CHAPTER 2

TYPES OF TIMBER BRIDGES

2.1 INTRODUCTION

Timber bridges are seen today in many types and configurations. Some of these bridges evolved from designs developed many years ago, while others have developed as a result of modem technological advances in timber design and fabrication. Regardless of the specific configuration, all timber bridges consist of two basic components, the superstructure and the substructure (Figure 2-1). The superstructure is the framework of the bridge span and includes the deck, floor system, main supporting members, railings, and other incidental components. The five basic types are the beam, deck (slab), truss, arch, and suspension superstructures. The substructure is the portion of the bridge that transmits loads from the superstructure to the supporting rock or soil. Timber substructures include abutments and bents. Abutments support the two bridge ends, while bents provide intermediate support for multiple-span crossings.

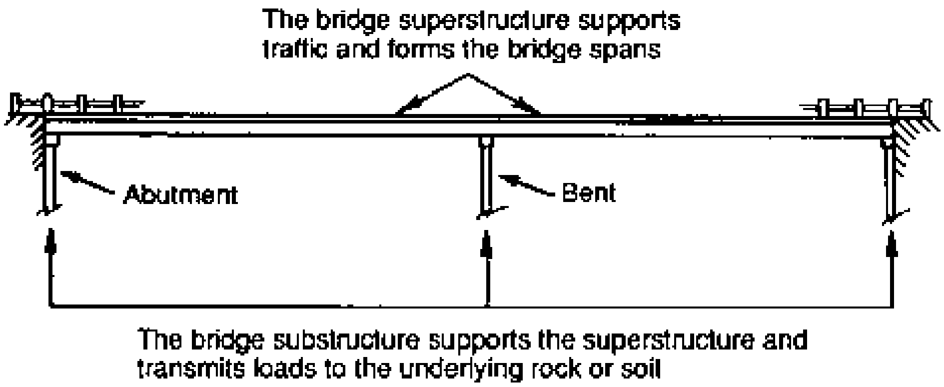


Figure 2-1.- Basic components of a timber bridge.

This chapter provides an introduction to the many types of timber bridges currently used in the United States. Superstructures are discussed first, followed by decks and substructures. Although decks are technically part of the superstructure, they are addressed separately because of their varied application on many superstructure types.

2.2 BEAM SUPERSTRUCTURES

Longitudinal beam superstructures are the simplest and most common timber bridge type (in bridge design, the longitudinal direction is measured in the direction of the traffic flow). Longitudinal beam superstructures consist of a deck system supported by a series of timber beams between two or more supports. Bridge beams are constructed from logs, sawn lumber, glued-laminated timber, or laminated veneer lumber (LVL). Individual beams may be termed stringers or girders, depending on the relative size of the member. Girders are larger than stingers; however, there is no clear-cut definition for either. For clarity, the word *beam* is used here to collectively define all longitudinal beam elements, including stringers and girders.

LOG BEAMS

The simplest type of timber bridge is the log beam or native timber bridge. It is constructed by placing round logs alternately tip to butt and binding them together with steel cables. A transverse (perpendicular to traffic flow) distributor log or needlebeam is normally attached to the bridge underside at centerspan to aid in load distribution. The deck for log beam bridges is formed by spiking sawn lumber planks across the log tops (Figure 2-2), or by placing soil and rocks on the logs (Figure 2-3).

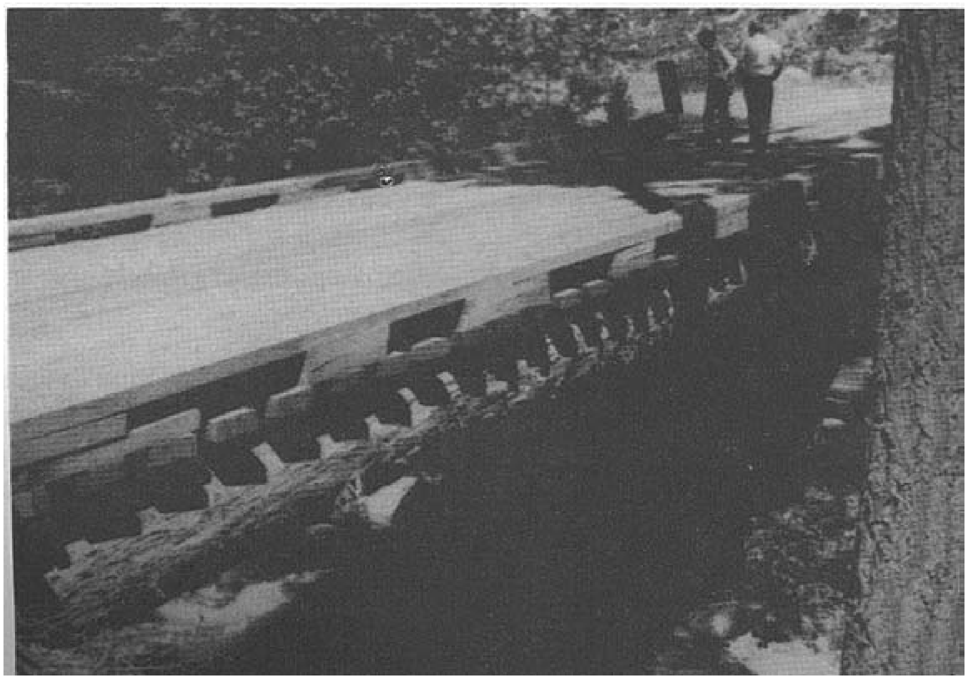


Figure 2-2.-Log beam bridge with a transverse plank deck.

Figure 2-3.- Log beam bridge with a gravel deck. The two large “brow” logs along each side serve to delineate the roadway and function as a type of railing.

The span of log beam bridges is limited by the available species and the diameter and length of trees. Clear spans of 20 to 60 feet are most common; however, spans approaching 100 feet have been built that support off-highway trucks weighing in excess of 100 tons. Log bridges are generally not treated with preservatives and are primarily used as temporary structures. Service life typically ranges from 10 to 20 years, depending on log species and local conditions of use. Although log beam bridges may appear to be rather crude, they have proven to be very functional. Hundreds of these bridges are currently in use in the United States and Canada, primarily on logging and other low-volume roads. The basic concept has been adapted into many configurations, some of which are quite sophisticated.

SAWN LUMBER BEAMS

Sawn lumber beam bridges are constructed of closely spaced lumber beams that are commonly 4 to 8 inches wide and 12 to 18 inches deep (Figure 2-4). Solid timber blocking or lumber bridging is placed between beams for alignment and lateral beam support. Sawn lumber beam bridges are limited in span by the availability of lumber beams in the required sizes. They are most commonly used for clear spans of 15 to 25 feet with a practical maximum for highway loads of approximately 30 feet (Figure 2-5). Longer crossings are achieved by using a series of simple spans with intermediate supports.

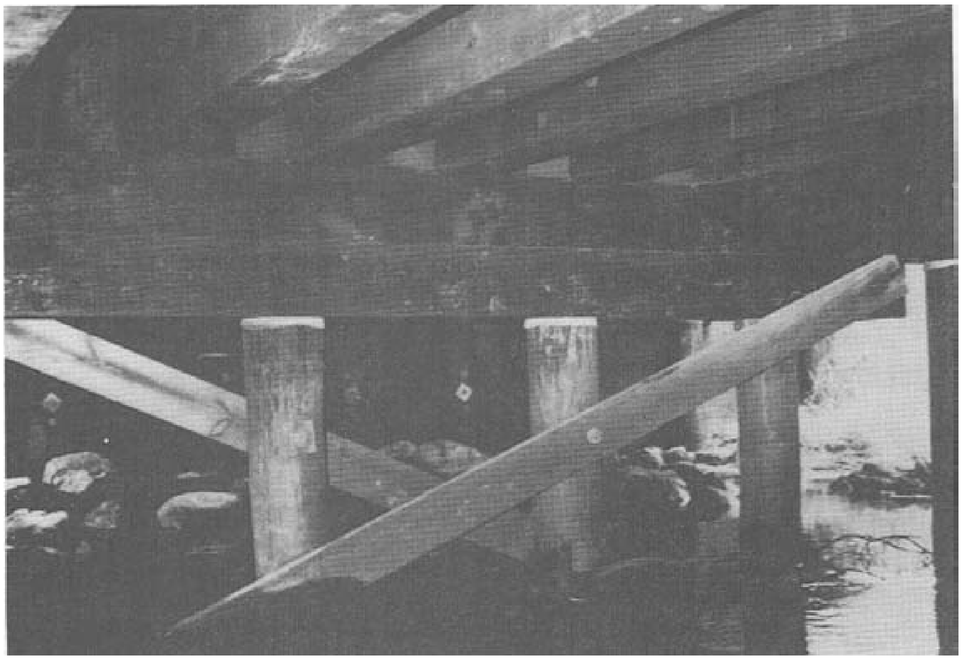


Figure 2-4.- Underside of a sawn lumber beam bridge showing the characteristic close beam spacing. This photo is of the center bent of a two-span crossing, where beams from the two spans overlap at the support.

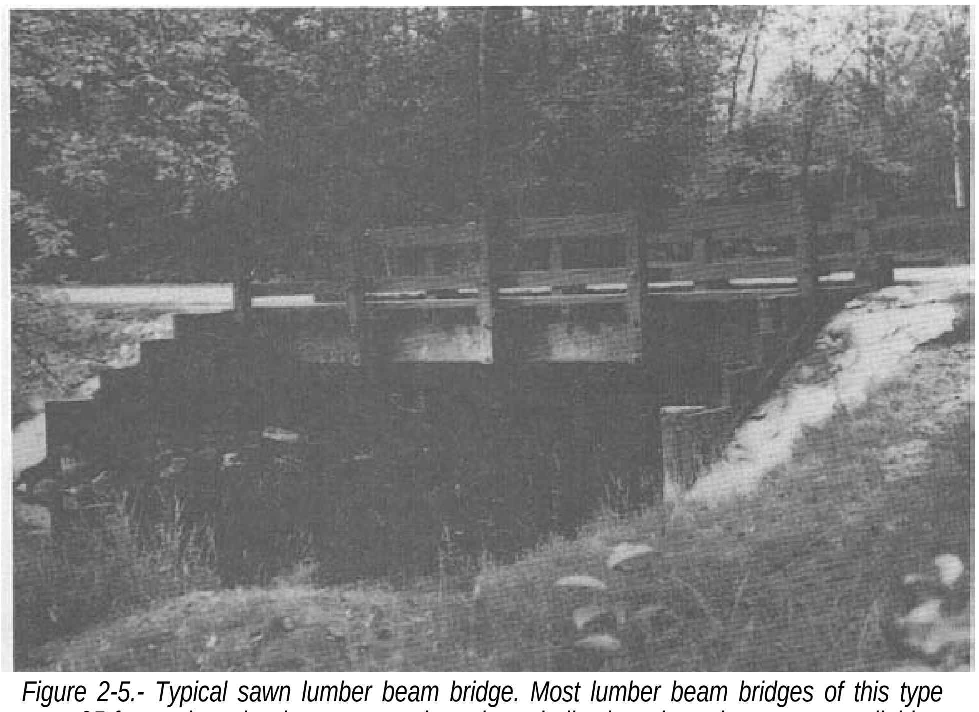


Figure 2-5.- Typical sawn lumber beam bridge. Most lumber beam bridges of this type span 25 feet or less, but longer spans have been built where large beams are available.

Sawn lumber beam bridges have been built in the United States for generations. They are economical, easy to construct, and well suited to secondary and local roads where long clear spans are not required. The service life of lumber bridges treated with preservatives averages about 40 years. Although their use has declined significantly since the introduction of glulam, many of the sawn lumber beam bridges built in the 1930's and 1940's are still in service.

GLUED-LAMINATED TIMBER BEAMS

Glulam bridges are constructed of glulam beams manufactured from 1-1/2- or 1-3/8-inch-thick lumber laminations that are bonded together on their wide faces with waterproof structural adhesive. The beams are available in standard widths ranging from 3 inches to 14-1/4 inches, with beam depth limited only by transportation and pressure-treating size considerations. Because of the large size of glulam beams, glulam beam bridges require fewer beams and are capable of much longer clear spans than conventional sawn lumber beam bridges (Figure 2-6). They are most commonly used for spans of 20 to 80 feet, but have been used for clear spans over 140 feet (Figure 2-7). The length of the beams, and thus the bridge, is normally limited only by transportation restrictions for moving the beams to the construction site.

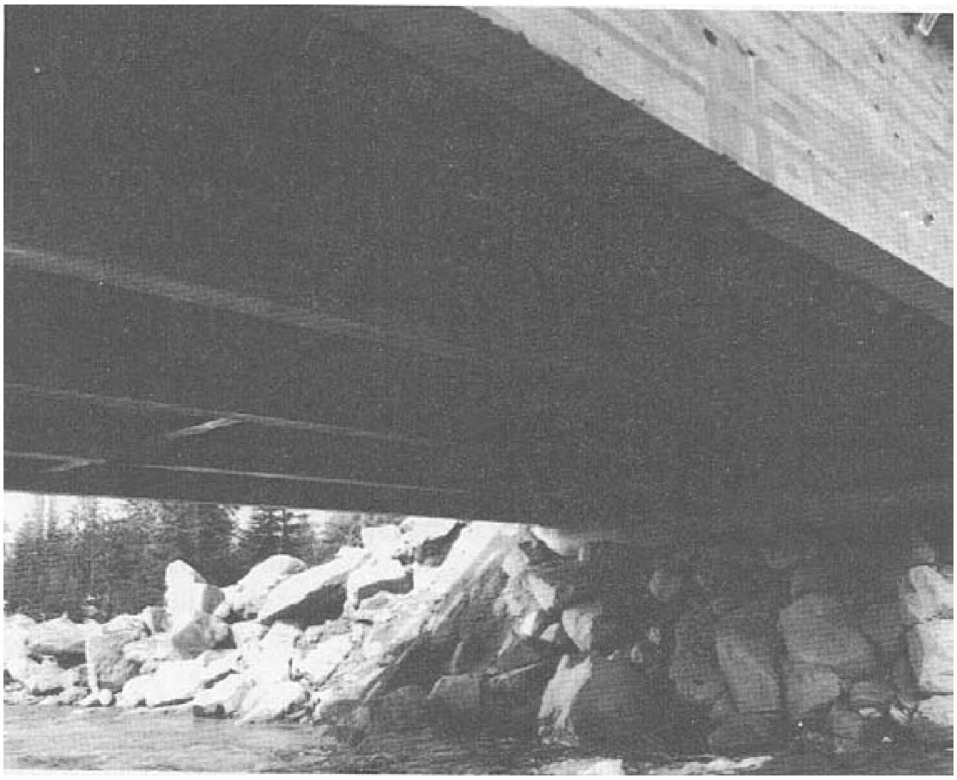


Figure 2-6.- Underside of a glulam beam bridge. Because glulam beams are manufactured in a wide range of sizes, glulam bridges typically have larger beams and a greater beam spacing compared to conventional sawn lumber beam bridges (photo courtesy of Weyerhaeuser Co.).

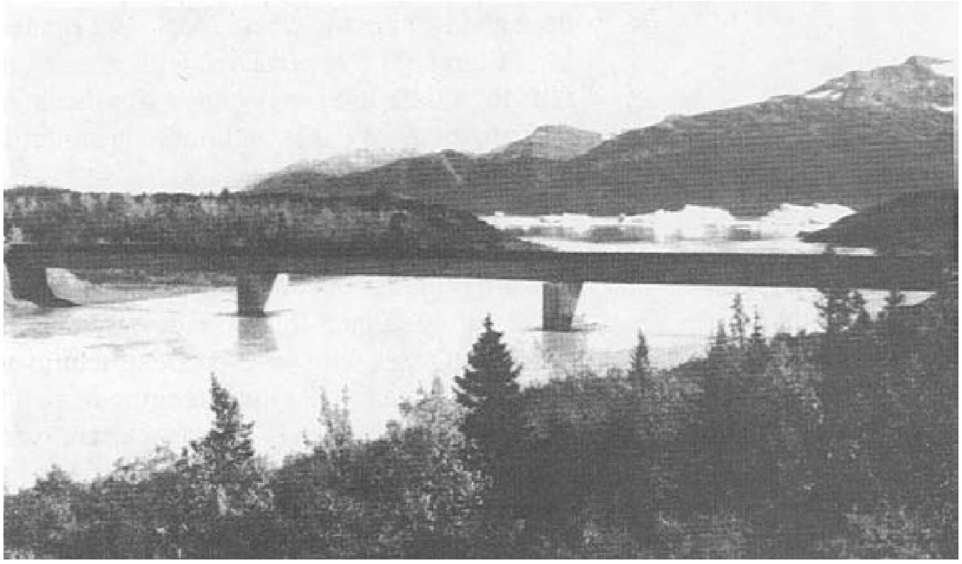


Figure 2-7.- Glulam beam bridge over Dangerous River, near Yukatat, Alaska. This bridge consists of three 143-foot spans, each of which is supported by four glulam beams that are 91-1/2 inches deep (photo courtesy of the Alaska Department of Transportation and Public Facilities).

The first glulam beam bridges were built in the mid-1940's. Since that time, they have become the most common type of timber bridge in both single- and multiple-span configurations. Glulam beam bridges are completely prefabricated in modular components and are treated with preservatives after fabrication. When properly designed and fabricated, no field cutting or boring is required, resulting in a service life of 50 years or more.

LAMINATED VENEER LUMBER BEAMS

Laminated veneer lumber, a subcategory of new wood products called structural composite lumber, is a relatively new material for use in bridge construction. It is made from sheets of thin veneer that are glued together to form structural members. The veneer laminations are approximately 1/10 inch to 1/2 inch thick and are oriented vertically, instead of horizontally, as in glulam beams (Figure 2-8). Although LVL is made from veneer, it is more like glulam than like plywood because the grain directions of adjacent plies are parallel rather than at right angles. The advantages of LVL are its high strength, stiffness, and excellent treatability with wood preservatives.

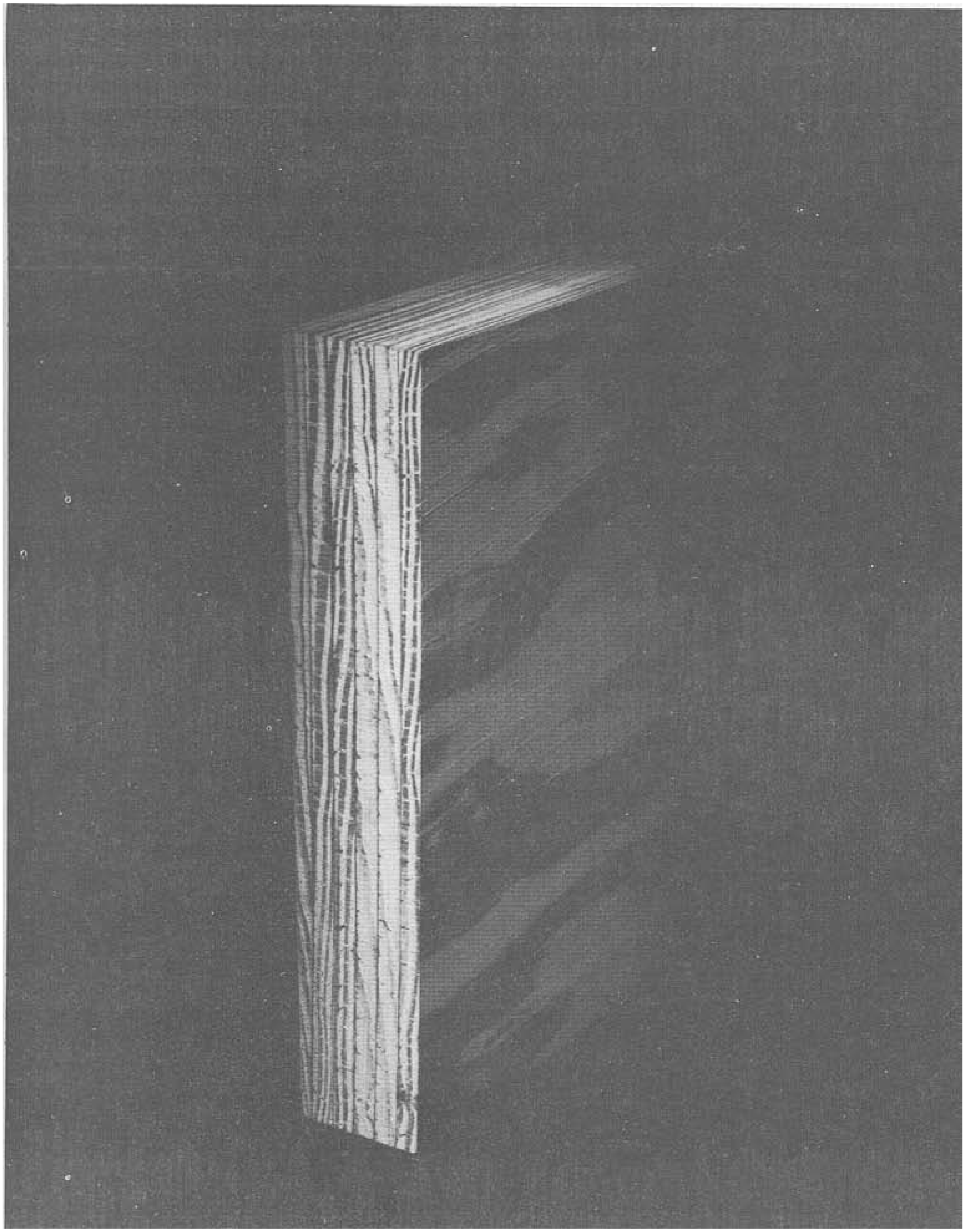


Figure 2-8.- End section of an LVL beam; LVL beams are manufactured by gluing together sheets of veneer. The grain direction of the veneer layers is oriented in the same direction, parallel to the direction of the beam span.

The only LVL beam bridge constructed to date is made of press-lam, a type of LVL developed at the USDA Forest Service, Forest Products Laboratory (FPL). This prototype structure, jointly sponsored by the Forest Service and the Virginia State Highway Department, consists of a 3-1/8-inch deck supported by 4-1/2- by 20-inch press-lam beams, spaced 30 inches on center (Figure 2-9). Design requirements and stresses for LVL are not included in current bridge design specifications, but they may be adopted in the future. Additional information on construction and performance of the press-lam demonstration bridge is given in references listed at the end of this chapter. [8,18,19,32]

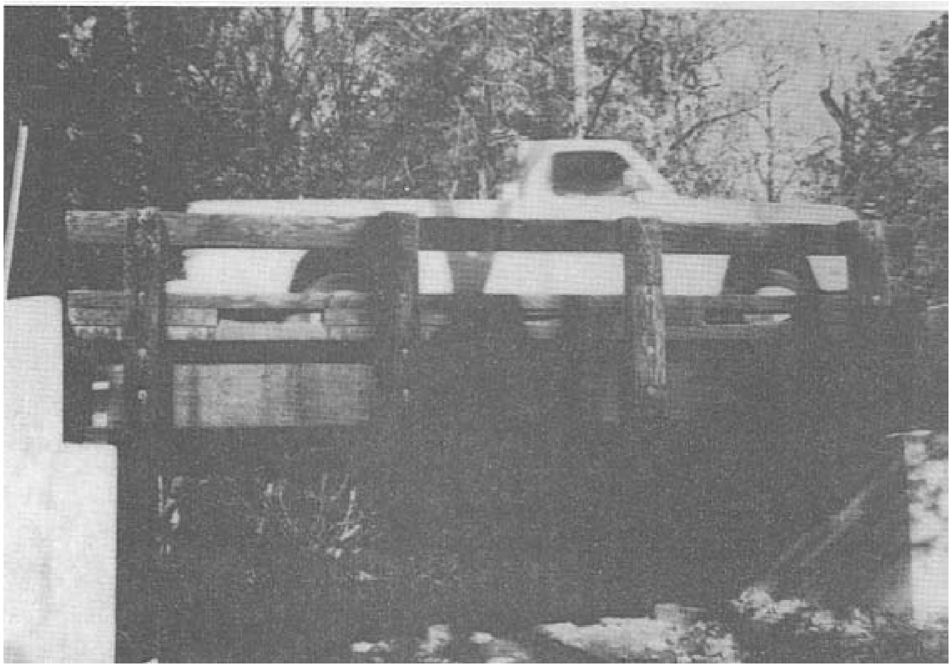


Figure 2-9.- Press-lam LVL bridge built in 1977 on the George Washington National Forest in Virginia. The bridge spans 20 feet and carries a 26-foot-wide roadway.

2.3 LONGITUDINAL DECK SUPERSTRUCTURES

Longitudinal deck or slab superstructures are constructed of glulam or nail-laminated sawn lumber placed longitudinally between supports, with the wide dimension of the laminations vertical. The deck is designed to resist all applied loads and deflection without additional supporting members or beams; however, transverse distributor beams are usually attached to the deck underside to assist in load distribution. Glulam longitudinal deck bridges are constructed of panels that are 6-3/4 to 14-1/4 inches deep and 42 to 54 inches wide (Figure 2-10). Sawn lumber bridges use 2- to 4-inch-wide lumber, 8 to 16 inches deep, that is nailed or spiked together to form a continuous surface (Figure 2-11). Longitudinal deck bridges are economical and practical for maximum clear spans up to approximately

36 feet. Longer crossings are achieved with multiple spans. The low profile of these bridges makes them desirable when vertical clearance below the bridge is limited.

Figure 2-10.- Longitudinal glulam deck bridge over Au Train Creek on the Hiawatha National Forest. This bridge is 58 feet long over three spans and supports a 26-foot roadway width.

Figure 2-11.- Sawn lumber longitudinal deck bridge. Note the transverse distributor beams attached to the deck underside between bents (photo courtesy of Wheeler Consolidated, Inc.).

2.4 **TRUSSES**

Trusses are structural frames consisting of straight members connected to form a series of triangles. In bridge applications, a typical truss superstructure consists of two main trusses, a floor system, and bracing (Figure 2-12). These superstructures are classified as deck trusses or through trusses, depending on the location of the floor system or deck. For deck trusses, the deck is at or above the level of the top chord. For through trusses, the deck is near the bottom chord. When the height of a through truss is insufficient for overhead bracing, it is referred to as a half-through or pony truss.

Timber trusses are constructed in many geometric configurations (Figure 2-13). Two of the most popular are the bowstring truss and parallel-chord truss (top chord and bottom chord parallel). In the bowstring truss,

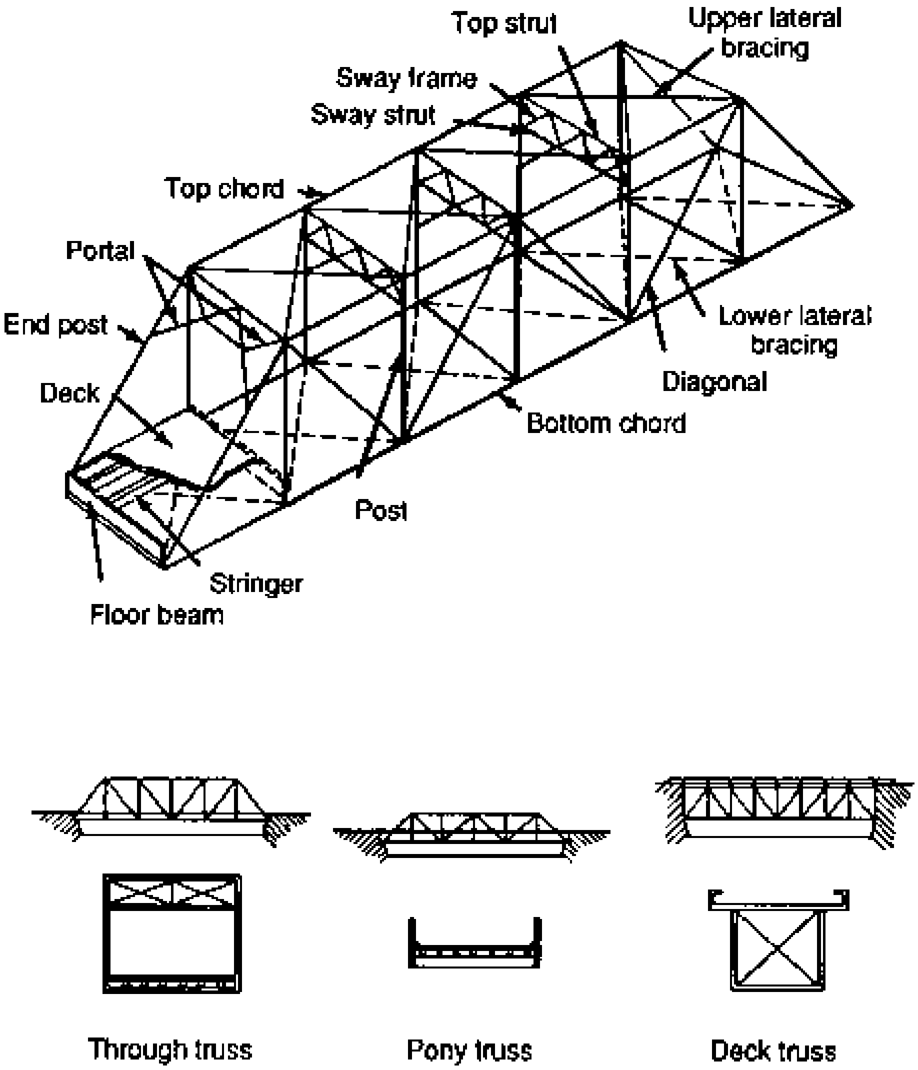


Figure 2-12.—Truss bridge nomenclature and classifications.

the top chord is constructed of curved glulam members or a series of straight sawn lumber members (Figure 2-14). As a pony truss, bowstrings are generally the most economical of all truss types for spans up to 100 feet.[1] For longer spans, the bowstring is designed as a through truss. Parallel-chord trusses are constructed in various through-truss or deck-truss configurations for spans up to approximately 250 feet. As a deck truss, parallel-chord designs are practical when vertical clearance is sufficient for the truss depth and arc especially economical for deep crossings where reduced bent height can result in substructure savings (Figure 2-15).

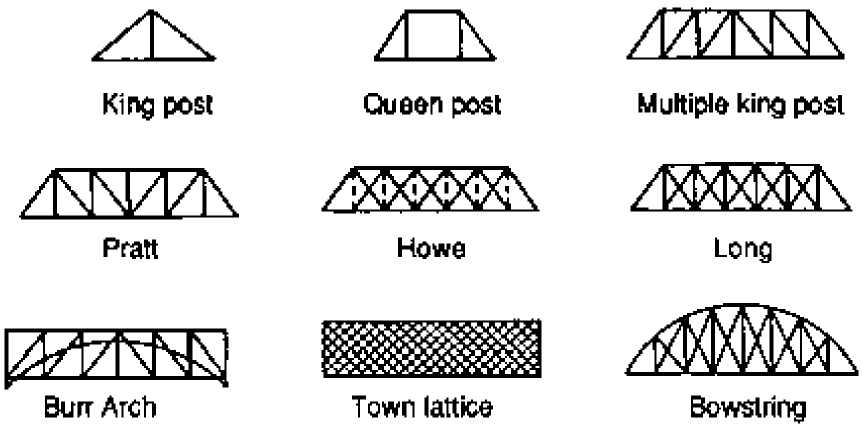


Figure 2-13.—Typical truss configurations for timber bridges.

Figure 2-14.- Lumber bowstring truss over Dinkey Creek on the Sierra National Forest in Central California. This truss spans 90 feet and was built in 1934 (photo courtesy of Raul Gonzalez, USDA Forest Service).

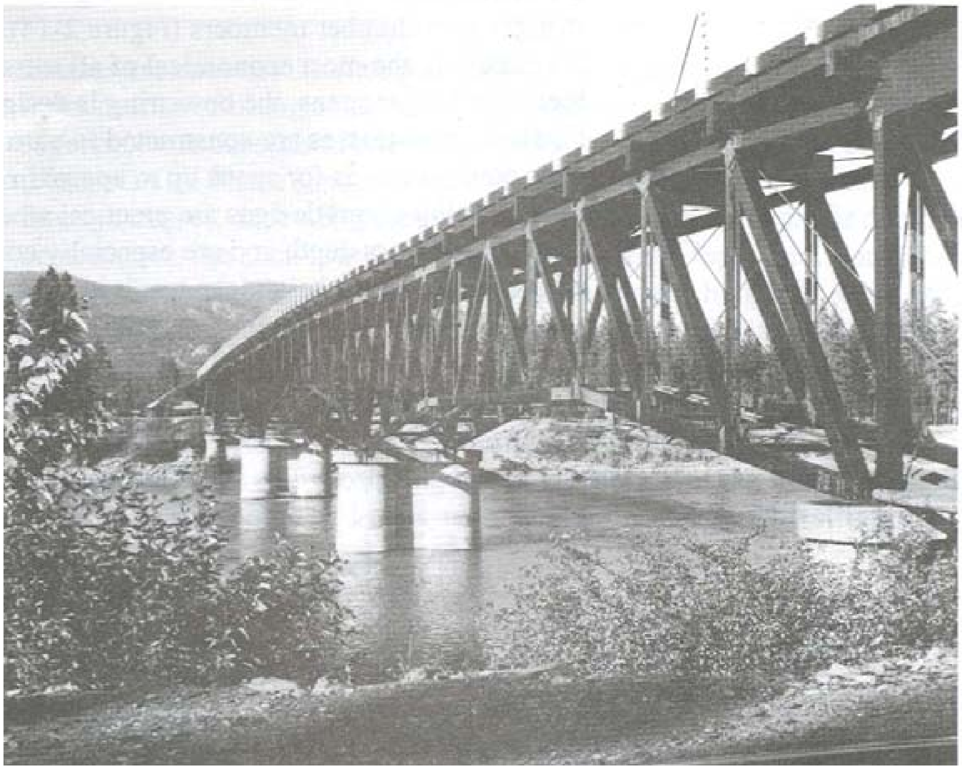


Figure 2-15.- A multiple-span parallel-chord deck truss bridge.

Timber trusses were used extensively for vehicle bridges through the late 1950's, but their popularity has declined because of the high cost of truss fabrication and erection. Trusses are also more costly to maintain than many other bridge superstructures because of the large number of members and joints. Most timber trusses are built today for aesthetic reasons or when the light weight and relatively small individual members make them advantageous for transportation or erection.

2.5 TRESTLES

A trestle is a series of beam, deck, or truss superstructures supported on timber bents (Figure 2-16). Trestles are used for long crossings when lengthy clear spans are unnecessary, impractical, or not economical. Superstructure support for trestle bridges is provided by bents constructed of timber piles or sawn lumber frames (Section 2.10). The spacing between bents is controlled by the span capability of the superstructure. The most common trestle configuration is a series of simply supported sawn lumber beams spanning 20 to 30 feet. Longer spans can be achieved with trusses or glulam beams.

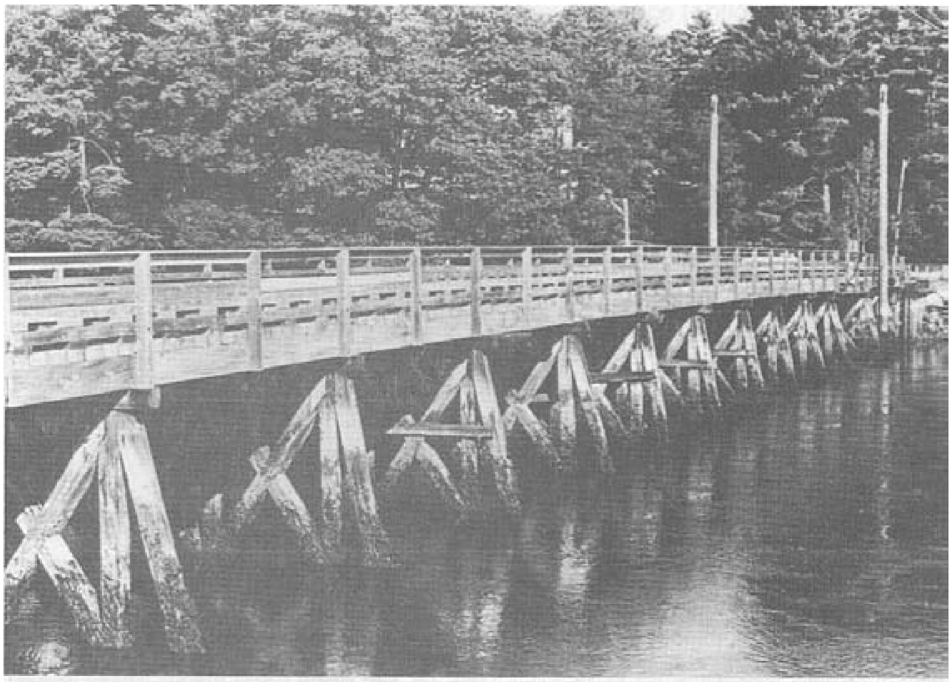


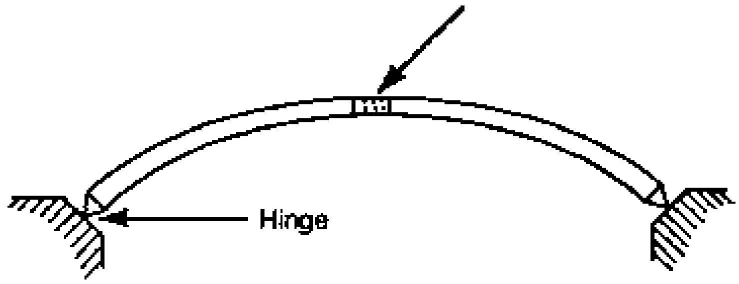
Figure 2-16.- Sewall's bridge is a timber trestle vehicle bridge in York, Maine. The bridge was built in 1933 using the same design features of the original bridge, built in 1761, that it replaced. This bridge became a designated landmark of the American Society of Civil Engineers in 1986 (photo courtesy of the American Society of Civil Engineers; Used by permission).

Trestle bridges have been used in the United States since the mid-1700's. Most were constructed as railroad bridges between 1900 and 1950 (Figure 2-17). In the mid-1950's, approximately 1,800 miles of timber trestles were in service on the Nation's railroads. Trestles were used for vehicle bridges through the 1950's, but their use has since declined because of the high cost of bent construction and the longer clear-span capabilities of glulam. With an average service life of 40 years or more, many treated-timber trestle bridges remain in service today.

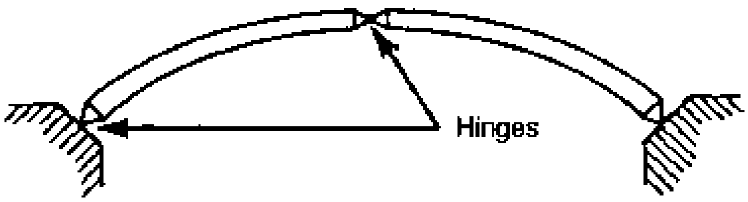
2.6 GLULAM DECK ARCHES

The versatility of glulam in bridge construction is perhaps best demonstrated by glulam deck arch bridges. These structures are constructed of glulam arches manufactured in segmental circular or parabolic shapes and can be used for clear spans in excess of 200 feet. Two basic arch types are used, the two-hinge arch and the three-hinge arch (Figure 2-18). Two-hinge designs are practical for short spans of approximately 80 feet or less. Three-hinge designs are more appropriate for longer spans and are most common for vehicle bridges. The roadway for deck arch bridges is supported by glulam post bents connected to the arches with steel gusset plates.

Figure 2-17.- Early railroad trestle on the Verona, South Park, and Sunset Steam Railroad. Many long-span timber trestles of this type were built for railroad use, requiring large volumes of wood for the complex bent substructures (photo from the Forest Service Collection, National Agriculture Library).



Two-hinge arch is hinged at reactions only.



Three-hinge arch is hinged at reactions and at the arch apex.

Figure 2-18.-Glulam arch configurations used for bridges.

The first glulam deck arches for vehicles were constructed in Oregon in the late 1940's (Figure 2-19). They have since been used in many applications, including the highly publicized Keystone Wye interchange in South Dakota (Figure 2-20). The design is most practical in applications where considerable height is required and where foundations can be constructed to resist horizontal end reactions. It is particularly suitable for deep crossings where savings in substructure costs over other bridge types make it economically competitive.

2.7 SUSPENSION BRIDGES

Timber suspension bridges consist of a timber deck structure suspended from flexible steel cables (or chains) that are supported by timber towers (Figure 2-21). They are capable of long clear spans (over 500 feet) and are normally used only when other bridge types are impractical because of span requirements or when the use of intermediate bents is not feasible. Most timber suspension bridges in the United States have been constructed for pedestrian or trail crossings. Although timber suspension bridges have been built for vehicle traffic, their number is small in relation to other timber bridge types.

Figure 2-19.-- The Loon Lake Bridge is a three-hinge glulam deck arch design, built near Roseburg, Oregon, in 1948. The bridge spans 104 feet and supports a 20-foot roadway.

Figure 2-20.- Three-hinge glulam deck arch bridge at the Keystone Wye interchange off U.S. Highway 16, near Mount Rushmore, South Dakota. The arch spans 155 feet and supports a 26-foot-wide roadway (photo courtesy of Wheeler Consolidated, Inc.).

Figure 2-21.- Typical timber suspension bridge designed for vehicle traffic.

2.8 DECKS

The deck is the portion of the bridge superstructure that forms the roadway and distributes vehicle loads to supporting elements of the structure. The type, thickness, and material of the deck are based on the weight and volume of traffic it must support. Timber decks are typically constructed of one of three materials: sawn lumber planks, nail-laminated lumber, and glulam. Composite timber-concrete decks are also used on timber superstructures in some applications.

SAWN LUMBER PLANKS

Sawn lumber plank decks are the oldest and simplest type of timber deck. They are constructed of lumber planks, 3 to 6 inches thick and 10 to 12 inches wide, that are placed flatwise and spiked to supporting beams. The planks are generally laid in the transverse direction and are attached directly to closely spaced timber beams with spikes (Figure 2-22). They are also used longitudinally on transverse floorbeams. Plank decks are most practical on low-volume or special-use bridges. They are not watertight and afford little protection to supporting members from the effects of weathering. Asphalt paving is not practical on plank decks because of large deck deflections that cause asphalt cracking and deterioration.

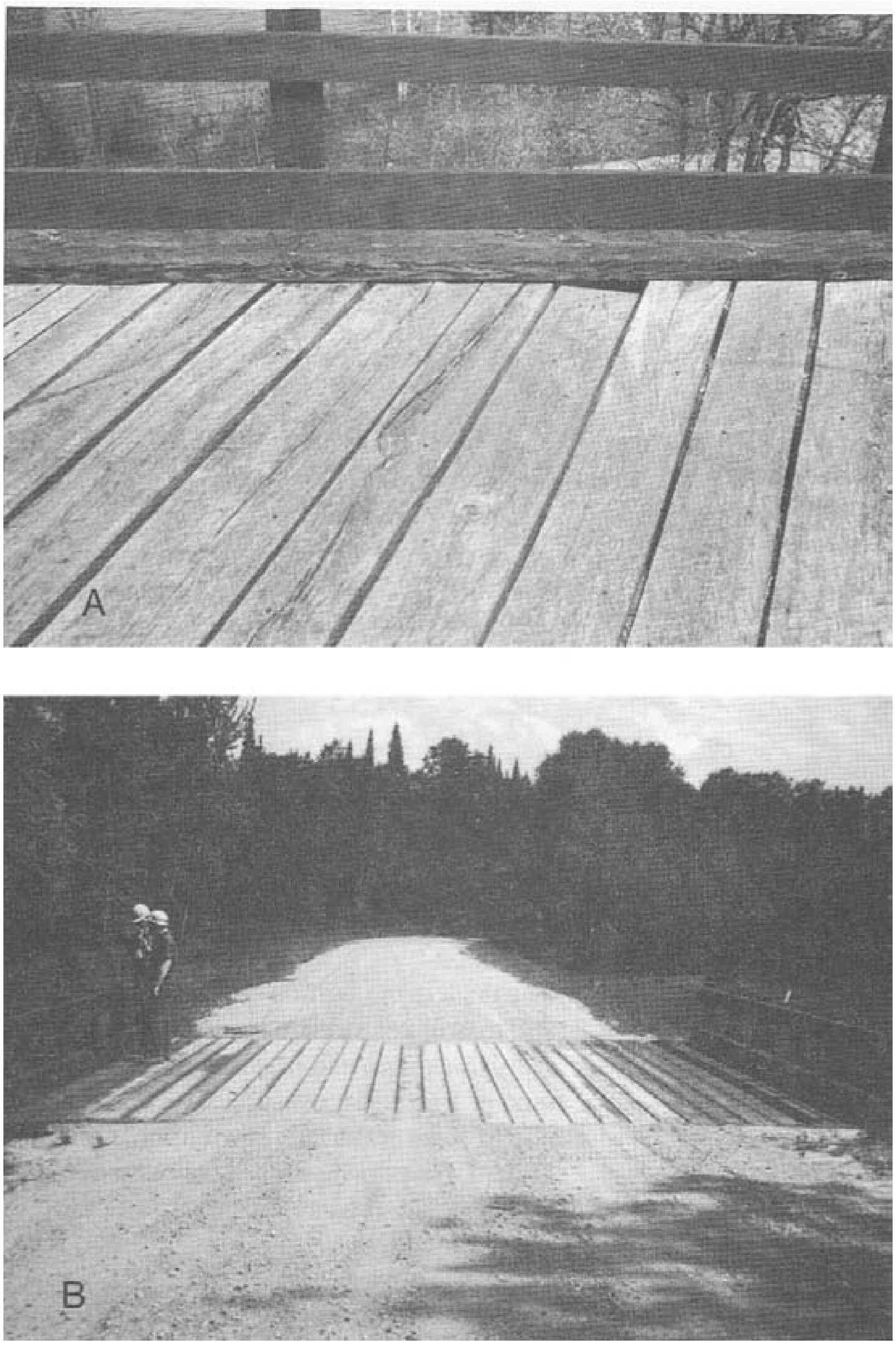


Figure 2-22.- Sawn lumber plank decks (A) in a transverse orientation and (B) in a longitudinal orientation.

NAIL-LAMINATED LUMBER

Nail-laminated lumber decks are constructed of sawn lumber laminations that are generally 2 inches thick and 4 to 12 inches deep. The laminations are placed with the wide dimension vertical and are nailed or spiked together to form a continuous surface (Figure 2-23). Nail-laminated decks are most commonly used in a transverse orientation on sawn lumber or steel beams spaced 2 to 6 feet apart. They are also used longitudinally over

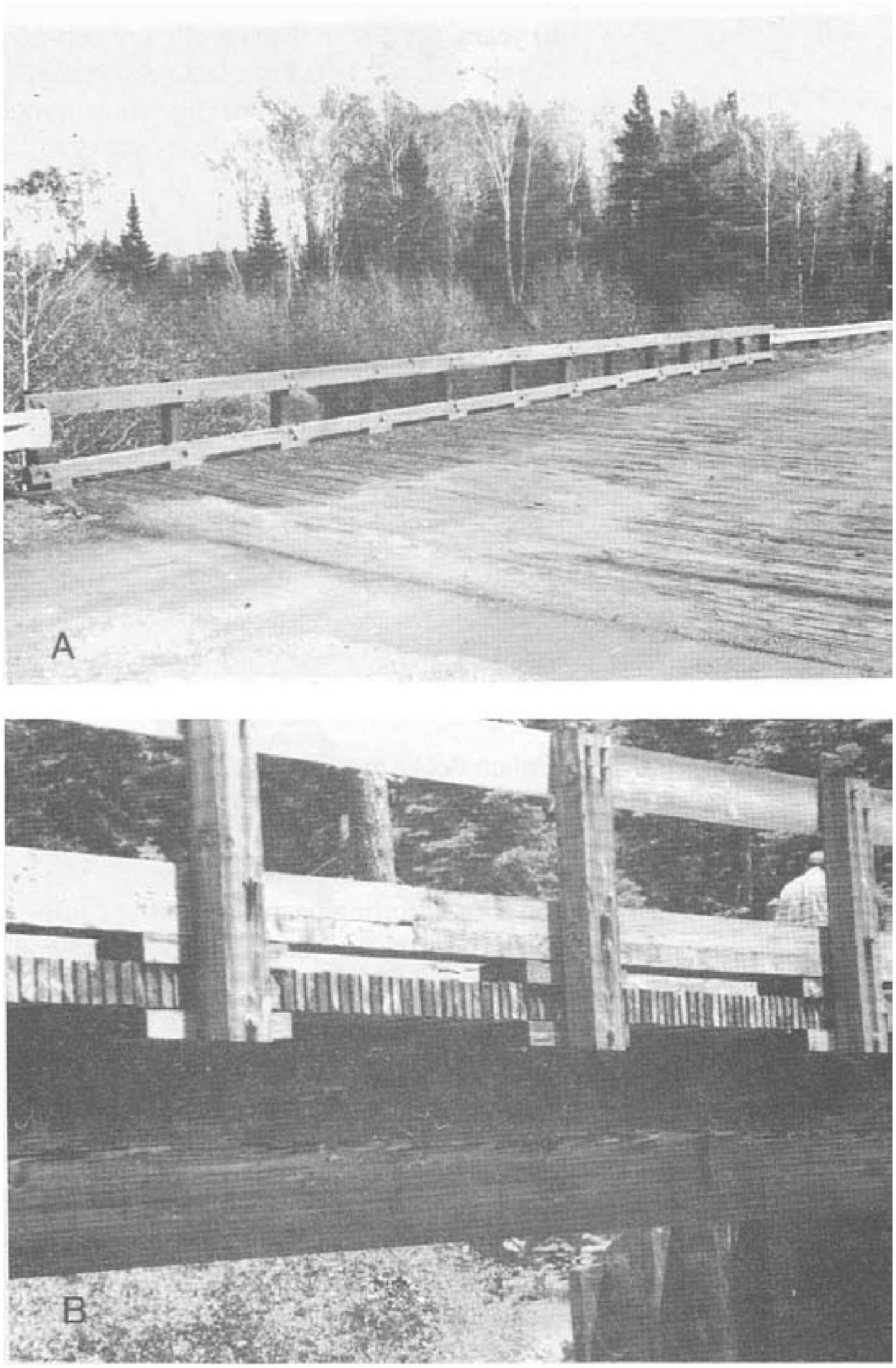


Figure 2-23.- Nail-laminated lumber deck as viewed from (A) the deck top and (B) the deck edge.

transverse floorbeams in a manner discussed for longitudinal deck superstructures (Section 2.3).

Nail-laminated lumber decks were the most commonly used type of timber deck from the 1920's through the mid-1960's. Their use has declined significantly since the introduction of glulam. Although many nail-laminated decks have provided satisfactory performance for over

40 years, the design is generally not suitable unless supporting beams are closely spaced. As beam spacing increases, deflection of the deck and dimensional changes, from variations in moisture content, cause delamination or loosening of the deck, reducing structural integrity and service life.

GLUED-LAMINATED TIMBER

Glulam decks are constructed of glulam panels that are normally 5-1/8 to 8-3/4 inches thick and 3 to 5 feet wide. They are used in both transverse and longitudinal orientations on glulam or steel beams.

The design criteria for glulam deck panels were developed in the mid-1970's at the FPL. They are the most common type of timber deck and are used in two basic configurations, noninterconnected and doweled (Figure 2-24). Noninterconnected panels are placed edge to edge, with no connection between adjacent panels. Doweled panels are interconnected with steel dowels to improve load distribution and reduce differential displacements at the panel joints. Doweled panels are more costly to fabricate and construct but can result in thinner decks and better performance for asphalt wearing surfaces.

Glulam decks are stronger and stiffer than conventional plank or nail-laminated decks because of the homogeneous bond between laminations and the dispersion of strength-reducing characteristics of glulam. Glulam panels can be constructed to form a watertight surface and afford protection for supporting beams and other components. Because of their increased stiffness, glulam decks also provide a firm base for asphalt pavement, which is frequently used as the wearing surface. Panels are completely fabricated and drilled for deck attachment prior to preservative treatment, producing estimated service lives of 50 years or more.

COMPOSITE TIMBER-CONCRETE

A composite timber-concrete deck consists of a concrete slab rigidly interlocked to supporting timber components so that the combination functions as a unit. On single, simple spans, the concrete resists compression, while the timber carries tension. At intermediate supports of continuous spans, the opposite is true. There are two basic types of composite timber-concrete decks: T-beam decks and slab decks (Figure 2-25). Composite T-beam decks are constructed by casting a concrete deck, which forms the flange of the T, on a glulam beam, which forms the web of the T. Composite action between the timber and concrete is developed by shear connectors along the beam tops. Numerous T-beam composite decks have been constructed in recent years, but they are not widely used because of the high cost of beam fabrication and the cost of in-place casting of concrete (Figure 2-26).

Composite slab decks are constructed by casting a concrete layer on a continuous base of longitudinal nail-laminated sawn lumber. The lumber

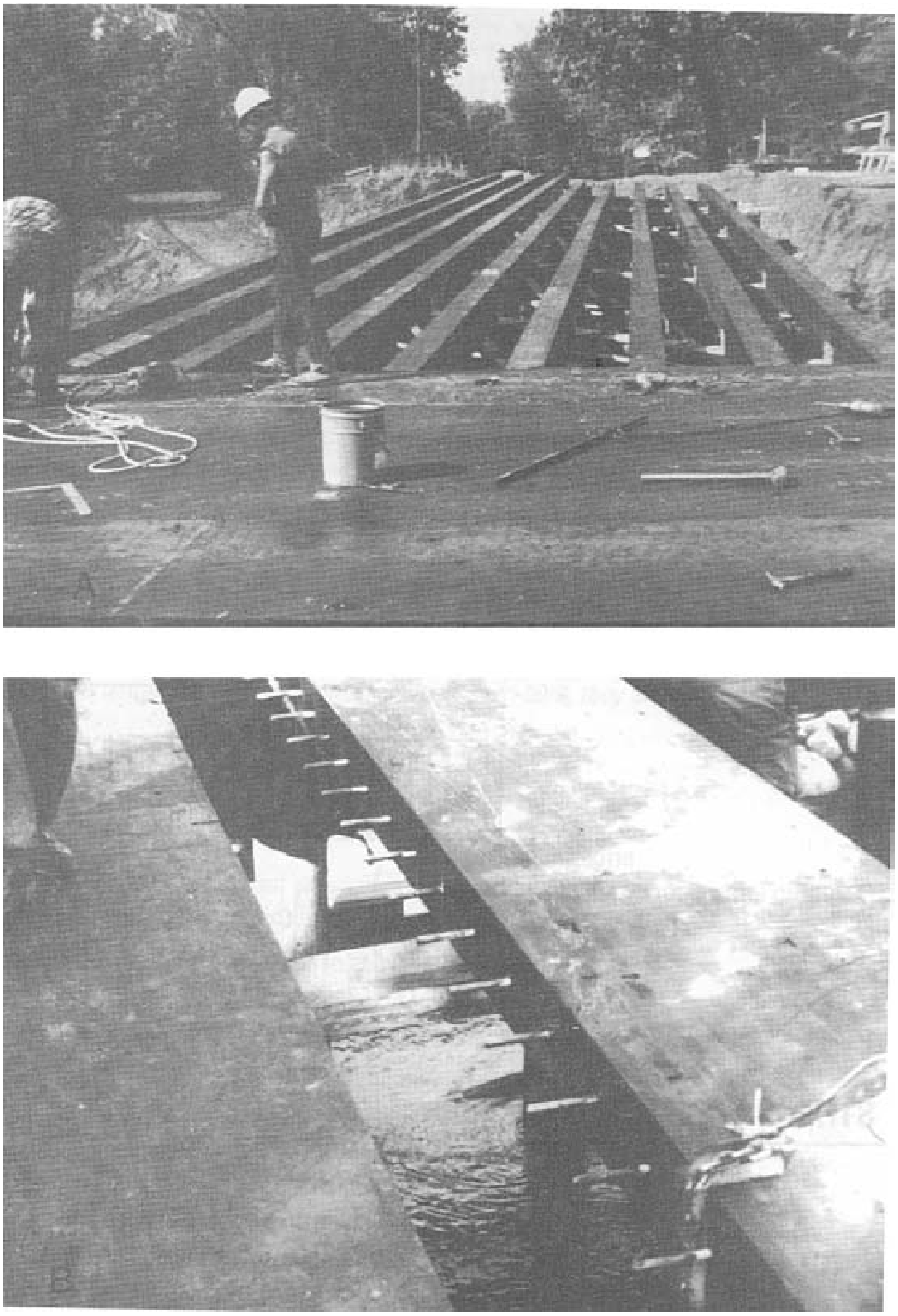


Figure 2-24.- Glued-laminated timber deck in the (A) noninterconnected and (B) doweled configurations.

is placed edgewise in the direction of traffic flow, with alternate laminations raised 1-3/8 to 2 inches to form grooves in the base. Composite action between the timber and concrete is most commonly achieved through the use of triangular steel shear developers driven into the grooves. Composite slab decks were first built in 1932 and were used mostly during the 1930's and 1940's. They are not commonly used today.

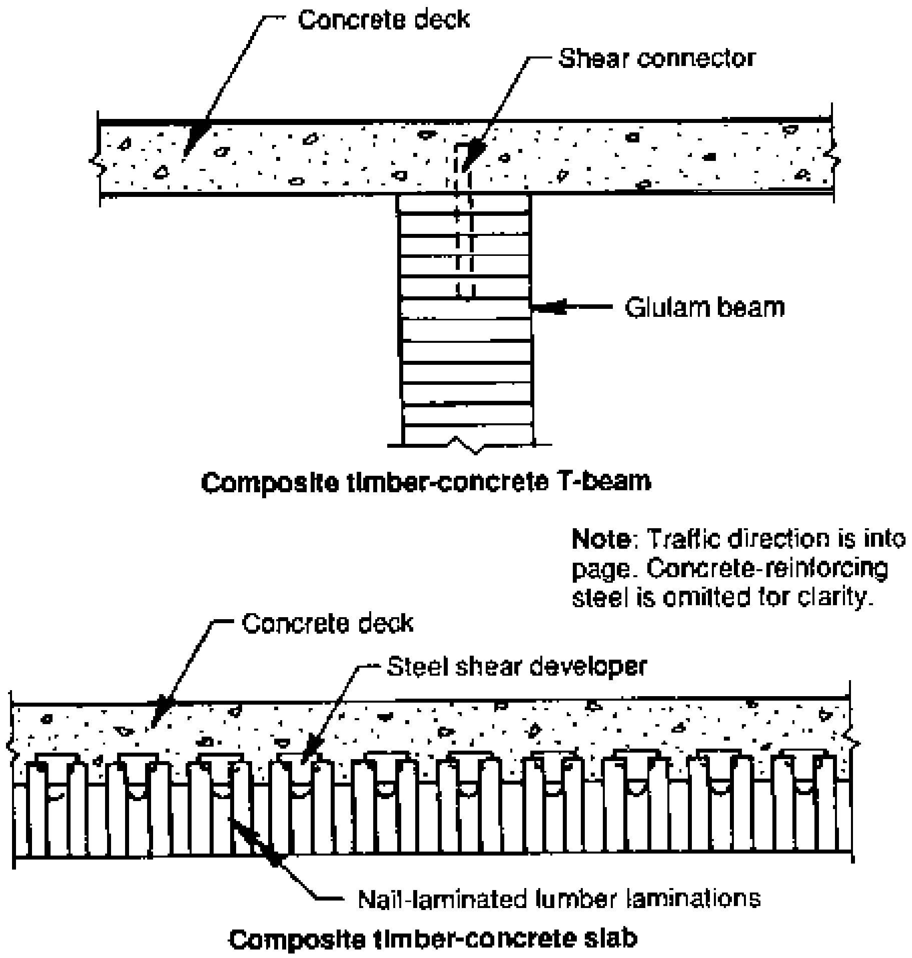


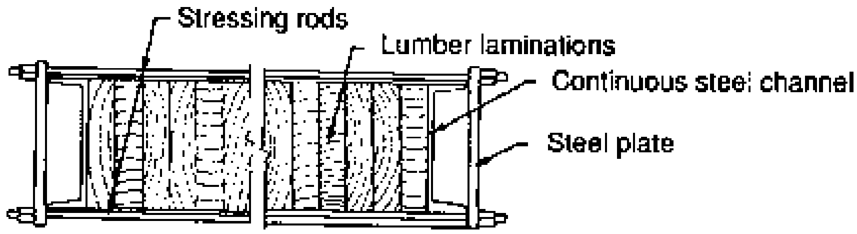
Figure 2-25.- Types of composite timber-concrete decks.

2.9 STRESS-LAMINATED TIMBER

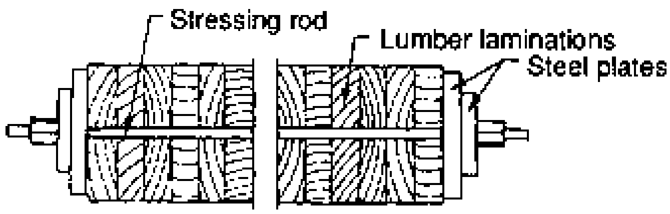
Stress-laminated timber is a relatively new concept for timber bridge applications. Using this system, vertical sawn lumber laminations are clamped together on their wide faces by high-strength steel stressing rods. These stressing rods are placed on the outsides of the laminations (external) or through the laminations (internal), depending on the type of structure (Figure 2-27). For both configurations, the stressing pressure is transferred to the timber through bearing plates located along the outer laminations. This pressure develops sufficient friction between the laminations to cause them to perform structurally as a unit, in a manner similar to the performance of glulam.

Stress-laminated timber has been used successfully in bridge construction and rehabilitation. In new construction, it is used primarily for longitudinal decks (Figure 2-28), but it has also been applied to other superstructure types (Figure 2-29). Stressing is also practical for rehabilitating nail-

Figure 2-26.- Composite glulam-concrete T-beam bridge located in northern California. Although numerous bridges of this type have been built, they are not common.



External rod configuration
(rods placed above and below the lumber laminations)



Internal rod configuration
(rods placed through the lumber laminations)

Figure 2-27.- Typical rod configurations for stress-laminated timber bridges.

laminated decks where load distribution characteristics of the deck have been reduced by delamination. The clamping action produced by the stressing rods restores deck integrity, increases load capacity, and substantially extends service life.

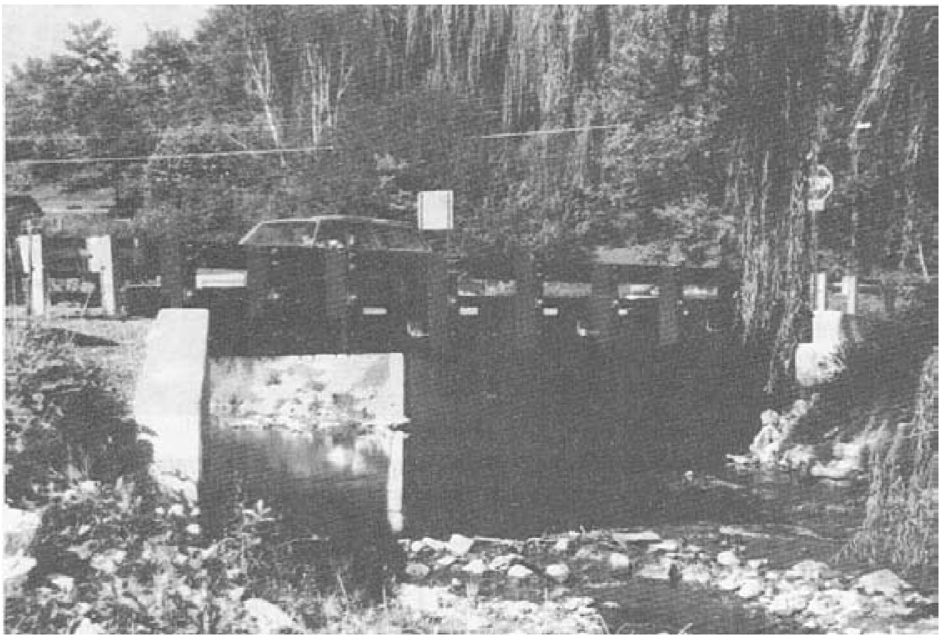


Figure 2-28- Stress-laminated deck bridge built near State College, Pennsylvania, in 1987. The bridge is 28 feet wide and was constructed from 4-inch-wide by 16-inch-deep lumber laminations.

Figure 2-29.- Stress-laminated deck bridge with stress-laminated slant-leg supports, built near Espanola, Ontario, Canada, in 1981. The bridge spans approximately 55 feet and supports two traffic lanes (photo courtesy of the Ontario Ministry of Transportation).

Stress-laminated timber for bridges was originally developed in Ontario, Canada, and adopted for use in the Ontario Highway Bridge Design Code in 1976. Although it has been successfully used in Canada, the system is relatively new in the United States and is not currently included in bridge design specifications. Research on stress-laminated timber, including the construction of several prototype structures, has been completed by the Forest Service in cooperation with the University of Wisconsin and West Virginia University. It is expected that the stress-laminated timber bridge system will be adopted in United States design specifications in the near future.

2.10 TIMBER SUBSTRUCTURES

The substructure is the portion of the bridge that supports the superstructure and transfers loads to the supporting soil or rock. The type of substructure used depends on the site conditions, quality of foundation material, and magnitude of the loads it must support. Timber bridges are adaptable to virtually any type of substructure constructed of timber, steel, or concrete. Discussions in this section will be limited to abutments or bents constructed of timber piles, sawn lumber, or glulam.

ABUTMENTS

Abutments support the bridge ends and contain roadway embankment material. The simplest timber abutment is a sawn lumber or glulam spread footing placed directly on the surface of the embankment (Figure 2-30). This type of abutment is used only when foundation material is of sufficient quality to support loads without excessive settlement, erosion, or scour. Another type of footing abutment is the post abutment (Figure 2-31). On post abutments, the superstructure is supported on sawn lumber or glulam posts connected to a spread footing located below the ground surface. Post abutments are used to elevate the superstructure and are provided with a backwall and wingwalls for retaining fill embankment.

When the quality of the foundation is not sufficient to support footings, pile abutments may be used (Figure 2-32). These abutments are constructed of timber piles driven to sufficient depth to develop the required load capacity by end bearing, or through friction between the pile surface and surrounding soil. The superstructure is connected to the piles by a continuous cap attached to the piles and to the superstructure at the bearings. Pile abutments are typically provided with backwalls and wingwalls to retain the embankment material.

BENTS

Bents are intermediate supports between abutments for multiple-span crossings. They are constructed of timber piles or sawn lumber frames, depending on required height and the suitability of foundation material.

Figure 2-30.- Surface bearing spread footing constructed of glulam (photo courtesy of Tim Chittenden, USDA Forest Service).

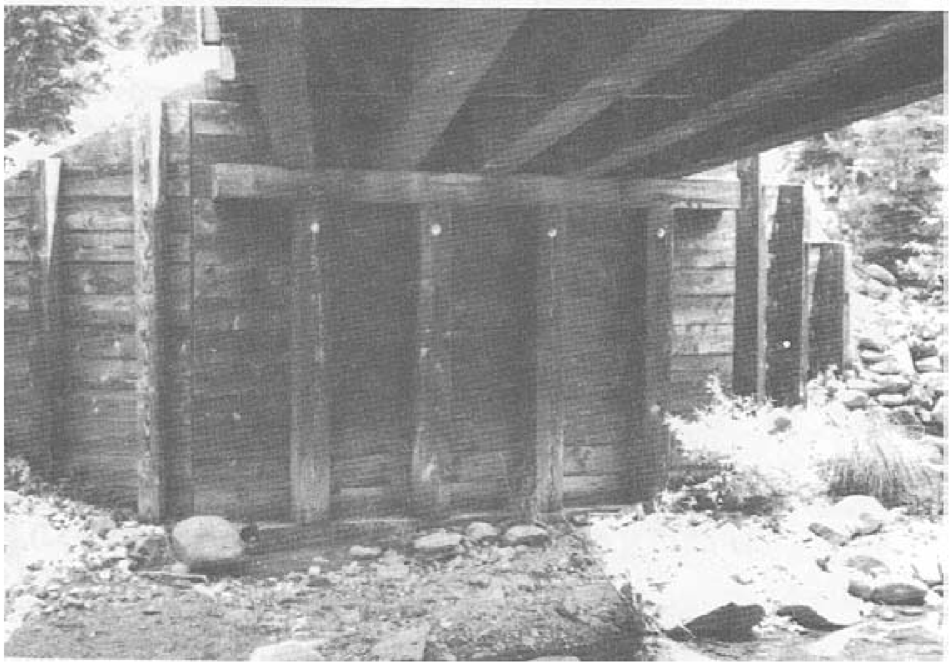


Figure 2-31.- Sawn lumber post abutment.

Pile bents are practical when foundation material is suitable and the required bent height, including pile penetration, is within the available length of timber piles (Figure 2-33). Frame bents are used for higher elevations or when rock or other foundation materials are not suitable for piles (Figure 2-34). Frames may be supported on footings or piles,

Figure 2-32.- Timber pile abutment.

Figure 2-33.- Timber pile bents.

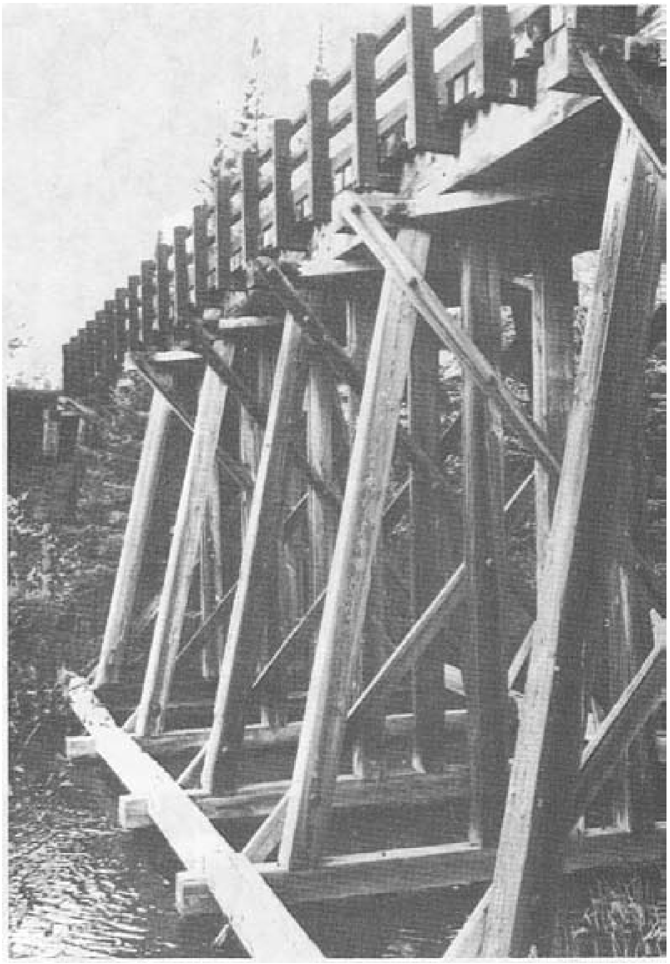


Figure 2-34.- Sawn lumber frame bent.

depending on the quality of the foundation. For both pile and frame bents, bracing is provided between members to provide stability and resist lateral loads. Superstructure bearing is on heavy timber caps fastened to the tops of the piles or frame posts.

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