Evaluation of a Decking Fall Protection System

System limits falls, improves site safety

By Daniel M. Paine and Michael McCann

CONSTRUCTION OF STEEL FRAME BUILDINGS is very hazardous, with a high risk of falling. The rate of work-related deaths from falling among structural metal workers is 68 deaths per 100,000 full-time equivalent (FTE) workers—16 times the rate for all construction workers (Center to Protect Workers' Rights Chart 37a).

Since 1999, Capco Steel Inc., a structural stell fabrication and erection contractor based in Providence, RI, has adopted a 100-percent fall protection policy above six feet. The company designed a fall protection system for metal decking installation in steel buildings: Two horizontal cables are placed seven feet above deck level running through prepunched holes in the steel columns before those columns are erected. A third cable, attached at right angles to the first two cables, can move forward as the leading edge advances. Lanyards with shock absorbers can be attached to any of these three cables.

The system's effectiveness was evaluated at six sites. Six falls occurred during 59,237 workhours of use in decking installation—a rate of 20.3 falls per 100 FTE workers. This high rate of falls demonstrates the need for active fall protection during decking installation. During this evaluation period, the fall protection system was shown to limit falls to a short distance, allowing self-rescue without injury. The two falls that occurred during installation of the system demonstrate the need to ensure that fall protection is provided and required during installation of the decking fall protection system as well.

Falls vs. Collapses

The causes of falls during steel erection can be classified into two basic categories: falls and collapses. A study of fatal falls from girders or other structural steel in the structural steel erection industry found that 19 percent were actually due to collapses of the structure or part of the structure (e.g., columns, girders or decking sheets) on which the worker was standing (CPWR Chart 37c). Other causes of falls included slips, loss of balance (especially while reaching), unhooking lanyard to change position, being struck by girders or other objects, falls through decking holes, and falls from unstable structures due to sudden motion of an inadequately secured beam or deck sheet.

Fall Prevention

Although most falls can be prevented, some contractors neither preplan nor plan for fall protection until it is too late to effectively eliminate or manage the hazards on the job. One misconception is that falls in

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Table 1

Hazards Associated with Steel Erection Tasks & Subtasks

Task or Subtask	Hazard	Interventions
Shake out of steel (preparing steel for erection)	Collapse, rolling, crushing	Site layout; site-specific erection plan construction sequence
Lifting (hoisting)	Collapse, falls, unstable structures	Preplanning; fall protection (active or passive)
Setting (erection) of columns	Collapse, falls, unstable structure falls	Preplanning; anchor bolts; fall protection; guying of structure
Placing beams	Unstable structure, collapse, falls	Guying; fall protection; lifts
Decking, including welding, crimping and screwing	Collapse, falls	Structural fall protection; preplanning
Joists	Collapse, falls	Fall protection; erection sequence; build on ground and lift
Structural roofing	Collapse, falls	Fall protection; guying
Connecting	Collapse, falls	Guying; lifts; fall protection; anchor bolts
Bolting up	Falls	Fall protection; lifts
Plumbing of structure	Collapse, falls	Preplanning; lifts; fall protection

structural steel erection can be addressed via some universal solution such as fall arrest equipment. However, many falls are not due to employer or employee action or negligence but rather are the result of unstable structures, collapses or being knocked or dislodged from heights. Therefore, solutions or interventions to reduce or eliminate these hazards must be multifaceted and require extensive preplanning and training. Preplanning, hazard elimination and well-developed solutions will make a job more cost-effective, safer and better managed.

Often, buildings and structures are not designed to have structural integrity until they are completed. Therefore, it becomes the responsibility of the general contractor/construction manager or controlling contractor to ensure that subcontractors are aware of unstable component structures and that the erection sequence plan affords adequate safety from collapse. Contracts for some larger projects require the responsible contractor to submit the means and methods to be employed in erecting the structure, including calculations such as wind loads stamped by a P.E., to the controlling authority for review. This procedure appears to be a good intervention and should be used more universally. Unfortunately, it is either not followed or not managed on many projects, which may be the reason for the large number of accidents and fatalities involving unstable structures or members.

Preplanning for fall prevention involves identifying hazards in advance, eliminating them where possible and managing those that cannot be eliminated. By using the project task analysis method of describing the operation, then describing the unsafe condition, action or hazard, the preventive or corrective action can be prescribed [ASSE(a)]. A typical project task analysis for structural steel erection of high-rise buildings involves dividing fall protection issues into the following categories:

- Erection tasks: Shake out of steel, lifting (hoisting), anchor bolts, setting of columns, beams, decking, joists and structural roofing.
- Subtasks: Connecting, bolting up, spreading decking, welding, crimping and screwing.

Table 1 describes fall and stability hazards associated with various tasks and subtasks.

When evaluating the safe performance of tasks and subtasks common in structural steel erection, the following process needs to take place, as described in ANSI A10.33:

- Preplanning: Recognition and identification of all fall hazards in the workplace.
- Job hazard analysis: At the start of a construction project and for critical stages of work, hazard analysis that describes potential dangers and actions required to provide a safe workplace must be performed.
- Construction process plan: The means and methods taking into consideration the erection sequence, wind loads, stability of components and structure; and procedures including temporary structures and bracing for safe construction of the project.
- Identification of fall hazards and the specific type of fall protection to be used.
- Design of task-specific fall protection for each hazard.
- Task-specific training for supervisors (foremen) and employees [ASSE(a)].

Decking

Installing decking is one of the most hazardous duties performed during structural steel erection. Bundles of metal decking must be hoisted to the proper location. Excessive weight can result in collapse of the structure on which the bundles are placed. Spreading the decking involves sequentially placing steel sheets over the beams to form a foundation for floors of the building. The metal decking sheets are then welded, crimped or screwed into place. These tasks involve risks of falling off the leading edge (the unprotected sides and edge of the deck that are constantly moving forward as more decking is spread); falling through holes in the decking; and falling due to sudden movement or buckling of decking before it is secured. From 1996 to 2000, 31 union ironworkers died while installing decking (Migliaccio).

Conventional fall protection methods include guardrails, safety nets and personal fall protection systems [OSHA(a) 40672; ASSE(b)]. These methods work for most tasks involved in high-rise steel erection except where unstable structures are involved or leading-edge work is being performed—both of which are found while installing decking.

Guardrails cannot be used at the leading edge since it is constantly moving forward. For safety nets to be

A well-planned and managed fall protection policy will be followed by workers, resulting in a safer construction environment.

effective, they must be located beneath the entire area where the decking is to be installed. In most cases, there would not be the required 25 feet of clearance for the safety net due to the metal deck on the floor below. Conventional horizontal lifelines anchored to the deck beams result in the worker's lanyard being attached below shoulder level; this results in a greater fall distance that could result in a falling worker impacting the deck below. In addition, workers have been concerned about entangling their lanyards when connected to the same horizontal lifeline.

The industry has not addressed the planning of the decking operation as it relates to workable fall protection solutions. The principles of fall protection are to first eliminate as many hazards as possible by changing plans, erection sequences, or means and methods, then to manage those hazards that cannot be eliminated using passive or active fall protection systems. Because no viable solutions were available for decking operations, the new negotiated rule on structural steel erection, Subpart R of OSHA's construction regulations, allows specially trained workers installing metal decking inside a controlled decking zone with fall hazards of less than 30 feet or two stories to work without fall protection [OSHA(b) 5196; 29 CFR 1926.760(c)]. Workers not installing decking are not allowed inside this controlled zone.

A Decking Fall Protection System

As noted, Capco has followed a 100-percent fall protection policy above six feet since 1999. The firm also instituted a new fall protection system that provides 100-percent fall protection for workers inside the controlled decking zone. This system calls for holes to be prepunched in the web or flange of the columns at three levels: seven feet, 42 inches and 21 inches above the decking levels.

The holes at seven feet above deck level are for horizontal lifelines. This height allows a lanyard to be attached to the lifeline above shoulder level. Traditional horizontal lifelines used in structural steel erection are at waist level with their supports fastened to the beam. These create concerns about lanyards tangling if more than one worker is attached to the same lifeline; another concern is the increased free-fall distance due to the difference in anchor heights between waist level and seven feet. The holes at the 42- and 21-inch levels on the columns are available for attaching guardrails at the perimeter or for interior edge protection as needed.

Two continuous cables are strung through the holes at the seven-foot level, parallel to the direction in which the leading edge is moving. Pre-engineered horizontal lifelines are readily available from most fall protection manufacturers. A third cable is attached perpendicular to the first two cables, with the two ends attached to these cables. The third cable can slide along the other two cables as the leading edge moves forward. These horizontal lifelines can be either engineered by a P.E. or purchased as pre-engineered systems from manufacturers since OSHA regulations do not cover horizontal lifelines.

Lanyards with shock absorbers to lower the maximum arresting force and that put less strain on the horizontal lifelines and on the worker can be connected to all three cables to provide fall protection for workers installing the decking. Retractable lanyards could not be used because the deflection of the horizontal lifeline in case of a fall might delay the locking of the retractable device.

Evaluating the System

The decking fall protection system was evaluated at six Capco Steel construction sites between April and June 2002:

Site 1: Two 12-story buildings and a single-story laboratory in Coventry, RI.

Site 2: A multistory pharmaceutical building in Boston.

Site 3: Three 10-story buildings in Glouster, RI.

Site 4: A multistory pharmaceutical building in New London, CT.

Site 5: A multistory office building in Everett, MA.

Site 6: A 12-story office building in Boston.

The evaluation involved: 1) observing worker training in this new fall protection system; 2) observaing installation of the system; 3) observing its use during decking operations; and 4) collecting fall data and workhours of installing decking. Site foremen were given only 24-hour notice of site visits.

Training

Training was observed on two sites, and training documentation was made available on the other four sites. Delivered by the company safety director or site safety director, the training consisted of generic and site-specific fall hazard training. The foreman and crew received task-specific instruction and training on proper use of PPE according to OSHA regulations and manufacturer instructions. In addition, safety information was provided at daily meetings and during weekly task-specific toolbox talks.

Capco employees were told that no one was allowed outside the guardrails or in front of the warning line unless they were using fall protection equipment. Only ironworkers were allowed on the decking floor before it was turned over to the general contractor. Only the decking crew was allowed on the leading edge in front of the warning line, and these workers received special training on how decking was to be installed and how they were to be tied off at all times.

One of the authors (Paine) observed that the two workers (of the three-person crew) moving decking wore full-body harnesses attached to separate overhead horizontal lifelines with six-foot shock-absorbing lanyards. They attached themselves prior to leaving the secured area and crossing the warning line. They remained 100-percent attached to the lifeline system while performing decking operations.

The third member of the decking team was a welder who worked behind the deckers and attached the decking. He was attached to the cable that ran between the other lifelines. Again, he was attached before entering the decking area and remained 100-percent tied off until he was safely back in the secured area.

System Installation

Horizontal and vertical lifeline systems were installed by three different methods, depending on individual site conditions. In all cases, holes were drilled in the columns seven feet above decking levels before the columns were erected. In addition, 100-percent fall protection was provided for installers of the fall protection system.

The first method involved installing cables from aerial lifts. The second involved attaching retractable lifelines to the columns before they were erected. A tagline was attached to the lifeline hook so that after the column is erected, the worker can pull out the line from the ground and attach it to a body harness. He can then climb the column and work with 100-percent fall protection. The third method uses a beam post system, available from many sources, that attaches to the beams prior to erection and provides a pre-engineered horizontal lifeline system erected on the ground that is ready to use when lifted and secured in place. Safety net cables can also be placed in the web of beams on the ground and lifted into place. The exact erection sequence must be preplanned and the system erected under the supervision of a competent person.

Use of the Fall Protection System

Each site was visited three times to observe decking operations and use of this fall protection system. As noted, a decking crew typically consists of three people: one person on each end of the decking being positioned, and a third worker attaching the decking to the structure. Only those workers actually performing decking operations were allowed into potential fall areas. During these visits, 100-percent compliance with use of fall protection equipment was observed. Safety directors verified that company policy mandated 100-percent fall protection above six feet and stated that the rule was enforced. Anyone who did not comply with the rule received a warning the first time the rule was violated and was fired the next time.

Fall Data

A total of 59,237 workhours (29.6 FTEs, based on 50 forty-hour weeks) were spent on decking operations at these six sites between January 1999 and June 2002. During this time, six falls occurred, with no injuries:

- One fall that did not open the shock-absorbing lanyard. This fall was less than two feet and the worker performed a self-rescue.
- Three falls of under two feet with self-rescue.
- One fall of less than one foot with self-rescue.
- One fall of six feet with self-rescue.

Two falls occurred while installing the decking fall protection system:

- One installer fell into the safety net with no injury.
- One installer fell six feet; for reasons unknown, this worker had not remained tied-off while changing position. He received minor injuries.

Discussion

This fall protection system ensures that workers installing decking have 100-percent fall protection during this hazardous activity. The ability to tie off to any of three cables and the location of the attachment point above shoulder height maximizes worker mobility and limits their fall exposure to a few feet. This small fall distance—less than two feet in all but one case—enables quick self-rescue and minimizes the chance of injury due to hanging in the harness for extended periods of time.

As noted, six workers fell during the period of this evaluation—covering some 29.6 FTEs of decking installation work. This produces a rate of 20.3 falls per 100 FTEs, which emphasizes the high risks of decking work. Although this rate is based on a small number of falls, it is 50 times higher than the rate of 40 falls per 10,000 FTEs for all construction involving days away from work (BLS). This rate also opens for discussion the OSHA-approved practice of allowing decking crews to work without fall protection inside a controlled decking zone.

The complete compliance with Capco's 100-percent fall protection policy observed during site visits and interviews demonstrates that a well-planned and managed fall protection policy will be followed by workers, resulting in a safer construction environment. The simplicity of this system, combined with the fact that it required minimal changes to the usual means and methods employed, resulted in little resistance to using this system. Most workers will accept a safer way to work, but they often do not like complicated solutions that they perceive as changing their work habits (often developed over years of practice) and perhaps making their jobs more hazardous. This system required little change in work habits and produced a clear benefit. ■

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