Safety should remain top concern

Technical requirements for fall protection systems

By Daniel Hindman, PhD

Workplace accidents such as falls are a source of great concern. The Occupational Safety and Health Administration recently increased its levels of job site surveillance and fines. As workers and companies are pushed toward higher levels of productivity, awareness of the expense and loss associated with workplace accidents is increasing.

Accidents are being viewed as unnecessary project expenses. Accidents result in severe physical and mental harm to workers, resulting in direct costs (hospital bills and time off work), indirect costs (workers’ compensation and insurance rates), and lost time (time associated with the affected worker, the crew coping with the accident scene and time to train new crew members).

One source estimates the average direct cost of a workplace accident at approximately $17,000 (Lipscomb, Li, & Dement, 2003). This estimate does not include additional costs of falls such as negative press and loss of reputation in the community and industry.

Discussions about safety in this publication usually focus on current OSHA regulations or litigation after accidents have occurred. This article focuses on preventing and eliminating hazards and situations that can lead to falls. Falls often are deadlier than other accidents and have been associated with higher costs than other accidents (Lipscomb, Dement, & Behlman, 2003). I wrote an article for Frame Building News in November 2008 titled “Safety should remain top concern.” The rationale for this policy was to encourage government and regulatory groups to prevent and apply an approach in which cooperation, education and training is the primary focus (ASCE, 1989). This article details the policy’s recommended responsibilities. The idea that safety should be a responsibility of all parties involved in construction is not yet a universal concept in the industry, however, especially among design professionals.

Construction site safety and prevention through design

In 1989 the American Society of Civil Engineers developed Policy Statement 350, titled Construction Site Safety. The rationale for this policy was to encourage government and regulatory groups to emphasize and apply an approach in which cooperation, education and training is the primary focus (ASCE, 1989). Table 1 presents values for a, and s, respectively, for different devices.

Table 1: Fall Arrest Device Reduction Factor

<table>
<thead>
<tr>
<th>Anchor Type</th>
<th>Wire Rope</th>
<th>Synthetic Lifeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Mechanical Level</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>No fall arrester</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 2: Shock Absorber Reduction Factor

|  | Tear Fabric (Synthetic) | Tear Fabric (Wire Rope) | No Shock Absorber |
|  | 0.6 | 0.7 | 1.0 |

F = \frac{1}{\sqrt{0.003125 \frac{W}{K}}} \left( \frac{g}{b} \right)^{0.5} s

where:

- \( W \) = maximum arresting force, lbs
- \( g \) = acceleration of gravity, 32.2, \text{ft/s}^2
- \( b \) = free fall distance, ft
- \( L \) = lanyard lifeline length, ft
- \( f \) = fall factor (ft/L) ratio
- \( K \) = lanyard tension modulus, psi
- \( a \) = arrest device reduction factor
- \( \alpha \) = body support reduction factor, 0.8 for body harness
- \( c \) = rigid weight modulus factor, 1.4
- \( s \) = shock absorber reduction factor

Fall protection systems

A variety of fall protection tools are available for workers. Fall protection systems for construction are regulated by OSHA 29 CFR 1926 (OSHA, 2010). This standard applies to all commercial construction, and, due to recent changes, will soon apply to all residential construction. Section 1926.502(d) describes PFAS. A PFAS is an active system (i.e., connected to the worker) that prevents injury in the event of a fall. A PFAS consists of three parts: anchorage, lifeline or lanyard and harness. Specific guidelines are provided for each component of the PFAS. A PFAS must be designed to prevent the force of a fall from injuring a worker. Safety is as important as everyone claims it is, shouldn’t there be clear, established guidelines and procedures to evaluate alternative systems?

Lifelines and lanyards

All lifelines and lanyards must have a minimum breaking strength of 5,000 pounds, while self-retracting lifelines may have a minimum tensile load of 3,000 pounds in some cases. An employee must not freefall more than 6 feet or contact a lower level. The maximum deceleration distance is limited to 3.5 feet. The most important value in lanyard or lanyard design is the maximum force applied to an employee during a fall must be restricted to 1,800 or fewer pounds. Ellis (2001) discussed the calculation of the maximum force placed upon an employee falling. The force is a function of the weight of the worker, the stiffness of the rope, and the type of fall arrestor and shock absorber used.

Construction site safety and prevention through design

Table 3: ASCE Policy Statement 350: Construction Site Safety Responsibility of Personnel

| ASCE Policy Statement 350: Construction Site Safety Responsibility of Personnel |
|-------------------------------|-------------------------------|
| Personal Responsibility | Personnel Responsibility |
| Owners | Design Engineers | Contractors |

- Assigning overall project safety responsibility and authority to a specific organization or individual (or specifically retaining that responsibility).
- Recognizing that safety and constructability are important considerations when preparing plans and specifications.
- Maintain safety of their employees and of all other persons in the work area or on the worksite.
made popular by John Gambetese, PhD, a professor at Oregon State University. The concept has been accepted at NIOSH, which is the construction safety research division under the National Institutes of Health. NIOSH is considered a sister organization to OSHA, which conducts regulatory activities. The National Occupational Research Agenda (http://www.cdc.gov/niosh/nora/), a roadmap document created by NIOSH to guide research efforts, has a heavy emphasis on PtD concepts. Gambetese and other researchers have worked to create a Design for Construction Safety Toolbox of PtD-specific skills for various types of construction.

A PtD idea that has been incorporated into post-frame construction for fall protection is the installation of permanent D-ring anchors at the ridge of a roof. Some post-frame companies already use these devices. The D-rings are connected to the truss top chord by rows of nails. The D-rings protrude under the ridge cap and can be accessed for roof maintenance and repair during construction. This simple and inexpensive addition to the project creates a safer environment during construction and afterward.

**Current Research at Virginia Tech**

Recently, Drs. Daniel Hindman and Tonya Smith-Jackson were awarded a NIOSH grant to study the use of personal fall arrest systems in construction. The focus of this project was to develop a PFAS for residential construction, given the exemptions from fall arrest equipment that have been in place for a number of years. The idea for this project has its roots in post-frame. When I attended the 2008 Frame Building Expo, I saw a presentation that was hosted by several post-frame companies (including Wick Buildings, Brickl Brothers, FBi, and Finger Lakes Construction) on the PFAS systems they used. I was intrigued with the system that Wick Building and Brickl Brothers used.

**Figure 1.** Personal fall arrest system used for post-frame construction: (a) eave-mount bracket, (b) ridge-mount bracket, (c) roof-mount-over-sheathing bracket.

In general, a better safety attitude results in a safer jobsite. There is no way to control for random accidents on a jobsite, so the safety climate can only provide trends and mostly is used as a research measure. The purpose of the Virginia Tech research is to explore the potential integration of post-frame construction fall- arrest systems into residential construction, given its seemingly more usable design. **Figure 2** shows the three components of their system. The first two elements shown (a and b) are attached to the end truss on the ground with ropes between the brackets. The end truss is lifted into place and the PFAS is in place as soon as roofers access the trusses. For the truss-setting portion of construction, workers continue setting roof and eave brackets at intervals along the length. When the sheathing is placed on the roof, the roof mount bracket (c) is used. From talking with the companies involved, the safety system seemed to have minimal effect upon the workers’ tasks.

Smith-Jackson, from the industrial systems and engineering department at Virginia Tech, specializes in understanding workers’ attitudes and actions. One of the problems encountered when conducting safety research is the ability to understand the ways in which safety equipment and tools are used. Successful safety programs need to influence workers to change their attitudes and behaviors and use safety equipment. Some safety literature discusses a “safety climate” measure, which is a measure of attitudes and impressions that workers have towards their employer, jobmates and peers.

In general, a better safety attitude results in a safer jobsite. There is no way to control for random accidents on a jobsite, so the safety climate can only provide trends and mostly is used as a research measure. The purpose of the Virginia Tech research is to explore the potential integration of post-frame construction fall-arrest systems into residential construction, given its seemingly more usable design. **Figure 2** provides a general outline of the tasks involved in this research. Three main objectives were identified. The first objective is to determine the baseline safety climate and usability studies for both residential construction workers and post-frame construction workers. These questionnaires serve as the basis to identify if post-frame workers have different attitudes towards using PFAS compared to residential construction workers. The second objective is the testing and redesign of the brackets shown in Figure 1 for use in residential construction. While the current system seems fitted for roofs, there are no provisions for second-story work, for which it would be preferable to have a central mast or tower exceeding the height of the workers. The second objective is to test the strength of the post-frame system, and, based on these measures, develop a residential fall arrest system (RFAS), which also will be tested. As part of the redesign for the second objective, some “scaled-world” testing will be conducted; a floor section will be constructed in the laboratory and workers will assemble the RFAS. In the third objective, the new RFAS will be field tested to determine the system’s usability. Field observations will be combined with surveys to help improve the final RFAS product.

Although the final output of this project will be a PFAS designed for residential use, we also hope to understand the qualities of a safe working environment and the ways in which the design and regulatory communities can take advantage of these qualities to help increase worker safety. The project approach is novel in several ways and incorporates Hindman’s expertise in falls, mechanical testing and the design with human factors, usability design and field testing experience of Smith-Jackson. The link between mechanical testing and worker attitudes as equal components in the use of safety equipment is unique. Our study area includes post-frame and residential contractors in Virginia, West Virginia and North Carolina. If you are interested in participating, contact Hindman at dhindman@vt.edu or 540.231.9442.

**Conclusions**

Construction site accidents are a serious matter resulting in lost time, injuries, expenses and loss of reputation. Workers are required to use PFAS or other safety equipment required by OSHA 1926.502. An anchorage must have a force of 5,000 pounds or an engineered system must be capable of carrying twice the rated load. The use of engineered systems needs to be clarified to expand the use of safety systems. Lifeline forces should be calculated, and methods to do so were presented in this article. All members of construction companies (owners, designers and contractors) play a role in jobsite safety. PtD concepts can be used in the design of a structure to reduce safety issues. Current research is being conducted at Virginia Tech to study the capacity of fall arrest systems for post frame and other wood buildings.

**References**


**Figure 2.** Schematic design of a residential fall arrest system.