

# FALL PROTECTION ON POST-FRAME ROOFS

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For the past several years, my research at Virginia Tech has examined the safety of workers who are constructing metal plate-connected wood truss roofs at height. This work can be very hazardous without proper fall protection systems and procedures in place. Falls from height are the result of many injuries and fatalities in construction. The Occupational Safety and Health Administration has recognized the need for increased fall protection on construction sites and has increased its focus on fall protection.

Fall protection for workers during roof construction is a particularly challenging task. Workers are in the process of assembling the structure, which may not have adequate bracing or a fully developed load path. If a worker is tied off to this incomplete structure and has a fall, the structure may not provide the needed strength to hold the worker from striking the ground, or the structure may fall down on top of the worker and possibly cause other workers to fall.

Perhaps the most common question that I have received from the post-frame community is how to safely tie off to a truss system or roof. The purpose of this article is to provide recommendations on how fall protection, particularly anchor-lifeline-harness systems, should be placed on the structure. These recommendations are based on laboratory testing of fall arrest systems, engineering analysis and discussions with safety experts. This article provides an overview of fall protection methods and discusses the placement of fall arrest anchors when they are needed.

## DISCLAIMER

This article contains only *recommendations* for fall protection in post-frame construction. A qualified person (as defined by OSHA) should recommend where fall arrest anchors are located on a particular structure. This article is not intended to, and does not, replace fall protection plans or other company-specific safety documents. The interpretations of OSHA rules given here are my opinions and do not represent opinions of the National Frame Building Association or OSHA. Applicable laws and interpretations

may differ from state to state. If conflict arises between the interpretations provided here and any state or local safety rule, standard or standard interpretation, the state or local rules, standards or interpretations will take precedence over the content of this article. In the case of any disparity, it is recommended that you contact your safety consultant.

## REQUIREMENTS FOR ALL FALL PROTECTION SYSTEMS

The fall protection systems discussed are those most commonly used in post-frame construction. All fall protection systems must follow 29 Code of Federal Regulations §1926.501, 502 and 503, which state that workers 6 feet or more above a lower level must be trained in fall protection and protected by a fall protection system, such as a guardrail, net or personal fall arrest system. Personal fall arrest systems are commonly used in post-frame construction. Other tools for accessing work at height include scissor lifts, aerial lifts, scaffolds and ladders.

A complete fall protection system must accomplish these three objectives:

1. *Provide a stable anchor point in case of a fall*—When a worker falls, the anchor must remain in place. This is especially important when an anchor is attached to a building under construction. Consultation with a qualified person is advised for proper anchor placement.

2. *Prevent the worker from contacting a lower level during a fall*—The length of the fall arrest system in the extended position when a worker falls must be less than the distance from the worker to the lower level. The distance a worker falls is dependent upon the free-fall distance (the distance of vertical travel before the lanyard pulls on the worker), the deceleration distance (the distance that the lanyard uses to absorb energy), the height of the worker (conservatively taken as 6 feet) and a safety factor (the distance between the worker and the lower surface—usually between 1 and 3 feet). A qualified person will consider all these distances and compare them to the distance to a lower level to create a safe

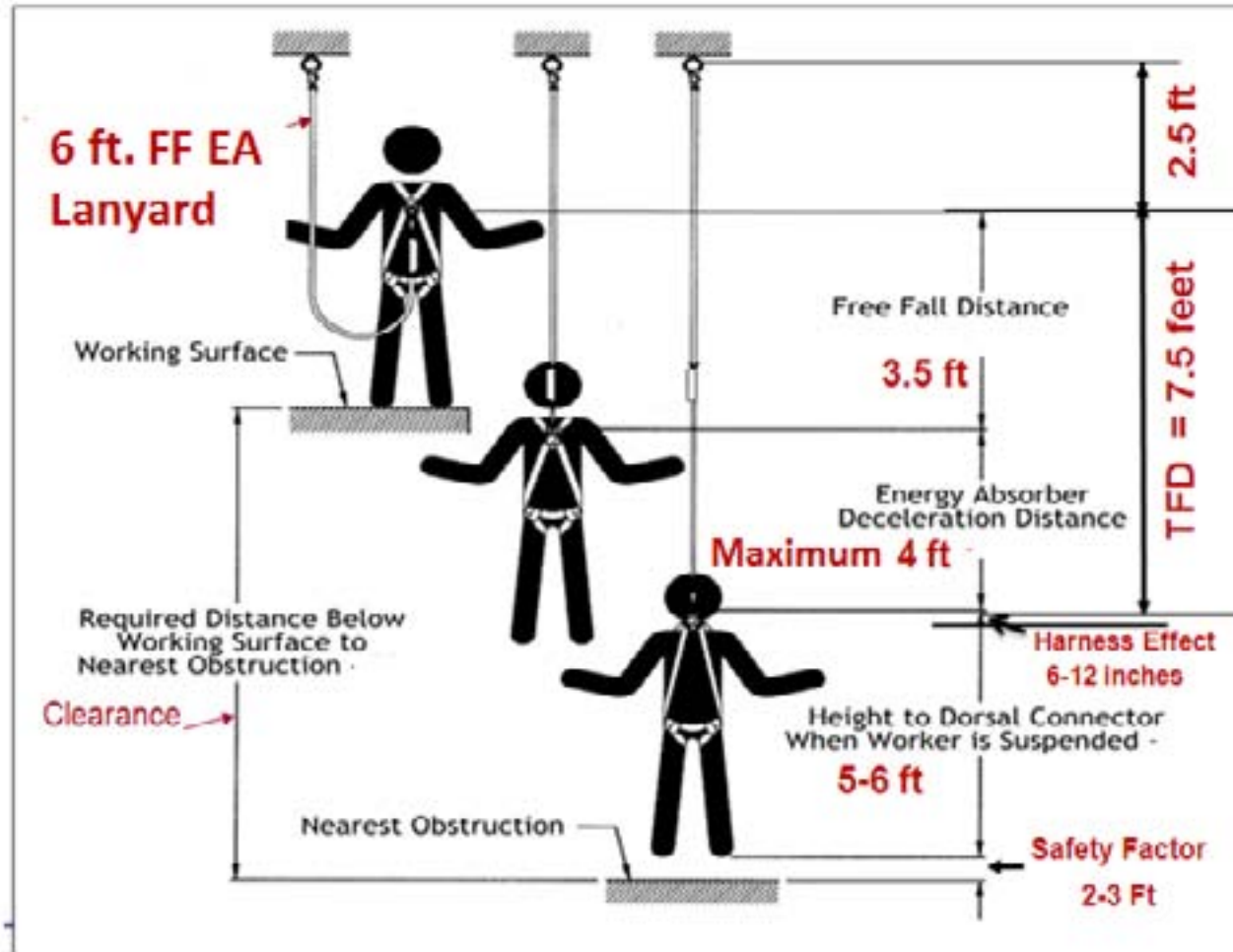


Figure 1. Example of a fall distance calculation from Engineer Manual 385-1-1 (Department of the Army, 2014). Note: FF EA is a free-fall energy-absorbing lanyard.

fall arrest system (Figure 1).

3. *Limit the maximum arresting force on the worker to 1,800 pounds or less (29 CFR §1926.502(d)(16)(ii))*—The fall protection system should be designed to include energy-absorbing components or limit the fall height so that a maximum force of 1,800 pounds or less is applied to the person. A qualified person or safety consultant should be consulted for the calculation of the arresting force.

### COMMON FALL PROTECTION SYSTEMS USED IN POST-FRAME CONSTRUCTION

The term *fall protection system* indicates that fall protection must be used as a *complete system* specified by a qualified person. Both personal fall arrest systems and fall restraint systems are discussed. Four standard types of fall protection systems are used in post-frame construction:

1. *Horizontal lifeline*—A horizontal lifeline consists of a cable or rope (usually a metal cable or a low-stretch rope to



Figure 2. Horizontal lifeline used with a scaffolding system attached to posts

prevent excessive sag) strung between two anchors or stanchions (Figure 2). The anchors are placed at the same height, such as at the eave or peak of a roof. Workers are attached to the horizontal lifeline by rings threaded onto the cable or



Figure 3. Vertical lifeline installed on a truss. Note the rope grab on the left side.

rope that serves as an anchor for the lanyard system used. Typically, horizontal lifelines can accommodate only two workers at any time.

Horizontal lifelines are most often used during the truss-setting process after posts have been placed. The anchors for horizontal lifelines often consist of outriggers connected to the posts by multiple fasteners. These outriggers tend to result in stable lifelines that a worker can tie off to. When one is using horizontal lifelines, it is important to calculate the fall height (Figure 1) to ensure that a worker falling does not strike the ground.

From a structural perspective, embedded posts are very stable elements to tie off to because of the end fixity at the ground. For use of above-ground posts combined with brackets, check with a qualified person or safety consultant.

2. *Vertical lifeline*—A vertical lifeline consists of a rope strung between two anchor points at different elevations (Figure 3). Workers are attached to the vertical lifeline by rope grabs, which are designed to allow free movement upward but require the worker to squeeze the rope grab to move down. Vertical lifelines are often installed on trusses before the trusses are lifted onto the structure.

Vertical lifelines are helpful in attaching bracing and purlins to the truss structure. The use of a rope grab on the vertical lifeline allows the anchor to easily move upward but requires the worker to actuate the rope grab to move the anchor point down slope. Anchors for vertical lifelines should be located at the eaves and peak of the truss. Depending upon the size of the truss, it's possible that additional anchors will need to be attached along the top chord. All anchors should be secured to prevent rotation of the anchor and should be attached to larger cross-sections of the truss, such as joints. Placing anchors at bracing or purlin locations is recommended to provide more rigidity to the



Figure 4. Worker using a single-point anchor

connection.

3. *Single-point anchor*—A single-point anchor is a single fixed anchor that a lanyard is attached to. Workers can move in a circle around the anchor location (Figure 4). A disadvantage of using a single-point anchor is that a worker can experience a swing fall if a worker is walking at an angle to the roof, falls and then strikes the ground before the fall protection system can activate. Single-point anchors are best used in the middle of roof sections where lanyard length can prevent or eliminate a swing fall. Single-point anchors can be used for purlin and bracing installation or for attachment of steel as shown in Figure 4.

4. *Fall restraint system*—A fall restraint system differs from a fall arrest system in that its purpose is to prevent a fall from occurring rather than to keep the worker from striking the ground after a fall occurs. Fall restraint systems are used with scissor and aerial lifts, where the force from a worker falling could lead to tipping of the lift or to the worker's making contact with lower sections. A fall restraint system also differs from a fall arrest system in using a shorter lanyard or self-retracting lifeline. A restraining body belt or body harness is acceptable for a fall restraint system, but a restraining belt is not recommended because the belt cannot be used in fall arrest systems.

### EQUIPMENT TO HELP WITH FALL PROTECTION

Although fall protection is useful to accomplish tasks at height, alternative means for performing these same tasks that do not create as much risk for workers and may allow workers to perform the jobs more quickly are available. These tools include aerial lifts and scissor lifts.

Current construction methods include a wide range of tools to help workers access construction at height. Many of



Figure 5.  
Scissor lift



these devices can be rented locally. OSHA divides motorized lifts and platforms into two categories: scissor lifts and aerial lifts. Motorized platforms should be used only by workers who have been specifically trained to use them.

### Scissor Lifts

Scissor lifts use a scissor, or pantograph, in an expanding shape to lift a platform vertically into the air (Figure 5). Scissor lifts are commonly used in a wide variety of tasks, including construction and maintenance. OSHA considers a scissor lift a mobile scaffold platform. As long as workers remain in the scissor lift *with both feet on the floor*, the primary fall protection system is the guardrails surrounding the worker. A guardrail at 42 inches  $\pm$  3 inches with a midrail and toe support is specified in 29 CFR §1926.452. However, it is highly recommended that all workers in a scissor lift use a fall restraint system. The fall restraint system is meant to prevent the fall of the worker and to prevent tipping of the scissor lift and the worker's contact with the pantograph arms. Anchors are identified in the lift cage and are the only locations where fall restraint or fall protection systems can be attached. OSHA does not allow fall restraint systems to be attached to guardrails (29 CFR §1926.502(d)(23)).

If workers climb out of the scissor lift onto a structure, they must immediately transfer their fall restraint system in the scissor lift to a fall arrest system attached to the structure. A Y-lanyard device would be appropriate for use in exiting a scissor lift to ensure that workers remain connected



Figure 6. Worker using an aerial lift

continuously to a fall protection system. Some older models of scissor lifts do not contain anchor points, so workers should remain inside these scissor lifts with both feet on the floor. Materials such as roofing or lumber should be placed on the scissor-lift guardrails only if their use is approved by the scissor-lift manufacturer.

### Aerial Lifts

Aerial lifts include motorized work platforms that are not considered scissor lifts: extendable boom platforms, aerial ladders, articulated boom platforms, vertical towers and combinations of these (Figure 6). Aerial lifts are governed by 29 CFR §1926.453. Workers are required to wear a fall restraint system at all times during operation of these lifts.

## ANCHORS AND STANCHIONS

### Determination of Anchor Force

Fall arrest anchors are rated to support at least 5,000 pounds, according to 29 CFR §1926.502(d)(15), and most anchors are made of steel sections that can easily carry this force. The question that arises is "Can the wood structure that the anchor is attached to carry the load?" There are very few situations where a wood structure can support 5,000 pounds applied while the structure is under construction. Such a large load cannot be realistically carried by most fall arrest systems used in any type of wood construction. A better approach to understanding the loads applied to fall arrest anchors comes from recognizing that a complete personal fall arrest system maintains a safety factor of at least two (29 CFR §1926.502(d)(15)(i)) and is designed and used under the supervision of a qualified person (29 CFR §1926.502(d)(15)(ii)). The personal fall arrest system must be designed for the maximum arresting force (MAF), which must be less than or equal to 1,800 pounds with a body harness (29

CFR §1926.502(d)(16)(ii)). Experience shows that the use of a personal fall arrest system is feasible in post-frame construction. The placement of anchors is a difficult subject to address unless one can observe the actual structure in use. A qualified person can determine what anchor points may be most useful.

### Anchor Connections

Regardless of the load calculation and direction of forces chosen, an anchor should always be securely attached to the structure. Using screws rather than nails to attach an anchor is preferable because screws have an increased withdrawal strength compared to nails. Screws are also much easier to remove during disassembly of the anchor. A preferred method of attachment uses a forked anchor placed around the wood member with a bolt or pin on the opposite side to hold the wood member securely. Another preferred anchor method is to use a web strap with a sewn loop that is placed around the wood member. In some cases, a ratchet strap may be used. The concern when using a ratchet strap is that the webbing can stretch, so a ratchet strap should be inspected more frequently during use.

### Types of Anchors

One observation made in laboratory testing is that taller anchors tend to produce a greater applied moment to the individual truss attached. Taller anchors are often preferred to prevent rope grabs or attached self-retracting lifelines from contacting the metal sheathing surface, producing abrasion or scratches.

### Inspection of Anchors

The anchor must be inspected to ensure a solid connection to the building structure. All fasteners should be properly installed and should be used. If any nails or screws become loose, they should be replaced with new fasteners, or the anchor should be moved to a new location and reattached to the structure. The connector on the anchor should be undamaged and provide a solid attachment for any lanyards. The anchorage and connector should be examined for any chipping or cracking of the paint or finish, which may indicate damage. Damaged equipment should be removed from service until it can be examined by a qualified person.

## SWING-FALL HAZARDS

As workers walk along a structure with a fall arrest system attached, they must be aware of the danger of a swing fall. A swing fall happens when a worker walks away from an anchor point, either by lengthening the self-retracting lifeline or moving along a rope. When a fall occurs, the

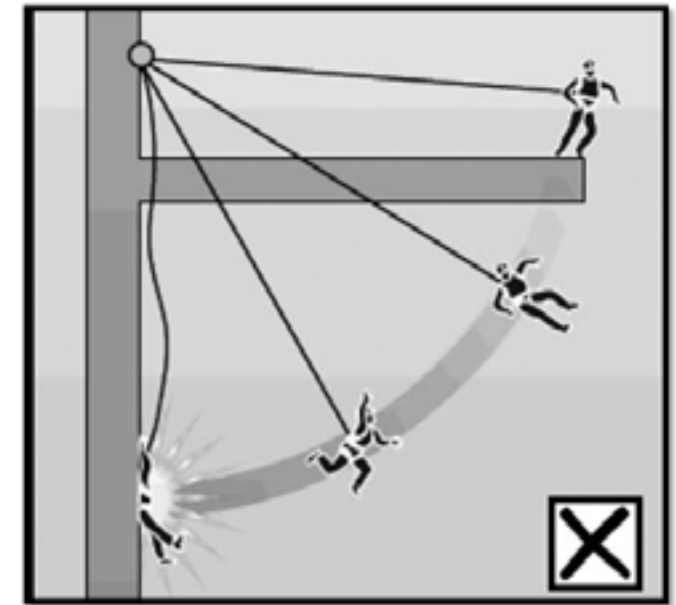


Figure 7. Example of a swing-fall hazard

worker swings back toward the anchor, similar to a pendulum (Figure 7), and can strike the lower level.

Unfortunately, no current design prevents a swing fall. One recommendation to lessen the likelihood of, or reduce injury from, a swing fall is to work at a maximum angle of 30 degrees per side from the anchor point. Thirty degrees is approximately equal to taking two steps downward for every one step to the side. Swing falls are a good topic for toolbox talks. Workers should be reminded to always work from the nearest fall arrest anchor, using a Y-lanyard to move between the anchor points.

The following example demonstrates how to use the 30-degree angle to define a zone of safety to prevent swing

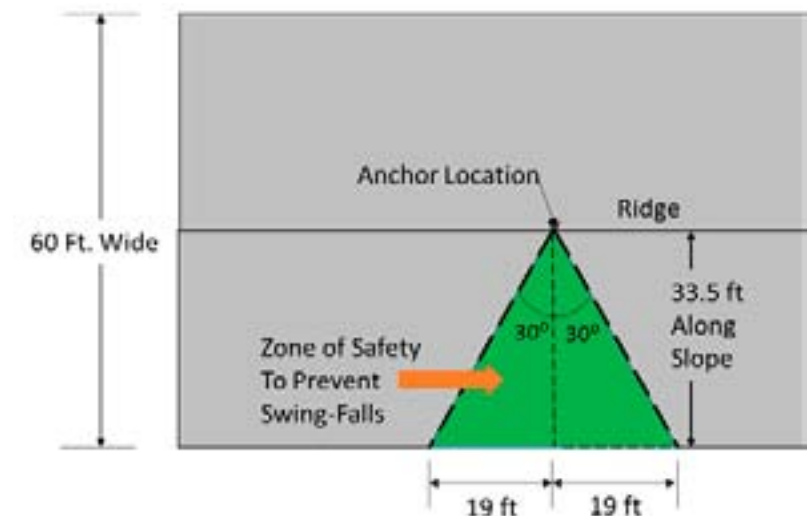


Figure 8. Example of the zone of safety to prevent a swing fall

falls. A 60-foot-wide roof has a 6:12 pitch and a distance from the ridge to the eave of 33.5 feet. To stay within the 30-degree arc on either side of the fall arrest anchor, a worker can travel only 19 feet to either side of the anchor at the farthest distance from the anchor (**Figure 8**). As the worker moves closer to the anchor, the maximum horizontal travel distance decreases.

## SUMMARY

The use of anchors for fall arrest systems in post-frame construction is crucially important. The placement and choice of post-frame anchors must be determined by the qualified person on the job site, but the following points provide some guidance:

- Anchors should be placed in secure locations, preferably at the eave, peak or joint.
- Anchors that wrap around the joint and lock using a pin or bolt are preferred.
- Ratchet straps can be used, but they need to be inspected more frequently.
- Taller anchors are more prone to applying greater moment at the connection point.
- Anchors should be frequently inspected.
- Swing-fall risks can be minimized through proper planning and system implementation.

## Additional Information

NFBA is dedicated to helping workers remain safe and productive in their jobs. In 2016, NFBA published *Fall Protection in Post-Frame Building: A Quick Reference Guide* (available in the Members section of the NFBA website at [www.nfba.org](http://www.nfba.org)). A complete manual on fall protection will be available in 2017 (excerpts and some photos from the forthcoming publication were used in this article).

## References

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