

# Controlling Falls on Stairways

## Highlights:

- Design, lighting and visibility deficiencies can cause falls as well as inattention
- Riser and tread design considerations
- Stairway visibility
- Stair rails and handrails
- One to three-step stairways: falling into thin air

Slip, trips, stumbles and falls from stairways, including one to three step stairways, can be attributed to any combination of deficiencies in design, lighting, visibility and attention.

Falls from stairs and serious injury are mostly attributed to missteps during stair descent:

- **Understep:** where the heel strikes the riser resulting in a forward stumble.
- **Overstep:** where the ball of the foot rolls off the tread nosing resulting in loss of balance and forward stumble.
- **Air step:** where the foot misses the tread all together resulting in a forward stumble.



Research has shown there are three times more injuries from stair descent than ascent.<sup>1</sup> The presence of handrails and their design is critical to aborting a fall should a misstep occur, and to avoiding serious injury.

This reference note will provide a summary of recommendations for safe stairway design, including: riser and tread design; stair rail and handrail design; lighting; visibility; and maintenance and use.

## Riser and Tread Design

Trips and falls during stairway ascent are often attributed to variation in riser (vertical surfaces) height.

Most building codes require risers not to vary more than 3/8 inch between the tallest and shortest riser within a given flight of stairs. The NFPA 101 Life Safety Code prohibits an excess of 3/16 inch from tread to tread. Research has shown that during stairway use pedestrians view only the first and last three steps when negotiating a given flight, with the rest of the stairway negotiated without looking. Therefore, design of the top three and bottom three steps is very important.<sup>2</sup>



The Liberty Mutual Research Institute for Safety completed a study of acceptable and preferred dimensions of stairway risers and treads and compared results with available guidelines as described in standards and codes. This study concluded riser heights below 6 inches (15.2 cm) and above 8 inches (20.3 cm), and tread depth more than 13 inches (33 cm) and less than 10 inches (25.4 cm) should not be allowed.<sup>3</sup>

Slope of the stair is important to riser and tread design.

In descent, tread depth (horizontal surfaces) or “going” in the UK must be adequate for the ball of the foot to land on without extending over the step below. If not, an over-step or misstep can occur causing a fall forward.

The following are current recommendations for riser and tread dimensions:

- All tread and riser dimensions should be uniform throughout the entire stairway.
- Riser heights should be 4 inches (10.2 cm) minimum and 7 inches (18.0 cm) maximum. Minimum tread depth should be 11 inches (28.0 cm), exclusive of overhang.
- Tread surfaces and floor surfaces leading to the stairway should be slip-resistant.
- Stairways with more than 12 steps should have an intermediate landing. Landings should be void of any raised areas or trip hazards.

### Stair Slope

A steep stairway can have a role in falls depending on tread design and handrails. This issue is mostly in industrial and construction stairways. A slope or pitch angle of 30-35 degrees is common. OSHA 1910.24 Table D-1 provides riser heights and tread runs per angle to horizontal.<sup>4</sup>

### Stairway Visibility

Misreading the stair edge can translate to faulty foot placement and an accident. This can be caused by poor visibility of both risers and treads.

Guidelines for stair visibility are as follows:

- Provide visual contrast on tread nosings or at the leading edges of treads without nosings, so that stair treads are more visible for people with low vision.
- ADA specifies that detectable warnings “shall contrast visually with adjoining surfaces, either light-on-dark, or dark-on-light.” (70% contrast in light reflectance value LRV). Surfaces colored Safety Yellow are the “most visually detectable.”<sup>5</sup>
- In low light areas, an option is to highlight each step using step lighting.
- Post signs calling attention to the stairway at waist height on the approaches from both directions.

### Stair Rails and Handrails

Stair rails and handrails are needed for very different purposes. Stair rails or stair guardrails protect pedestrians from falling off the edge of the stairs or landings. Handrails serve to help pedestrians keep their balance and provide leverage when ascending/descending stairs.

#### Stair Rails

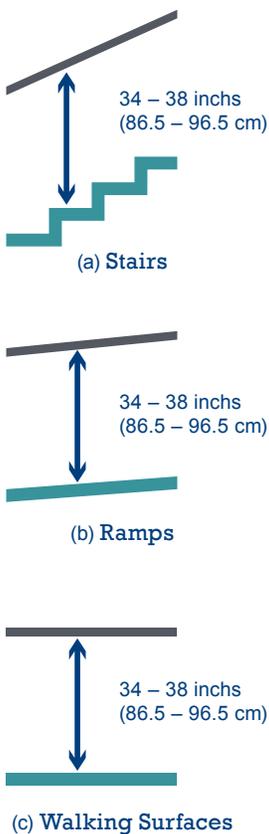
A handrail is usually too low to prevent pedestrians from falling over the edge of open stairways and landings while guardrails are too high to be used as handrails.

The following are recommendations for stair rails and handrails for open stairs and landings:

- Install a two-rail system; a top rail at 42 inches (106.7 cm) high and a second handrail at 34 inches (86.5 cm) minimum, and 38 inches (96.5 cm) maximum vertically above stair nosings (see Figure 1).
- Protect the open area under the top rail to the stairway steps by installing a fixed barrier. Fixed barriers are preferred to balusters in public settings, as balusters can represent a hazard for small children. Be sure to check code requirements before installing balusters.
- Midrails, screens and mesh are recommended between the top rail and stairway steps for stairways used during construction.

#### Handrails

Lack of, or improperly positioned and designed handrails are often cited as proximal causes of stairway falls. Well-designed handrails not only can reduce the chance of a fall, but may also serve to limit the distance down the stairs one may fall.



**Figure 1:** Handrail Height Measurement

There is considerable variation in the building codes and standards on when and how many intermediate hand rails are needed.

The following are recommendations for handrail design, including intermediate or middle handrails:

- Install highly visible handrails on both sides of the stairs.
- Handrails should be at a consistent height above stair nosings, ramp surfaces and walking surfaces. Top of handrail gripping surfaces should be 34 inches (86.5 cm) minimum and 38 inches (96.5 cm) maximum vertically above the stair nosing (see Figure 1.).
- Handrails should allow continuous holding (gliding above) without encountering support obstacles.
- On the upper floor surface, the handrails should start out horizontally, at the beginning of the demarcation zone (about 12 inches). This gives people one more visual cue to the stairway's presence and allows them to grip the railing before they begin to descend the stairs.
- At the bottom of the stairway, the handrail should continue horizontally beyond the bottom step for a distance at least equal to the depth of one tread.
- Handrails with a circular cross section should have an outside diameter of 1¼ inches (3.2 cm) minimum and 2 inches (5.1 cm) maximum.
- Handrails with a non-circular cross section should have a perimeter dimension of 4 inches (10.2 cm) minimum and 6¼ inches (16.0 cm) maximum, and a cross-section dimension of 2¼ inches (5.7 cm) maximum.
- Clearance between handrail gripping surface and adjacent surfaces should be 1½ inches (3.8 cm) minimum.
- If the stairway is two or more lanes wide, install intermediate railings in the middle to make the stairway more noticeable and to help people avoid or correct missteps.
- New stairways greater than 75 inches should have intermediate handrails so that handrails are within 30 inches of all portions of the egress route.
- Open stairways or stairways with open risers may not be permitted. Check your local building codes.
- Intermediate handrails; new stairs, provided within 30 in. (760 mm) of all portions of the required egress width and existing stairs within 44 in. (1120 mm) of all portions of the required egress width.



### **Adequate Lighting**

As people descend a stairway, the floor below and the treads are in their line of sight, but the risers are not. Therefore, the top safety priority is to make the treads more visible through contrasting nosings and adequate lighting.

- Install at least 20 foot-candles (200 lux) of local spot or floodlight illumination to highlight the stairway and the floor approaching it on both levels. Measure the illumination at the applicable floor or stair tread surface.
- Make sure the edge of each tread is properly illuminated
- Aim the lighting so that shadows are not cast on the stairway and glare does not disrupt the vision of those approaching the stairway.
- Ensure that stairways are lit at all times and do not require employees to turn on a light switch to light the stairs. Back-up power is especially critical for stairway lighting.

### **One to Three-Step Stairways**

Low stairways consisting of one, two or three steps are commonly found inside public buildings such as hotels, restaurants, retail establishments and theaters. A significant number of trips and falls occur on these low stairways because people fail to perceive the modest change in floor level.

The most serious accidents on low stairways usually occur when people fall from the higher floor surface. In effect, they step off into thin air, not having seen the stair or stairs at all.

Tripping is also a hazard, especially when people do not notice the stairway as they approach from the lower level. Though failure to detect the presence of low stairways is the biggest reason for such falls, inadequate stair dimensions, missing railings, improper railing heights and poor lighting are contributing factors.

If it is feasible from an operational and a financial standpoint, consider the following:

- Change the stairway approach path to require people to slow down and turn about 5 to 10 feet (1.5 to 3 meters) before reaching the stairway. This type of approach makes it more likely that people will notice the stairway.
- Use railings and other assistive fixtures to achieve a right angle or oblique turn.
- Remodel the stairway into a ramp. State, local and national codes specify guidelines/ requirements for ramp design. For example, ramp slopes 1:15 minimum to 1:12 maximum with “slip-resistant” surfaces is often cited.
- Visually contrast the leading edge of each step using Safety Yellow. Another option is to highlight the step using step lighting.

### **Maintenance and Use**

Many stairway accidents occur due to poor maintenance, inattention and use.

- Keep stair treads clean and in good condition.
- There should be no excessive wear, missing treads or loose treads. Carpeted stairs should be in good condition with no noticeable deterioration.
- Never use stairs for storing objects.
- Do not carry items in the hands on stairs and do not rush up or down stairs.
- Address importance of stair safety in employee safety training sessions.

### **References**

1. Mian, et al., Kinematics of Stair Descent in Young and Older Adults and the Impact of Exercise Training, *Gait & Posture*, Vol. 25, Issue 1, 2005.
2. Templer, John, *The Staircase: Studies of Hazards, Falls, and Safer Design*, MIT Press, Cambridge, MA, 1994.
3. Irvine, C.H., Snook, S.H., and Sparshatt, J.H., Stairway Risers and Treads: Acceptable and Preferred Dimensions. *Applied Ergonomics*, 21.3, pp. 215-225, 1990.
4. OSHA 1910.24, Subpart D, Fixed Industrial Stairs.
5. U.S. Access Board Research, Research on Visual Contrast in “Detectable Warnings: Synthesis of U.S. and International Practice.”

### **Additional Resources**

American National Standards Institute (ANSI) A117.1, Standard on Accessible and Usable Buildings and Facilities.

American National Standards Institute (ANSI) Z535.1, Safety Color Code.

Roy, M. S., Serious Stair Injuries Can Be Prevented by Improved Stair Design. *Applied Ergonomics*, 32 (2), 135-139, 2001.

International Organization for Standardization (ISO) 3864, Safety Colours and Safety Signs.

NFPA 101, Chapter 7, Means of Egress, section 7.2.2 Stairs.

U.S. Access Board: Americans with Disabilities Act (ADA) ADA and ABA Accessibility Guidelines for Buildings and Facilities.

U.S. Department of Labor, Occupational Safety and Health Administration. Stairways and Ladders. OSHA 3124-12R, 20039. Illuminating Engineering Society of North America, *Lighting Handbook*.

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