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Fall Prevention on Residential Construction Sites

By Vicki Kaskutas, Bradley Evanoff and Harry Miller

Falls from height remain the most common cause of workplace fatalities among residential construction workers, accounting for 64% of the fatalities in residential building and 100% of the fatalities among framing contractors in 2010 (BLS, 2011). Despite a recent decrease in fall incidence rates (BLS, 2011), 164 of the 1,025 carpenter apprentices surveyed (16%) reported a fall from height in the past year, and 512 of these carpenters (50%) knew someone who had recently fallen (Kaskutas, Dale, Lipscomb, et al., 2010).

Work site fall safety audits at 197 residential sites demonstrated an average compliance of 59% with fall protection and/or prevention measures, ranging from 28% for roof truss installation to 80% for

roof sheathing (Kaskutas, Dale, Nolan, et al., 2009). As a result, residential construction workers frequently work at heights without fall protection. For example, workers installing roof trusses may stand on the top of walls (Photo 1) or in the roof truss without fall arrest or protection (Photo 2).

OSHA (2010) now requires use of conventional fall protection at residential construction sites when workers are more than 6 ft from a lower level; this includes safety nets, guardrails and/or personal fall arrest systems (OSHA, 2006). OSHA's (2011) Guidance Document for Residential Construction outlines technologies to

provide conventional fall protection during home construction. It is critical to identify and evaluate these technologies and to diffuse these technolo-

gies to construction professionals. This pilot study identified fall protection technologies, measured a small sample of carpentry professionals' perceptions of these technologies, and pilot tested two devices with several residential contractors in St. Louis, MO.

Study Methods

Device Rating

Commercially available fall protection devices appropriate for residential construction were identified by an Internet search and discussion with carpentry experts, safety professionals and equipment representatives. After reviewing manufacturers' instructions for technologies identified, a brief presentation was developed to describe and demonstrate the technologies, including purpose, cost and potential uses.

A written survey was designed to measure workers' perception of ease of use, cost, durability, effect on productivity and overall effectiveness on a 10-cm visual analogue scale. A sample of 36 carpentry professionals in the St. Louis, MO, metropolitan area participated in this study. Participants were shown the presentation describing each fall protection technology in a group or individual setting. Discussion about each device was facilitated and participants' questions were answered to the best of the researchers' abilities. Each participant completed the written survey and chose the best device in three categories: 1) protection of floor openings; 2) provision of temporary walking surfaces; and 3) personal fall arrest anchorage.

A group of apprenticeship instructors ($n = 9$) at the St. Louis Carpenters' Joint Apprenticeship Program rated all devices identified to streamline rating sessions with subsequent groups, including apprentice carpenters, journeymen carpenters, safety professionals and contractor owners/operators.

One instructor recruited residential apprentice carpenters attending regularly scheduled school-based training to participate in a lunchtime focus group with the researchers. Sixteen apprentices representing all 4 years of the apprenticeship participated in two focus groups. Two journeymen carpenters attending training at the school were asked to participate in a separate group. Three safety professionals employed by a safety consulting firm that provides safety oversight to contractor participants in OSHA's St. Louis area residential on-site safety

IN BRIEF

- Many types of fall protection technologies are available for residential building.
- Many workers believe these technologies will prevent falls, but decrease productivity.
- Two fall protection devices were pilot tested with residential builders in this study.
- Conventional fall protection devices are slow to diffuse into residential construction.

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initiative participated in a focus group at their office. Residential contractors who employ carpenter members of the Carpenters' District Council of Greater St. Louis and Vicinity were also recruited to participate in individual presentations ($n = 6$).

Comments from the apprentice focus group were recorded and transcribed; detailed notes from the other sessions were written and transcribed. Mean ratings were computed for use, durability, cost, and effect on productivity and safety on a 100-point scale for each category of carpentry professionals. Analysis of variance compared ratings between apprentices, journeymen, safety directors and contractors to explore differences in perceptions. The devices rated as the best for each of the three categories were tallied.

Pilot Testing

Two of the top-rated devices were purchased for pilot testing with residential carpentry crews. Carpenter trainers with safety expertise and researchers developed training methods and materials for these devices. Residential contractors who employ union carpenters were recruited for pilot testing ($n = 4$). Participating work crews were trained to install and use the device by a carpenter trainer; crews were allowed to use the device while building one to three new homes.

A carpenter research assistant visited the work site midbuild to assess device installation and use; this was achieved using a brief checklist developed for this project. After the build, this assistant interviewed each crew member to measure perceptions of the fall protection technology on a 10-point scale (0 = strongly disagree, 10 = strongly agree) for 1) ease of installation, use and removal; 2) time to install, use and remove the device; 3) device durability; 4) device maintenance; 5) improved safety; and 6) ability to prevent worker falls.

Descriptive statistics and central tendencies for the work site checklist and worker ratings were calculated. At several work sites, the St. Louis Audit of Fall Risks (SAFR) (Kaskutas, Dale, Lipscomb, et al., 2008) was also administered. This 52-item audit measures fall prevention safety practices during the home framing process (see *PS Extra* at www.asse.org/psextras). The audit's nine domains are general safety/housekeeping; floor joist/subfloor installation; walking surfaces/edges; wall openings; truss setting; roof sheathing; ladders; scaffolds; and personal fall arrest equipment. The SAFR has excellent inter-rater reliability ($\kappa = 0.93$) and is content valid (Kaskutas, et al., 2008). The Electronic Library of Construction Occupational Safety and Health has posted the audit (<http://goo.gl/IApA3>) and SAFR administrator's manual/protocol (<http://goo.gl/kjUu>).

Results

Device Ratings

The Internet search and discussions identified 43 different technologies, all of which were presented to the apprenticeship trainers' group. The 13 devices that received the highest ratings by the



(From top): Photos 1 and 2 show unprotected workers during roof truss installation.

trainers (Table 1, p. 38) were presented to the 16 apprentice carpenters, 2 journeymen carpenters, 3 safety consultants and 6 contractor participants. The mean overall ratings for these 13 devices among the 27 individuals were highest for ability to prevent falls, followed by durability and ease of use, and lowest for the effect on productivity and cost. Device ratings varied between the different categories of carpentry professionals, although the differences were statistically significant for only the ladder jack railing (Table 1, p. 38).



The apprentice carpenters had the highest mean ratings for the devices overall, while the journeymen had the lowest. The devices identified as having the most potential for residential construction were not always the devices that received the highest mean ratings as the research team performed both quantitative ratings and qualitative rankings.

The top device identified for protecting floor openings at residential sites was a plastic housing that supports guardrails at floor openings and stairways (Safety Boot manufactured by Safety Maker Inc.) (Photo 3 p. 39). This device keeps the guardrail in place until the permanent railing is installed, thus protecting framers, drywall installers/finishers and painters.

The device selected as the best for providing temporary walking surfaces was the pump jack scaffold, followed closely by a hanging scaffold system (Photos 4 and 5, p. 39). Since pump jack scaffolds were already widely used for siding installation by the sample population, the hanging scaffold system (WallWalker manufactured by WallWalker LLC) was chosen for the pilot study. This system provides an adjustable-height elevated work surface that hangs over the top of an interior or exterior wall of the home. It can be used to install floor joists, roof trusses and windows, and can serve as a guardrail during roof sheathing and shingling.

The top-rated anchor for personal fall arrest anchorage was a reusable webbing strap (Photo 6, p. 40), which is secured around truss members

Table 1

Device Ratings by Carpentry Professionals

	Safety professional (n = 3)	Contractors (n = 6)	Journeyman (n = 2)	Apprentices (n = 16)
Reusable strap	89.6	75.5	66.6	82.6
Disposable strap	65.4	65.3	50.3	61.6
Truss peak anchor	68.8	74.9	43.8	60.7
Truss anchor	58.3	70.6	56.9	58.8
Double roof anchor	91.0	82.3	67.8	76.0
Single roof anchor	70.5	74.5	44.4	76.5
Hanging scaffold	47.5	55.6	66.9	74.4
Pump jack scaffold	85.4	72.2	82.8	76.1
Power scaffold	55.8	52.6	67.8	71.3
Roof guardrail	50.0	43.2	--	48.6
Ladder jack railing	47.5	66.0	36.9	91.1
Guardrail housing	92.1	71.8	83.4	71.8
Hole cover	81.0	74.7	75.9	85.5
Mean rating	69.5	67.6	62.0	71.9

or floor joists, or on top of a wall during installation of trusses and sheathing, or other operations. Since slide guards were commonly used during roof sheathing and shingling as they were allowed by OSHA's residential guidelines at the time of this research, anchors that could be used for other phases of construction besides roofing were a priority.

The carpentry professionals identified many barriers to using the various technologies, most often concerning use of personal fall arrest systems. These included safety of the worker installing and removing the anchor; concerns about whether a coworker had installed the anchor securely; ability of the device to stop a fall before the worker hit the lower surface due to lanyard length; contractor liability; roof aesthetics if anchor is permanently installed; and lack of a secure construction member to which the anchor is fastened (especially during roof truss installation). The safety testing data for the anchors included in this study demonstrated that the anchors could withstand the forces applied during a fall and stay affixed to the structure if installed according to manufacturer's directions; however, the structure to which the anchor is affixed must also withstand these forces.

Laboratory testing has shown that unless appropriately braced, roof trusses often collapse when exposed to forces similar to those generated during a worker fall (Fiorini & Garritano, 2008; SBCA & Truss Plate Institute, 2011). Since contractors in the St. Louis region do not use the amount of temporary truss restraint/bracing recommended by the truss manufacturers (SBCA), personal fall arrest anchorage was not tested in this study.

Hanging Scaffold System Pilot Testing Results

Two small contractors and one large contractor pilot tested the hanging scaffold system at 15 construction sites. The carpenter trainer visited each work crew and instructed them in installation, use and maintenance. Most crews used the device to construct one home, two crews used it for two homes and one crew used it to build three homes.

During follow-up work site visits, the carpenter research assistant administered the brief hanging scaffold checklist and brief worker interview developed for this project. Five of the eight items on the checklist were performed correctly 100% of the time; the overall compliance with all items was 92%. The SAFR was also administered at five of the 15 sites; compliance with the truss setting domain of the SAFR was 100%. No workers were observed standing on top of walls (which are only 3.5-in. wide) during any phase of truss installation, whereas this was observed at 85% of work sites not using the hanging scaffold during audits performed in a prior study of this same working population (Kaskutas, et al., 2009).

The 41 carpenters interviewed after pilot testing the system had an average of 12 years in the construction trade (range 3 to 30 years). The mean level of agreement rating for the item "the device is durable" was 8.5 (range of 5 to 10); "the device improves safety" was 7.6 (range 2 to 10); and "using the device prevents worker falls" was 7.3 (range of 3 to 10). Ratings were much lower for "time to install, use and remove device is reasonable" (5.7) and "the device is easy to install, use and remove" (6.6), with a wide range of scores for these two items noted (0 to 10). Ninety percent (n = 36) of carpenters who used the hanging scaffold perceived that it decreased productivity, four noted it increased productivity and one said productivity was not affected. One journeyman who described increased productivity had used the system on three home builds. When asked if they would like to use the hanging scaffold on future builds, 22 answered "yes" (54%), 18 answered "no" (44%) and one said "maybe."

When asked about the benefits of using the hanging scaffold, worker responses fell primarily into these four categories: 1) improve safety; 2) prevent falls; 3) provide a stable work surface; and 4) decrease time spent on walls and ladders. Crew members identified many barriers to device use, including excessive setup and use time; knowing the height to set the scaffold so that it is in the correct position for a guardrail that accommodates different height workers; pinch points caused by the device; moving around the device without hitting one's head; obstructing the crane operator's view of hand signals when a worker is on scaffold (and takes too long to exit the scaffold to get in position for the operator to see); and difficulty setting the 16-ft-long walk boards used in this testing.

Guardrail Housing Pilot Testing Results

Only one small contractor field tested the guardrail housing as most contractors contacted had already used this device. The guardrail housing was observed in use at three sites and five carpenters were interviewed; mean age was 33 years and average time in the trade was 15 years.

When researchers visited the work sites to admin-

ister the device checklist, the devices were always installed and used correctly. All carpenters interviewed stated that the housing did not affect productivity and that they would prefer to use it on future builds. Ratings for ease of use, durability, maintenance and improving safety were similar to the hanging scaffold system; however, time to use (7.6) and ability to prevent falls (9.2) were much higher.

Discussion

This study identified commercially available fall protection technologies to protect residential construction workers at floor openings, to provide temporary walking surfaces and to anchor personal fall arrest systems. The research team identified many commercially available technologies, and the preferred devices were a hanging scaffold system, a guardrail housing device, and a webbing choker strap with a ring on one end to strap around a building component.

Among participants, a trend was noted that experienced workers tended to rate fall protection technologies less favorably than inexperienced workers; this may be due to greater expertise or hesitancy to accept new work practices. Residential builders and carpentry professionals were willing to pilot test devices that they believed would protect them from falls; however, one primary concern was the effect of device use on productivity.

After brief field training, construction crews quickly learned to install and use the hanging scaffolding and guardrail housing according to manufacturers' instructions. Use of the scaffold system during truss setting improved compliance with the truss setting domain of SAFR to 100%, in comparison to only 28% compliance in previous research at sites that did not use the system. Crew members perceived that these devices prevented falls, but they were hesitant to adopt the technology on a long-term basis. Repetitive use of the device may be the key to long-term adoption, as this allows workers the opportunity to determine how to use the device in their work contexts and to change their beliefs and habits.

Since OSHA's interim residential guidelines were rescinded, contractors in most states must ensure that conventional fall protection is used when employees work on surfaces 6 ft or more above the lower level. OSHA has indicated that Subpart M is being enforced at residential sites; however, contractors must identify fall protection devices and methods to protect the workforce while constructing residential structures. This can be difficult for small- or medium-sized contractors that likely do not have the time, knowledge and financial resources to investigate all available options.

The research team continues to loan the pilot-tested fall protection equipment and other fall protection devices to contractors to allow them to test out the technology and attempt to integrate it into their work processes before they purchase it. Since equipment may be needed for only a short duration during the construction process, increased availability for equipment rental may be an effective

way to improve the dissemination of new fall protection technologies. Rental companies may also be able to help contractors identify and locate the best equipment for their situation.

This pilot study suggests that more research is needed to understand the role of personal fall arrest systems during roof truss installation. While personal fall arrest harnesses are widely available, a safe and feasible point to anchor the harness may not be available during some stages of home construction. Also, temporary bracing methods that render the truss assembly capable of withstanding the tensile and compressive forces applied during a fall must be explored to identify viable solutions.

For example, Fiorini and Garritano (2008) found that stabilizing truss toes with two common nails



From top: Photo 3 shows the guardrail device in place at a construction site, while Photos 4 and 5 show the hanging scaffolding system in use (hanging exterior and interior to the structure).



Photo 6 depicts a reusable web strap in use. This personal fall arrest anchorage was not tested in this study.

adjacent to each side of the toe on the wall, installing metal strapping over the braces secured into the truss chords, and using an anchor choker at the truss joints rather than midchord positions achieved the amount of stabilization needed. Temporary methods of bracing have been documented by SBCA and Truss

Plate Industry (2011); however, the time to install the bracing is extensive.

Thus, designers and manufactures of roof trusses and truss anchorage systems need to collaborate with construction professionals, safety professionals and safety researchers to develop, design and test roof truss and anchorage systems and to describe specific installation and use directions so that trusses can be safely used for personal fall arrest anchorage. Until this occurs, residential contractors face a difficult dilemma. There is insufficient scientific evidence to prove when and how personal fall arrest anchorage can be used during roof truss installation, but contractors must comply with OSHA standards that require conventional fall protection. This is an arduous position for contractors struggling to recover from a huge decline in residential construction.

This study is a first step toward increasing the use of fall prevention technologies during residential framing. This pilot study provides feedback from a small group of carpentry professionals in different roles; however, the sample size was small. In addition, this research occurred in a region of the country where residential construction is unionized, which is not the norm across the U.S. Also, this study occurred before OSHA rescinded the residential guidelines and home construction declined due to the economic recession; therefore, it may not represent workers' current perceptions about fall protection technologies.

Furthermore, since the devices were loaned to contractors and construction times were not formally measured, the actual financial impact of fall protection device use remains unknown. Future research should allow for a longer period of device use to allow workers to become competent and competitive, possibly through a short-term loan program. As contractors adopt these technologies, training and monitoring systems must be in place to ensure that devices are installed and used correctly over time.

Conclusion

Alternatives to unsafe work practices at height must be identified and tested to ensure the safety of residential construction workers. Fall protection

device manufacturers and the building components industry should partner to test anchorage for personal fall arrest; this will help generate definitive evidence about the safety of personal fall arrest systems in various applications. Researchers and safety professionals must diffuse results from research and share best practices with contractors, unions and the construction workforce. It is especially challenging to reach the small, nonunionized contractor who performs home building or remodeling and has no formal means to receive such information.

The national Campaign to Prevent Falls in Construction aims to provide fall protection resources to a wide range of construction workers through a unified approach among several government and private agencies (<http://stopconstructionfalls.com>). A multitude of methods must be used in order to ensure that the residential construction industry embraces fall protection and that workers are protected while working at heights. **PS**

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