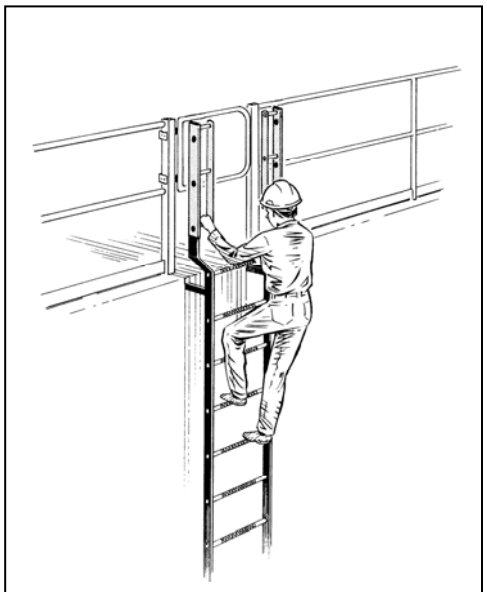
CONSTRUCTION SAFETY DESIGN SOLUTION
DESIGN CATEGORY: Roof Access
HAZARD: Falls from ladders and other climbing structures
DESIGN SOLUTION: Incorporate horizontal grab features for effective three-point control

Fatalities caused by falls from elevation continue to be the leading cause of death for construction workers, accounting for 345 of the 899 construction fatalities recorded in 2014.[1] Falls from ladders make up nearly a third of those deaths.[2] Some of these deaths can be prevented if designers incorporate horizontal grab features to enable workers to more effectively use three-point control when climbing ladders and other structures.

SOLUTIONS

Providing Horizontal Grab Features to Prevent Falls From Ladders

For walk-through fixed ladders, designers should specify that the ladders or ladder equivalent have horizontal round grab bars. If a fall occurs, a vertical rail extension is less effective in stopping the fall due to low sliding friction and lack of a horizontal power grip.[3] However, if a worker is holding rungs on the ladder or equipment or structure horizontal grab bars, sliding is avoided when a fall starts at the top three-foot extension of a fixed ladder during transition due to the high-strength, non-sliding hook grip.



Worker using horizontal grab bars on fixed ladder.

Workers should be trained to hold only horizontal rungs and horizontal grab bars when possible and to use the three-point control climbing technique. See below for a discussion of three-point control versus three-point contact.

Designers of ladder climbing systems should consider human factors when planning the use of effective three-point control. These factors include handgrip strength capacities, the maximum breakaway force if a hand is forcibly pulled away from a support, and the size, shape, orientation, and spacing of handholds/grab bars.

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[1] BLS, 2014 Census of Fatal Occupational Injuries,
[2] Falling Off Ladders Can Kill, OSHA Publication 3625 (2015). *See also* CDC, Morbidity and Mortality Weekly Report, Occupational Ladder Fall Injuries – United States 2011 (Apr. 25, 2014) ("Among construction workers, an estimated 81% of fall injuries treated in U.S. emergency departments (EDs) involve a ladder.")
[3] A horizontal power grip refers to holding a rung or horizontal bar, as opposed to holding side rails or vertically placed holds. *See* Barnett and Poczynok (2000). Ladder rung vs. siderail hand grip strategies. Triodyne Safety Brief, 16(4), 1-15. Depending on the rung size, the horizontal power grip can result in a 75-94% larger breakaway force than when gripping a vertical rail of the same shape and size. *See* Young, Woodley, Armstrong, et al. (2012). The effect of handle orientation, size and wearing gloves on the hand/handhold breakaway strength. *Human Factors*, 54(3), 316-333.

While not a design solution, portable ladders can also be fitted with extension grab bars when used to access roofs or an elevated deck surface to provide a three foot extension. These bars provide the horizontal handholds necessary for three-point control to access or exit a structure. In addition, roof hatches should be equipped with walk-through horizontal grab bars for safer access to or from the roof or higher level.

Three-Point Control v. Three-Point Contact

When using ladders or other climbing structures, workers should consider using the ***three-point control*** technique. Three-point control requires a worker to use three limbs for reliable, stable support, including gripping a horizontal support using a horizontal power grip. It is safer for a worker to hold a horizontal support member than a vertical one. Research has shown that holding a horizontal round object or grab bar with a horizontal power grip provides a greater safety margin for preventing a fall than holding onto a vertical side object or rail when a fall starts.[4] The approximate shape should be 1 to 1.5" rounded. Vertical side rails of any shape promote uncontrolled sliding of the hand in a fall.

Climbing a ladder using three-point contact (left) and three-point control (right).

Unlike three-point control, three-point contact requires three points of support without specified body parts with an unspecified ladder or structure. No shapes or sizes exist for adequate support using three points of contact. Three-point control requires using the hands to grab and hold a support so that one hand can reasonably support the climber's body weight or more in an emergency.

BACKGROUND INFORMATION

OSHA regulations

- 29 CFR 1926 Subpart M (1926.500-503 and appendices)
- 29 CFR 1926 Subpart X (1926.1050-1053 and appendices)
- 29 CFR 1926 Subpart L (1926.450-454 and appendices)

Other information

- U.S. Army Corps of Engineers, EM 385-1-1 Safety and Health Requirements Manual
- ANSI Z359.2, Minimum Requirements for a Comprehensive Managed Fall Protection Program
- ANSI Z359, fall equipment component standards

[4] *See* Young, Woodley, Armstrong et al. (2009). Hand/handhold coupling: Effect of handle shape, orientation and friction on breakaway strength. *Human Factors*, 51(5), 705-717. *See also* Young, Woodley, Armstrong, et al. (2012). The effect of handle orientation, size and wearing gloves on the hand/handhold breakaway strength. *Human Factors*, 54(3), 316-333.

- ANSI A10.32, Personal Fall Protection Used in Construction and Demolition Operations
- A10.24 Roofing Safety Requirements for Low-Sloped Roofing, and other A10 equipment component standards
- ANSI A14.3 Fixed Ladders
- ANSI A14.2 Metal Ladders
- ANSI A14.5 Fiberglass Ladders

OTHER CONSIDERATIONS

In addition to incorporating horizontal grab features at elevated work locations, designers can also reduce falls from ladders by specifying fixed ladders or stairways when possible. This would reduce the need for portable ladders when accessing a roof, work platform, or upper level, thereby reducing the chance that a worker may use a defective or improper ladder. See Construction Safety Design Solution #6, Specify Fixed Ladders or Stairs.

References:

- J. Nigel Ellis, Three Point Control, Analysis & Recommendations for Climbing Ladders, Stairs & Step Bolts, Professional Safety Journal, Nov. 2012.
- Justin G. Young, Charles Woodley, Thomas Armstrong, and James A. Ashton-Miller, University of Michigan, Ann Arbor, Hand-Handhold Coupling: Effect of Handle Shape, Orientation, and Friction on Breakaway Strength, Human Factors Vol. 51, No. 5, Nov. 2009.
- Justin G. Young Ph.D thesis, Biomechanics of Hand/Handhold Coupling and Factors Affecting the Capacity to Hang On (2011).
- Kurt Beschorner et al: Biomechanical Response to ladder slipping events: Effects of hand placement, Journal of Biomechanics 48 (2015) 3810-3815.