

REPAIR, REPLACEMENT OR STRENGTHENING
OF SHORT SPAN STEEL BRIDGES ON
SECONDARY HIGHWAYS

by

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INTRODUCTION

Problem Statement

Every year, some 150 bridges in this country sag, collapse, or otherwise become impassable. Millions of people put their lives in jeopardy each day as they cross the tens of thousands of bridges that are either structurally deficient or functionally obsolete. A structurally deficient bridge is defined as one that, because of damage or deterioration, has been restricted to carrying light traffic only or has been closed. A functionally obsolete bridge is one whose deck geometry, load carrying capacity, clearance, or approach roadway alignment can no longer safely service the system of which it is a part. More than 1,000 lives are lost annually in bridge-related collisions (4)*. In fact, it has been estimated that more than 100,000 bridges in this country are inadequate for heavy loads or in need of major repairs. Further, it has been estimated that over 50,000 bridges are functionally obsolete because of such geometric constraints as narrow width, poor clearances, and dangerous approaches. Thousands of additional bridges fall into one of these categories each year (11).

Speaking at the AISC National Engineering Conference held in Pittsburgh in the Spring of 1980, Larwig (14) stated that nearly 20 percent of this country's bridges, 106,000 out of 564,000, are unsafe. The challenge is immense, and it is estimated that the United States must spend \$25 billion to repair or replace these bridges. The Federal Highway Administration (9) estimates even grimmer remedial measures totalling about \$41 billion.

* Numbers in parentheses refer to references cited in Appendix I.

How did bridges get into such poor condition? Many are just too old. More than 75 percent were built before 1935. Others are unsafe because they now carry more traffic than they were built to carry--truck loads constantly grow heavier and more cars hit the road each year. Weather also ruins bridges, destroying paint and eroding decks beyond recovery. Finally, state and county bridge maintenance has starved financially for 20 years. Ever since the interstate highway system began to siphon off most of the highway funding, little has been available to keep local bridges in condition (14). American City and County (4) estimates that it would cost billions of dollars to replace all the inadequate bridges in this country, and that most of the money would have to come from state and local levels. Unlike federal legislators, lawmakers at these levels must balance the various needs of competing interests, rather than merely deciding how much to appropriate for a worthy project, and adding the cost to the national debt.

Since government budgets already are strained to provide services considered necessary, the highway engineer who will not receive the funding to replace inadequate bridges is left with alternatives ranging from second-best to downright dangerous:

1. Do nothing, assuming that the bridge hasn't collapsed yet and probably won't before you retire.
2. Post the bridge with a lower weight limit, and not worry about who enforces the restriction. After all, if a bridge posted for 8 tons collapses under the weight of a loaded ready-mix truck weighing 29 tons, as happened in 1978 on a county road in Ohio, at least you can't be blamed.

3. Close the bridge. People will find some way to cross the river, no matter how far they have to drive, how much fuel they waste, or how much congestion they cause.
4. Rehabilitate the bridge so that it can safely carry essential traffic.

The last option is obviously the most logical course, but it should not be undertaken without further investigation. If the problem involves the approaches to the bridge and no land is available for alignment, then perhaps the only alternatives are warning signs and a prayer.

If the problem is inadequate width on a through truss bridge, then the cost of widening the bridge may exceed the cost of replacement, and the result could still be a bridge with a shorter life expectancy than its replacement would have (4).

Major structural failures of bridges with resulting loss of life and significant requirements for structural replacement in terms of cost are not infrequent occurrences. It has been reported (11) that approximately 150 bridge failures occur in the United States each year. This unsatisfactory condition of thousands of bridges, accompanied by periodic failures and potential disasters in terms of loss of life and damage, simply cannot be tolerated much longer. According to Larwig (14), now is the time to start work on bridges. Once job specs are settled and Government agencies approve financial arrangements, contractors and fabricators can begin construction. Responding to dramatic surges in the costs of bridge construction, Government authorities are attempting to hold price guidelines by encouraging competition among alternative designs, and providing price adjustments for cost-saving ideas from contractors and fabricators.

It is clear that crumbling bridges are the weak links in the chains of American highways. Builders are needed with clever cost-cutting ideas for strengthening bridges to handle the traffic of tomorrow.

Scope

The problem of repairing various components of highway bridges is not a new one. Studies relating to this problem have been under way for a number of years. Thus, maximum use of previous related work has been made.

This study has been directed at steel bridges on both major and secondary highways but with particular emphasis on those on the latter. This is because, with major emphasis being placed on bridges on the major highways, especially those on the interstate system, and new construction in recent years, bridges on secondary highways have frequently been neglected (3). They have been given irregular inspections, inadequate maintenance, and infrequent load capacity ratings. A large number of these bridges are in serious need of structural repair, or, as is the case in many instances, their load carrying capacity is so impaired that total replacement is necessary. Thus, in identifying deficiencies and developing repair procedures, most of such techniques and procedures were restricted to those types of bridges occurring on highways under local agencies. For example, no effort was directed toward identifying and correcting deficiencies that occur on long span bridges carrying large volumes of traffic.

As a final part of this section, it is desirable to establish some basic definitions of terms related to the repair of bridges which will be adhered to throughout. The definitions are as follows:

1. Maintenance - The work required to continue a bridge in its present condition and to control future deterioration.
2. Repair - Action taken to correct damage or deterioration on a structure or element to return the structure to its original capacity.
3. Rehabilitate - To carry out an extensive repair procedure.
4. Restore - To return a structure or element to its original condition (often used in connection with historic structures).
5. Upgrade - To raise a structure's capacity to a level above that of the original design.
6. Retrofit - To add a new element to an existing structure to prevent distress or to upgrade.
7. Replacement - To install a new structure at the site of a previously existing structure.

Background

On December 15, 1967, the Silver Bridge over the Ohio River at Point Pleasant, West Virginia, collapsed, plunging 24 cars into the Ohio River, and 7 on the Ohio shore, causing the death of 46 people. This event precipitated a sudden awareness in both the public and the congress of the potential danger of unsafe bridges on the nation's highways and the seriousness of the deficiencies in these bridges. This tragedy proved to be the catalyst that produced a concerted effort by federal and state agencies to identify and repair highway bridges with serious deficiencies (11).

The initial program arising from these efforts began when Congress added a section to the Federal-Aid Highway Act of 1968 that required

the Secretary of Transportation to establish national bridge inspection standards, and to help to develop a program to train inspectors. This addendum to the 1968 Highway Act was naturally directed only to those bridges on the federal-aid system of highways. The reasons for this restriction were reasonable and obvious at the time. Federal-aid system highways, particularly the interstate roads, were the most heavily traveled and the most visible, and deficient bridges on this system naturally were assigned first priority for repair and replacement. Further, data regarding these bridges, such as number and condition, could be easily obtained from state highway departments.

The FHWA's "Eighth Annual Report to Congress on the Special Bridge Replacement Program" showed a total of 242,000 bridges on the federal-aid system. Of these, a total of 40,700 were classified as deficient, i.e., either structurally deficient or functionally obsolete. The data provided by the FHWA were developed from the inventory of bridges of the federal-aid system tabulated by each state as required by the 1978 Highway Act.

Although the addendum to the Highway Act of 1968 did much to focus attention on bridges on the Federal-aid system, and resulted in a detailed inspection system and an awareness of the needs for repair and replacement, those bridges not on the federal-aid system (or off-system bridges) continued to be ignored, at least on a national level. Again, the reasons for this neglect seemed logical. The majority of off-system bridges were typically on secondary and rural roads, and thus had lower traffic volume and lower visibility than did the on-system bridges. In addition, most of these off-system rural and secondary bridges were the

responsibility of a variety of local agencies, and obtaining information on these bridges was difficult at best.

Because off-system bridges were not covered by the Highway Act of 1968 (11), there were few available data concerning the number and condition of these bridges until very recently. However, in 1978 the National Association of Counties (NACo) conducted a survey of all counties in 38 states in which the counties have primary responsibility for local highways and bridges. This survey requested data on off-system bridges 20 ft. or longer that were under direct county supervision. Although the number of responses from the counties was modest, several statistical approaches to the data indicated a total of 233,800 off-system bridges under county jurisdiction, of which 77,900 are structurally deficient and 88,900 are functionally obsolete.

Also, recent FHWA reports emphasizing the urgent need for bridge construction quoted the following figures. There are more than 331,000 bridges on county, secondary, municipal and rural roads outside of the federal-aid system. Of these, only 4% are maintained by states and 90% (297,000 bridges) are more than 40 years old. It has also been estimated that more than 50%, or about 170,000 of the bridges on the county and local systems, are in need of immediate replacement.

It has also been noted that approximately 84% of the nation's roads are classified as rural by the FHWA, and that about one-third of these roads need repair and improvements to make them safe for motorists. Clearly the same statistics can be expected to apply to rural bridges.

Although the above numbers are conflicting to some extent, one fact is clear. Regardless of which statistics are the most accurate, there

are at least as many off-system bridges as there are bridges on the federal-aid system. Further, the majority of these off-system bridges are either structurally deficient or functionally obsolete and desperately in need of repair or replacement. These figures indicate that the nation's bridges on rural and secondary highways are in a deplorable condition, even if the reported data are only roughly accurate.

The impressive statistics briefly cited in the foregoing were brought to the attention of the 95th Congress by the FHWA, the NACo, and many concerned local governments. This Congress was influenced to hold its own investigation and extensive hearings on this serious nationwide situation. The result was new legislation that included the Highway Bridge Replacement and Rehabilitation program of the Surface Transportation Assistance Act of 1978, signed into law by the President on November 6, 1978. This legislation has been hailed as introducing a new era in surface transportation. The Highway Replacement and Rehabilitation program included the following features:

1. A total of \$4.2 billion was to be spent in the following four fiscal years: \$0.9 billion for FY 1979, \$1.1 billion for FY 1980, \$1.3 billion for FY 1981 and \$0.9 billion for FY 1982.
2. The federal-state matching ratio for bridge funding was increased from 75/25 to 80/20.
3. No state could receive more than 8% of the total and no state can receive less than 0.25% of the total.
4. Each state was required to use not less than 15% and not more than 35% for off-system bridges.
5. To expedite the availability of the bridge funds, the FY 1979 bridge money came out of the Highway Trust Fund, and was available for obligation immediately.

6. Funds were provided for rehabilitation of highway bridges as well as bridge replacement.

There are several requirements that local governments must meet in order to qualify for these funds. The principal requirements include a) an inventory and classification of all off-system bridges on the basis of serviceability, safety and essentiality for public use prior to December 31, 1980, and b) a priority ranking system to determine which bridges should be repaired or replaced first. However, the FHWA recognizes the intent of Congress that the off-system program should get moving quickly, and has developed an arrangement by which federal funding can be provided immediately for a bridge that is plainly unsafe without waiting for the complete inventory.

BRIDGE DEFICIENCIES

Structural Deficiencies

Inadequate strength of the main structural members due to a light original design was identified (11) as a frequent and severe problem in the case of steel beams and steel truss spans. This problem may be largely attributed to increase in allowable traffic loads subsequent to the construction of the old structures. Limitations in carrying capacity due to the strength of the deck was found to be a severe problem in the steel trusses, due in large measure to deterioration. Fatigue cracking, while a subject of national concern in major highway bridges, does not appear to be a serious problem in secondary road structures. Corrosion of superstructure elements constitutes a significant problem on steel beam and steel truss bridges. Corrosion of beams and bearings is usually a result of poor handling of the deck drainage and leaking expansion joints. Collision damage to steel beam bridges was found to be a frequent problem.

Functional Deficiencies

The difficulties associated with steel truss bridges are particularly significant, especially in terms of limitations on roadway clearances posed by the structures themselves. The problems of narrow roadway and exposure of the truss members to impact are very serious, while inadequate vertical clearance is a significant though less severe deficiency.

Unsafe alignment of the approach roadway was considered a significant problem, but with a scope that extends beyond the repair of the bridge itself, it is one that is difficult to handle. Right-of-way acquisition and changes in road geometrics away from the structure can present extraordinary problems.

REPAIR OR REPLACE?

Introduction

The problem of deciding whether to repair or replace a bridge is not an easy one. The repair or replace decision, then, is the one that will usually require the most thought and consideration, and the following logical step-by-step process has been recommended by the N.C.H.R.P. (11):

Step 1: Here, the engineer should list the most significant factors that could affect the decision. These factors could be selected from the following:

1. Degree or extent of deficiency
2. Functional obsolescence of structure
3. Present and future traffic volumes
4. Time out of service
5. Acceptability of structure if repaired
6. Anticipated length of service
7. Permanence of possible repair
8. Local factors (bus routes, funding, political, etc.)
9. Essentiality of structure
10. Maintenance costs
11. Environmental consideration
12. Safety consideration
13. Aesthetics

This list should be extended by the engineer and his staff, and those factors most appropriate for the bridge under consideration should be selected for further scrutiny.

Step 2: In some subjective, arbitrary manner, the engineer should determine the degree to which either "repair" or "replace" would satisfy the criteria or meet the objectives implied by the list of factors. This could be done by assigning weights from 0 to 10 for each factor under each alternative. At this stage, the intent is not to provide some numerical index on which to base a decision, but rather to provide a structured mechanism for clarifying the way in which "repair" or "replace" would meet the needs of the project. If the decision is made to repair a bridge, due consideration should be given to the ability of the repaired structure to meet the minimum standards for geometrics and load capacity of the AASHTO standard specifications for highway bridges.

Step 3: Based on the best information available to the engineer and his staff, approximate costs should be assigned to the "repair" and "replace" alternatives. These cost figures should be based on experience within the county or local agency, or they could be obtained from the state highway department. Or, in extreme cases, they could even be a "best guess" on the part of the local engineer. Whatever the source, they will at least provide another relative measure on which to base the decision.

Step 4: At this stage, it is likely that a "repair" or "replace" decision that was not obvious before should now be. The engineer knows that he has taken the important factors into consideration and has even looked at a rough cost comparison. Certainly, if the cost of repair is, say, less than 30 percent of the replacement cost and if the repaired bridge will meet the service requirements, repair would be the choice. On the other hand, if bringing the bridge up to current standards would

cost 70 percent of replacement, replace is probably the choice. For those structures where the cost of repair is between 30 percent and 70 percent of replacement, the engineer must rely on his best judgment considering the factors tabulated in Step 1 and the cost discussed in Step 3. The decision between repair or replace in many cases where the repair cost is in the proximity of 50 percent of the replacement cost will always be a subjective one.

Examples

To check the economics of repairing actual existing bridges, Byrd, Tallamy, MacDonal and Lewis (4) prepared plans for rehabilitating some steel bridges. Based on these plans, repair costs were estimated and compared to the estimated cost of constructing a replacement bridge. For comparison purposes, the replacement was assumed to have a total length equal to that of the existing bridge. The usable roadway width was 28 feet, with a 1 ft. curb on each side. If the roadway on the existing bridge was wider than 28 ft., the replacement was priced to have the greater width, plus two feet for curbs.

- a. A steel through-truss bridge had a single 120 ft. span and a usable roadway width of 18 ft. Its load-carrying capacity was to be increased by replacing the deck with open-steel grid decking. A King post was to be added to increase the capacity of the floor beams. Vertical clearance was to be increased by lowering the floor system and modifying the portal frame.

These improvements were estimated to cost \$81,500, but they would leave unchanged the inadequate 18 ft. roadway.

Widening a through-truss bridge often is economically

unjustified. The replacement bridge, with a 28 ft. roadway, was estimated to cost \$144,000.

- b. Two bridges supported by multiple steel beams were examined. The first had four spans--one of 55 ft., two of 45 ft., and one of 22 ft. Usable roadway width was 24 ft. The major planned improvement was a widening of the roadway to 26 ft. Load-carrying capacity was to be increased by adding supplemental stringers and by replacing the concrete deck with lightweight corrugated metal and an asphalt surface. Abutments and pier caps would require widening.

Cost of these improvements was estimated to be \$151,000.

A new bridge would cost an estimated \$198,000.

- c. The second simple-span multiple steel-beam bridge had 24 ft. roadway, one 47-foot span, and four 40-foot spans. Rehabilitation plans called for widening the roadway to 34 ft. and increasing the load-carrying capacity by making the spans continuous and by replacing the concrete deck with open steel-grid decking. Tiebacks would be needed to stabilize the abutments. The bearings required adjustments, and new expansion joints were needed. Finally, redirectional barriers were needed to improve safety.

Cost of these improvements totaled \$327,000. A replacement structure could be constructed for only \$304,000.

Choice of Repair Alternative

Once the decision has been made to repair a deficient bridge rather than to replace it, the bridge engineer must select a particular bridge

repair procedure that will effectively remedy an identified deficiency. A number of repair procedures are presented in this report, which should provide local bridge engineers with the concepts necessary to correct the large majority of common deficiencies in steel bridges on secondary highways. In some cases, only one repair procedure may be available for the deficiency. In other cases, however, more than one procedure may be available, and it becomes necessary for the local engineer to select the most appropriate one. Numerous considerations may enter into the selection process. For example, the skilled trades required to perform a repair procedure may not be readily available to the repair site, or the availability of special equipment may be an important influence. Frequently the initial cost of the repair is an important consideration, and in other cases the annual maintenance costs may be a major factor. In some cases, the engineer may simply prefer one procedure over another on purely subjective grounds.

Choice of Replacement Alternative

Various factors may influence the decision to completely replace rather than repair a deficient bridge structure. As was discussed under "Repair or Replace", cost may be the primary determining factor in the decision to replace an existing structure. But, whatever the reason for the replace decision, the bridge engineer must decide the type of replacement system that will best satisfy the requirements. The following factors will almost always need to be considered:

1. Required structural capacity
2. Traffic volume
3. Anticipated future use

4. Labor required for replacement
5. Cost

In addition, there are always a number of influencing factors that are unique to the particular site and to the local region. These include such things as:

1. Experience
2. Available contractors
3. Budget restraints
4. Material availability
5. Environmental priorities

Although there might be two or more systems that would meet the engineering needs of the project, the requirement to meet local needs will occasionally identify a single replacement system that seems best. And where two or more systems seem equally acceptable, the factor of cost can always be used as the final decision criterion.

REPAIR PROCEDURES

NCHRP Suggested Procedures

Some repair procedures for common bridge deficiencies were obtained from the "National Cooperative Highway Research Program Report 222" (11), and are reproduced in Appendix II of this report. Below is a brief summary of these repair methods.

1. Steel Truss Repair - Tensile Member:

In this method, the new tensile section is first designed. A cable is then installed to carry the full dead load in the tensile member. The old tensile member is then replaced with the new one. Finally the cable is removed, and the bridge is restored to normal traffic conditions.

2. Repair of Damaged Truss Member:

This involves bolting a splice plate to the side and a tie plate to the bottom of the damaged member.

3. Replacement of Steel Beams:

The damaged beam is cleared of the bearing surface by jacking the bridge. Then the damaged portion of the steel beam is removed. Finally, the new steel beam is welded in place.

4. Repair of Corroded Steel Beam Ends:

The damaged beam is cleared of the bearing surface by jacking under the sound portion of the beams. The corroded area is cut out. Then the new section is welded into place.

5. Increase Flexure Capacity of Steel Beam Stringers by Addition of Cover Plates:

The cover plates are designed to the desired capacity,

clamped to the bottom flange of the stringers and welded to the beams.

6. King-Post Truss for Increasing Beam Capacity:

First, the rods and attachments to carry the post-tensioning forces are designed. The end anchors of the rods are bolted to the lower flange of the steel beam. Then the rods are placed through the anchors, and tensioned to the desired level of stress.

7. Installation of Distribution Beam:

Holes are first drilled at mid-depth of the web of the existing stringers. Next the web shear reinforcement is welded into place. Hangers are inserted into web holes. The distribution beam is then lifted up into the hangers.

8. Installation of an Intermediate Support for Steel Girder Bridges:

The new transverse beam and the pile group are first designed, and the piles are driven outboard of the pile groups. Finally the new support beam is placed and jacked snug against the existing stringers.

9. Increasing Vertical Clearance of Through Truss Bridge by Modifying the Portal Bracing:

All portal bracing is removed, and replacement members are installed. As an alternative, the lower horizontal member is removed, and diagonals are cut to the new length, after which the horizontal member is replaced in its new position, and new diagonals are added. Finally, the knee braces can be removed.

Example Bridge Repair Job

An example of a successful bridge repair job will be given to complete this section on repairs. The Drake Hill Road bridge over the Farmington River in Simsbury, Connecticut was inspected by Connecticut Department of Transportation inspectors and found to have severe deterioration of web truss members above the bottom chord in June 1977 (1). They recommended that the bridge be declared unsafe, and the town responded by immediately closing it to traffic. But because of the town's critical need for the bridge, it elected to investigate the possibility that temporary repairs might keep it in service until a permanent replacement could be designed and constructed. Macchi Engineers was engaged to evaluate the bridge's structural condition and to prepare plans for rehabilitation. Major hazards were found:

1. The original vertical members were seven-inch channel sections, paired and tied with lacing. The webs of these channels were completely rusted through.
2. The tension diagonals in the first three panels from each end were paired flat eyebars. In one location, an eyebar was completely corroded, and the entire load was carried by the remaining bar. Dead load stresses in this bar were estimated to be 24,000 pounds per square inch.

The vertical struts were rehabilitated by removing the steel lacing and replacing it with five-foot lengths of 10-inch channel (see Fig. 1). The channel backs were welded to the flanges of the existing seven-inch channels. This formed a box section at the bottom of each vertical strut for added strength.

Vertical connection repair schematic

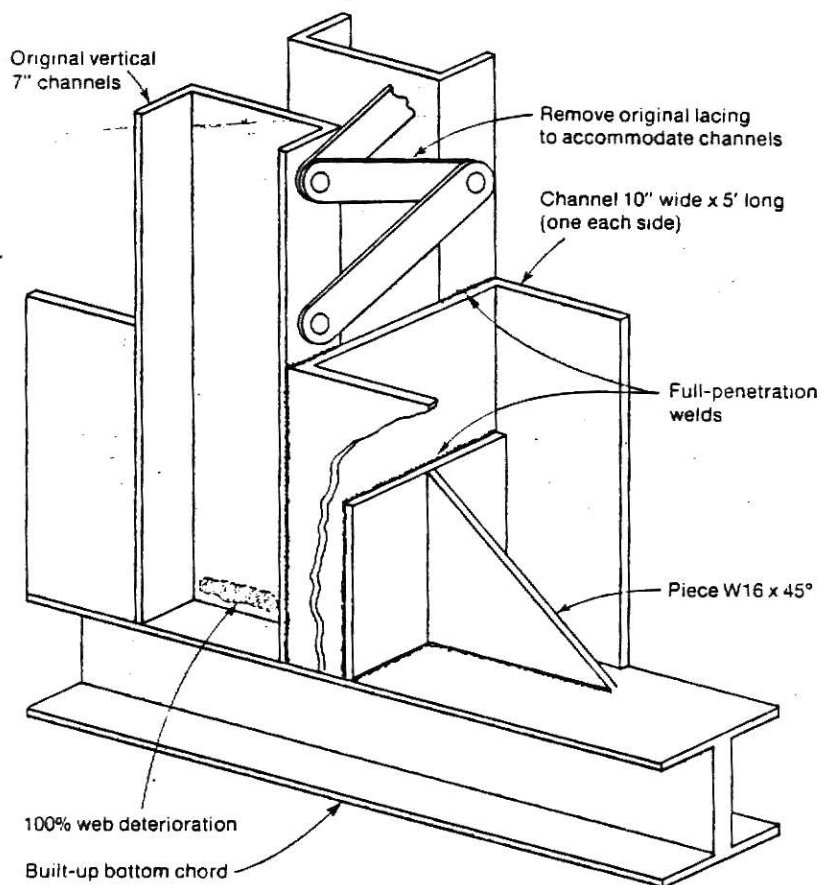


Fig. 1 Vertical Connection Repair Schematic (1)

Load was transferred from the rehabilitated struts to the bottom channel through pieces of W16x45 beam (see Fig. 1). The web of the W16x45 was tied with a full-penetration weld to the web of the built-up bottom chord. Its flanges were welded to the new 10 inch channels. Ultrasonic testing verified the integrity of the full-penetration welds.

Load from the diagonals was transferred to the W16x45 gusset by four plates. One was welded to the top and bottom of each diagonal on each side of the W16x45 flange.

This conversion of the diagonal connections from pinned connections to rigid connections induced some moment into the connected members, but an investigation concluded that these moments were negligible.

REPLACEMENT ALTERNATIVES

NCHRP Suggested Alternatives

Some replacement alternatives which were obtained from the "National Cooperative Highway Research Program Report 222" (11) have been reproduced in Appendix III of this report. These replacement alternatives are briefly summarized below:

1. Prefabricated Steel Bridges

Standard prefabricated steel superstructure components are connected, and topped with a wearing surface to provide a fast-assembly bridge.

2. Temporary Bridges

The temporary bridges are steel-truss bridges which are quickly assembled at the site from standard preassembled components.

3. Laminated Timber Deck on Steel Beams

Timber laminations connected by glue or nails are placed on steel stringers.

4. Steel Grid Deck on Steel Beam

Modular steel grid units are placed on steel stringers.

Precast Concrete Units

Another replacement system that has been used is the BEBO arch bridge (7). This is a bridge made of precast reinforced concrete arches. The 41-ft. span precast concrete arches are merely laid side by side on top of a concrete foundation. Seventy-six of these precast concrete bridges have been erected in West Germany, Switzerland, and other areas

of Western Europe. Each precast arch is 41 ft. long, 6 ft. wide, made of 10 in. thick reinforced concrete, and weighs 18,000 lbs.

This system was used by the City of Edina, Minnesota to ford a stream so that an access road could be built into the industrialized southwest part of the town. This system was used for the following reasons:

1. There was a 17% cost savings compared with the next most competitive type bridge--or a savings of \$22,500.
2. The bridge could be built rapidly. It took only a week from the time digging began for the bridge footings till the backfill was placed over the structure.
3. There would be no future anticipated problems with bridge deck deterioration. In fact, here there is no bridge deck. The top of the arch is covered with a granular material. And on top of that is placed a blacktop pavement.

The only disadvantages are:

1. The bridge requires an extensive footing.
2. The precast concrete arches have to be transported to the site, and a large crane must be available to lift the arches off the flatbed truck and place them into position.

The city supervisor of design, Robert Obermeyer, believes that this BEBO arch bridge has considerable potential for replacing obsolete or deteriorated county and township bridges in rural areas of the U.S.

According to a document prepared by the staff director of the Transportation Research Board, W. N. Carey, Jr. (6), the use of standard precast concrete units is an expedient means of constructing short-span bridges.

He sited the need to develop criteria and techniques for design, fabricating and constructing precast modular bridge systems that are structurally complete (including deck, curbs and guard rails).

METHODS OF STRENGTHENING

Introduction

The strengthening of existing bridges is usually occasioned by the necessity for carrying heavier live loads than those for which the bridges were designed. It may also be required because of inadequate design (usually in the proportioning of details) or as the result of localized deterioration (5).

Bridges that are structurally inadequate can be increased in carrying capacity by using one or more of 4 techniques (4):

1. Adding supplemental members
2. Strengthening critical members
3. Reducing the dead load
4. Modifying the structural system.

1. Supplemental Members

Highway engineers often increase the carrying capacity of inadequate bridges by either replacing the deficient members with stronger ones, or adding more members so that the total load is carried by a greater number. Additional floor girders, for example, could be inserted between the existing girders. They need not be of the same material, either. Steel girders could be used to strengthen a timber bridge, for example. The primary consideration in member replacement is proper support of the bridge during the project.

Adding replacements is not limited to the bridge superstructure. One of the more common repairs to a substructure is the installation of a pair of piles to replace one that has failed. One is driven on each

side of the failed pile, in a plane transverse to the pile bent. A needle beam carries the failed pile's share of the load from the pile cap to the replacement piles.

This installation is called a crutch bent. A support bent added under a truss bridge can strengthen it in a second way if it is practical to install it under one of the interior truss panel points. This installation will reduce the unsupported length of the truss, substantially reducing stresses in it. The support bent can be designed to be pin connected to carry only vertical loads.

Perhaps the ultimate in strengthening substructures is a system of supplemental transverse floor beams that support the existing stringers. These beams are, in turn, supported on supplemental girders installed outboard of the existing framing system. This procedure is most often seen as part of a bridge widening project.

2. Strengthening Critical Members

Steel bridges are routinely strengthened by state highway agencies. Cover plates are welded to steel beams or girders, and plates or structural shapes to truss members. Through experience, agencies have learned the necessity for two precautions: the weldability of the steel in the existing member must be determined, and the details of the welding connection must be designed by an engineer qualified to analyze its effects on such properties as fatigue strength. Another method of increasing the carrying capacity of tension members is post-stressing. Cables are stretched along a tension member of a truss or along a beam or girder. They are attached at the member ends and tightened with turnbuckles. Tension in the cable is resisted by

compression in the member. This induced compressive stress allows the member to carry more tensile load, either the dead load of the structure or the live load of the traffic. Minnesota used this technique to strengthen the steel beam system supporting a timber deck.

A variation of post-stressing, usable where underbridge clearance permits, is the King post-truss system. In this system, high strength steel rods or cables are used to induce compressive stress in the normally tensioned bottom flange of a beam or girder. Instead of stringing the cable or rod along the bottom of the member, it is attached to the ends and stretched under one or more posts that extend below the member. Using the King post as a lever arm permits more efficient application of compression to the original bridge member.

Sometimes, the capacity of a steel bridge is limited not by the structural members, but by the connectors between members. In this case, additional connectors can be installed in critical areas, or the original connections can be replaced with connectors having greater capacities.

3. Dead Load Reduction

The simplest method of reducing dead load is to remove part or all of the existing deck or appurtenances, and replace them with lighter weight substitutes. A number of substitute deck systems have been developed to provide adequate strength with lower than standard weights. Perhaps most common is the open steel grid. This is welded to the top flange of the stringers, using adjustment plates where necessary. In addition to light weight, an advantage of open-grid steel flooring is the fact that rain and snow pass through it, eliminating the need for

deck drainage systems and for the use of snow and ice control chemicals on the bridge. Still, details over support members should be designed to eliminate the possibility of trapping water.

4. Structural Redesign

This consists of modifying the structural system. Two modification methods merit consideration:

1. Obtaining composite action between the deck and the existing beam and girder system. This can be done by use of welded studs or epoxy glues to provide a shear connection between the deck and the substructure.
2. Converting a series of simple spans into a continuous span by splicing beam ends together so that they transmit moment across a pier or another support. This modification also reduces maintenance requirements because it eliminates one set of bearings and a roadway joint at each pier.

Cable-Stressing Steel Bridges

Steel presents more difficulties than concrete when repairs are necessary. A new approach that may improve the ability of engineers to repair steel structures has been devised by T. Y. Lin (13). According to Lin, the major material used in modern bridge building is steel, which goes into the cables that are both inside and outside the structure. Working from the post-tensioning theory and from technology developed for concrete, Lin and his engineers are examining ways to incorporate high strength cables into steel bridges. The technique is still at an early stage of development. Details must be worked out in the design of cable anchorages and of the cable protection system so that corrosion and fatigue can be avoided.

In other cases, recabbling has been known to add life to bridges. For example, the 52-year old U.S. Grant suspension bridge was re-strengthened by making a full-scale cable and suspender renewal in a continuous operation (8). This is a contrast to the standard practice, in which such a bridge would have only parts of its wire suspension system replaced at one time.

Also, a study is being conducted by a team of researchers at Iowa State University, Ames, Iowa (12) on the feasibility of strengthening single span, steel beam, concrete deck bridges by post-tensioning. Post tensioning is an inexpensive procedure which involves bolting high-strength steel tendons to the bridge support beams. Tightening the tendons causes upward bending of the beams to counteract part of the downward force exerted on the bridge by heavy vehicles. This decreases the critical stress to the bottom of the beams.

Post tensioning is not a new procedure, but using it for bridge strengthening is a new application. One of the goals of the project is to develop a method for mass application of the procedure to virtually all bridges of this design. It will allow bridge engineers and inspectors to conduct their own studies of bridges to determine if post-tensioning is feasible, then to proceed with modifications of their own.

The design of a bridge strengthening scheme utilizing post-tensioning is quite complex. The design involves composite construction stressed in an abnormal manner (possible tension in the deck slab), consideration of different sizes of exterior and interior beams, cover-plated beams already designed for maximum moments at midspan and at plate cut-off points, complex live load distribution, and distribution of post-tensioning forces and moments among the bridge beams.

The post-tensioning schemes employed in the experimental work are, in effect, means of strengthening critical members and modifying the structural system of the bridge.

Rehabilitation Using Composite Construction

Deteriorating bridges are now being rehabilitated by use of composite construction. One such project is the reconstruction of the Pulaski Skyway, one of the approaches to the Holland tunnel linking New Jersey and New York (10). The existing asphalt overlay and up to 6 inches of old concrete at joint locations were removed, leaving several inches of concrete on the steel framework. Holes are then drilled through the concrete, down to the steel floor beams. Stud shear connectors are welded to the beams through the holes. The last step is to repave the skyway with latex modified concrete, which is tied to the steel framework by the shear connectors. The concrete and steel then act as one and live load capacity is increased.

Filling Steel Bridge Decks with Concrete

Another strengthening method that has been tried by the West Virginia Department of Highways (2) is filling steel bridge decks with concrete. They used this method on the Point Pleasant-Henderson Bridge in West Virginia. By 1979, more than 80% of the welds securing the open-mesh portion of the steel-grid deck had failed. Solid steel plates extended over much of the deck surface, covering the resulting holes. The West Virginia Department of Highways elected to try a deck of fabricated steel grid panels designed to be filled with concrete. Higgs Erectors and Haulers of Buffalo, New York handled the redecking contract under Project Superintendent Joe Gordon. First, the crews cleared the old

steel grids from deck segments. Then they laid steel beams, 30 ft. long and 30 inches deep, parallel to the bridge centerline. Six beams were laid across the beam width.

A Pettibone "cherry picker" moved the 17' x 10' x 5" panels from alongside the bridge to their final positions. After the panels were welded into place, a 20-gage bottom pan was welded beneath to contain the concrete.

More than 300 cubic yards of ready-mix concrete filled the grid and an integral curbing. One side of the bridge also incorporated a concrete sidewalk.

Project Superintendent Gordon considers the deck far superior to its successor: "It bears the traffic weight better, allows the concrete to wear evenly, and has less overall weight than conventional reinforced concrete decks."

CONCLUSION AND RECOMMENDATION

Conclusion

This report relating to the repair, replacement and strengthening of bridges on secondary highway achieved several distinct objectives:

1. The identification of the more common bridge deficiencies and corresponding repair procedures.
2. The identification and evaluation of feasible replacement methods.
3. The suggestion of a procedure to assist in the selection between repair and replace alternatives on the basis of cost-effectiveness.
4. The identification of some bridge-strengthening methods.

Recommendation

Although considerable effort was made during this report to identify the common bridge deficiencies and their corresponding remedies, it is inevitable that some problems have been overlooked. Therefore particular attention should be given to obtaining new innovative repair procedures which have been tried successfully on a local level, but which were not uncovered in this report.

APPENDIX I

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APPENDIX II
REPAIR PROCEDURES (11)

Title: 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 end diagonal are also 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 shall be removed and replaced at a time. The new diagonal is to have a capacity equal to that of the member being replaced. Care must be taken to avoid damage to the members 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. 2.
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. 3, 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. 3, first one channel is removed and replaced,

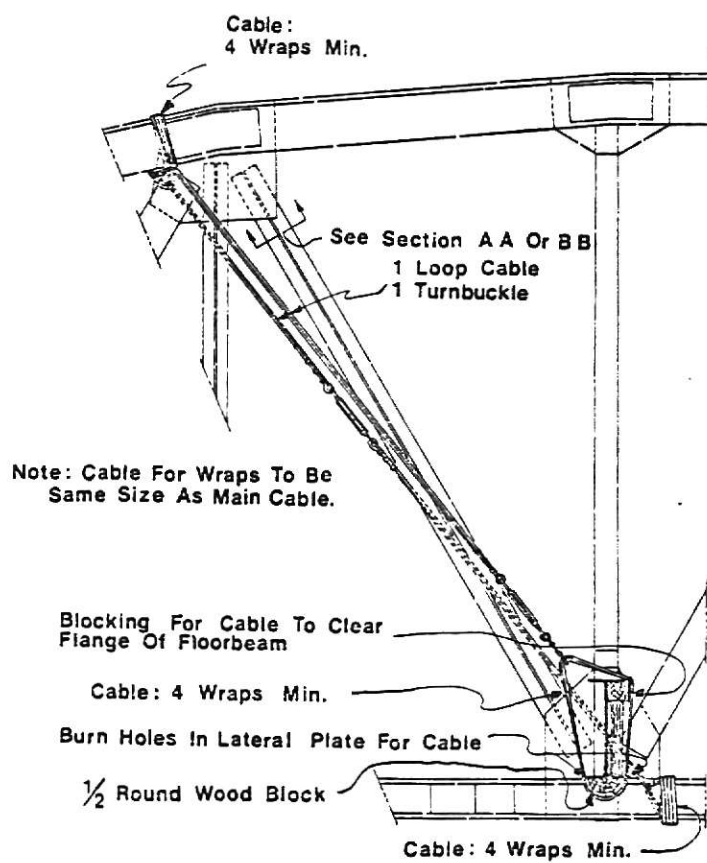
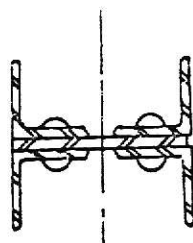
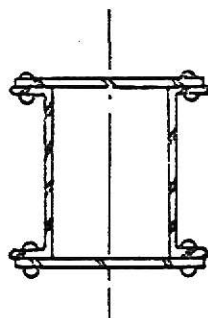


Fig. 2 Truss Diagonal Replacement for Riveted
or Bolted Connections (11)



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. 3 Sections of a Diagonal Tensile Truss Member (11)

then the other. High strength bolts are used for connecting the new diagonal members (see Fig. 4 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.

Resource requirements: cable sling with turnbuckles; prefabricated steel replacement components, torch and/or other cutting tools.

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.

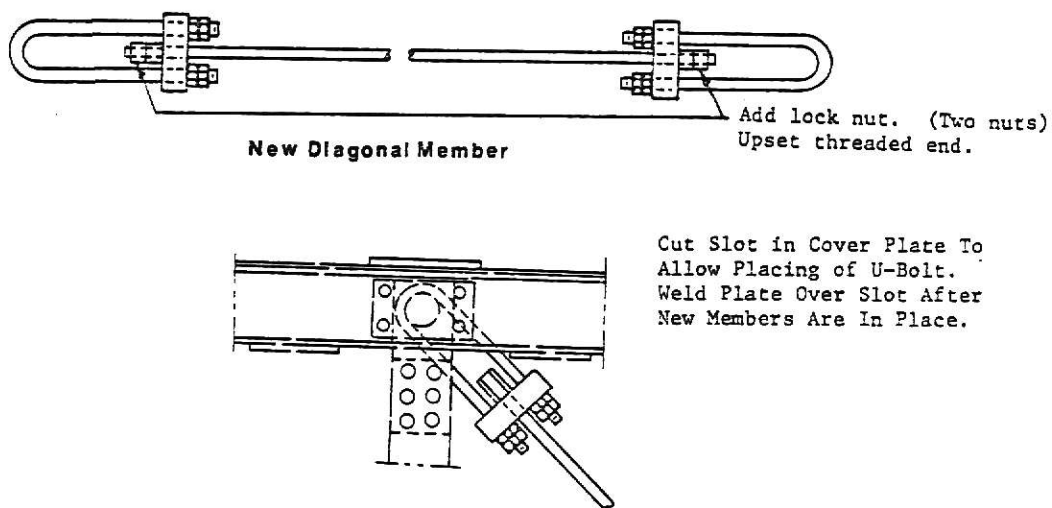


Fig. 4 Truss Diagonal Replacement for Pinned End Connections (11)

Title: 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 is to 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 opposite side of the bridge.
3. Install the wood blocking and WF beam as shown in Figs. 5 and 6, Section AA.
4. Install a cable having the capacity to carry the maximum load in the vertical member being repaired. See Fig. 5.
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. 6, 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. 6, first one channel is removed and replaced, then the other. If the entire member can be safely removed, it can be replaced with other type sections of equal strength. High strength bolts are used for connecting the new vertical members.

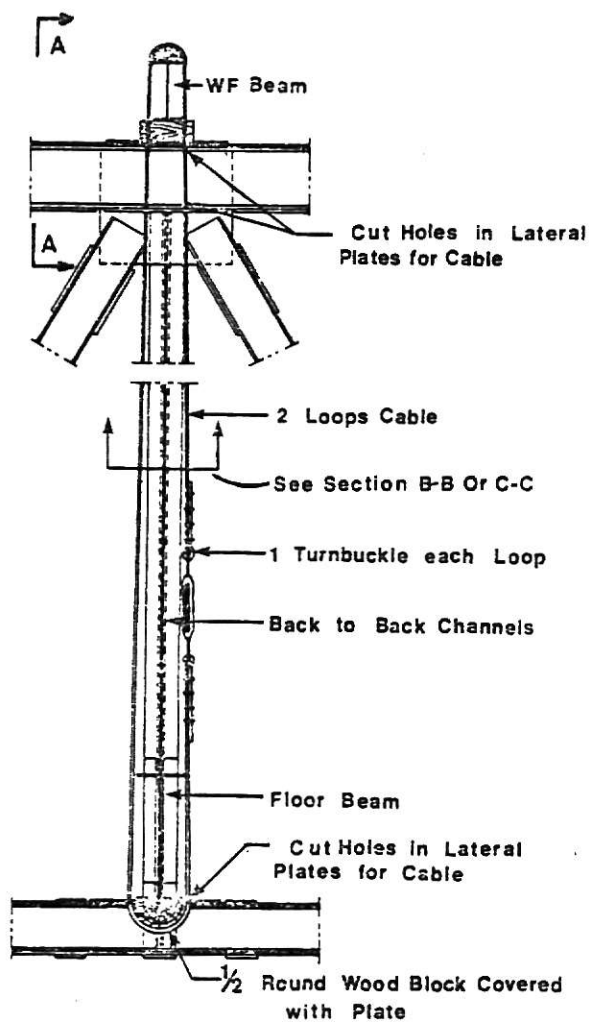
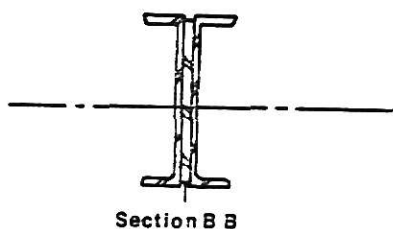
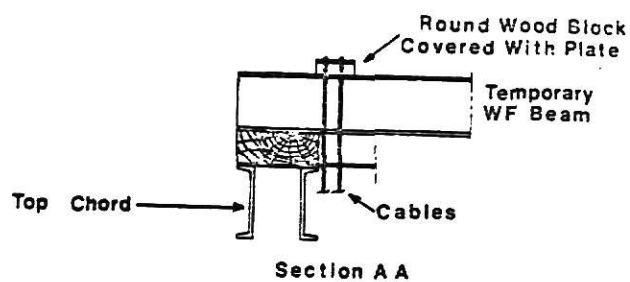


Fig. 5 Vertical Tensile Member Replacement for Riveted or Bolted Connections (11)



Existing members are frequently composed of angles or channels with batten plates or lace bars and may be replaced with the same section or ST sections with suitable batten plates or lace bars.

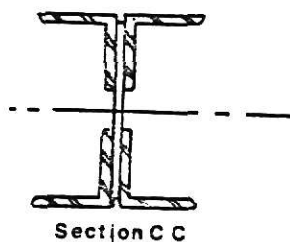


Fig. 6 Typical Sections of a Vertical Tensile Truss Member (11)

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.

Title: 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 a damaged member as shown in Fig. 7.

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. 7.

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 preferable.

Resource requirements: Torch and/or other cutting tools. Power drills. Alternatively, welding equipment and a certified welder.

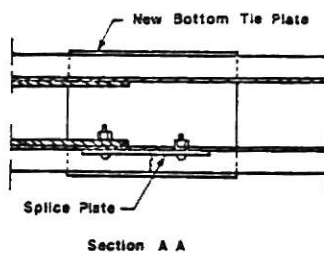
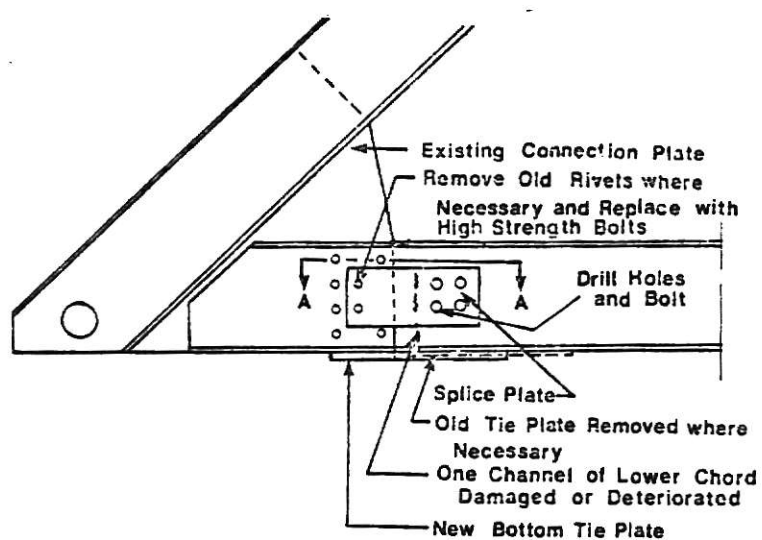


Fig. 7 Repair of Typical Truss Member Where Complete Removal is not Required (11)

Title: Replacement of steel beams.

Description: For either composite or non-composite construction where a beam has been damaged by collision or corrosion.

Limitations: The top flange must be in sound concrete and in good condition.

Construction procedure:

1. Limit traffic to light vehicles and direct to far side of bridge roadway until completion of repair.
2. Jack the bridge so that the damaged beam is clear of the bearing surface.
3. If necessary, provide temporary support adjacent to the beam to be removed.
4. Remove the damaged portion of the steel beam from the bridge slab by cutting through the web directly below the top flange. The top flange must remain in the concrete slab. See Fig. 8a.
5. Grind bottom face of top flange smooth.
6. Select or fabricate a replacement beam having a top flange width smaller than that of the original beam to allow for welding. See Fig. 8b.
7. Weld the new steel beam in place with continuous fillet welds. See Fig. 8b.
8. Remove temporary supports if used.
9. Seat the new beam and remove the jacking equipment.

Note: A cover plate may be advisable on the new beam to lower the neutral axis and thereby reduce the lower flange flexural stress.

Resource requirements: Jacking equipment, steel cutting equipment such as acetylene torch, qualified welding crew, a crane or other suitable lifting equipment.

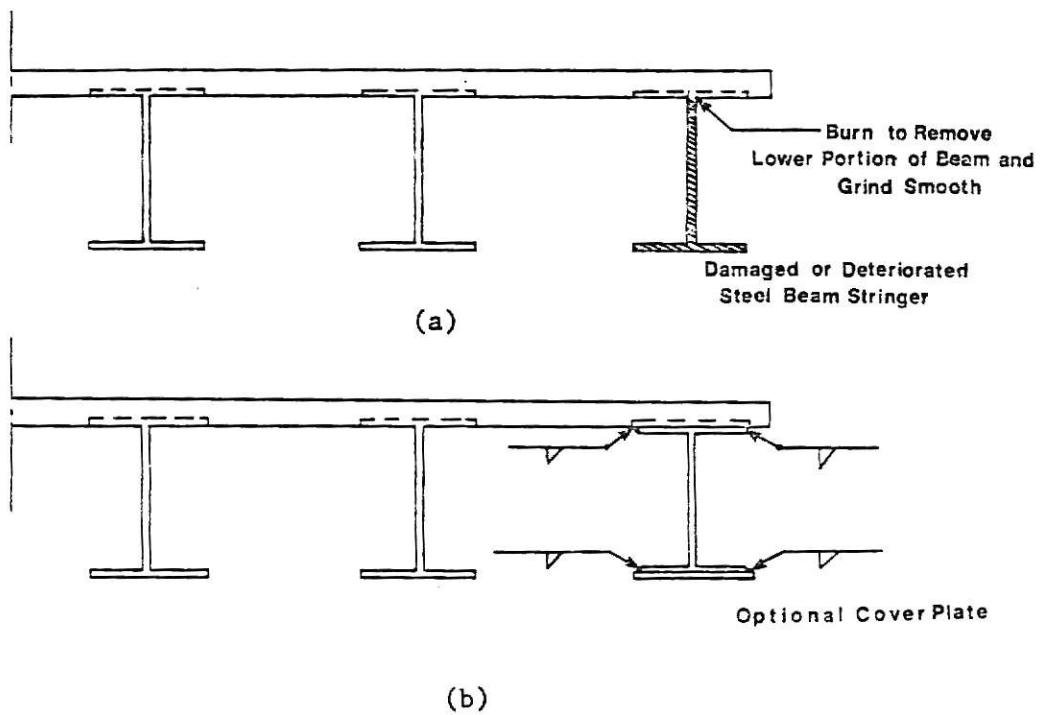


Fig. 8 Replacement of a Steel Beam (11)

Title: Repair of corroded steel beam ends.

Description: The corroded ends of steel beams are replaced by cutting out damaged portion and replacing it with a new WT section or built-up plate section.

Limitations: Suitable for simply supported spans. The top flange and a part of the web must be sound. The steel must be weldable. All stringers must be lifted simultaneously whether they are to be repaired or not.

Construction procedure:

1. Relieve the load at the bearing by jacking under the sound portion of the beams.
2. Cut out the corroded area as marked by the dashed lines in Fig. 9. Bearing stiffeners, if present, must be removed.
3. Weld the new section into place using full penetration welds. The new section may be either a suitable WT or be shop fabricated from other suitable shapes. Replace the bearing stiffeners where required.
4. Lower the span to bear; check for distress.
5. Remove jacking equipment and other temporary supports.

Resource requirements: Qualified welding personnel, light equipment, hydraulic jacks, clamps and hand tools.

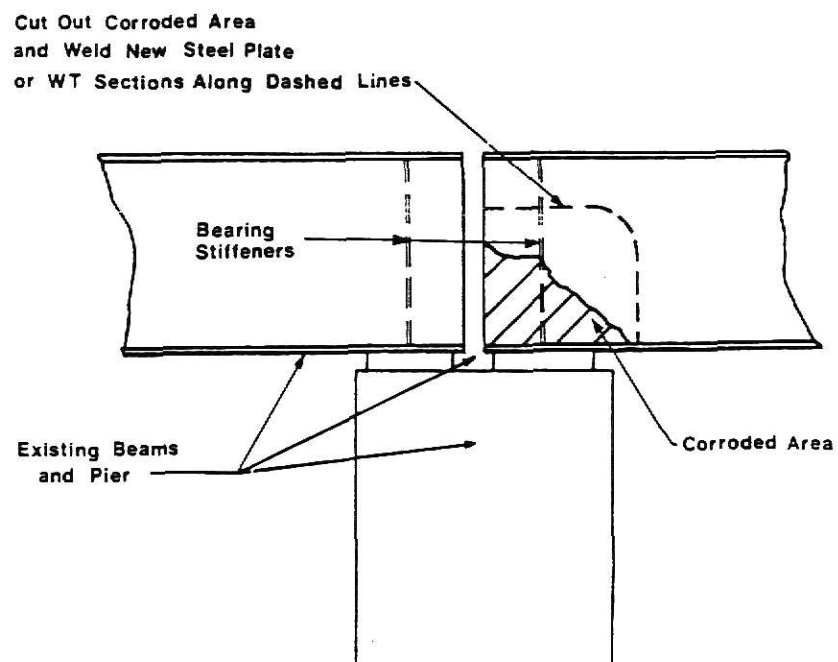


Fig. 9 Repair of Corroded Steel Beam Ends (11)

Title: Increase flexure capacity of steel beam stringers by addition of cover plates.

Description: Cover plates can be added to existing non-composite simple steel beam spans to increase the load carrying capacity.

Limitations: The existing steel beam flanges must be weldable.

Construction procedure:

1. Design the cover plates to achieve the desired capacity. Check the stresses in the modified section to assure adequacy of the existing beam.
2. Close the bridge to traffic while it is being supported by jacks.
3. Prepare the surface of the existing beam flanges for welding of the flange plates.
4. Clamp the cover plates on the bottom flange of the stringers. Plates may also be added to the underside of the top flange.
5. Calculate the load that would be necessary to jack the center of the span to eliminate the dead load deflection. The beams should be raised by exactly that amount at midspan.
6. Place temporary supports similar to that shown in Figs. 10 and 11 and jack all beams simultaneously.
7. Weld the cover plates to the beams. The welding of a cover plate should be completed within a period of a working day.
8. Remove jacking equipment and other temporary supports.

Resource requirements: Excavating equipment, qualified welding personnel, light lifting equipment, hydraulic jacks, clamps and hand tools.

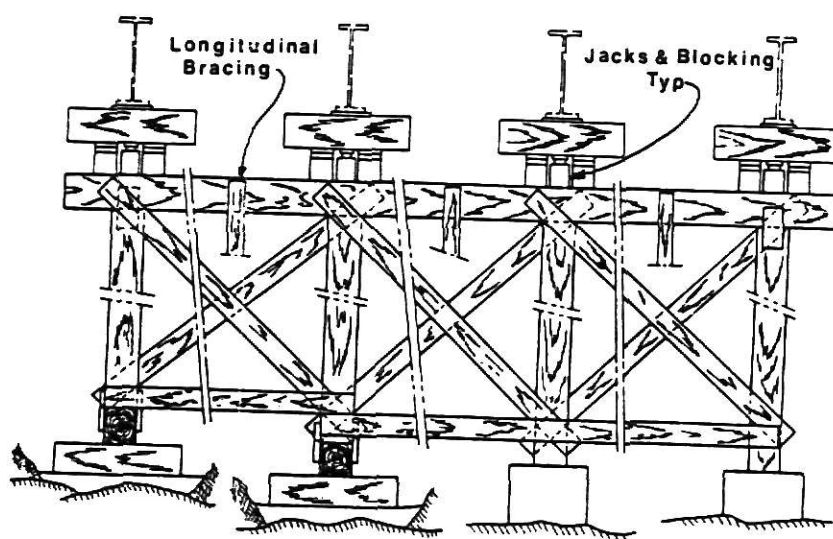


Fig. 10 Transverse Elevation of Temporary Support (11)

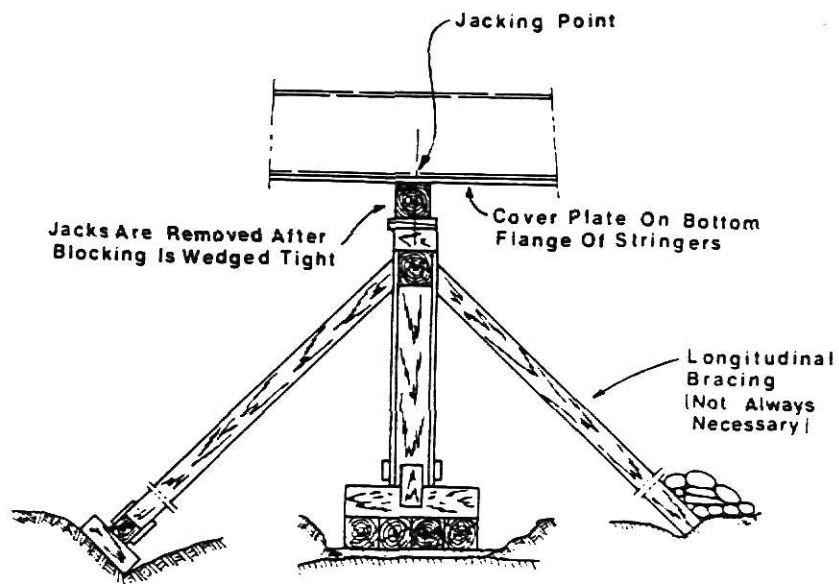


Fig. 11 Partial Side Elevation of Temporary Support (11)

Title: King-post truss for increasing beam capacity.

Description: High strength steel rods may be used to increase the load carrying capacity of a steel beam. Two techniques may be used, namely: (A) Providing vertical supports at one or two positions along the beam and (B) Prestressing the lower flange with a small vertical force at the King-post.

Limitations: Attachments of the steel rod at the ends of the steel beam must be carefully designed to transfer the tensile forces in the rods to the steel beam. Clearance under structure is lessened by depth of King-post. Consideration must be given to induced local stresses in the beam by the intermediate support. Corrosion protection should be provided for the rods.

Construction procedures:

Technique A. The rods are placed with as much slope as feasible and attached to the ends of the beam at mid-height. The mid-span support should be as deep as practical for the site. See Figs. 12 and 13.

1. Bolt end anchors to the beam web in the desired position. The end anchors must project far enough out from the web to provide clearance between the lower flange and rods. See Figs. 12 and 14.
2. Attach the King-post support.
3. Place and tension the rods to the desired level of stress.

Technique B. The high strength rods are placed parallel (or nearly so) to the bottom flange (see Fig. 12). These rods are then tensioned so as to place a compressive prestress in the lower flange of the beams.

1. Design the rods and attachments to carry the intended post-tensioning forces.

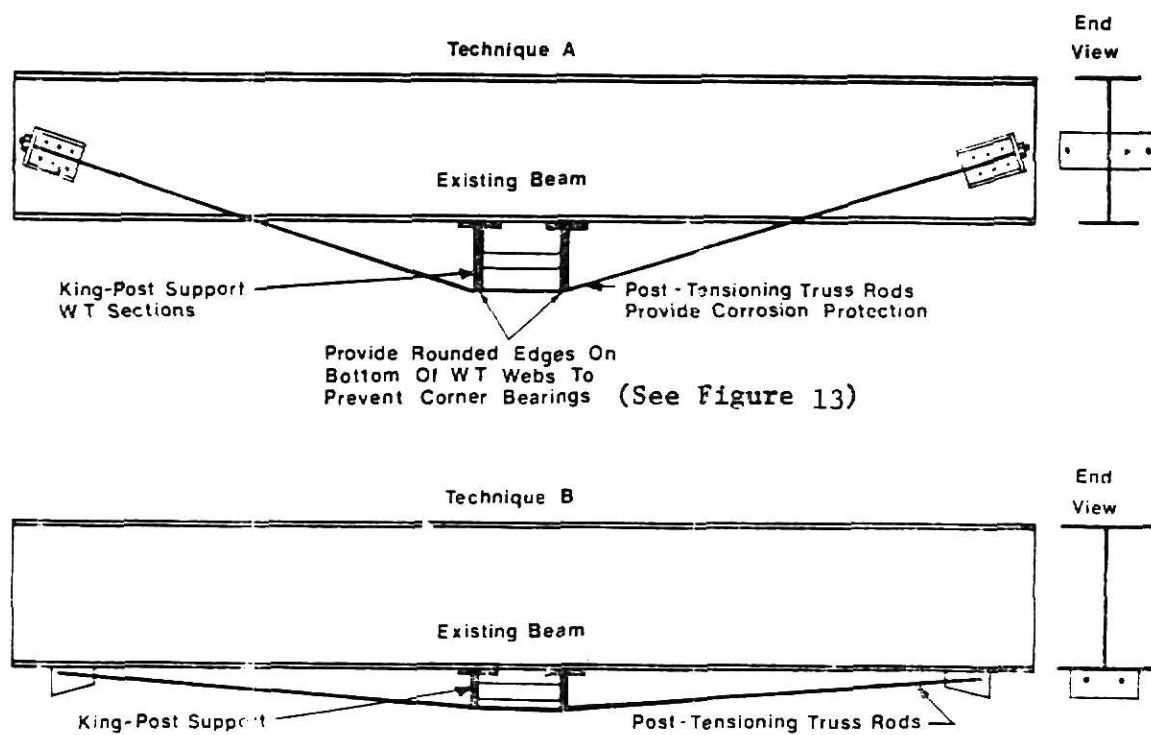


Fig. 12 Elevation of a King-post Strengthened Beam.
Two Techniques are Shown. (11)

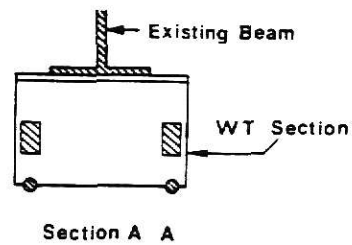
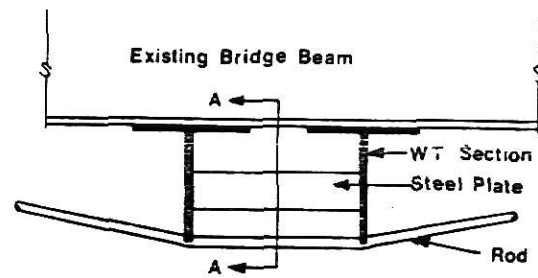
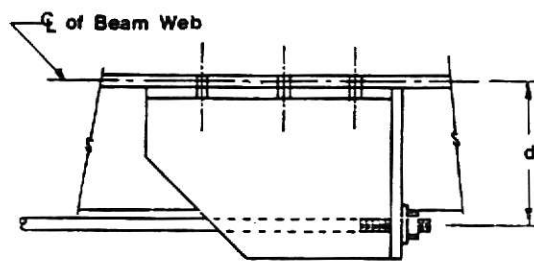


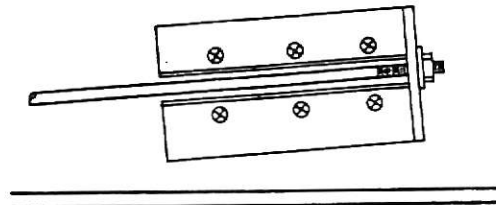
Fig. 13 Partial Elevation Showing Typical King-post Design at Midspan (11)



Partial Plan

* - 'd' should not exceed the minimum distance required for the tensioning rods to clear the flange.

Note: A built up section may sometimes be required.



Partial Elevation

Fig. 14 Typical Rod Connection Detail at Ends of Beam (11)

2. Bolt the end anchors for the high strength rods to the lower flange of the steel beam. A short center support may be used to provide a small vertical force at mid-span. See Fig. 13.
3. Place the high strength rods through the anchors and tension to the desired stress level.

Resource requirements: Jacking equipment for post-tensioning, lifting equipment; welding equipment.

Title: Installation of distribution beam.

Description: For existing multi-stringer spans. By using an under-mounted transverse distribution beam, the normal live load stringer distribution requirements of the AASHTO Specifications can be liberalized, thereby equalizing the live load distribution to stringers and consequently allowing a higher live load rating.

Limitations:

1. Should be considered an expedient measure and not a permanent solution.
2. For use with steel beam spans with timber decks and closely spaced stringers.
3. The technique is best adapted to bridges having all I or WF beams of equal size with at least a 10 in. depth.

Construction procedure:

1. Provide necessary underbridge scaffolding for workers.
2. Drill holes at mid-depth of the web of all existing stringers. The holes shall be of sufficient diameter to accommodate the hangers shown in Figs. 15 and 16.
3. Weld the web shear reinforcement as shown in Fig. 15.
4. Insert all hangers without yokes, saddles or nuts in the web holes. See Fig. 15.
5. Position the distribution beam directly under the hanger rods; install the yoke plates on all rods and temporarily wire or wedge them in place. Lift the distribution beam up into the hangers far enough that the yoke plate wedges can be removed.
6. Raise both ends of the distribution beam to the final location; install saddles and tighten all nuts just enough to take all the slack.

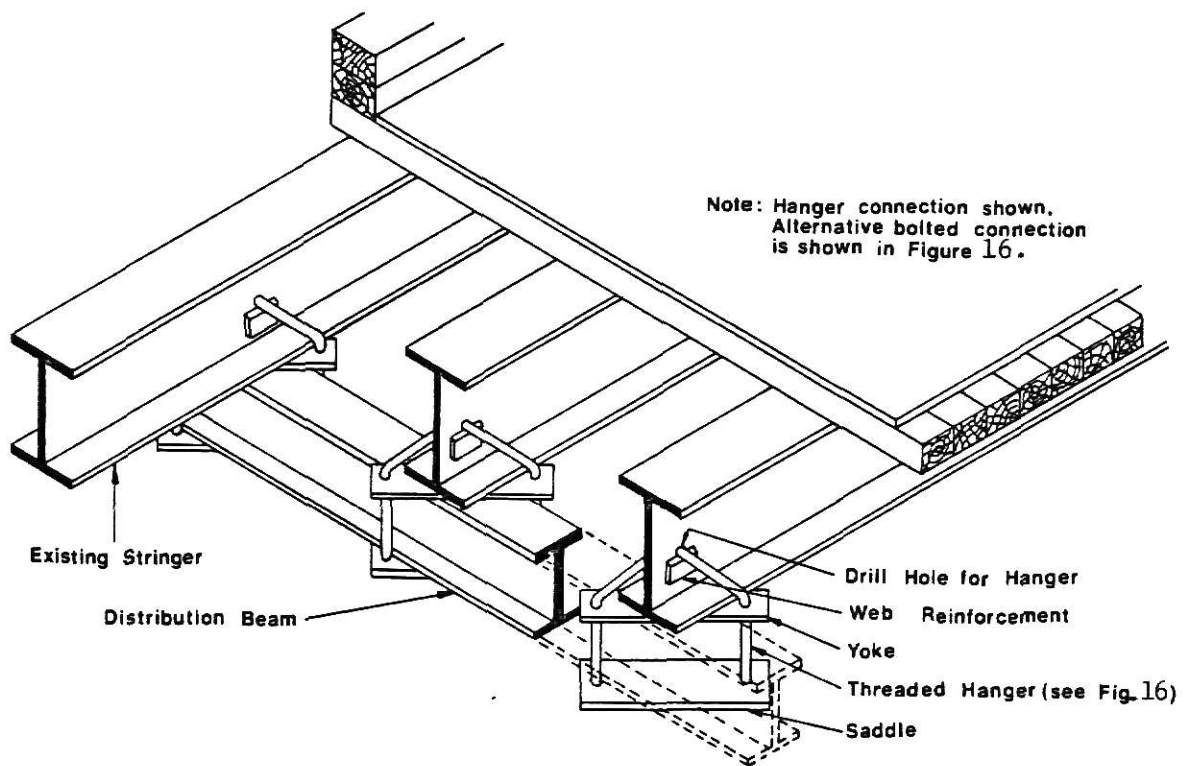


Fig. 15 Distribution Beam Attachment (11)

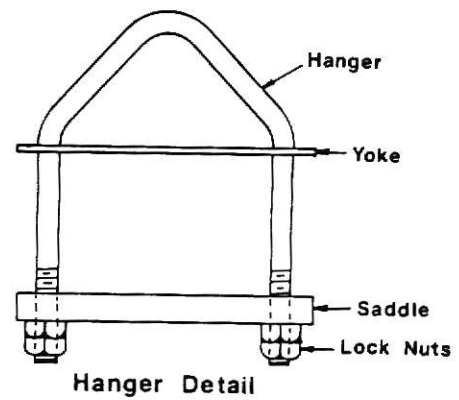
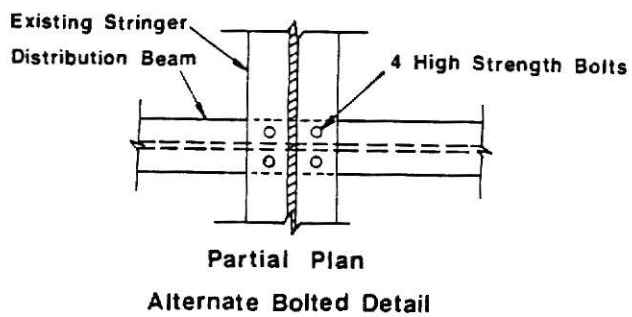
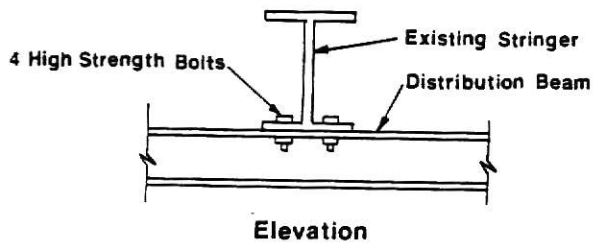


Fig. 16 Attachment Details (11)

7. As an alternate procedure, the upper flange of the distribution beam can be bolted to the lower flanges of the main stringers. See Fig. 16. The flexural capacity of the stringer is, of course, reduced when bolt holes are drilled through the lower flanges and the engineer is cautioned to check the resulting live load capacity when this type connection is used.

8. Remove scaffolding.

Resource requirements: "come-alongs", chains, acetylene torch, electric welding machine, small tools, fabricated materials. Installation can be done by bridge maintenance crew.

Title: Installation of an intermediate support for steel girder bridges.

Description: A steel and concrete pier is erected at or near mid-span to convert a single simply supported span into two shorter continuous spans. The supporting pile groups are driven to the sides of the existing bridge so interruption of traffic is kept to a minimum.

Limitations: The main flexural members of the existing structure must be capable of resisting the negative moment over the new support. If used on a truss a detailed analysis should be carried out to ensure that the truss members are not subject to stress reversals or over-stress.

Construction procedure:

1. Design the new transverse beam and pile up to support the load to be imposed.
2. Drive piles at the desired locations outboard of the bridge rails.
See Fig. 17.
3. Cast the concrete pile caps on top of the pile groups. See Fig. 18.
4. After the concrete has reached sufficient strength, place and jack the new support beam snug against existing stringers. See Fig. 19.
Shim plates are used as required.
5. Place a non-shrink epoxy grout between the beam and the concrete pile caps. See Fig. 20.
6. After the grout has set, drill holes in the concrete pier cap and place the dowels as shown in Fig. 20.
7. Remove the jacks.

Resource requirements: Jacking equipment, crane, pile driving equipment, concrete drilling equipment.

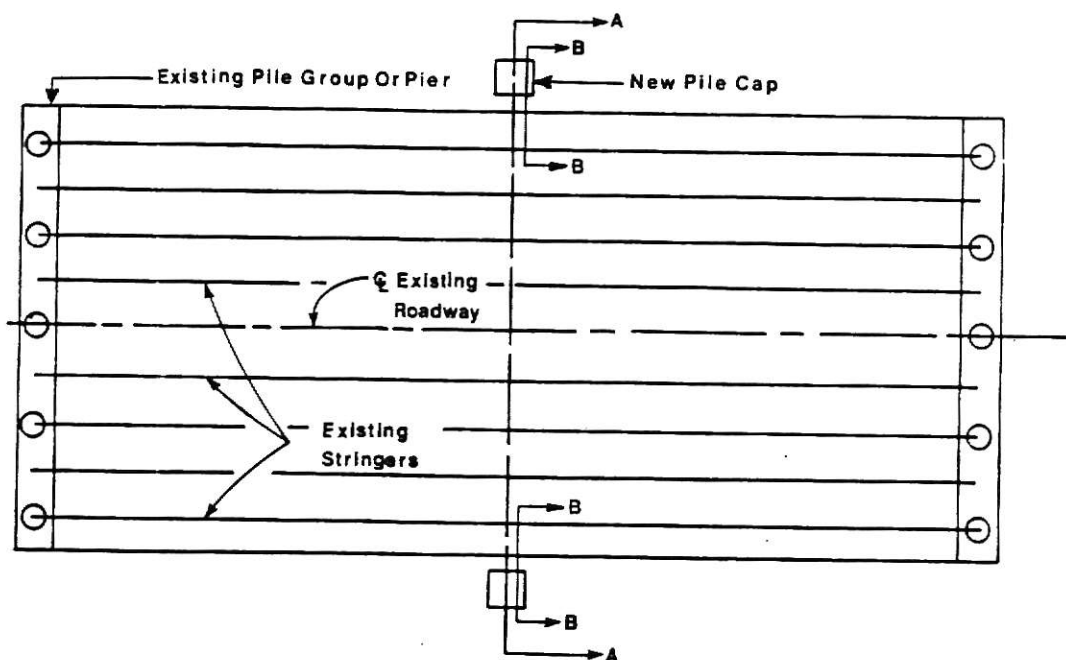
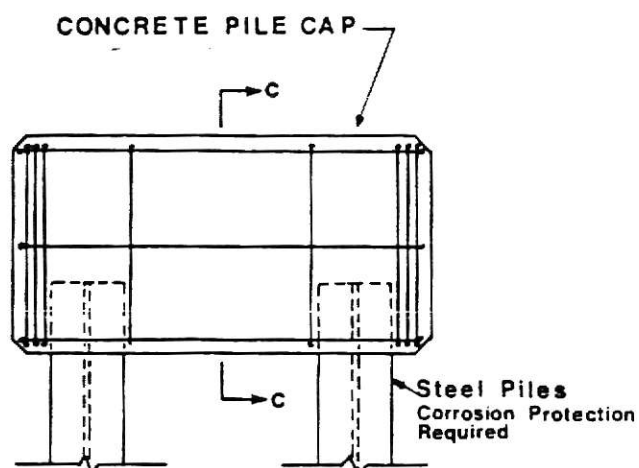


Fig. 17 Plan of Bridge (11)



SIDE ELEVATION OF PILE CAP [Typical]
 The Number And Capacity Of Piles Required Would Depend
 Upon Span And Live Load Requirement Of The Structure

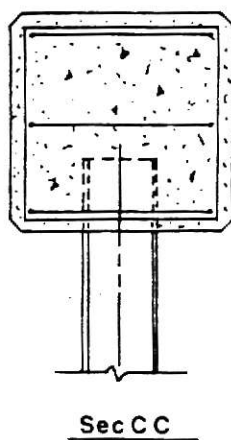


Fig. 18 Details of Pile Cap (11)

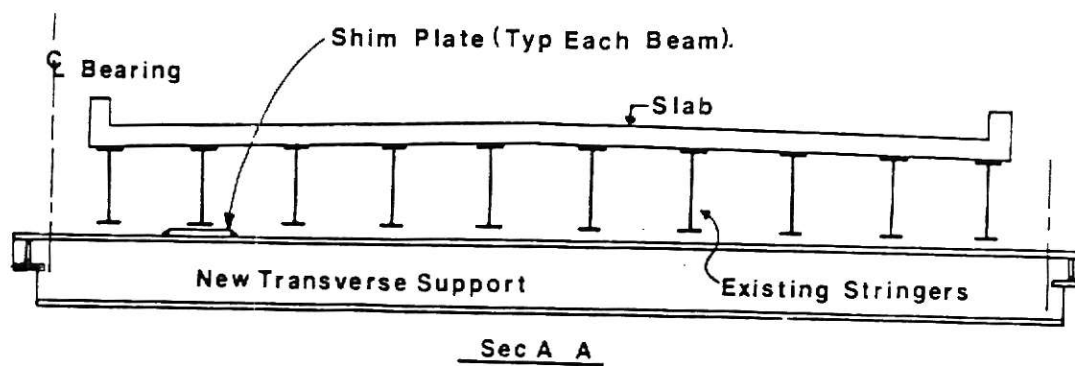


Fig. 19 New Transverse Beam (11)

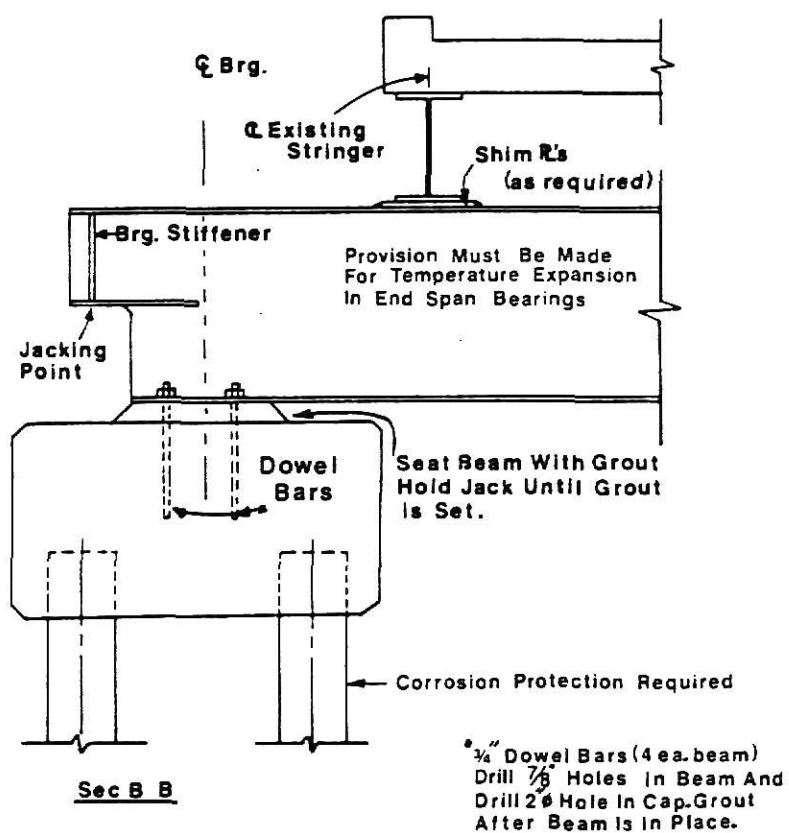


Fig. 20 Detail of New Beam Support (11)

Title: Increasing vertical clearance of through truss bridge by modifying the portal bracing.

Description: Clearance on through truss bridge 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. See Fig. 21.

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

Technique B. See Fig. 21.

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

Technique C. See Fig. 21.

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, tongue wrenches and small hand tools.

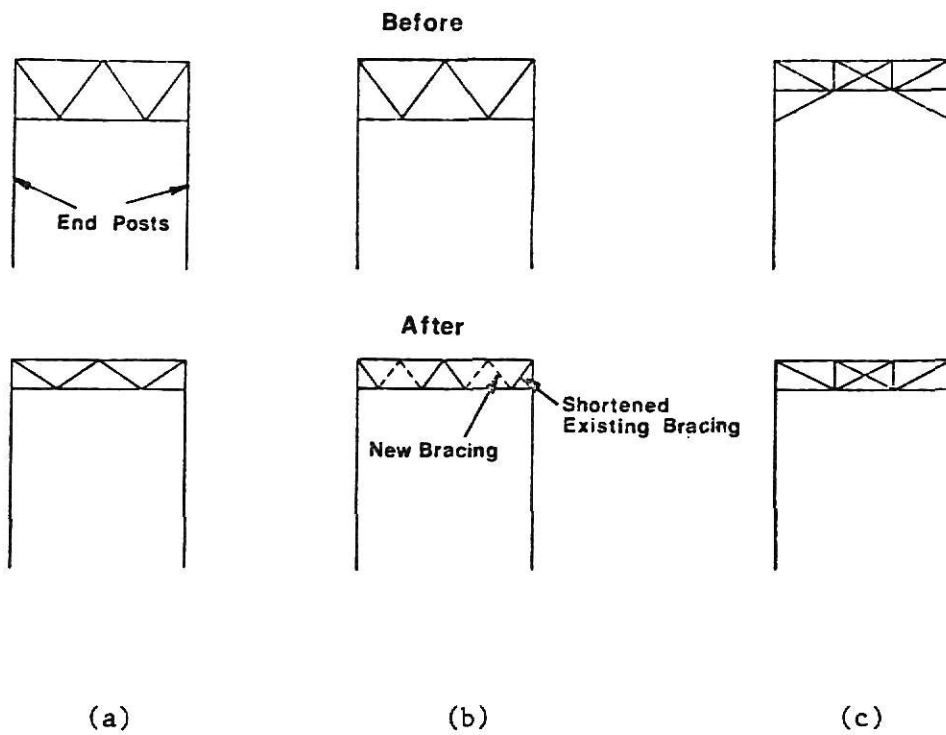


Fig. 21 Examples of Portal Modifications (11)

APPENDIX III
REPLACEMENT ALTERNATIVES (13)

Title: Prefabricated steel bridges.

Description: Standard prefabricated steel superstructure components are connected and topped with a wearing surface to provide a fast-assembly bridge.

Prominent feature: Typically an orthotropic deck is prefabricated as an integral part of a standard steel superstructure component. The standard superstructure components are transported to the bridge site, connected together and covered with a wearing surface to provide a fast-assembly bridge. Several types of systems are available. One system consists of prefabricated T-shaped units which are bolted together at the site. The units are 80 ft. long and 6 ft. wide, and are suitable for multiple span situations requiring spans of 50-110 ft. See Fig. 22.

Another system consists of prefabricated rectangular units which are usually bolted together at the site. Four standard units are available which are interchangeable so that many site conditions can be accommodated. Two of the units are shown in Fig. 23. One is a two-web main girder unit, and the other is a one-web unit which can be bolted to either side of a main girder unit or to another one-web unit to provide a range of roadway widths. The other two standard units are identical to the ones shown in Fig. 23 with the exception that their length is only 19'-8" and their webs are tapered from a depth of 39-1/2" at one end to 19-3/4" at the other end.

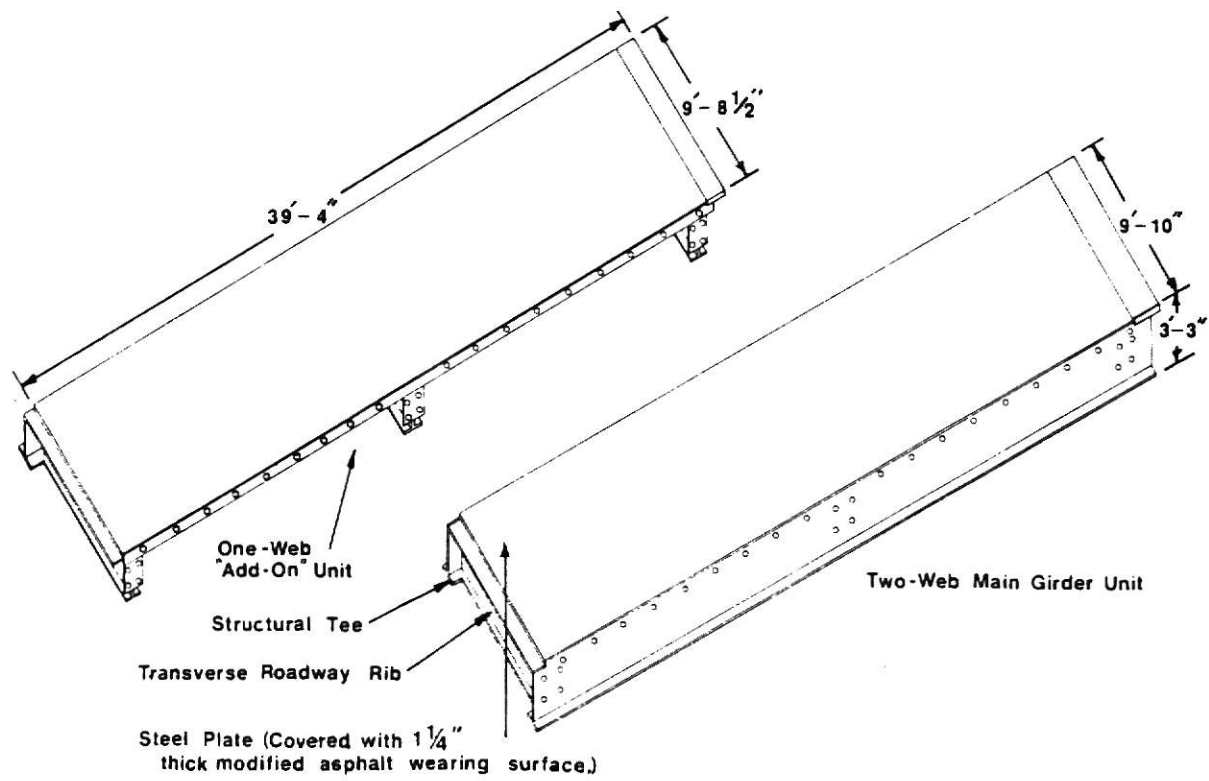


Fig. 22 Prefabricated Steel Tee-Shaped Units (11)

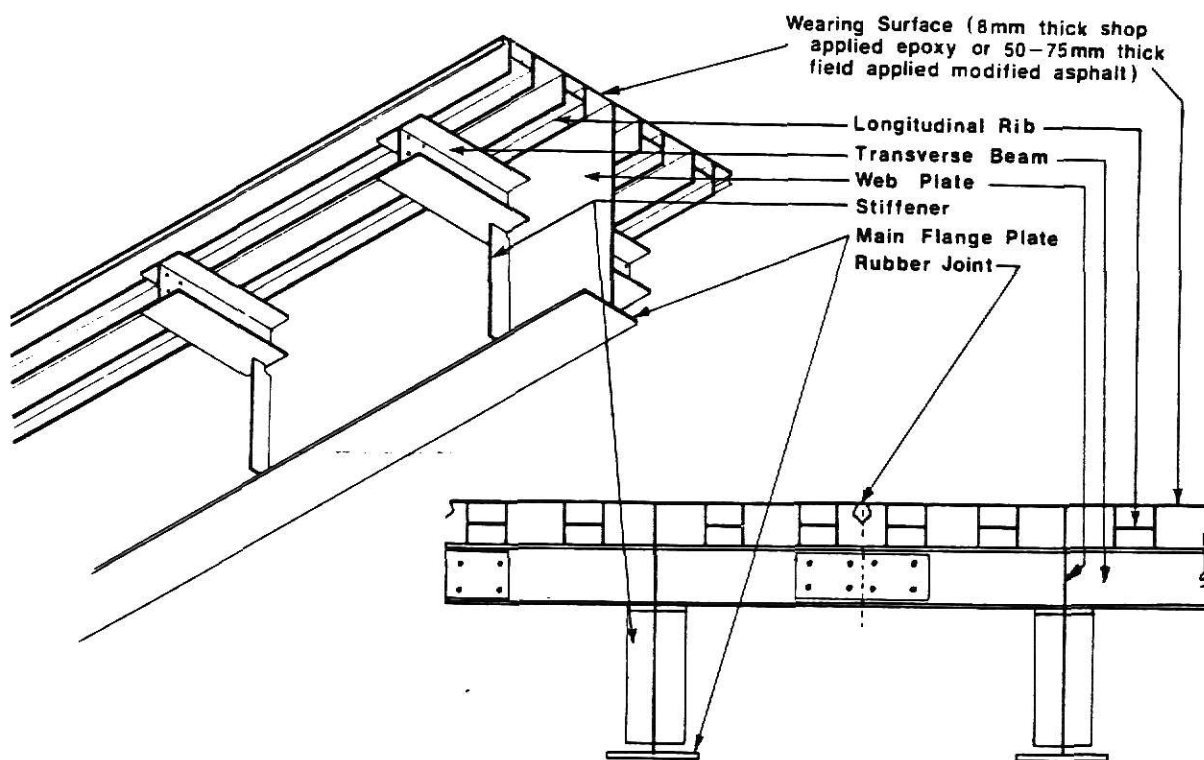


Fig. 23 Prefabricated Steel Rectangular Units (11)

A third system is made up of prefabricated units which consist of several plate girders or rolled sections which are topped with steel bridge plank. The modular units with the plate girders can be used for spans up to 100 ft. and the units with the rolled sections are suited for spans up to 50 ft. See Fig. 24.

A fourth system consists of steel girders and a treated timber deck. Each prefabricated unit supports one line of wheels and the units are connected with diaphragms which are bolted to the units. The structures are presently designed for off-highway logging loadings and the typical span range is 30 to 80 feet. See Fig. 25. Manufacturers who are known to have supplied these steel bridges are indicated below but it is likely that in most instances a local steel fabricator could supply comparable prefabricated units.

Case examples: Tee-shaped units fabricated by Nobels-Kline have been used in South America and Europe and are available in the United States. Rectangular units fabricated by Krupp Company have been used in Germany. Units consisting of bridge plank and plate girders are popular in the Northwest United States, and the units with the rolled sections are popular in the Mid-West United States. The units with the treated timber deck are popular in the logging territories of Alaska.

Manufacturers: Nobels-Kline, Ltd., Columbia, South Carolina; Krupp Company, Rheinhausen, Germany; Spokane Culvert Company, Spokane, Washington; Armco Steel Company, Middletown, Ohio; Hamilton Construction Company, Springfield, Oregon.

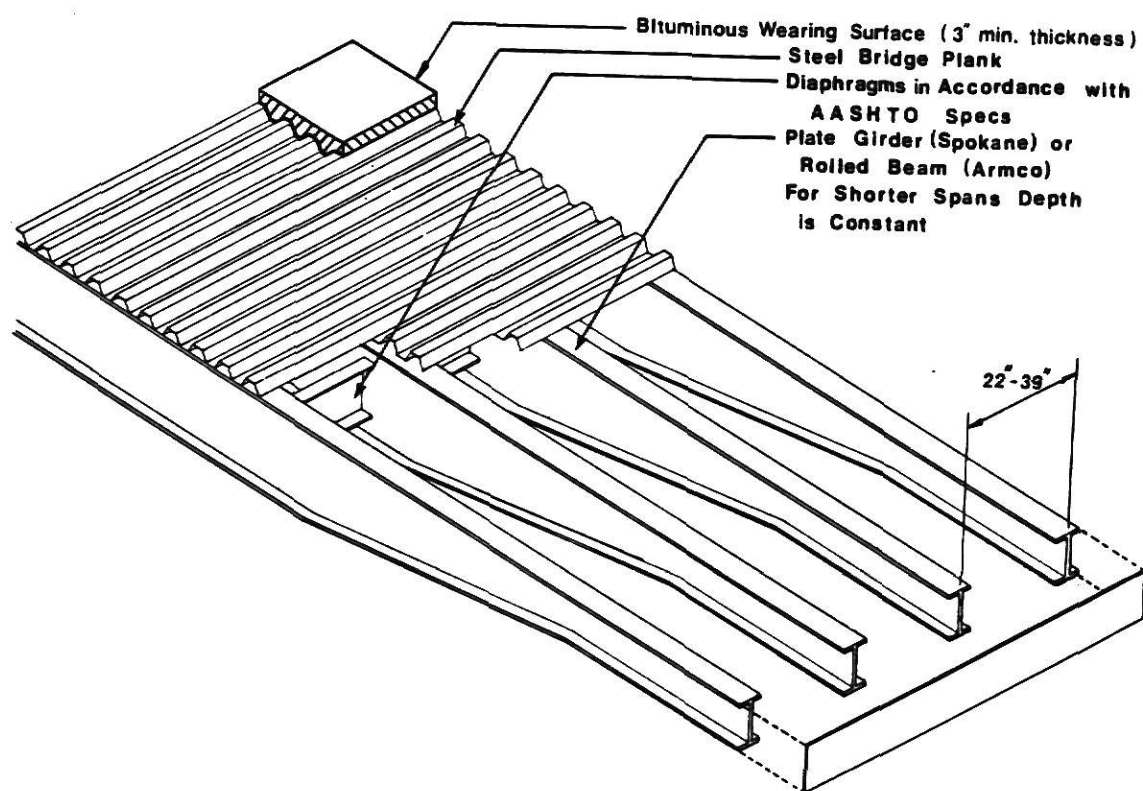


Fig. 24 Steel Bridge Plank on Plate Girders (11)

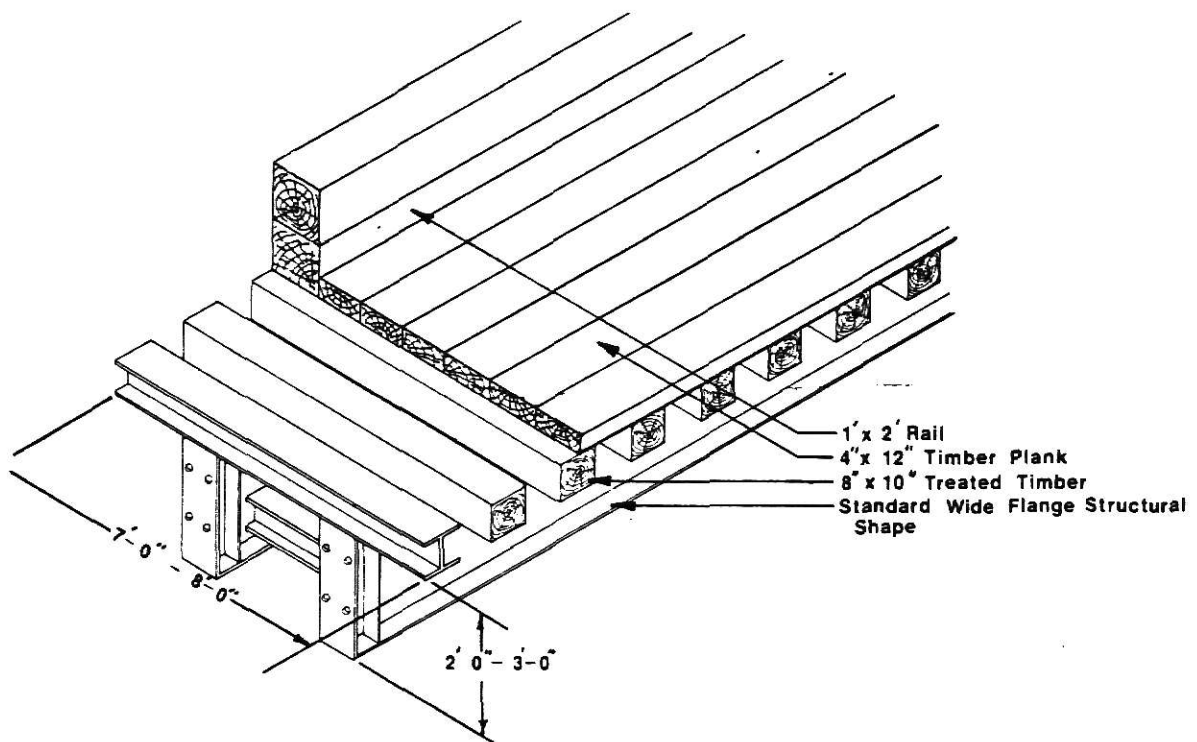


Fig. 25 Treated Timber Deck on Steel Stringers (11)

Title: Temporary bridges.

Description: Steel truss bridges which are quickly assembled at the site from standard preassembled components.

Prominent features: Standard preassembled steel components are easily assembled at the site by unskilled labor. The truss bridges come in a range of widths and can accommodate spans up to 300 ft. (see Fig. 26). The standard components of the bridge are stocked by manufacturers and can be easily transported to the site. Some of the bridges can be launched into place from one end. The bridges are overdesigned for most installations but are extremely versatile as they can be disassembled and used at other sites. Also the bridges can be leased or purchased.

Case examples: Bridges can be found all over the United States and other parts of the world.

Manufacturers: Baily Bridges, Inc., San Luis Obispo, California;
Acrow Corporation of America, Carlstadt, New Jersey.

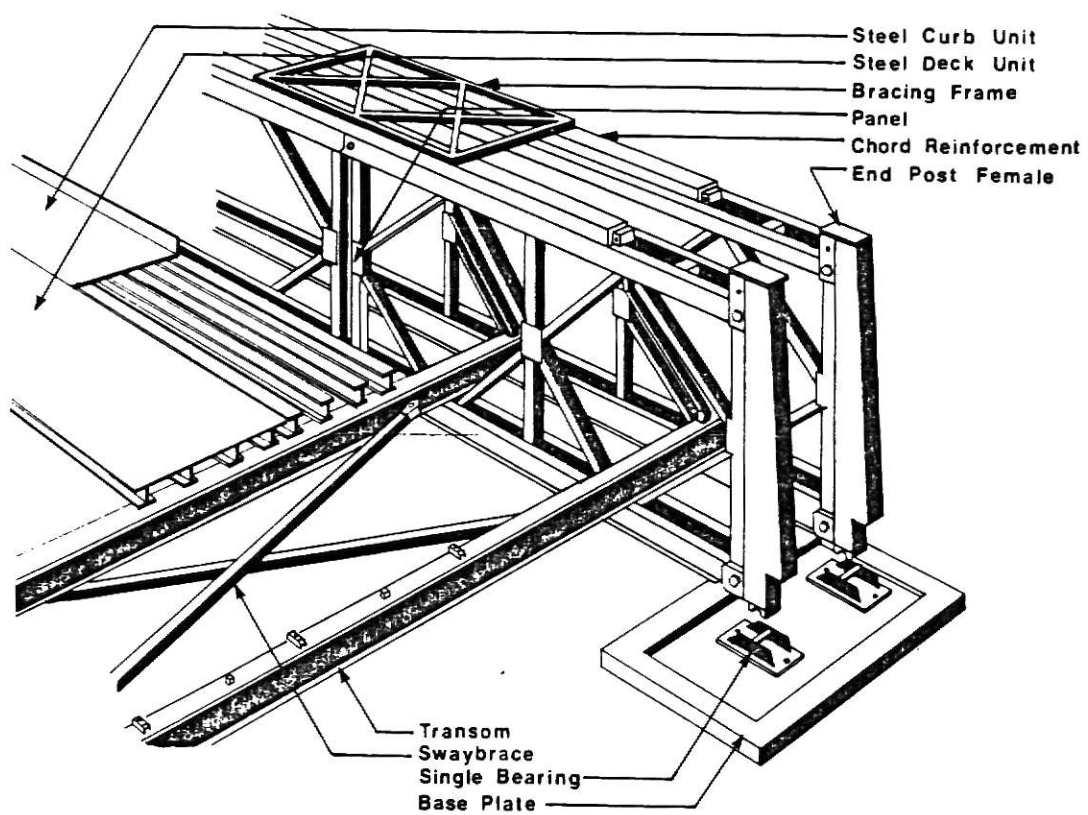


Fig. 26 Temporary Bridge (11)

Title: Laminated timber deck on steel beams.

Description: Laminated timber deck is placed on steel stringers.

Prominent features: The timber laminations may be connected with glue or nails. When the laminations are glued together (glulam) the deck is assembled from panels which are fabricated at a plant. Dowels are usually used to provide for load transfer between panels. When the laminations are nailed together, the deck is usually constructed at the site, in which case dowels are not used, however, panels could be nail laminated at a plant and assembled at the site. The deck is usually connected to a timber bolster with lag bolts as shown in Fig. 27 or connected directly to the flange of the stringers with bolts and clips as shown in Fig. 28. A surfacing material is generally used on the deck for increased resistance to skidding and weathering.

Case examples: Virginia, Alaska and a number of other states.

Manufacturers: Supplies can be obtained from distributions located throughout the country.

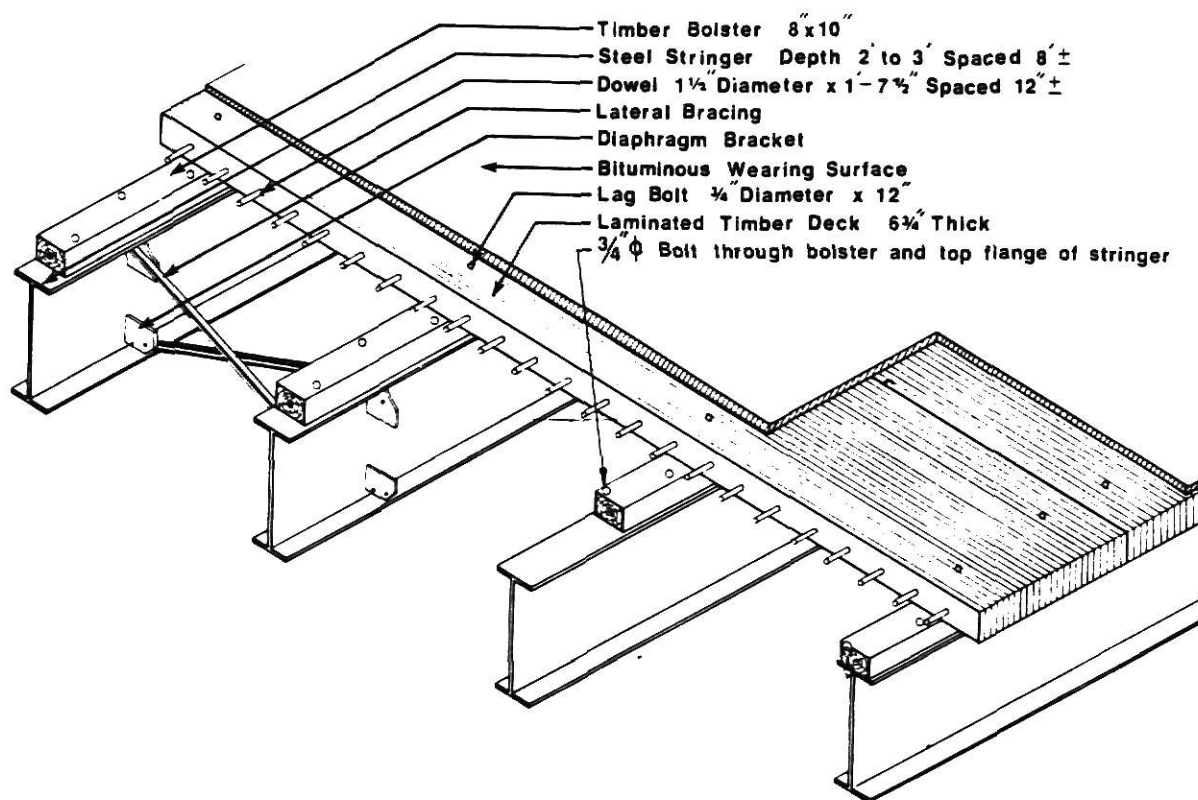


Fig. 27 Laminated Timber Deck on Steel Stringers (11)

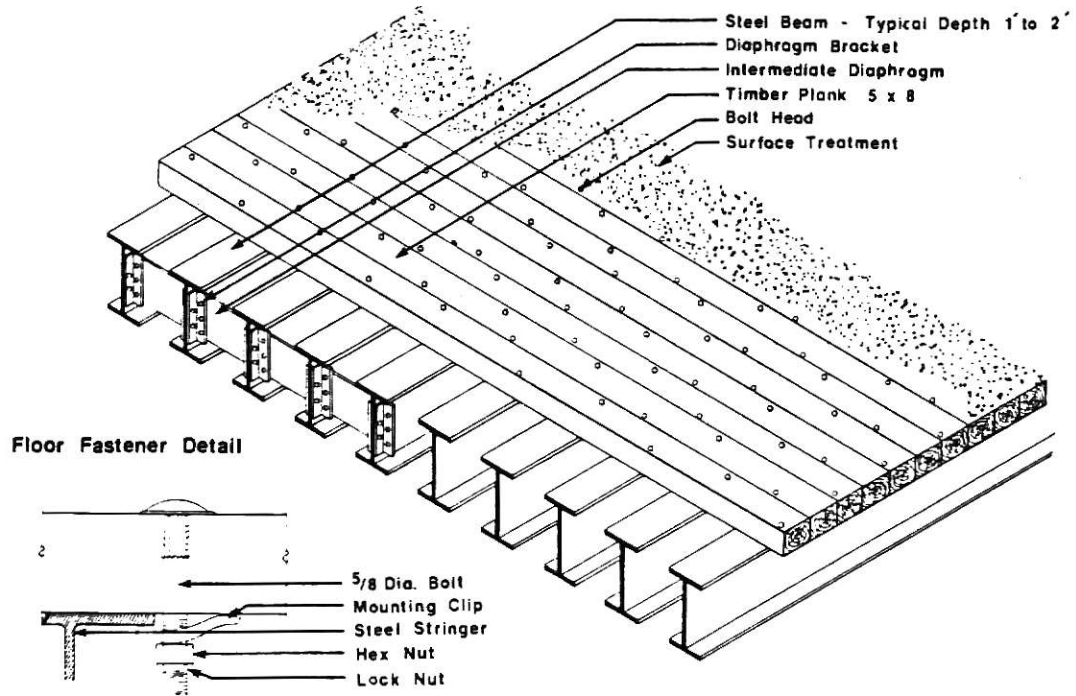


Fig. 28 Timber Plank Deck on Steel Beams (11)

Title: Steel grid deck on steel beams.

Description: Modular steel grid units are placed on steel stringers.

Prominent features: The system consists of steel stringers and modular

open steel grids. The grids may or may not be filled with concrete.

A variety of sizes and grid styles are available to suit the needs of

a particular site. Typically the individual grids are 5 in. x 5 in. x

4 in. deep (see Fig. 29). The panels are usually prefabricated to meet

the needs of a bridge. The grids are relatively light and modular and

therefore lend themselves to rapid deck construction or replacement.

The grids are unique in that they provide a relatively light and shallow

deck system. Skid resistance characteristics can be improved by adding

steel studs or roughening the top surface by other means. Filling the

grid with concrete also improves the skid resistance.

Case examples: Kansas, Pennsylvania and Virginia.

Manufacturers: Greulich, Inc., specializes in grids. Other steel

companies should be able to fabricate the grids.

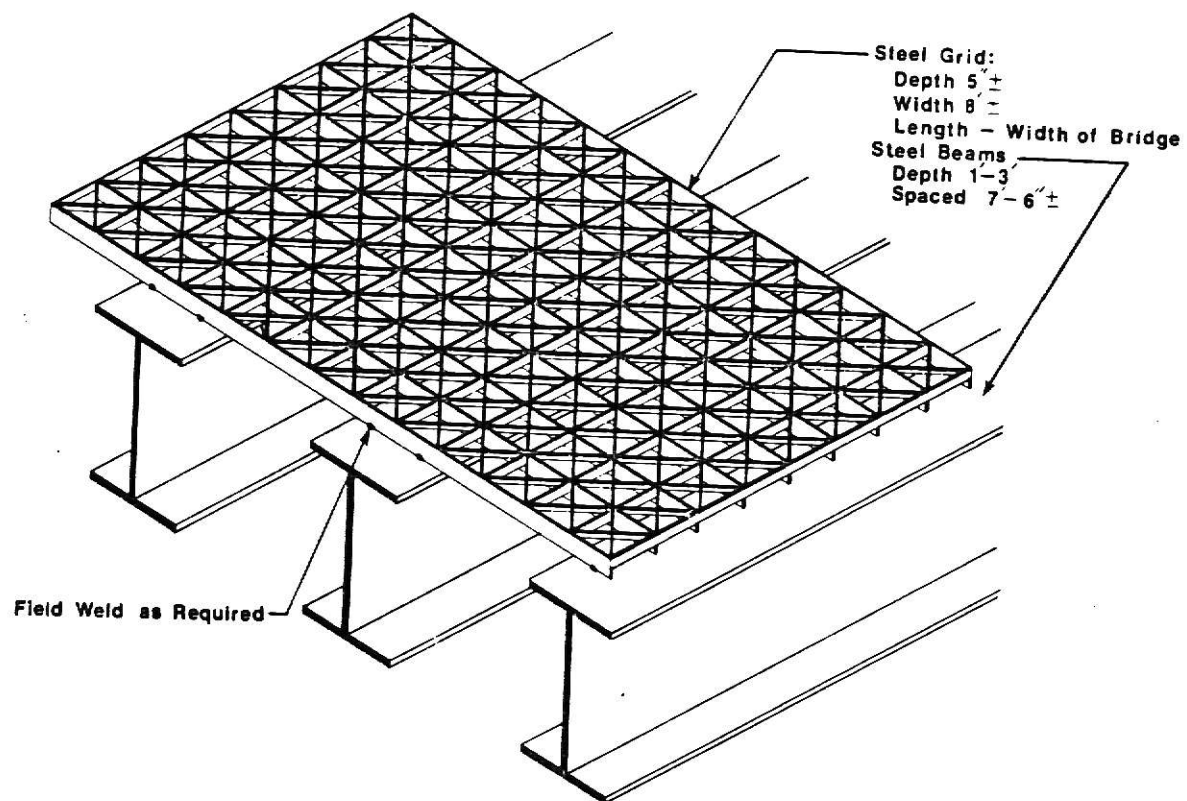


Fig. 29 Steel Grid Deck on Steel Beams (11)

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REPAIR, REPLACEMENT OR STRENGTHENING
OF SHORT SPAN STEEL BRIDGES ON
SECONDARY HIGHWAYS

by

PETER MICHAEL OBINOMEN

B.S., Kansas State University, 1980

AN ABSTRACT OF A MASTER'S REPORT

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requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

ABSTRACT

With major emphasis being placed on the major highways, especially those on the interstate system, and new construction in recent years, bridges on secondary highways have frequently been neglected. They have been given irregular inspections, inadequate maintenance and infrequent load capacity ratings. This study identifies the more common bridge deficiencies, and suggests a procedure to help in deciding whether to repair or replace deficient bridges. Repair procedures are identified in the event that the repair alternative is chosen. Replacement alternatives are identified in the event that the replacement alternative is chosen. Lastly, some methods are described for strengthening deficient steel bridge members.