

**RAIL SYSTEMS FOR TIMBER DECKS****10.1 INTRODUCTION**

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Railing is provided on bridges for the protection of vehicles and pedestrians that use the structure. It is normally placed along bridge sides to prevent users from going off the edge, but railing is also used to separate vehicle from pedestrian traffic and to protect exposed structural components. The four basic types of bridge railing are vehicular, pedestrian, bicycle, and combination railing (Figure 10-1). Vehicular railing is placed along roadway edges to safely contain and redirect impacting vehicles. Pedestrian and bicycle railings are installed on the outside edge of sidewalks intended for foot or bicycle traffic. Combination railing is a combination of vehicular and pedestrian or bicycle railing placed primarily to separate vehicle traffic from pedestrian or bicycle traffic.

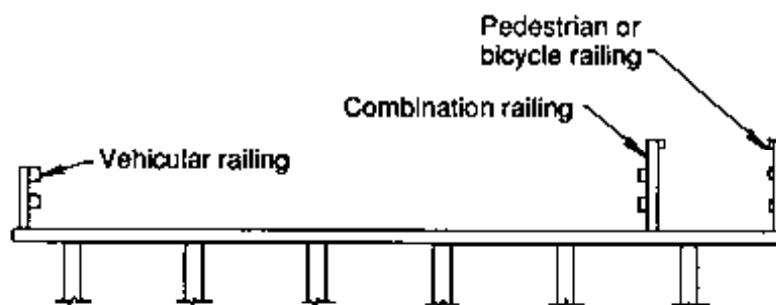


Figure 10-1. - Types of timber bridge railing.

All types of bridge railing must be strong enough to contain the intended traffic, be resistant to damage, be economical in construction and maintenance, and have a pleasing functional appearance. Specific design requirements for railing geometry and loads are given in AASHTO.<sup>3</sup> These requirements represent the minimum criteria for railing design, but allow the designer moderate flexibility in determining the most appropriate configuration and materials for a specific structure. This chapter discusses AASHTO railing requirements, including design considerations and recommended criteria for timber decks.

**10.2 VEHICULAR RAILING**

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The purpose of vehicular railing is to safely restrain an impacting vehicle. In addition, consideration must be given to the protection of the occupants in the vehicles, the protection of other vehicles or pedestrians near the

collision, the effects of railing impact on the structure, and the railing appearance. Although each of these considerations may be addressed somewhat independently, they all interact to determine the performance of the railing system.

## DESIGN REQUIREMENTS

Vehicular railing systems for timber bridges normally consist of horizontal rails mounted on vertical posts, solid timber parapets, or a combination of the two (Figure 10-2). The design requirements for these systems are given in AASHTO as geometric requirements for railing height, spacing and alignment, and static load requirements for rails, posts, and parapets. Although actual loads are dynamic in nature, the use of static loading simplifies design and has been used by AASHTO since 1964. Materials for vehicular railing may be timber, metal, or concrete; however, metal materials must have a minimum 10-percent tested elongation (AASHTO 2.7.1.1.2). Any railing configuration may be used provided it complies with the minimum criteria stated in AASHTO or has been verified by full-scale crash testing.

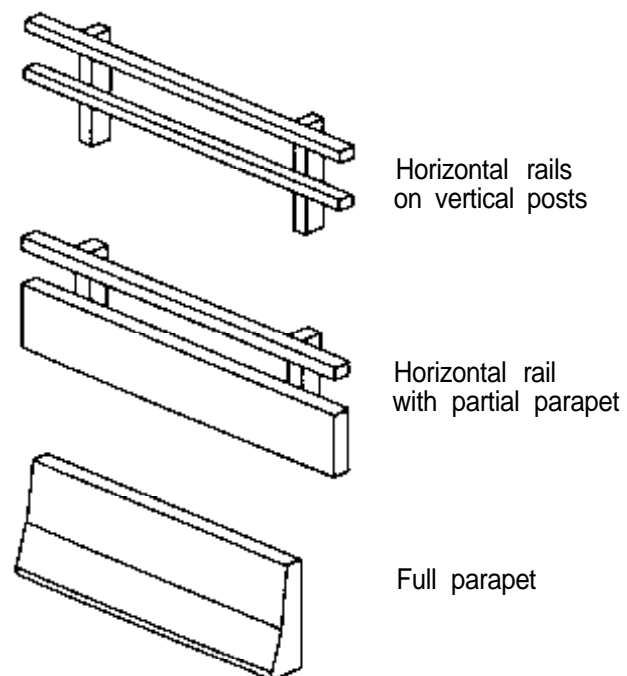


Figure 10-2. - Typical configurations for vehicular railing used on timber bridges.

Current AASHTO railing requirements (through 1987 interim) are independent of the service level or type of structure and are based on static load design criteria. The same requirements apply to all bridges from single-lane bridges on dirt roads to multiple-span structures on interstate highways. These criteria have been under criticism for several years on the premise that they represent a compromise approach that does not

accurately reflect loading and safety requirements for all bridges. For heavily traveled highways, the static load criteria may be insufficient, while use of the same criteria on low-volume rural roads could result in overly conservative designs. There have been several proposals for a service-level approach to railing design that would vary requirements for structures based on the functional classification of the roadway, bridge geometry, and the type, speed, and volume of traffic.<sup>9</sup> There is also a movement to eliminate static load requirements and require full-scale crash tests of all vehicular railing systems (Figure 10-3). Although AASHTO does not currently require full-scale crash tests for railing acceptance, guide specifications for railing crash testing are being prepared by AASHTO and will be available in the near future. It is expected that full-scale crash testing will eventually be required for all vehicular railing systems. Current design requirements, based on AASHTO geometric requirements and static load criteria, are discussed in the following paragraphs.

### Geometric Requirements

Vehicular railing must be positioned to safely contain an impacting vehicle without allowing it to pass over, under, or through the rail elements. In addition, it must be free of features that may catch on the vehicle or cause it to overturn or decelerate too rapidly. To ensure a minimum level of safety and uniformity for vehicular railing, the following minimum geometric requirements are given in AASHTO (Figure 10-4).

1. **Reference Surface.** Vertical requirements for railing height and spacing are measured relative to a roadway reference surface defined as the top of the roadway surface, the top of the future overlay if resurfacing of the roadway is anticipated, or the top of the curb when the curb projects more than 9 inches beyond the traffic face of the railing (AASHTO 2.7.1.2.1). When the reference surface is a future overlay, minimum heights are measured from the overlay elevation while maximum heights are measured from the original roadway elevation.
2. **Railing Height.** The height of vehicular railing shall not be less than 2 feet 3 inches above the reference surface (AASHTO 2.7.1.2.2). The height of parapets designed with sloping traffic faces intended to allow vehicles to ride up them under low-angle contacts shall be at least 2 feet 8 inches above the reference surface.
3. **Railing Placement.** The maximum clear opening below the bottom rail shall not exceed 17 inches. The maximum clear opening between succeeding rails shall not exceed 15 inches (AASHTO 2.7.1.2.4). The lower rail element should consist of a rail centered 15 to 20 inches above the reference surface, or a parapet projecting a minimum of 18 inches above the reference surface (AASHTO 2.7.1.2.3).

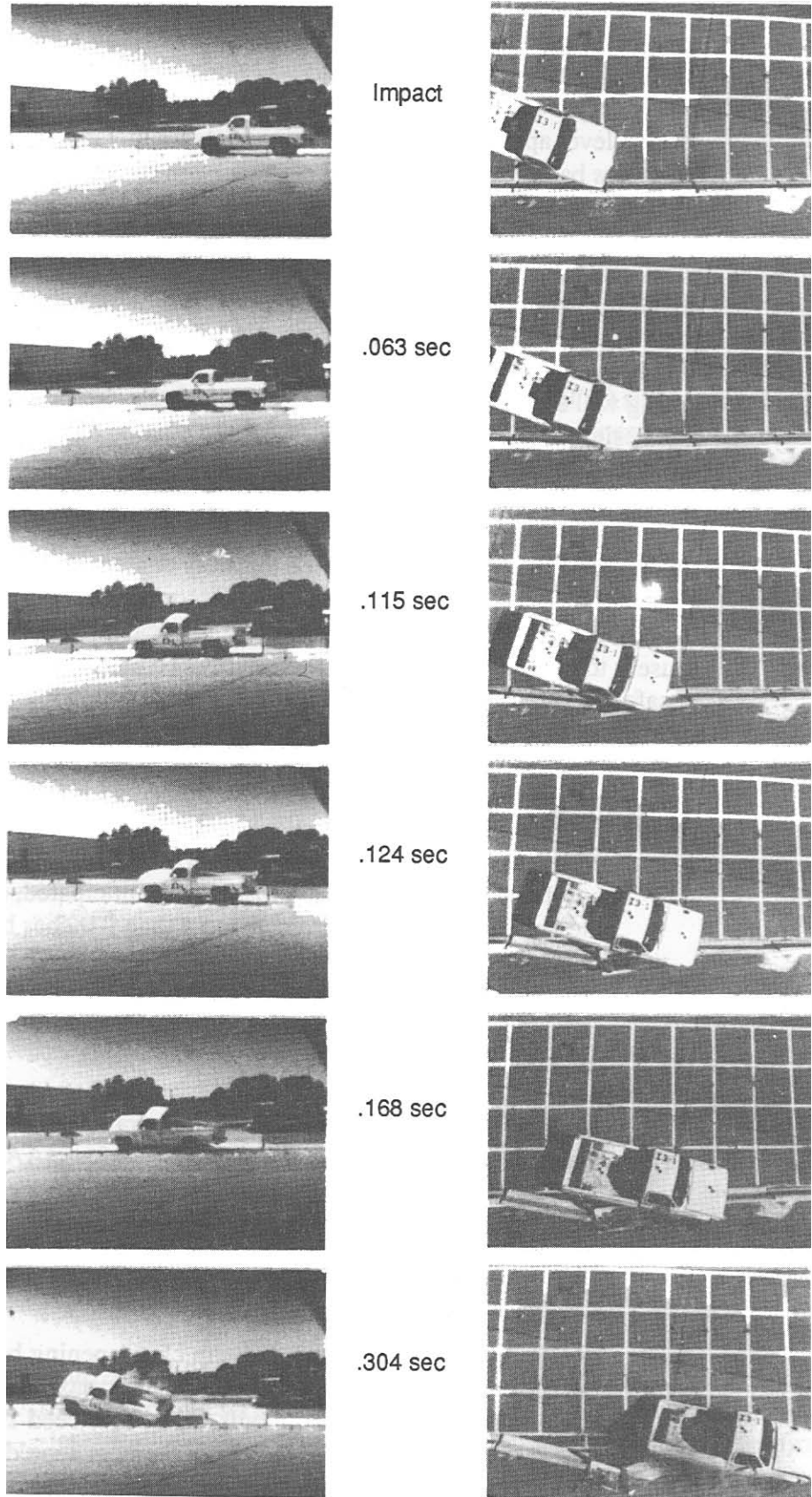
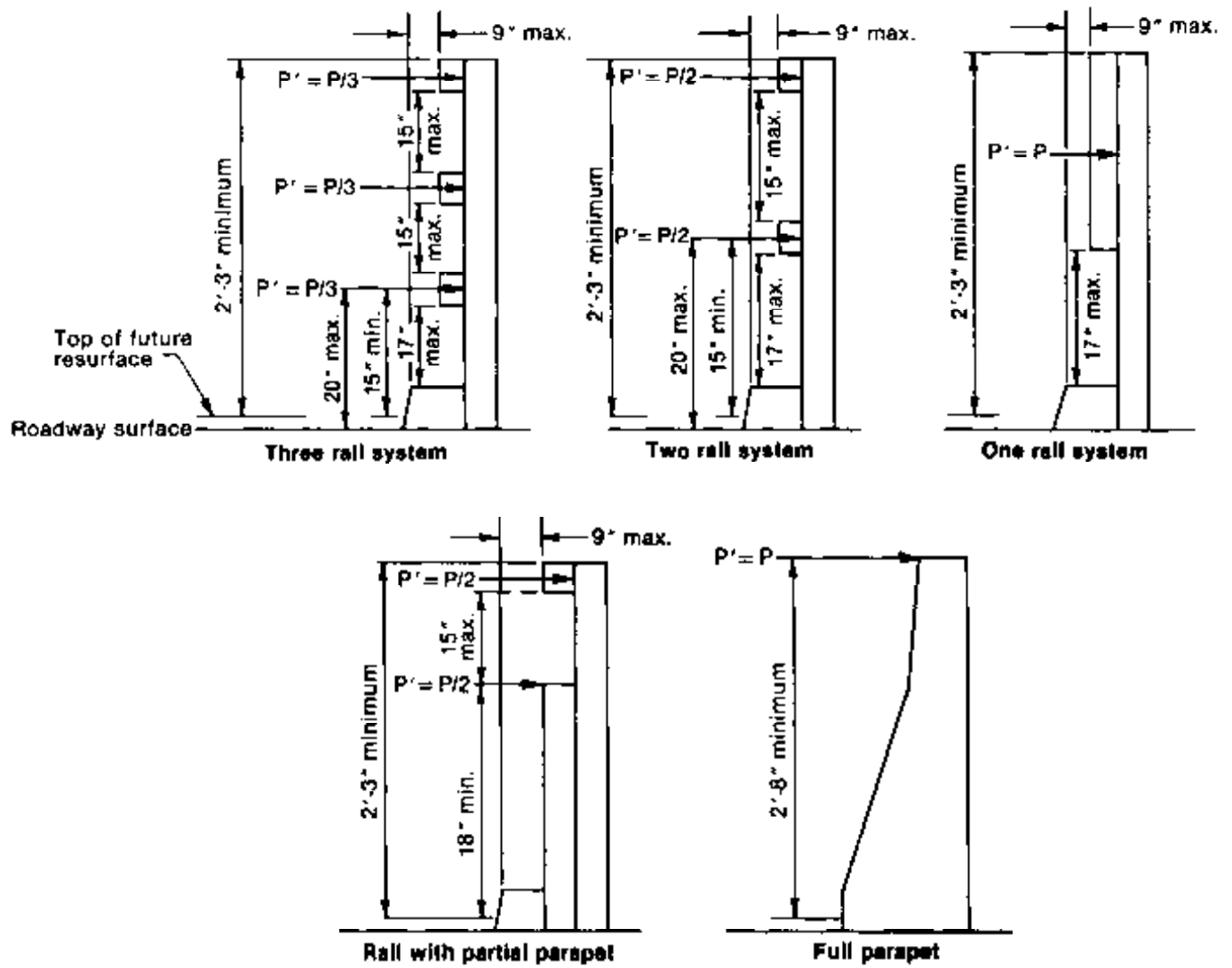


Figure 10-3. - Partial sequence of a full-scale crash test of vehicular railing (photos courtesy of Dr. Edward Post, University of Nebraska at Lincoln).



Notes:

1. Rail and post shapes are illustrative only. Any material or combination of materials may be used in any configuration provided minimum AASHTO requirements are met.
2. Refer to AASHTO for illustrations of other railing configurations and for design requirements when the curb projects more than 9 inches from the traffic face of railing.
3. Additional post and rail loading requirements are illustrated in Figures 10-5 and 10-6.

Figure 10-4. - AASHTO requirements for vehicular railing geometry and outward transverse static loads when there is no curb or the curb projects 9 inches or less from the traffic face of railing (adapted from AASHTO<sup>3</sup> Figure 2.7.4B). © 1983. Used by permission.

4. **Vertical Alignment.** The traffic face of all rails must be within 1 inch of a vertical plane through the traffic face of the rail closest to traffic (AASHTO 2.7.1.2.5).

In addition to the above requirements, vehicular railing should provide a smooth, continuous traffic face with posts set back from the rail face. Protrusions or depressions at rail joints are acceptable provided their thickness or depth is no greater than the wall thickness of the rail members or 3/8 inch, whichever is less (AASHTO 2.7.1.1.4).

### Loading Requirements

AASHTO specifications state that the primary purpose of vehicular railing is to contain the average vehicle using the structure. Although the average vehicle is not defined in the specifications, it is generally considered to be a full-size domestic passenger car weighing approximately 4,500 pounds. The static design loads are intended to safely contain the design vehicle at an impact angle of approximately 25 degrees at a speed of 60 miles per hour (mph). Railing configurations that have been successfully tested by full-scale impact tests are exempt from these static load requirements (AASHTO 2.7.1.3.7).

Design loads for vehicular railing are based on a minimum highway design load that is distributed to post, rail, and parapet elements. Requirements for load magnitude and distribution are as follows:

1. **Highway Design Load.** The basic design load for posts and rails is the highway design load,  $P$ . The magnitude of  $P$  depends on the height of the top rail element above the reference surface. When the distance to the top of the upper rail is less than or equal to 2 feet 9 inches,  $P = 10,000$  pounds (AASHTO Figure 2.7.4B). When the height of the top rail exceeds 2 feet 9 inches,  $P$  equals 10,000 pounds times the adjustment factor,  $C$ , as computed by

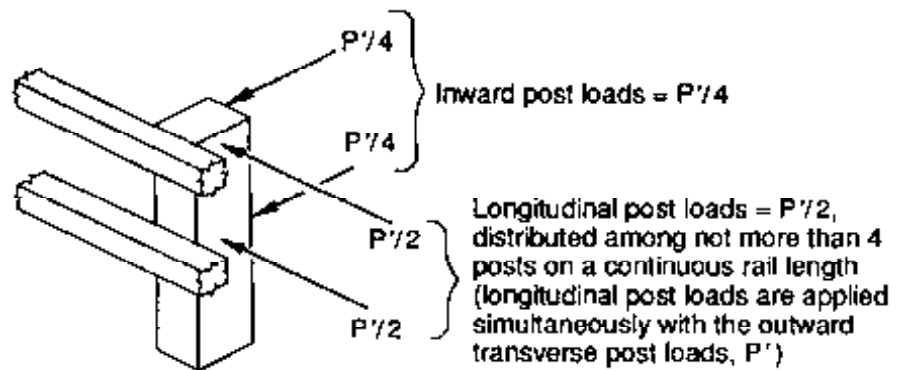
$$C = 1 + \left( \frac{h - 33}{18} \right) \quad \text{and} \quad C \geq 1.0 \quad (10-1)$$

where  $h$  is the height of the top of the top rail element above the reference surface, in inches.

2. **Post Loads.** The highway design load,  $P$ , is distributed to each rail post as an outward transverse load. The distribution of  $P$  along the post height depends on the number and position of rail elements. When the railing configuration complies with minimum AASHTO geometric requirements,  $P$  is distributed equally at the center of each rail, and the distributed outward transverse post load,  $P'$  equals  $P$ ,  $P/2$ , or  $P/3$ , depending on the railing

configuration (Figure 10-4). Rails with a traffic face more than 1 inch behind the vertical plane through the face of the rail closest to traffic, or centered less than 15 inches above the roadway reference surface, are not considered as traffic rails for distributing  $P$  (AASHTO 2.7.1.3.2). However, they may be used in determining the maximum vertical clear opening, provided they are designed for a transverse loading equal to that applied to an adjacent traffic rail or  $P/2$ , whichever is less (see the following discussions on rail loads).

In addition to the outward transverse loads, rail posts must also be designed to resist longitudinal loads and inward transverse loads (Figure 10-5). A longitudinal post load equal to  $P'/2$  is applied simultaneously with the outward transverse load and is divided among not more than four posts in a continuous rail length (AASHTO 2.7.1.3.3). Posts must be designed to resist an independently applied inward transverse load equal to  $P'/4$ .



$P'$  = the outward transverse post load applied to the post at each rail location ( $P$ ,  $P/2$ , or  $P/3$  from Figure 10-4)

Figure 10-5. - AASHTO requirements for longitudinal and inward transverse post loads, illustrated for a two-rail system.

3. **Rail Loads.** Rails are designed for a moment from an outward transverse load applied at the center of the panel and at the posts, equal to  $P'L/6$  where  $L$  is the post spacing and  $P'$  is the portion of the outward transverse post load ( $P$ ,  $P/2$ , or  $P/3$ ) applied to the post at each rail location (AASHTO 2.7.1.3.5). The rail attachment to the post must be designed to resist a vertical load, applied alternately upward or downward, equal to  $P'/4$  (AASHTO 2.7.1.3.4). The rail attachment must be designed to resist an inward transverse load equal to  $P'/4$  (Figure 10-6).

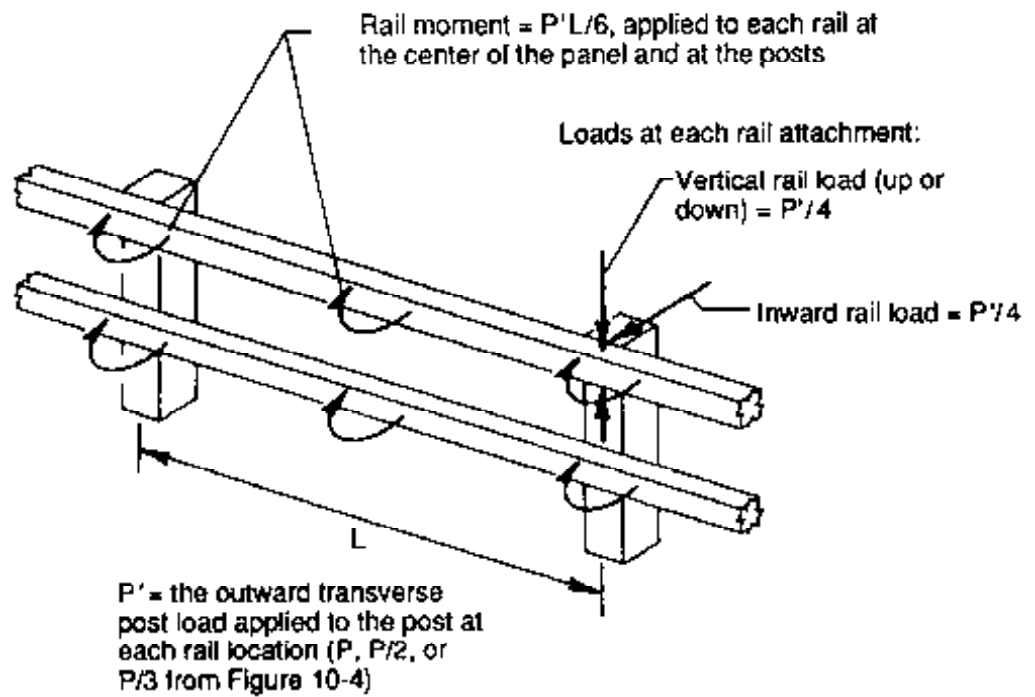


Figure 10-6. - AASHTO requirements for rail loading, illustrated for a two-rail system.

4. **Parapet Loads.** The highway design load,  $P$ , is applied as an outward transverse load along the top of parapets. The load is assumed to act at any location along the parapet and is distributed over a longitudinal length of 5 feet (AASHTO 2.7.1.3.6).

Although AASHTO requires that all vehicular railing be designed for a minimum highway design load of  $P = 10,000$  pounds, some agencies have reduced this loading for certain types of bridges. For example, the USDA Forest Service uses 50 percent of the AASHTO loading, or  $P = 5,000$  pounds, for all single-lane low-volume bridges with a design speed less than 45 mph and a probable vehicle-railing impact angle less than or equal to 15 degrees. Many counties also follow reduced AASHTO loading criteria on similar low-volume roads. It is expected that AASHTO will eventually recognize a service level design approach that will allow lower railing loads for certain types of bridges.

## DESIGN GUIDELINES

Within the railing design requirements given in AASHTO, many railing configurations can be used on timber bridges. The system that is most appropriate for a specific bridge depends on factors such as the deck configuration and material as well as the economy and availability of railing materials. Some of the design considerations for rail elements, posts, and parapets are discussed in the following paragraphs.

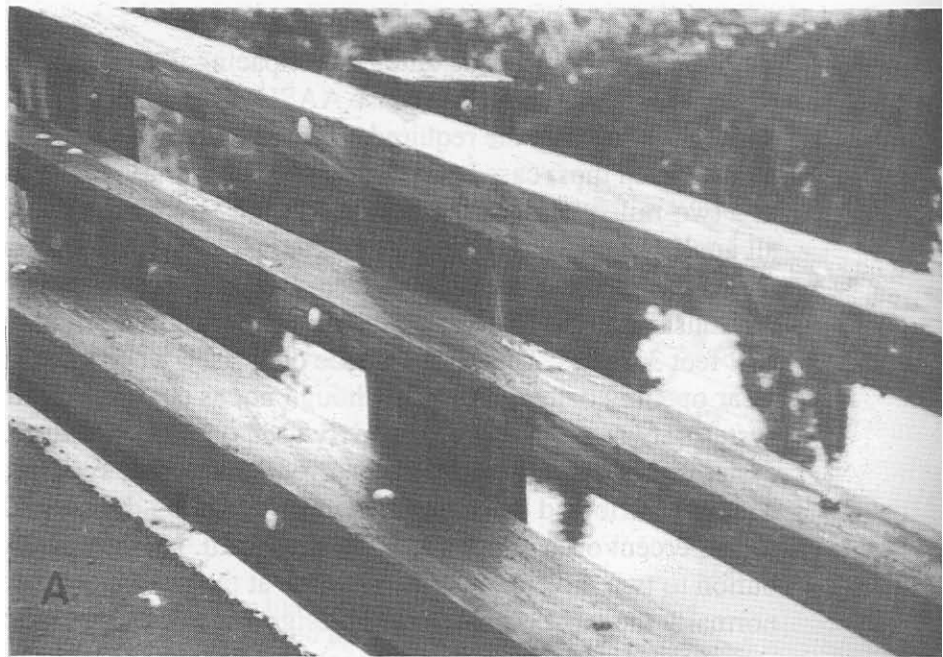


## Rails

Railing selection depends on the post spacing and the aesthetic qualities desired for the structure. Because AASHTO rail loads are directly related to the post spacing, the required rail load increases as post spacing increases. In most cases, the choice for configuration is between a one-rail or a two-rail system. When one-rail designs are used, the rail must resist all applied loads and be deep enough to meet AASHTO geometric requirements for the clear opening below the rail. If a curb is not provided, the rail must be a minimum of 10 inches deep, assuming minimum rail height of 2 feet 3 inches. This depth can be decreased when a curb reduces the clear opening below the rail. Although not as common as single-rail systems, two-rail designs are widely used on timber bridges. Two-rail systems are generally more expensive than one-rail systems, but loads are equally distributed to each rail element, reducing the individual rail loads to 50 percent of that required for a single rail. In addition, the load distribution to two rails reduces the reaction at the post attachment, which is normally the most critical railing design consideration on timber decks.

The three types of vehicular rails most commonly used on timber bridges are timber, semirigid steel, and rigid steel (Figure 10-7). Each of these railing types is discussed in subsequent paragraphs, and approximate maximum post spacings for various configurations are shown in Table 10-1.

1. **Timber Rails.** Timber rails constructed of sawn lumber or glulam are widely used on timber bridges because of their good energy-absorbing properties and the pleasing appearance of wood. Lumber rails for one-rail configurations are generally 4 to 6 inches thick and 10 to 12 inches deep. For two-rail lumber configurations, 6- by 8-inch members are typically used with the 8-inch dimension horizontal. Glulam rails are normally 10-3/4 inches deep for single rails and 6-3/4 inches deep for double rails. Glulam rails are preferable to sawn lumber in most applications because they can be manufactured in longer lengths (up to the bridge length) and provide better dimensional stability in service.
2. **Semirigid Steel Rails.** Semirigid steel rails are cold-formed standard sections including the W-beam or Thrie-beam (Table 10-2). These rails must conform to the requirements of AASHTO M 180 and are fabricated in standard 12-foot-6-inch and 25-foot-0-inch sections. The rails are available in two thicknesses: Class A, which is 0.105 inch thick (12 gage), and Class B, which is 0.135 inch thick (10 gage). Sections are available in the following four types, depending on the surface finish of the rail: Type 1, zinc coated, 1.80 oz/ft<sup>2</sup>; Type 2, zinc coated, 3.60 oz/ft<sup>2</sup>; Type 3, uncoated, to be painted; and Type 4, corrosion-resistant steel (weathering steel).



*Figure 10-7. - Types of vehicular rails commonly used on timber bridges. (A) Glulam beams. (B) Sawn lumber beam.*

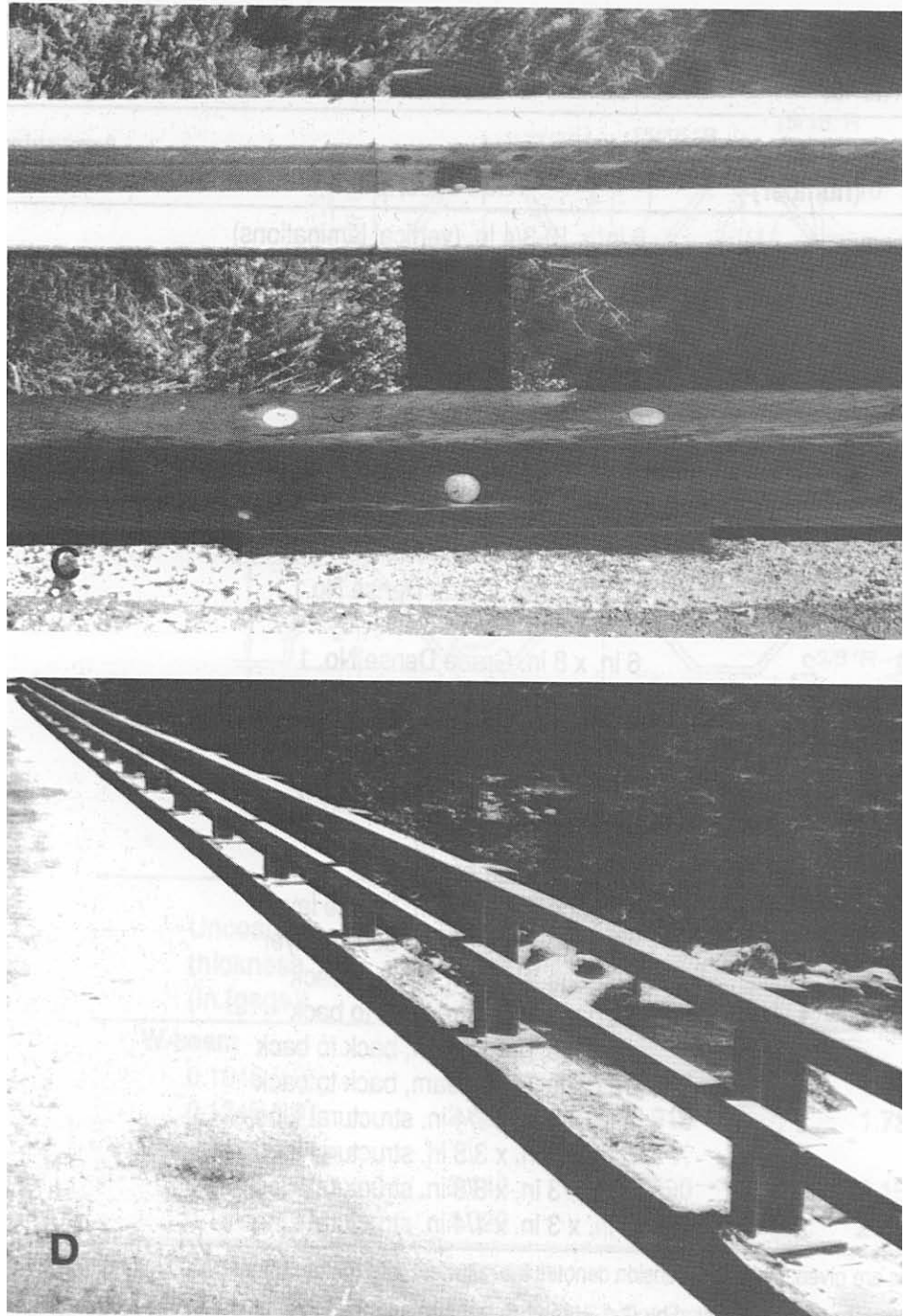


Figure 10-7. - Types of vehicular rails commonly used on timber bridges (continued).  
(C) Semirigid steel W-beam. (D) Rigid-steel structural tubes.

Table 10-1. - Approximate maximum post spacing for vehicular railing designed to full AASHTO static load criteria.

| Material                     | Rails (number)                   | Rail description <sup>a</sup>               | Approximate maximum post spacing (ft) |
|------------------------------|----------------------------------|---|---------------------------------------|
| Glulam <sup>b</sup>          | 1                                | 6 in. x 10-3/4 in. (vertical laminations)   | 7.2                                   |
|                              | 1                                | 5-1/8 in. x 12 in. (horizontal laminations) | 6.9                                   |
|                              | 1                                | 6-3/4 in. x 12 in. (horizontal laminations) | 11.6                                  |
|                              | 2                                | 6 in. x 6-3/4 in. (vertical laminations)    | 9.1                                   |
| Sawn lumber <sup>c</sup>     | 1                                | 4 in. x 10 in. Grade Dense No.1             | 2.7                                   |
|                              | 1                                | 4 in. x 12 in. Grade No.1                   | 2.7                                   |
|                              | 1                                | 4 in. x 12 in. Grade Dense No.1             | 3.2                                   |
|                              | 1                                | 6 in. x 10 in. Grade No.1                   | 5.3                                   |
|                              | 1                                | 6 in. x 10 in. Grade Dense No.1             | 6.1                                   |
|                              | 1                                | 6 in. x 12 in. Grade No.1                   | 6.6                                   |
|                              | 1                                | 6 in. x 12 in. Grade Dense No.1             | 7.6                                   |
|                              | 2                                | 6 in. x 8 in. Grade No.1                    | 8.4                                   |
|                              | 2                                | 6 in. x 8 in. Grade Dense No. 1             | 9.7                                   |
|                              | Flexible steel <sup>d</sup>      | 1   | 10 gage W-beam                        |
| 1                            |                                  | 12 gage W-beam                              | 2.1                                   |
| 1                            |                                  | 10 gage W-beam, double layer                | 5.2                                   |
| 1                            |                                  | 12 gage W-beam, double layer                | 4.1                                   |
| 1                            |                                  | 10 gage Thrie-beam                          | 4.3                                   |
| 1                            |                                  | 12 gage Thrie-beam                          | 3.2                                   |
| 1                            |                                  | 10 gage Thrie-beam, double layer            | 8.6                                   |
| 1                            |                                  | 12 gage Thrie-beam, double layer            | 6.5                                   |
| 1                            |                                  | 10 gage W-beam, back to back                | 8.7                                   |
| 1                            |                                  | 12 gage W-beam, back to back                | 6.8                                   |
| 1                            |                                  | 10 gage Thrie-beam, back to back            | 13.9                                  |
| 1                            | 12 gage Thrie-beam, back to back | 10.7  |                                       |
| Semirigid steel <sup>e</sup> | 2                                | 4 in. x 4 in. x 1/4 in. structural tube     | 8.9                                   |
|                              | 1                                | 5 in. x 5 in. x 3/8 in. structural tube     | 9.8                                   |
|                              | 2                                | 6 in. x 3 in. x 3/8 in. structural tube     | 11.2                                  |
|                              | 2                                | 6 in. x 3 in. x 1/4 in. structural tube     | 12.9                                  |

<sup>a</sup> When dimensions are given, the first dimension denotes the rail width (horizontal) dimension.

<sup>b</sup> Combination 2 Western species adjusted by  $C_M$ ,  $C_D$ , and  $C_F$ , when applicable.  $F_b = 1800 \text{ lb/in}^2$  for horizontal laminations and  $1,700 \text{ lb/in}^2$  for vertical laminations per *AITC 117—Design*.<sup>4</sup>

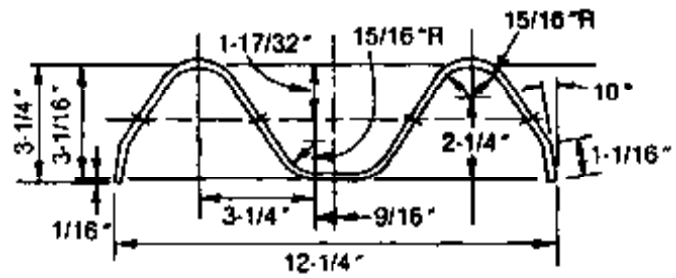
<sup>c</sup> Based on dressed lumber sizes for the Douglas-fir grades shown. 4-inch lumber widths are in the Joists and Planks size classification. 6-in. lumber is in the Beams and Stringers size classification graded to WWPA rules. Tabulated bending stresses from the NDS<sup>20</sup> were adjusted by  $C_M$ ,  $C_D$ , and flatwise use factors, when applicable.

<sup>d</sup>  $F_y = 50,000 \text{ lb/in}^2$  per AASHTO M180;  $F_b = 0.60F_y$  per AASHTO 2.7.4.2.<sup>3</sup>

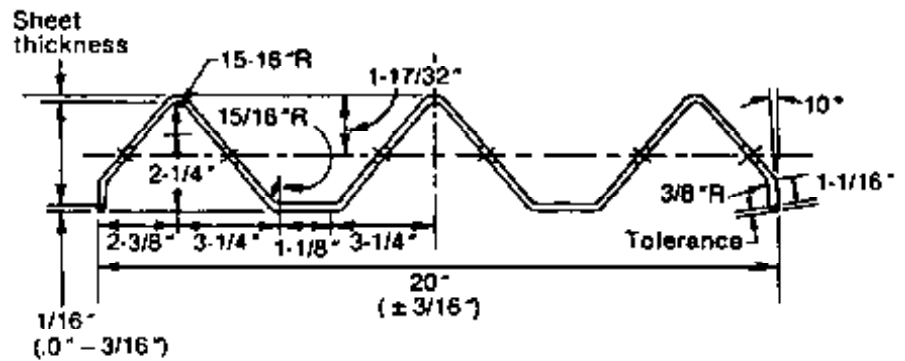
<sup>e</sup>  $F_y = 36,000 \text{ lb/in}^2$  per ASTM A501;  $F_b = 0.60F_y$  per AASHTO 2.7.4.2.<sup>3</sup>

Loads are based on full AASHTO railing requirements for the materials specified. Values are for estimating purposes only and should be verified for specific design applications.

Table 10-2. - Section properties of W-beam and Thrie-beam guardrail.



**W - beam**



**Thrie - beam**

| Uncoated thickness (In.(gage)) | Area (In <sup>2</sup> ) | Moment of Inertia (In <sup>4</sup> ) | Section modulus (In <sup>3</sup> ) |
|--------------------------------|-------------------------|--------------------------------------|------------------------------------|
| <b>W-beam</b>                  |                         |                                      |                                    |
| 0.1046 (12)                    | 1.987                   | 2.296                                | 1.364                              |
| 0.1345 (10)                    | 2.555                   | 2.919                                | 1.732                              |
| <b>Thrie-beam</b>              |                         |                                      |                                    |
| 0.1046 (12)                    | 3.140                   | 3.590                                | 2.150                              |
| 0.1345 (10)                    | 4.020                   | 4.790                                | 2.870                              |

Bolt holes are not considered in section properties.

From *Handbook of Steel Drainage and Highway Construction Products*.<sup>6</sup> Used by Permission.

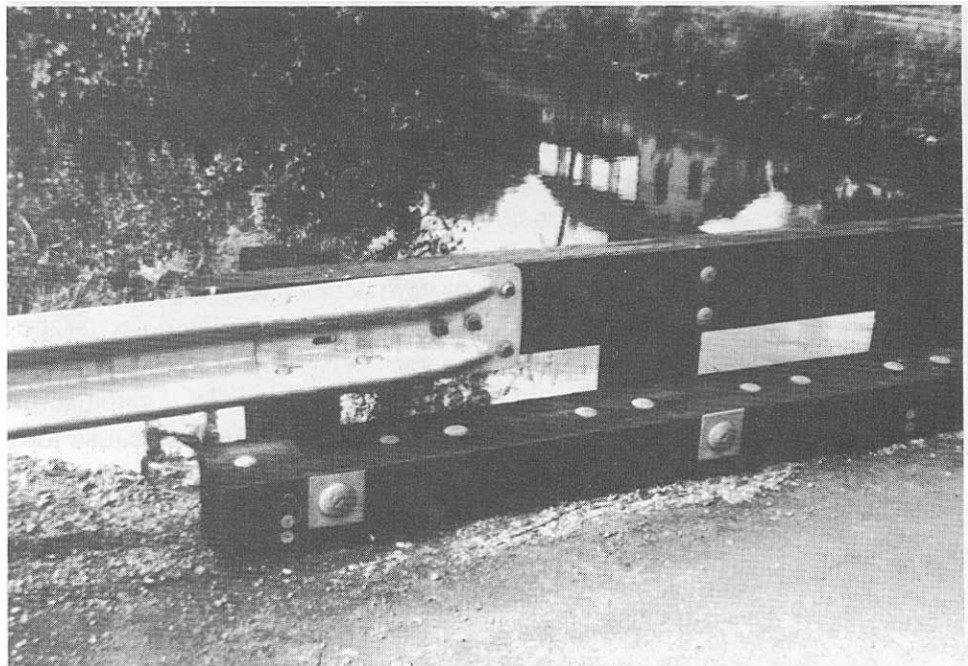
The W-beam and Thrie-beam sections are primarily used as highway guardrail and median barriers. Because of the low moment of inertia of the sections, their use as bridge railing is generally restricted to single-lane bridges where the design loading is 50 percent of that required by AASHTO. The strength and span capabilities of semirigid railing can be increased by doubling the rail elements (nesting one section inside the other), or by placing two elements back to back. Additional strength is achieved by backing the sections with steel pipes, channels, or timber members. Because these rail elements are quite flexible, the rail should be blocked away from the post 6 to 8 inches to prevent impacting vehicles from catching the post.

3. **Rigid Steel Rails.** Rigid steel rails are structural steel shapes adapted for use as bridge railing. They are normally rectangular or round steel tubes that are used in both one- and two-rail configurations. Although any steel shape can be used provided it meets strength and geometric size requirements, the most practical and economical designs are from standardized shapes specifically adapted for bridge railing. These typically consist of tubular steel sections or box beams that are available in a variety of sizes.<sup>6,7</sup> Rigid steel rails provide the highest stiffness to prevent vehicles from snagging the posts on impact. They may be attached directly to the post or to offset blocks that project the traffic face away from the post.

For all types of railing, two considerations that must be addressed are rail splices and the transition from bridge railing to roadway approach railing. Splices are important because they give continuity and strength to the overall rail system. With the exception of glulam rails, which can be fabricated in one piece for the bridge length, all types of rails must normally be spliced on the bridge. AASHTO loading criteria require that rails meet strength requirements at the post and at the center of the span, so that the strength of the splice will be sufficient to develop the full strength of the rail. For lumber and glulam rails, splices are normally made at the posts using steel angle or plate splices to transfer applied bending and tension. For W-beam and Thrie-beam sections, splicing is accomplished by bolting sections in prefabricated slots that are normally 6 feet 3 inches on center. For steel tubes, splices are made with smaller tube sections that are inserted inside the rail and bolted in place. Splices for steel rails serve not only to facilitate transportation and construction but also to provide a mechanism for expansion and contraction from temperature changes.

When designing bridge railing, careful attention must be given to the treatment of the railing at the bridge ends. Exposed rail ends, posts, and sharp changes in the geometry of the rail present a significant hazard to vehicles and must be avoided. The transition between the bridge and the approach roadway is generally accomplished by continuing the bridge

railing a distance along the roadway or by transitioning the bridge railing to approach roadway railing (Figure 10-8). In both cases, the transition must be smooth and of sufficient strength to protect the traffic from direct collision with the bridge-rail ends.



*Figure 10-8. - Standard rail transition between a glulam bridge rail and a steel W-beam approach rail.*

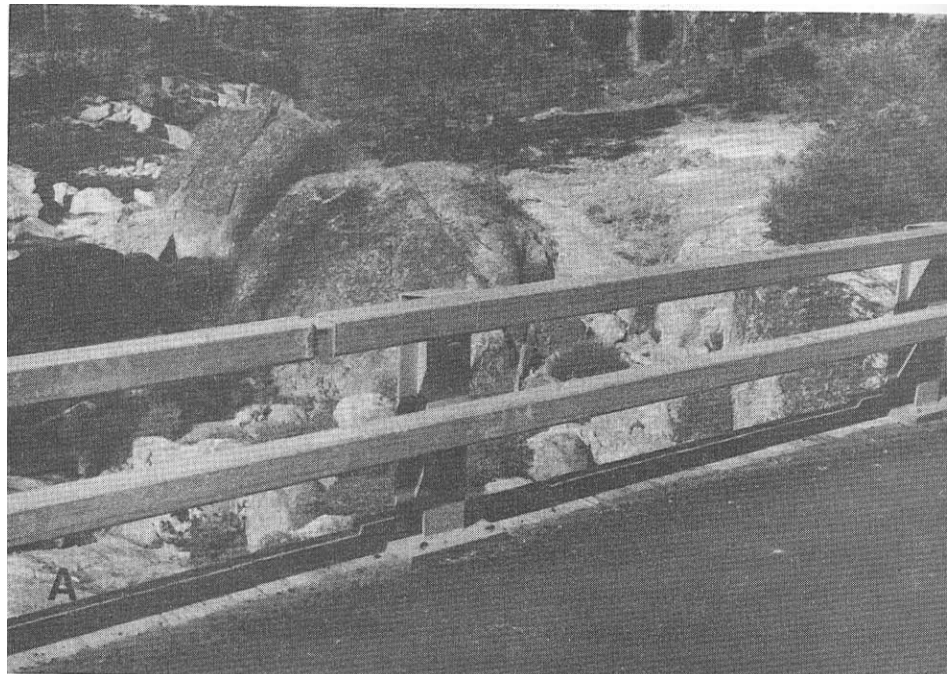
### Posts

Rail posts for timber bridges consist of timber or steel posts attached to the deck edge, or steel posts welded to base plates bolted to the top deck surface (Figure 10-9). Timber posts are either sawn or glulam members 8 to 12 inches wide and 10 to 12 inches deep. Steel posts are WF 6 x 20 or WF 6 x 25 sections fabricated from galvanized steel (ASTM A 36) or weathering steel (ASTM A 588). For edge-mounted posts, configurations vary for decks with and without curbs. When curbs are provided, posts are generally bolted through the curb at their midsection, with the lower end connected to brackets attached to supporting beams. When curbs are absent, posts are attached with steel brackets that bolt around or over the deck edge. The top mount configuration uses a steel base plate that bolts through the deck, most commonly a transverse-laminated deck.

Static load requirements for posts in AASHTO are the same regardless of post spacing. Hypothetically, posts spaced 1 foot apart are designed for the same loads as posts spaced 10 feet apart. In practice, the most common post spacing on timber decks is between 5 and 8 feet. Economically, materials and installation costs for posts increase as spacing decreases, while the required strength and cost of rails decrease as post spacing

decreases. Post spacing on glulam deck panels should consider the economics of panel fabrication and should be related to panel width. Placing a post on every other or every third panel in a repeating sequence allows standardized panel fabrication that can reduce costs and construction time.

One of the primary considerations in post design is the load transfer mechanism from the post to supporting components of the superstructure. When improperly designed, rail impact can cause substantial damage to the structure, requiring extensive and costly repairs (Figure 10-10). Longitudinal glulam and nail-laminated lumber decks require special attention because rail forces produce bending at the deck attachment, which in turn introduces tension perpendicular to the wide faces of the laminations. Because wood is weak in tension perpendicular to grain, these loads can cause longitudinal glulam decks to separate or break when railing loads are applied. On longitudinal nail-laminated decks, the same effects can cause the deck to separate between laminations. When a post is attached to a longitudinal beam, the outward post load can also produce loading against the weak axis of the beam. This can cause torque, tension perpendicular to grain, or lateral displacement of the beam. These effects can damage large members such as glulam beams, but their effects are much more pronounced in smaller beams, particularly sawn lumber. When attaching rail components to longitudinal beams, the beams must be sufficiently braced to distribute loads to adjacent members of the superstructure and to prevent adverse loading conditions on the members.



*Figure 10-9. - Typical vehicular railing configurations used on timber bridges. (A) Steel posts welded to base plates that are bolted through a glulam deck.*





Figure 10-9. - Typical vehicular railing configurations used on timber bridges (continued).  
(B) Lumber posts attached to steel plates that are bolted through a glulam deck.  
(C) Lumber posts bolted to a lumber curb with braces attached to a glulam beam.

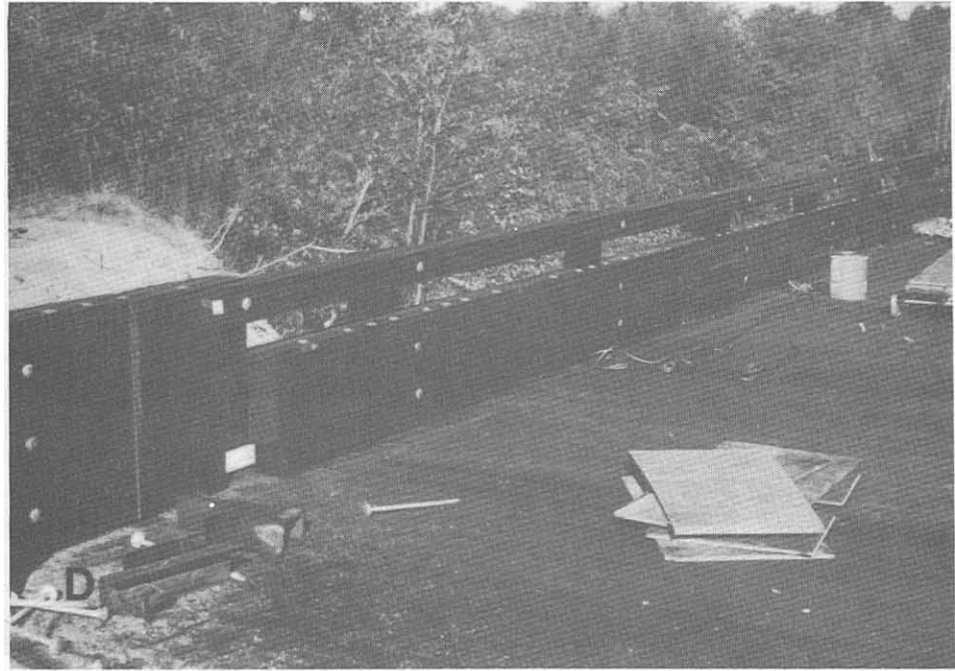


Figure 10-9. - Typical vehicular railing configurations used on timber bridges (continued). (D) Glulam posts and rail with a partial parapet bolted to a glulam deck (photo courtesy of LamFab Wood Structures, inc.). (E) Lumberposts bolted to the lumber curb on a longitudinal nail-laminated lumber deck (photo courtesy of Wheeler Consolidated, Inc.).

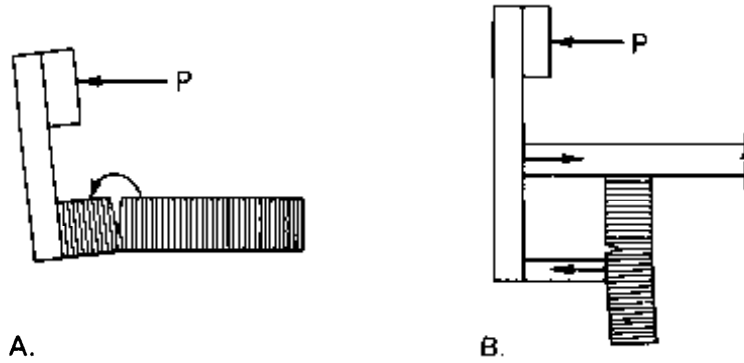


Figure 10-10. - Two types of potential timber bridge damage resulting from rail impact loads. (A) Separation in a longitudinal glulam or nail-laminated lumber deck from tension perpendicular to the laminations. (B) Beam damage resulting from forces transferred by a post brace.

### Parapets

Parapets are solid barrier walls that are designed to resist vehicle impact loads and safely redirect vehicles without causing significant damage to the structure or injury to the vehicle passengers. The most widely used type of parapet is the New Jersey-style barrier fabricated from reinforced concrete. Although these concrete barriers can be used on timber bridges they are generally impractical because of their high dead load. The same configuration can be fabricated from glulam when a barrier-type containment is desired (Figure 10-11). These barriers bolt to the bridge deck and must be evaluated in terms of deck effect in the same manner previously discussed for post configurations.

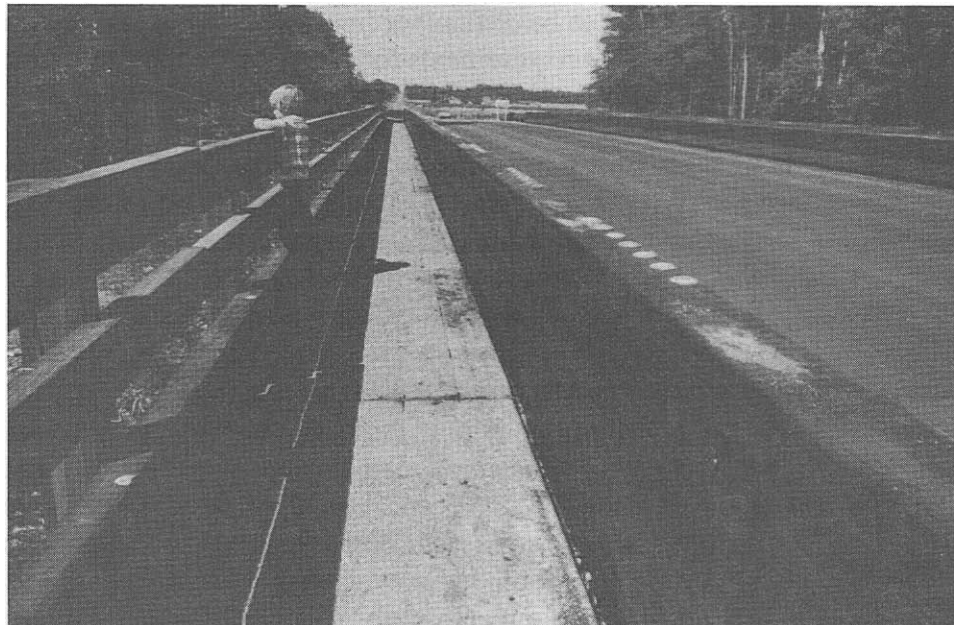


Figure 10-11. - Glulam parapets (photo courtesy of the Weyerhaeuser Co.).

## 10.3 PEDESTRIAN AND BICYCLE RAILING

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Pedestrian or bicycle railing is provided along the outside edge of sidewalks when vehicle and pedestrian traffic is separated by vehicular or combination railing. Pedestrian railing is used when the walkway is limited to foot traffic, while bicycle railing is used for bicycle traffic or a mix of bicycle and pedestrian traffic. Both railing types are designed for pedestrian loads and are not intended to resist vehicle impact. If a vehicle barrier is not provided between pedestrian and vehicle traffic, sidewalk railing should be combination railing discussed later in this chapter.

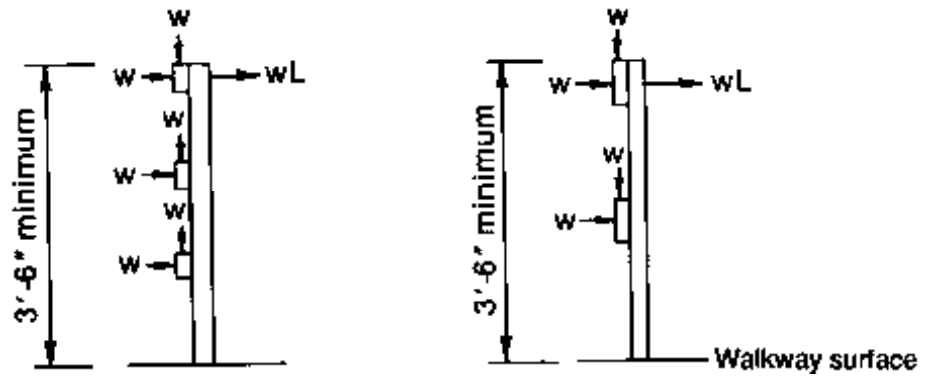
### DESIGN REQUIREMENTS

Design requirements for pedestrian and bicycle railing are based on minimum geometric and static load criteria given in AASHTO. Railing components should be proportioned commensurate with the type and volume of anticipated traffic with consideration given to safety and appearance. As with vehicular railing, any configuration or combination of materials is permissible provided minimum AASHTO requirements for geometry and loading are met. In cases where the structure will carry equestrians or other specialized traffic, more restrictive design requirements may be appropriate based on designer judgment. Requirements in AASHTO for rail geometry and loads are discussed below and shown in Figure 10-12.

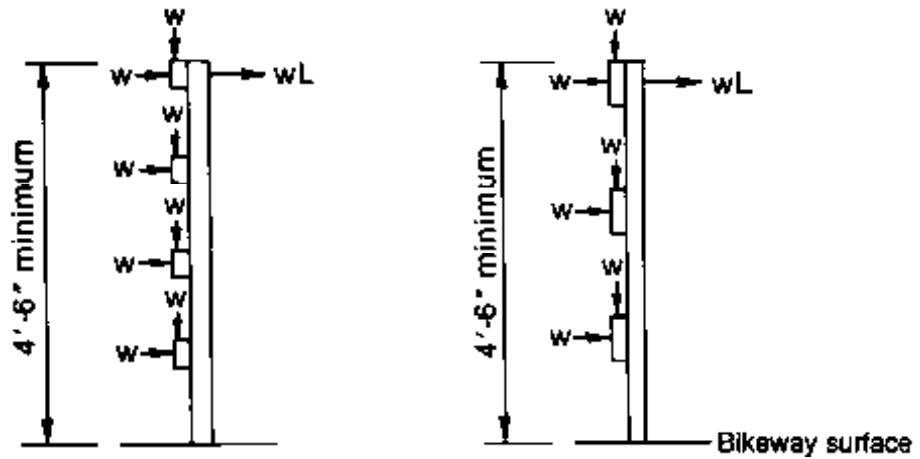
#### Geometric Requirements

Geometric requirements are the same for pedestrian and bicycle railing, with the exception of minimum rail height, which must be higher for bicycles. In both cases, the railing should provide a safe barrier to prevent adults and children from falling through. The system should also be designed to be difficult or impossible to crawl over or under. Minimum AASHTO requirements for railing geometry are as follows.

1. **Rail Height.** The minimum height of the railing measured from the top of the walkway surface to the top of the top rail is 3 feet 6 inches for pedestrian railing (AASHTO 2.7.3.2.1) and 4 feet 6 inches for bicycle railing (AASHTO 2.7.2.2.1).
2. **Rail Spacing.** Within a vertical band bordered by the walkway surface and a horizontal line 3 feet 6 inches above the surface for pedestrian railing, and 4 feet 6 inches above the surface for bicycle railing, the maximum clear vertical opening between horizontal rail elements is 15 inches (AASHTO 2.7.1.2.4 and 2.7.2.2.2). Vertical elements of the railing assembly shall have a maximum clear spacing of 8 inches within this band. If the railing uses both horizontal and vertical elements, the spacing requirements apply to one or the other, but not both.



Pedestrian railing



Bicycle railing

Notes:

1. Loadings shown to the left of the post are applied to the rails. Loads shown to the right of the post are applied to the post.
2.  $w = 50 \text{ lb/ft}$ ;  $L = \text{post spacing in feet}$ .
3. The maximum clear opening between rails, or between the lower rail and the walkway or bikeway surface, is 15 inches.
4. Rail and post shapes are illustrative only. Any material or combination of materials may be used in any configuration provided minimum AASHTO requirements are met.
5. Refer to AASHTO for illustrations of other railing configurations.

Figure 10-12 - AASHTO requirements for pedestrian and bicycle railing geometry and static loads (adapted from AASHTO Figure 2.7.4A); © 1983. Used by permission.

## Loading Requirements

Load requirements for pedestrian and bicycle railing are based on a uniformly distributed load acting on rail elements. Unlike vehicular railing, post loads are directly related to post spacing. Minimum requirements for rail and post loads are as follows:

1. **Rail Loads.** The minimum design loading for each pedestrian and bicycle rail element is  $w = 50$  lb/ft, applied simultaneously in the transverse and vertical directions (AASHTO 2.7.3.2.2 and 2.7.2.2.3). When rails are located more than 5 feet above the walkway for pedestrian railing, or 4 feet 6 inches above the walkway for bicycle railing, AASHTO loading is not required and loads are left to designer judgment (AASHTO 2.7.3.2.2 and 2.7.2.2.4).
2. **Post Loads.** Posts are designed for an outward transverse load  $wL$ , where  $L$  is the post spacing and  $w = 50$  lb/ft, as described above (AASHTO 2.7.3.2.3 and 2.7.2.2.5). The load is applied to the post at the center of gravity of the upper rail member, but not more than 5 feet above the walkway for pedestrian railing or 4 feet 6 inches above the walkway for bicycle railing (more severe loading for higher posts is left to designer judgment).

## DESIGN GUIDELINES

The most common pedestrian and bicycle railing configurations for timber bridges use horizontal rails on vertical posts, or vertical pickets on longitudinal rails (Figure 10-13). Rails are generally 3-1/8-inch glulam, nominal 2-inch dimension lumber, or steel tubes. Posts are 5-1/8-inch glulam, nominal 4-inch or 6-inch dimension lumber, or steel tubes. Posts are mounted to the sidewalk or supporting beam sides, or to the deck top with a base plate, in the same manner discussed for vehicular railing (Section 10.2). Although lower in magnitude, the structural effects of loads produced by pedestrian or bicycle railing also must be given the same attention discussed for vehicular railing. Of particular concern are the forces produced at the post attachment, where bending and shear can introduce tension perpendicular to grain in supporting members. On beam-type structures, transverse loads can also produce torsion in the beams, and the resulting stresses must be evaluated.

Pedestrian and bicycle railing differs significantly from traffic railing in one very important aspect: it is subject to human contact. The railing should be free of both chemical and physical hazards. Railing components should not be treated with oil-type preservatives that may cause skin irritations. Rather, surfaces should be treated with waterborne preservatives that are dried after treatment to prevent checking and warping (Chapter 4). Where aesthetic considerations are important, treated surfaces may be stained or painted to the desired color. Timber surfaces and edges should be planed and may be sanded smooth so that the potential for abrasion and

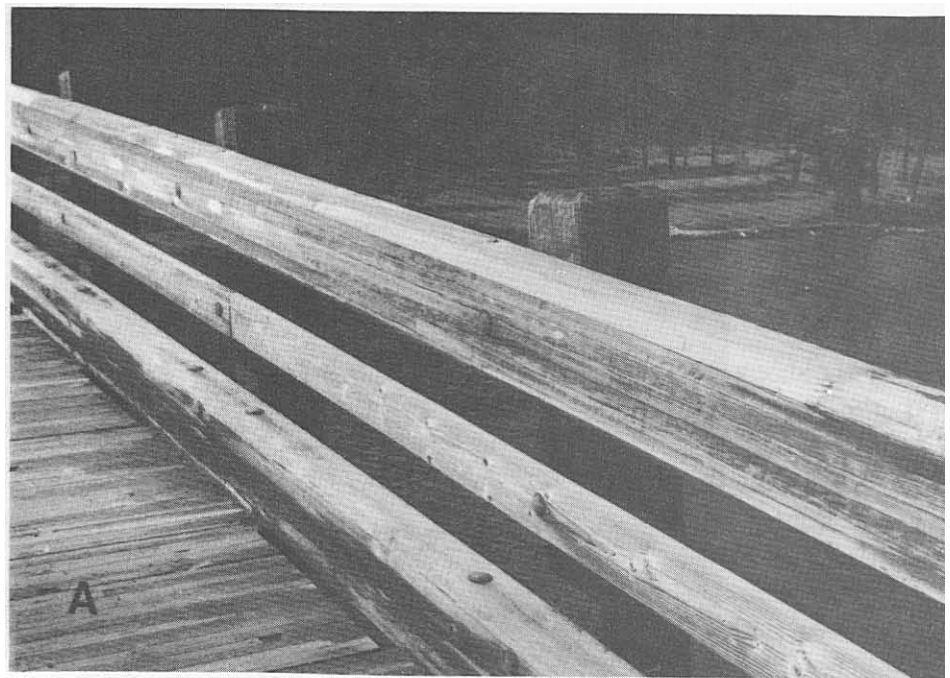


Figure 10-13. - Typical pedestrian/bicycle railing configurations used on timber bridges. (A) Glulam rails mounted on glulam posts. (B) Lumber posts with horizontal rails and vertical pickets.



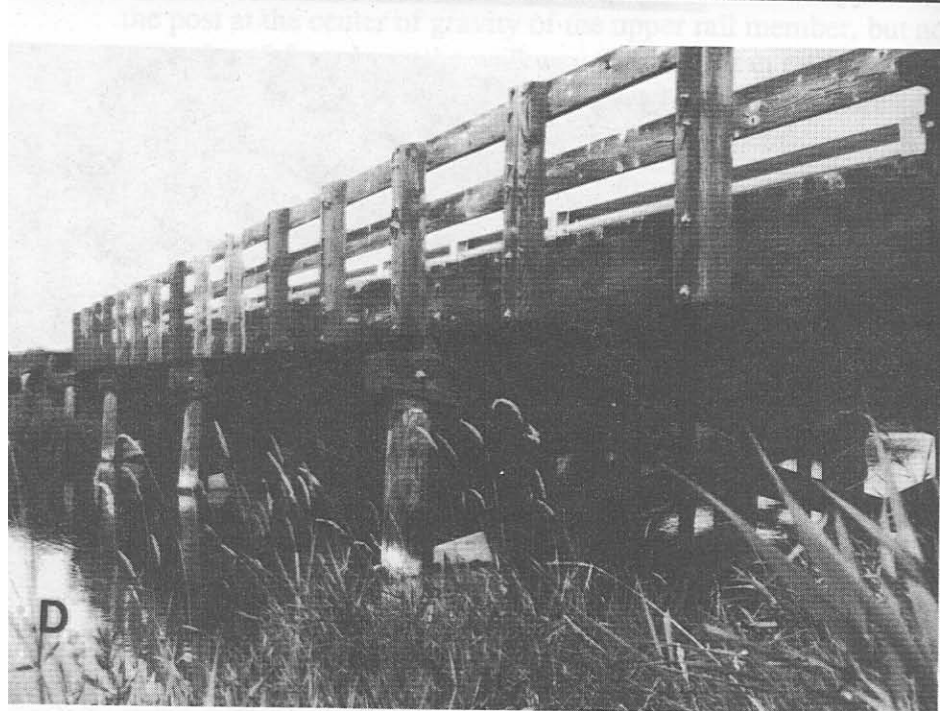
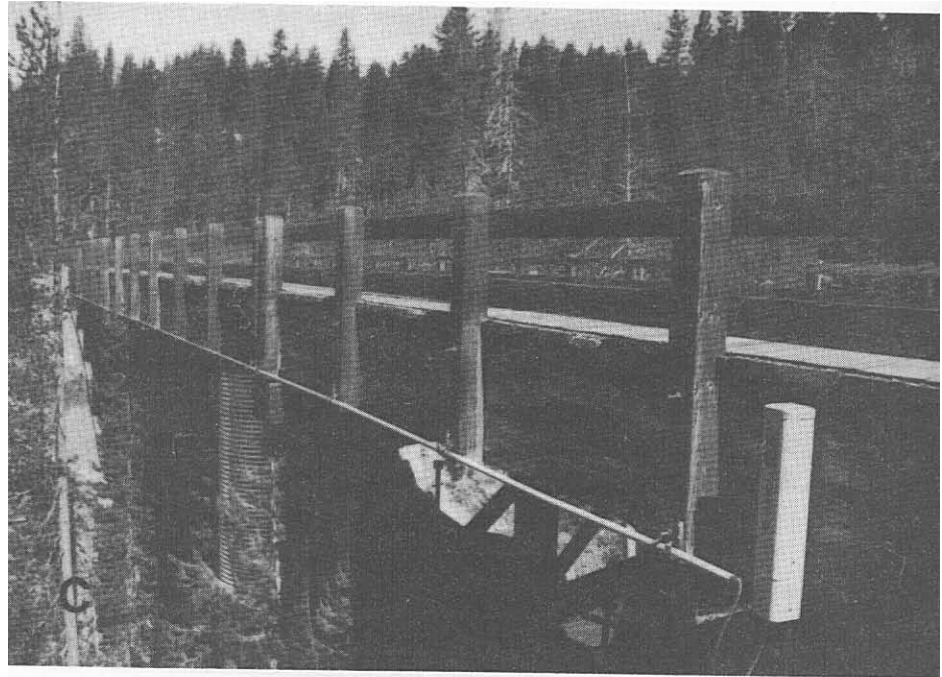


Figure 10-13. - Typical pedestrian/bicycle railing configurations used on timber bridges (continued). (C) Lumber rails on lumber posts that are bolted to a glulam beam. (D) Lumber rails on lumberposts that are bolted to a lumber beam (photo courtesy of Wheeler Consolidated, Inc.).



splintering is reduced. Hardware should be countersunk, with threaded bolt ends and nuts placed on the side opposite the sidewalk. When steel components are used, all edges and weldments should be ground smooth so that sharp edges and weld points are eliminated.

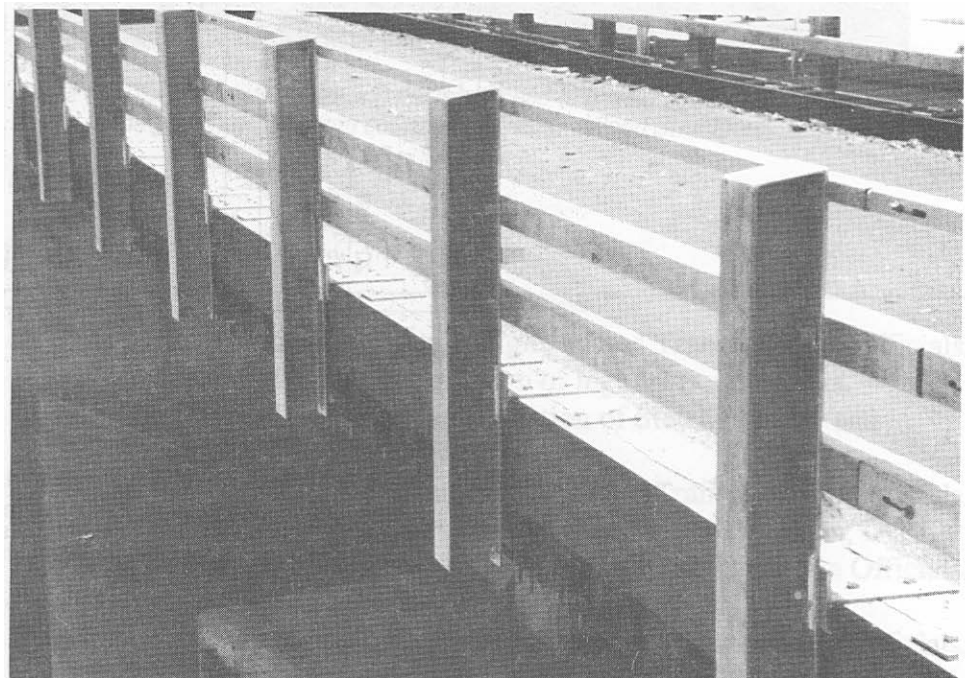
## 10.4 COMBINATION RAILING

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Combination railing is a multipurpose railing designed to perform the dual functions of vehicular railing and pedestrian or bicycle railing. It is used to separate sidewalks and bikeways from adjacent vehicle traffic, or is used along the outside edge of sidewalks when vehicle and sidewalk traffic are not separated by railing (Figure 10-14). AASHTO specifications require combination railing between the sidewalk and roadway for bridges on urban expressways (AASHTO 2.7). On other structures, the separation can be made with vehicular railing or combination railing; however, combination railing is recommended on bridges with an anticipated high volume of pedestrian or bicycle traffic to provide added protection for users.

### DESIGN REQUIREMENTS

Combination railing must be designed to function safely for two types of users. The lower traffic portion of the railing must meet the requirements specified for vehicular railing, while the upper portion must comply with the requirements for pedestrian or bicycle railing, including minimum rail height. The loading and geometric requirements previously given for



*Figure 10-14. - Combination traffic and pedestrian railing placed along the outside edge of a timber bridge.*

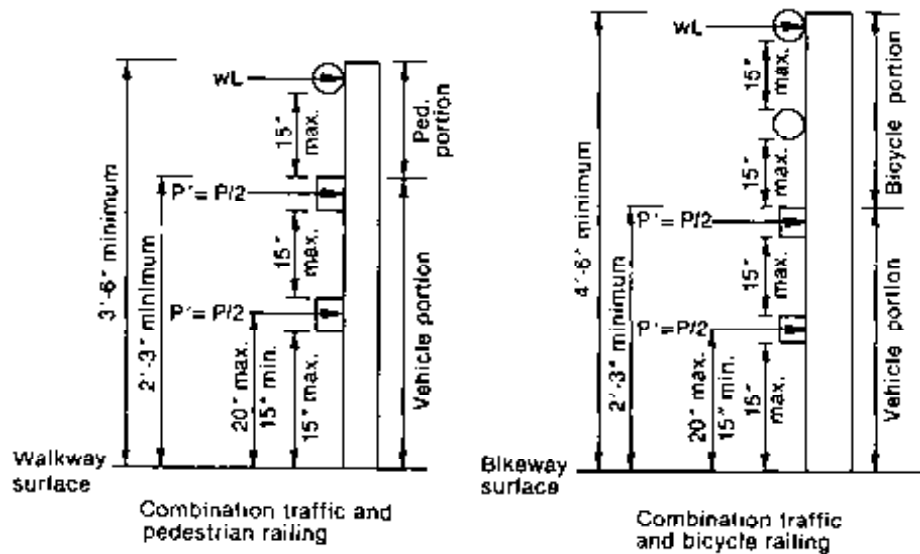
vehicular, pedestrian, and bicycle railing also apply to the respective portions of combination railing, with the following exceptions:

1. The maximum vertical clear opening between the lowest rail and the reference surface is 15 inches rather than the 17 inches specified for vehicular railing (AASHTO 2.7.1.2.4).
2. Handrail members of combination railings are designed for a moment at the center of the panel and at the posts of  $0.1 wL^2$ , where  $w = 50 \text{ lb/ft}$  and  $L$  is the post spacing in feet (AASHTO 2.7.1.3.5).

Minimum AASHTO requirements for combination railing geometry and outward transverse post loads are illustrated in Figure 10-15.

## DESIGN GUIDELINES

The most significant design consideration for combination railings used between a roadway and walkway/bikeway is the attachment of the posts to the deck or supporting components. On glulam, stress-laminated lumber, and transverse nail-laminated lumber decks, the most convenient and practical approach is generally to use steel posts that are welded to base



Notes:

1.  $w = 50 \text{ lb/ft}$ ;  $L = \text{post spacing in feet}$ .
2. Rail and post shapes are illustrative only. Any material or combination of materials may be used in any configuration provided minimum AASHTO requirements are met.
3. Refer to AASHTO for illustrations of other railing configurations.

Figure 10-15. - AASHTO requirements for combination railing geometry and outward transverse static loads (adapted from AASHTO Figure 2.7.4B); © 1983. Used by permission.

plates and bolted through the deck in the same manner previously discussed for vehicular railing. An alternate approach, and one that can be adapted to other deck types, is to carry the post through a cutout in the deck and attach it directly to the supporting beam (Figure 10-16). When this is done, the beam capacity must be sufficient to resist potential railing loads and the torsion they create. In addition, attachments of this type require that transverse bracing between the beams be of sufficient strength and spacing to adequately distribute loads applied through the posts.



*Figure 10-16. - Combination railing posts attached to glulam beams (arrow) through a cutout in the glulam deck (photo courtesy of Western Wood Structures, Inc.).*

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