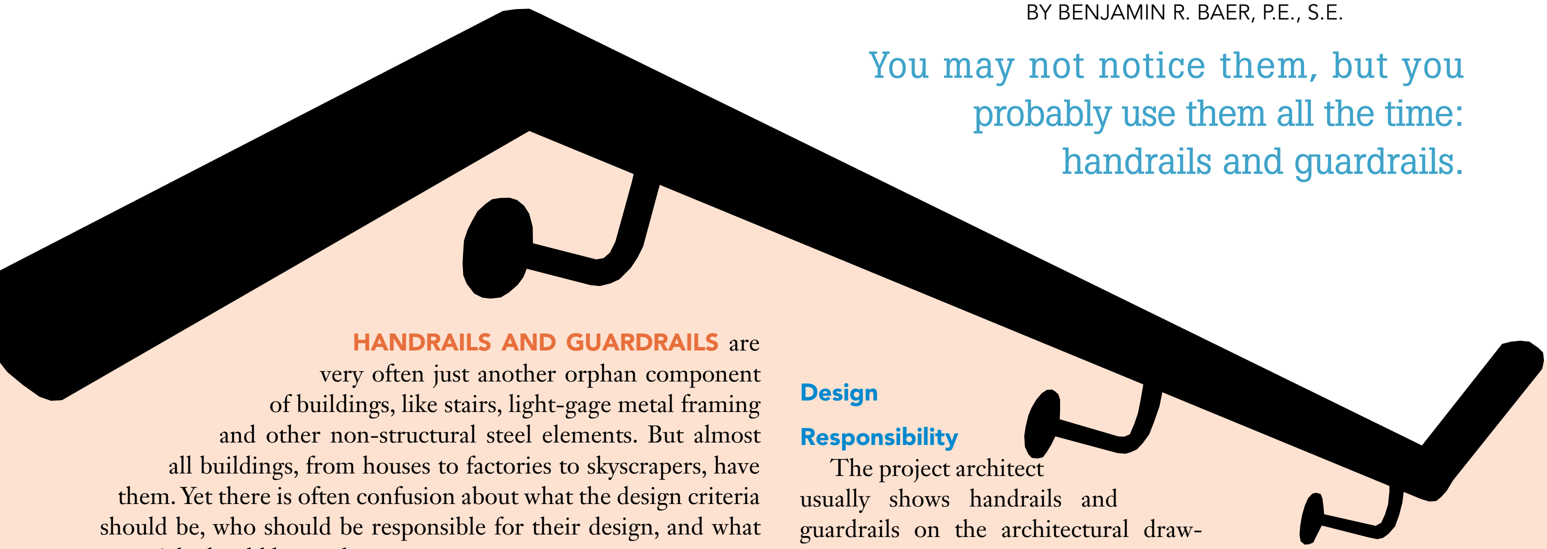
Holding On

BY BENJAMIN R. BAER, P.E., S.E.

You may not notice them, but you probably use them all the time: handrails and guardrails.



HANDRAILS AND GUARDRAILS are very often just another orphan component of buildings, like stairs, light-gage metal framing and other non-structural steel elements. But almost all buildings, from houses to factories to skyscrapers, have them. Yet there is often confusion about what the design criteria should be, who should be responsible for their design, and what materials should be used.

Handrail vs. Guardrail

The terms handrail and guardrail are often used interchangeably, although they have two different definitions. According to most building codes, guardrails (or guards) are required at the open side of elevated walking surfaces to prevent a fall to the lower surface. The 2006 International Building Code (IBC 2006) generally requires guardrails when the difference in elevation between the upper and lower surfaces is 30 in. or more. Handrails, on the other hand, are something that can be grasped for guidance or support while walking, usually on a stair. The biggest difference between a guardrail and a handrail is that the area below the top rail of a guardrail is infilled with additional components such that there is no opening large enough for a 4-in.-diameter sphere to pass through; this approximates the size of a small child's head. Openings should be small enough to prevent a child's head from entering, where it could become trapped with disastrous results.

The Occupational Safety and Health Administration (OSHA) has requirements for handrails and guardrails that apply to all permanent places of employment, except where only domestic, agricultural, or mining work is performed. OSHA generally requires a guardrail when the walking surface is elevated 4 ft or more above the lower surface. For guardrails, the OSHA standards require one intermediate rail approximately halfway between the top rail and the walking surface (as opposed to the closely spaced infill required by the IBC). Jurisdictions that do not use a model building code, or have adopted an older version of a model building code, may have less restrictive requirements than the OSHA standards, in which case the OSHA standards would govern the design.

Design Responsibility

The project architect usually shows handrails and guardrails on the architectural drawings. Sometimes, just a schematic representation of the desired architectural profile is shown; other times, all of the members' sizes are provided. Even in this case, project specifications very often require signed and sealed calculations from a specialty structural engineer (retained by the fabricator). It is important that the drawings and specifications be consistent and compatible. If there are specific member sizes or details required by the project design team, they should be shown on the design drawings. However, once specific member sizes or details are shown on the design drawings, the licensed design professional who signs those drawings—i.e., the architect or structural engineer of record—retains full responsibility for those member sizes or details, even if delegation language is included in the project specifications. If the project design team wants the fabricator's structural engineer to be completely responsible for the design of the handrails, only schematic information should be shown on the design drawings.

Structural Design Criteria

The 2006 IBC requires that handrails, guardrails, and their supports be designed for 50 lb per linear foot, applied in any direction at the top of the top rail, and a concentrated load of 200 lb applied in any direction at any location along the top of the top rail. The uniform load and concentrated loads are not to be applied simultaneously. Other components, including guardrail infill and bottom rails, are to be designed for 100 lb acting on a projected area of 1 sq. ft, including the open space between components. The effects of this load are not to be combined with the load on the top rail. One- and two-family residences need only be designed for the 200-lb concentrated load, and certain low-occupancy areas not accessible to the general public need only be designed for 20

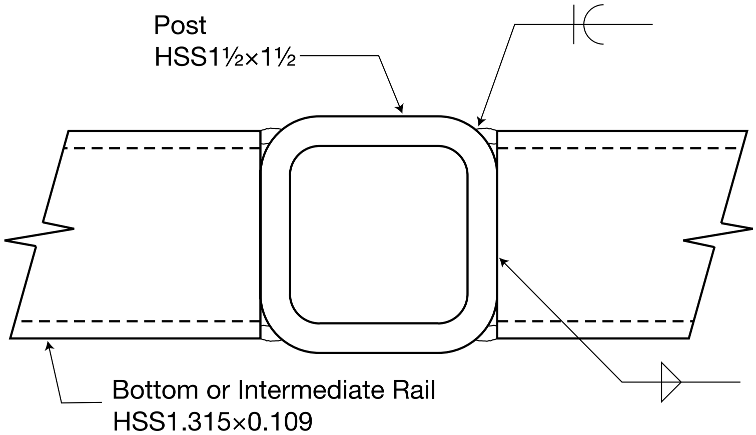


Figure 1.
Connection of bottom or intermediate rail to post.

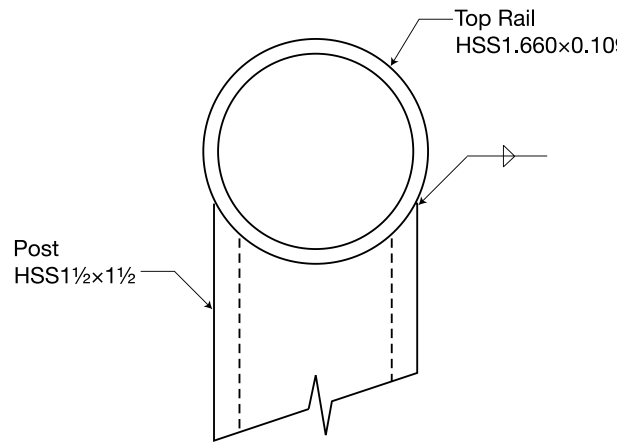


Figure 2.
Connection of top rail to post.

lb per linear foot, in addition to the 200-lb concentrated load.

OSHA standards require both guardrails and handrails be designed for a concentrated load of 200 lb applied in any direction at any location along the top of the top rail. These standards also include specific member sizes for railings constructed of wood, steel pipe, and steel angles. Other sizes and configurations are equally acceptable, as long as they comply with the strength requirement and provide at least the same level of protection as the stated sizes.

Since its inception in 2000, the IBC has permitted the allowable stresses for handrails and guardrails to be increased by one-third when the design is based on working stress. This provision, which does not appear in any other codes or specifications, is based on a perceived disparity between allowable (working) stress design (ASD) and load and resistance factor design (LRFD) for both steel and wood, and on the lack of widespread use of LRFD for wood. While this provision actually results in non-conservative and potentially unsafe design for critically important components, it has been continued in the 2006 IBC. Informally, there are efforts to remove this provision from the 2009 edition. Engineers are strongly urged *not* to use this stress increase.

Handrail Size

The biggest source of confusion for handrails and guardrails is the diameter of the member to be gripped. When the Americans with Disabilities Act Accessibility Guidelines (ADAAG) were enacted in 1992, they specified a diameter of 1¼ in. to 1½ in. for the handrail, and the corresponding figures clearly showed this to be the outside diameter of the handrail. However, standard industry pipe and hollow structural section (HSS) sizes are not based on the outside diameter (or the inside diameter), and confusion arose almost immediately.

According to one source, the original ADAAG were based on an outdated version of the underlying American National Standards Institute (ANSI) A117.1, *Accessible and Usable Buildings and Standards*. At the time the ADAAG became effective in 1992, it was based on the 1986 version of ANSI A117.1, which stated that handrails were to be between 1¼ and 1½ in. in diameter. However, ANSI 117.1 had been revised in 1990 to clarify that the intention was to allow for nominal pipe sizes of 1¼ in. to 1½ in.

The ADA is a civil rights protection law (not a building code), and as such, enforcement of the pertinent sections is by the

Photos: Livers Bronze Co.

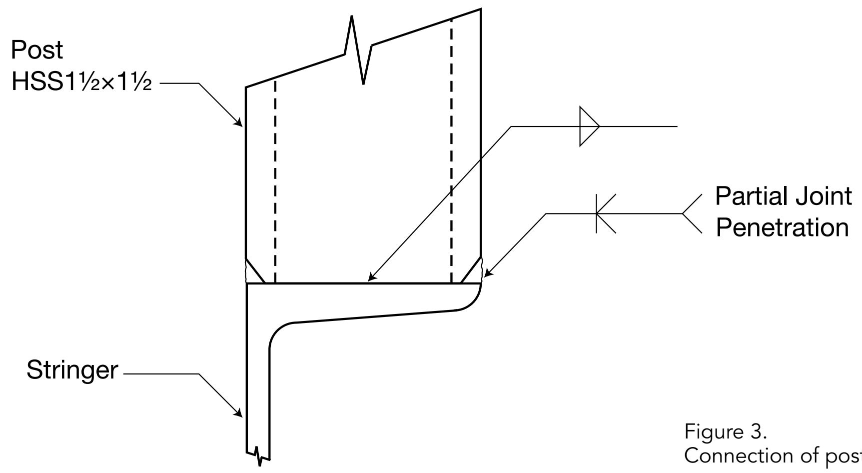


Figure 3.
Connection of post to stringer.

U.S. Department of Justice (DOJ). In 1993, DOJ issued a letter clarifying that 1¼-in. to 1½-in. standard pipe sizes (1.660-in. and 1.900-in. outside diameter, respectively) are acceptable for compliance with the ADA.

In 1998, the Access Board, a Federal agency that administers the ADA, published an explanatory manual on the ADAAG. It states that "standard IPS pipe designated as 1¼ to 1½ in. is acceptable." Further, the manual actually recommends the use of 1¼-in. pipe, because the diameter of 1½-in. pipe approaches 2 in., which is a bit too large to be comfortably gripped. To this day, the Access Board provides the same clarification among the "Frequently Asked Questions" on its website.

An updated version of the ADAAG was issued in 2004 and amended in 2005. This latest version changed the language on handrail size to eliminate the confusion, and only specifies a minimum outside diameter of 1¼ in. and maximum outside diameter of 2 in. This language is the same as that in IBC 2006, and in fact, earlier editions of the other model building codes—e.g., UBC 1991 and BOCA 1993.

Recommendations

There is no single handrail or guardrail design that will work for all situations. There are different functional code requirements, different load requirements, and different aesthetic requirements. Each handrail is unique, and each requires architectural and structural design by licensed professionals. Nevertheless, there are a few general recommendations that can simplify design, fabrication, and installation and result in a more economical solution.

To comply with the accessibility guidelines and strength requirements, it is recommended that the top rail be HSS1.660×0.109 (equivalent to the size of a 1¼-in. nominal Schedule 10 pipe). This material is commonly available as A500, Grade C (F_y=46 ksi), and the cost per lineal foot is about the same as the slightly heavier standard (Schedule 40) A53 pipe. There are no accessibility requirements for the bottom rail of guardrails, and they do not have the same load-bearing requirements of the top rail. Therefore, a slightly smaller, HSS1.315×0.109 (equivalent to the size of a 1-in. nominal Schedule 10 pipe) can be used. This too, is commonly available as A500, Grade C. These rail sizes are usually sufficient for most common post spacings.

It is recommended that posts be HSS1½×1½ to simplify the fabrication. This square hollow section is commonly available in 0.145-in., 3⁄16-in. and ¼-in. wall thicknesses as A500, Grade B material. The difference in cost between a round post and a square post is offset by the easier fabrication with square posts. When using a square post, the ends of the bottom rails do not need to be cut to fit around a circular section. The bottom rail can be fillet welded to the flat face of the post. The top rail fits well on top of the profiled post (Figure 1). Welds on the top rail provide structural strength and seal the top of the post (Figure 2). Also, the bottom of square post fits on the flange of common stair stringers members, or to the side of plate stringers. When attached to the top flange of stringer channels, the base of the post can be fillet welded on two sides and partial-penetration welded on two sides (Figure 3). The common stair stringer channel (MC12×10.6) has a flange width of 1½ in., which is too narrow for 1.9-in.-diameter HSS or pipe. One steel mill has begun producing a channel specifically for stair stringers with a 2-in. flange to accommodate 1.9-in.-diameter HSS or pipe.

For guardrails, there can be a wide variety of choices for the infill, such as individual pickets, glass panels, solid or perforated metal panels, or wire mesh. The simplest, easiest, and usually most economical choice is solid round or square bars for individual pickets. The diameter will depend on the distance between the top rail and the bottom rail, but will generally be ½ in. to ¾ in. in diameter. Nominal ½-in. pipe could be used, but it usually costs more than solid ½-in. or ¾-in. rod.

Wire mesh is an alternative for the infill in guardrails. While it would seem the installation should be easier than individual vertical pickets, this may not always be the case. Even though there are many more pieces to fabricate and install, individual pickets are usually less expensive than wire mesh. To be most effective, wire mesh should be manufactured from 6 or 7 gage wires (approximately 3⁄16 in. in diameter) to provide sufficient strength, and sufficient resistant to impact loads—i.e., kicking. The mesh should be lock-crimped or welded to keep the wires in place, and the openings should be no more than 2 in. square to prevent people from climbing on the mesh. When using wire mesh in high security applications such as correctional institutions, each wire has to be secured—i.e., welded—to a "U-shaped" perimeter steel frame to prevent removal of the wire, which could then become a weapon.

In 1993, the BOCA Code introduced a new provision for guardrails, stating that they could not have an ornamental pattern that would provide a ladder effect. A common guardrail design is a series of horizontal pipes as the infill. However, the horizontal pipes can be used as a convenient ladder, defeating the purpose of the guardrail. While this provision does not appear in the IBC or other codes, it is a good practice not to use infill that could be used as a ladder, especially in uncontrolled public areas. Aside from making for a safer barrier, it can help limit potential liability.

Specific Condition, Specific Design

Although there may be confusion about the responsibility or design of handrails and guardrails, a structural design is required for each specific condition. As with any component, the design must consider strength and serviceability, which includes ADA requirements.

Code requirements, material availability, and labor and material costs can affect efficiencies in design. (Note that the welding featured in this article is done to meet National Association of Architectural Metal Manufacturers standards and not necessarily those of the American Welding Society.) As always, it is good to check with a local fabricator to get the best information on feasibility and costs. MSC

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History of Standard Pipe Sizes

A better understanding of handrail size comes from a little background on pipe sizes. Standard industry pipe sizes are based on a system of nominal pipe sizes. Standard 1¼-in. pipe has an outside diameter of 1.660 in., and standard 1½-in. pipe has an outside diameter of 1.900 in. There is also "mechanical grade" tubing available with an outside diameter of 1½ in. However, this tubing is not manufactured to the material specifications referenced by the building codes for load-bearing components. The governing standards for steel components specify that handrail material must comply with ASTM A53 (pipe), A500 (HSS), or A501 (HSS), and there is no 1¼-in. or 1½-in. outside diameter material available that complies with these standards. Only standard industry pipe sizes are manufactured to meet these material requirements.

The exact origin of pipe size designations is lost to history. It is known that nominal pipe sizes were first tabulated around 1862 by Robert Briggs, superintendent of Pascal Iron Works in Pennsylvania. To this day, nominal pipe sizes are sometimes referred to as "Briggs Standard." The basis for Briggs' standardization is not known, but it is thought that his standard was based on the size of the dies used by Pascal Iron Works. One method of producing seamless pipe is by piercing a hot solid round bar or billet with a die. The bar is then worked with increasing sized dies to achieve the desired diameter and wall thickness.