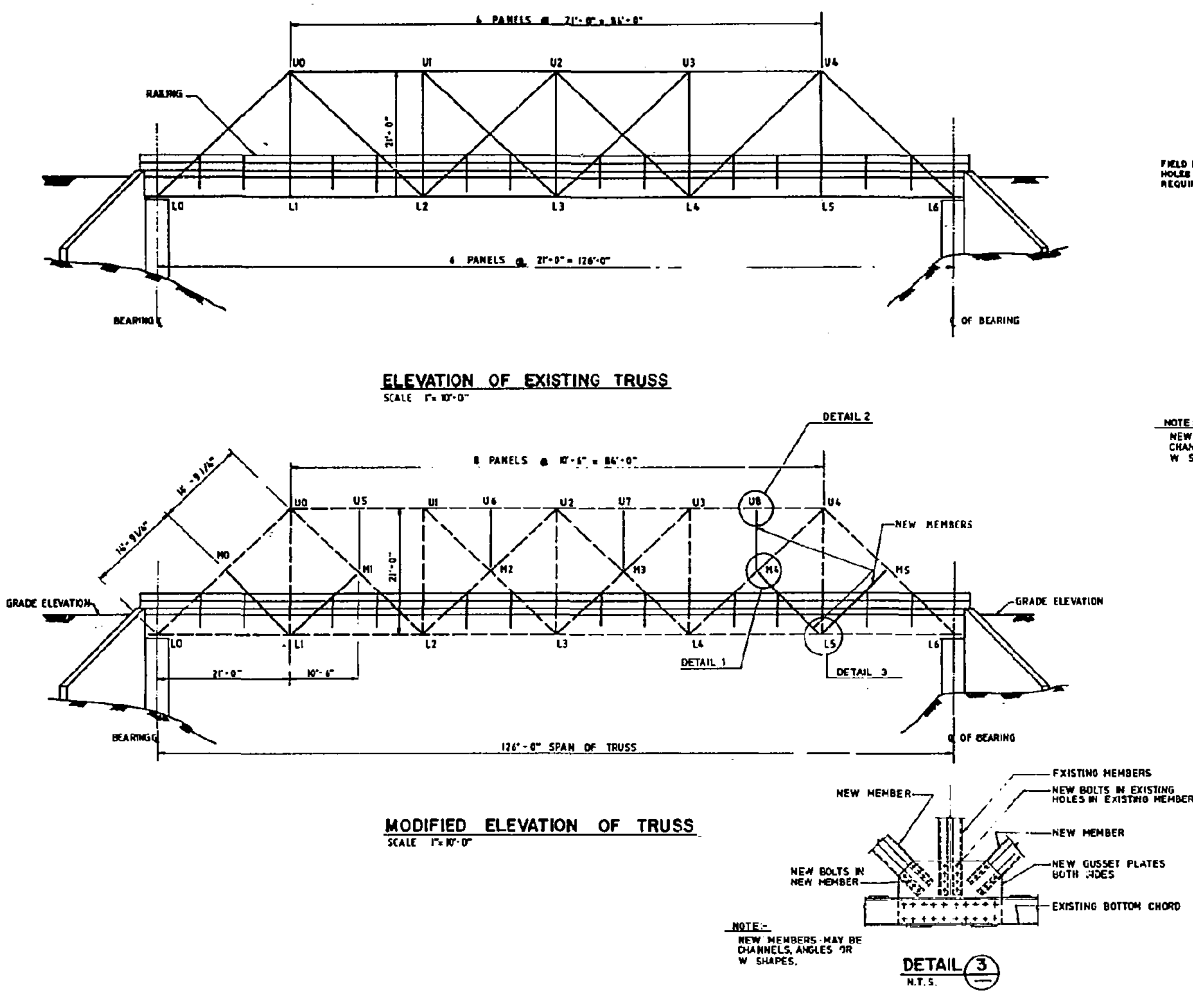
U S DEPT OF TRANSPORTATION-
FEDERAL HIGHWAY ADMINISTRATION

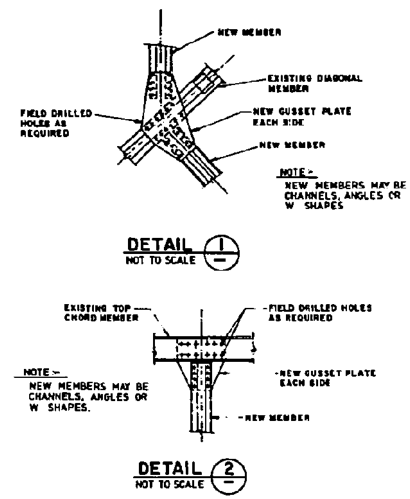
RESEARCH PROJECT No DTFH 61-80-00096
METHODS TO UPGRADE THE STRUCTURALLY
DEFICIENT THROUGH TRUSS BRIDGES

PREPARED BY
SHELADIA Associates, Inc.
Consulting Engineers

DATE

DWG No
9 OF 13





NOTES

1. FOR NOTES SEE DWG. NO.6
2. FO' ELEVATION OF EXISTING TRUSS SEE DWG. NO.1
3. THIS METHOD OF REHABILITATION MAY NEED STRENGTHENING OF SOME EXISTING MEMBERS.

METHOD OF SUBDIVISION
PRATT TRUSS BRIDGE

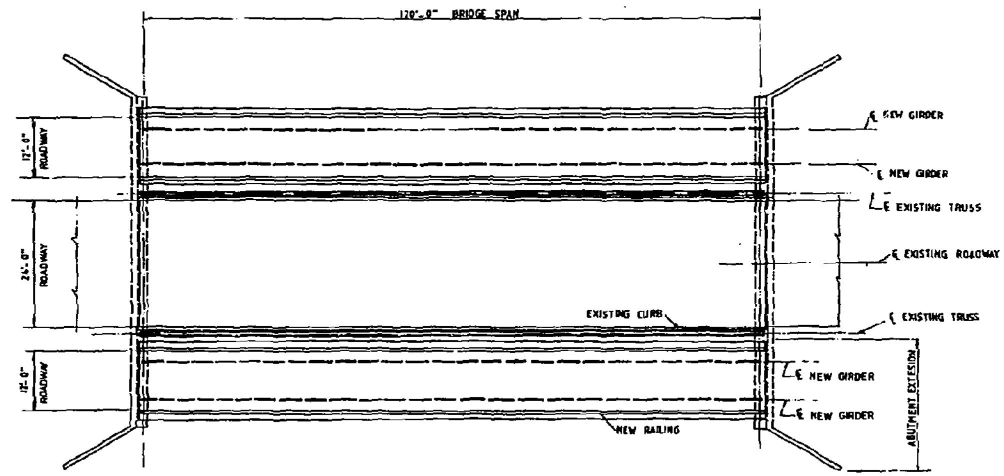
U S DEPT OF TRANSPORTATION–
FEDERAL HIGHWAY ADMINISTRATION

RESEARCH PROJECT NO. DTFH 61-8C-00096
METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES

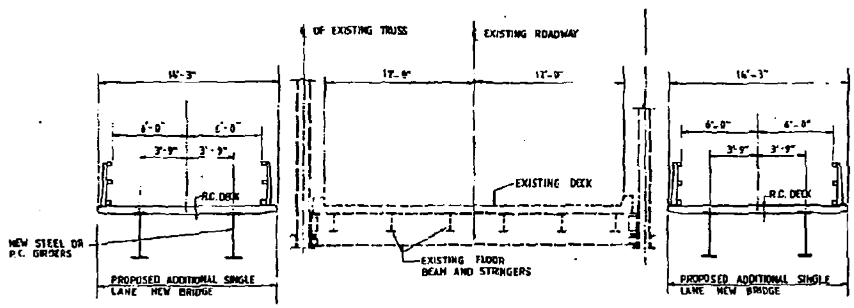
PREPARED BY
SHELADIA Associates, Inc.
Consulting Engineers
5711 Sarvis Avenue, Riverdale, Maryland 20840
Telephone (301) 779-4313

DATE

DWG No
10 OF 13



PLAN
SCALE 1"=10'-0"



TYPICAL CROSS SECTION
SCALE 1/4"=1'-0"

NOTES
1. FOR GENERAL NOTES SEE DWG. No. 4
2. SCHEME SHOWN IS APPLICABLE TO ANY TYPE BRIDGE.

ADDITIONAL LANES FOR HEAVIER LOADING DETAILS

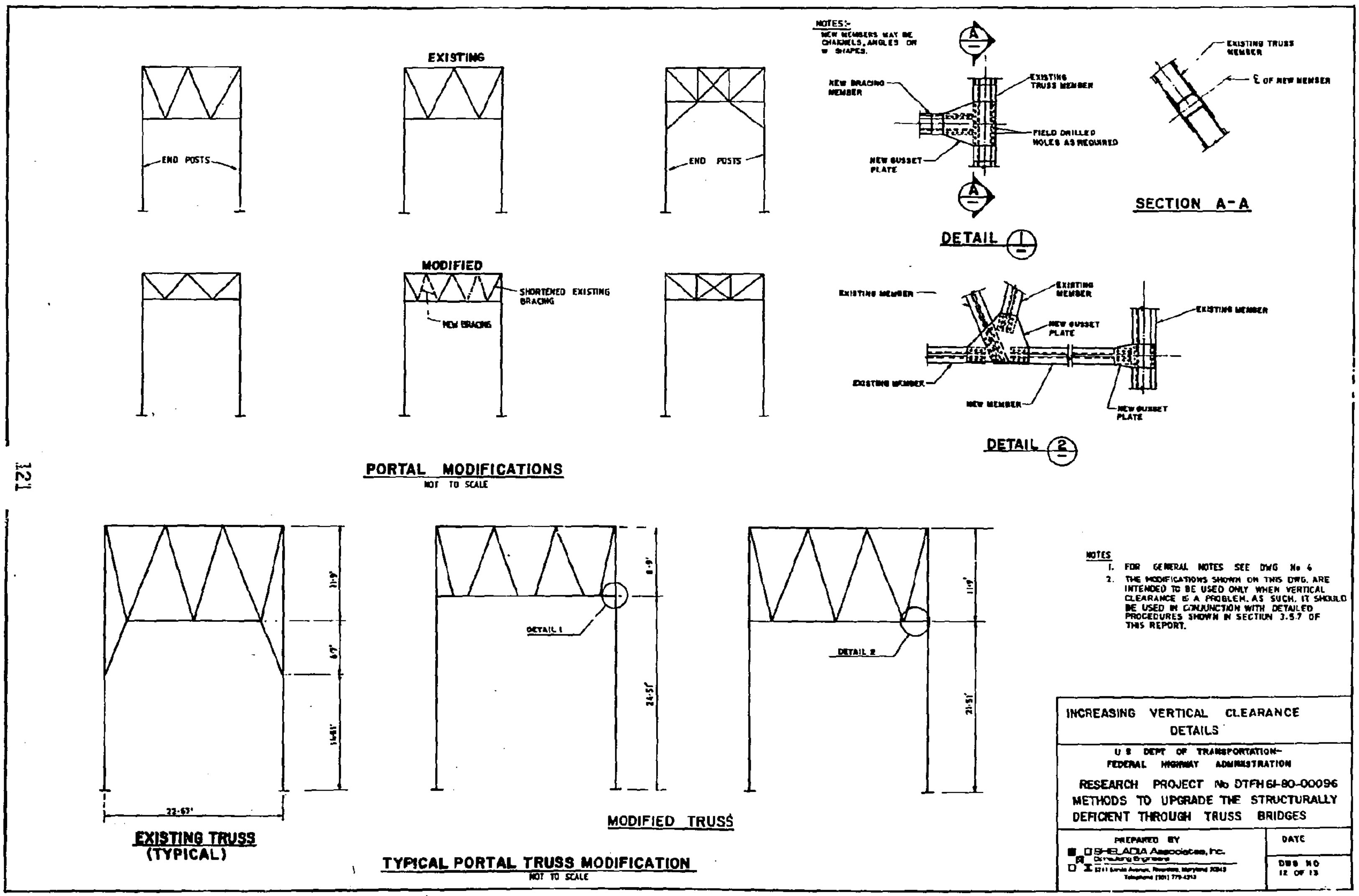
U S DEPT OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION

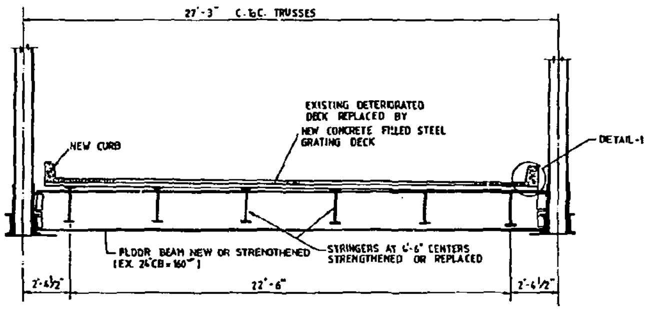
RESEARCH PROJECT No DTFH 61-80-C0096
METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES

PREPARED BY
SHELADIA Associates, Inc.
Consulting Engineers

DATE

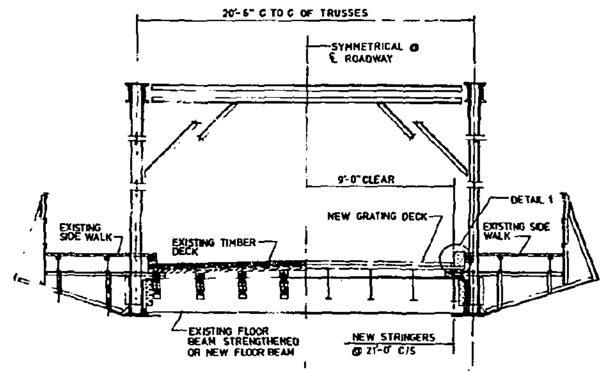
DWG NO
11 OF 13


EXISTING
END POSTS
END POSTS
MODIFIED
SHORTENED EXISTING BRACING
NEW BRACING
PORTAL MODIFICATIONS
NOT TO SCALE
NOTES:-
NEW MEMBERS MAY BE CHANNELS, ANGLES OR W SHAPES.
A
NEW BRACING MEMBER
EXISTING TRUSS MEMBER
FIELD DRILLED HOLES AS REQUIRED
NEW GUSSET PLATE
DETAIL 1
EXISTING TRUSS MEMBER
℄ OF NEW MEMBER
SECTION A-A
EXISTING MEMBER
EXISTING MEMBER
NEW GUSSET PLATE
EXISTING MEMBER
EXISTING MEMBER
NEW MEMBER
NEW GUSSET PLATE
DETAIL 2
11'-9"
6'-0"
14'-6"
22'-6"
EXISTING TRUSS (TYPICAL)
8'-9"
24'-5"
DETAIL 1
11'-9"
21'-5"
DETAIL 2
MODIFIED TRUSS
TYPICAL PORTAL TRUSS MODIFICATION
NOT TO SCALE
NOTES
1. FOR GENERAL NOTES SEE DWG No 6
2. THE MODIFICATIONS SHOWN ON THIS DWG. ARE INTENDED TO BE USED ONLY WHEN VERTICAL CLEARANCE IS A PROBLEM. AS SUCH, IT SHOULD BE USED IN CONJUNCTION WITH DETAILED PROCEDURES SHOWN IN SECTION 3.5.7 OF THIS REPORT.
INCREASING VERTICAL CLEARANCE DETAILS
U S DEPT OF TRANSPORTATION-
FEDERAL HIGHWAY ADMINISTRATION
RESEARCH PROJECT No DTFH 61-80-00096
METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES
PREPARED BY
SHELADIA Associates, Inc.
Consulting Engineers
DATE
DWG NO
12 OF 13



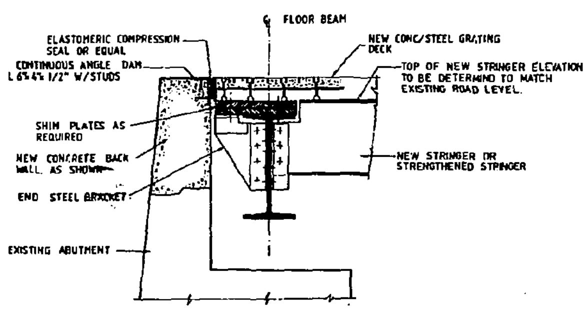
TYPICAL CROSS SECTION

SCALE: NOT TO SCALE



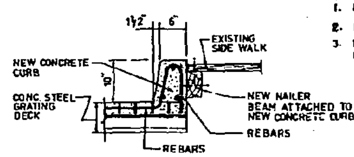
TYPICAL CROSS SECTION (MULLEN BRIDGE)

NOT TO SCALE



SECTION THROUGH END FLOOR BEAM

SCALE: NOT TO SCALE



DETAIL - 1

SCALE: NOT TO SCALE

NOTE:-
SIDE WALK NAILER APPLICABLE TO MULLENS BRIDGE ONLY.

NOTES

1. FOR GENERAL NOTES SEE DWG. No. 4
2. FOR PLAN OF BRIDGE SEE DWG. No. 1 AND 3
3. FOR PLAN AND ELEVATIO OF MULLENS BRIDGE SEE DWG. NO. 1 AND 2.

REPLACEMENT OF EXISTING BRIDGE DECKS	
U S DEPT OF TRANSPORTATION-FEDERAL HIGHWAY ADMINISTRATION RESEARCH PROJECT No DTFH 61-80-00036 METHODS TO UPGRADE THE STRUCTURALLY DEFICIENT THROUGH TRUSS BRIDGES	
PREPARED BY BHELADIA Associates, Inc. Consulting Engineers 5711 Sonia Avenue, Riverdale, Maryland 20840 Telephone (301) 779-4313	DATE DWG. No. 13 OF 13

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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, 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 that affect the quality of the human environment. The 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 and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.