

# **PROBLEM AREAS IN PERSONAL FALL PROTECTION**

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## **ABSTRACT**

Falls from elevation have historically constituted the largest portion of construction worker fatalities, and this proportion has increased in recent years. Fall protection can be provided by many means including the minimization of work at heights, the use of guardrails or nets, and the use of personal fall arrest systems. This paper is focused on those fatalities resulting from incidents where there was some type of failure in the use of the personal fall arrest system, the last line of defense against fall hazards. A review of 184 fall fatalities will demonstrate several of the common shortcomings in the use of personal fall arrest systems. From these identified shortcomings, several recommendations are offered on how personal fall arrest systems can be made more effective.

Key words: Falls, Roofs, Personal Fall Arrest Systems (PFAS), Roof Anchors

## **1. INTRODUCTION**

Construction workers are employed in one of the most dangerous industries. In the United States, approximately 1300 construction workers die as a result of a construction accident each year. Of these, over a third of the deaths are attributed to falls from elevation. There are a number of ways by which workers can be protected from falls. For example, work can be arranged so that more tasks are performed at ground elevation. Work on ladders can be minimized and work performed on scaffolding should be performed on fully installed scaffolds. Thereafter, if fall hazards are still presented, guardrails or nets might be employed. If none of these approaches are deemed adequate, personal fall arrest systems (PFAS) must be employed as the last line of defense against fall hazards.

In an earlier study, the Occupational Safety and Health Administration (OSHA) fatality data were examined for the inclusive years of 1985 and 1989. The results showed that 33% of the fatalities were due to falls. In the mid 1990s, OSHA made significant changes in its regulations to reduce the number of fatalities due to falls, including the reduction in the height at which fall protection must be provided and the elimination of

the use of safety belts (safety harnesses were mandated). More recent data on construction worker fatalities has determined that there has been an increase in the proportion (up to about 38%) of fatalities due to falls.

Since there has been a notable increase in fall fatalities, it was apparent that this subject warranted additional study. While there are many aspects of fall protection that can be examined, this study was focused on those fall accidents that were associated with incidents in which personal fall arrest systems were or should have been employed. The objective of the study was to determine the primary areas of weakness in the use of personal fall arrest systems and to devise recommendations by which these fatalities might be reduced significantly.

## **2. LITERATURE REVIEW**

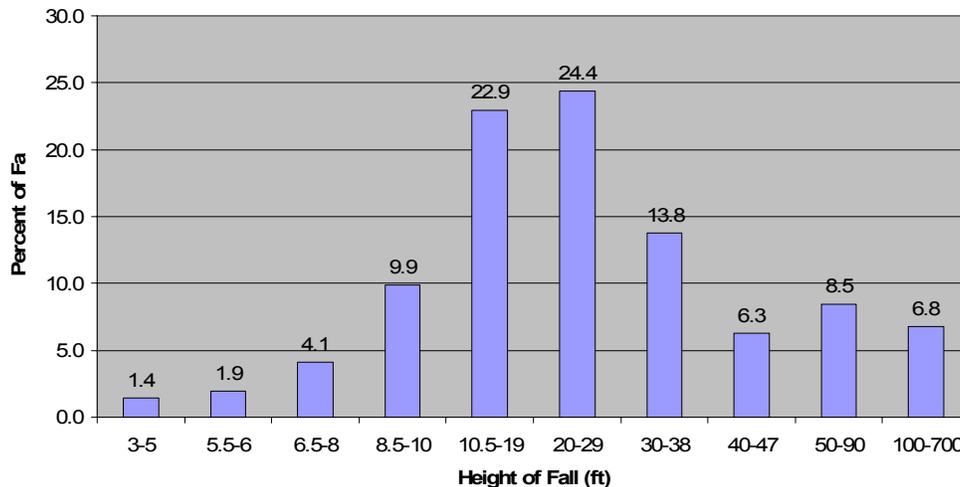
Falls have the focus of several studies in the area of construction safety. The first notable study in which falls were identified as a major area of concern in the construction industry was conducted on the fatality data collected by OSHA in the inclusive year of 1985 through 1989. That study showed that construction worker deaths were attributed primarily to falls (33%), struck by accidents (22%), caught in/between accidents (18%), electrocutions (17%), and other causes (10%).

Based on national construction industry statistics, in 1994 and 1995 about 30% of the fatal injuries to construction workers were due to falls. Falls from roofs accounted for 20% of these falls, mostly sustained by roofers and framing carpenters. Based on national residential construction fall statistics, fall-related fatalities accounted for 33% of all fatalities in residential construction (Singh 2000).

Huang and Hinze (2003) analyzed construction worker fall accidents based on data collected by OSHA from January 1990 through October 2001. The results showed that falls accounted for 36% of the construction-fall accidents, and that the proportion of fall related accidents increased from 1990 through 2000. Inadequate/inappropriate use of fall protection (harnesses) was a cause of more than 30% of the falls. The data were examined separately for the period from 1997 through 2000 to evaluate the influence or effect of the new fall standards implemented after 1997. The analysis of that data showed that more than 50% of the falls occurred on such projects as commercial buildings and single-family or duplex dwellings. Almost 30% of the falls were from roofs and more than 70% of the falls occurred at heights less than 30 feet. At the time of the fall accidents, 21 percent of the injured workers were performing roofing activities, 8% were erecting structural steel and 7% were working on exterior carpentry.

Another study about falls in the construction industry was conducted at the University of Florida by using OSHA fatality inspection data for the years 2002 and 2003. The analysis of the data shows that 36% of the construction worker deaths were due to falls, 37% of the fall injuries occurred on roofs, while 47% of the fall injuries were related to scaffolds. The results also revealed that 29% of the injured workers were roofers, 13.4% were

carpenters, and 13% were ironworkers. Figure 1 shows the relationship between the frequency of fatalities and the heights of the falls. Almost half of the falls occurred at the elevations of 20 to 29 ft (24.4%) and 10.5 to 19 ft (22.9%).



**Figure 1. Distribution of fall fatalities by height of fall**

Failure to provide adequate fall protection ranked #1 among the most frequently cited OSHA construction regulations and had a total of six rankings in the top 50 citations (OSHA 1993). Standards related to scaffolding were ranked seven times while standards related to ladders/stairways were ranked four times in the top 50 citations. Thus, 17 (34%) of the top 50 frequently-cited OSHA Construction Standards were associated with fall protection.

Bobick (2004) examined Bureau of Labor (BLS) data from 1992-2000 to analyze falls through roofs and floor openings and surfaces. He found that more than 50% of all fall-caused deaths occurred on projects built for private firms. Fall-related deaths accounted for about 32% of all deaths in the private sector of the construction industry. The number of fatal injuries caused by falls on private construction projects increased to 40% from 1992 to 2000. Most fall-related deaths occurred when workers were performing roofing, siding and sheet metal activities, as well as erecting structural steel. The average number of fall-related deaths for roofers was 20.9 deaths per 100,000 roofers.

Fredericks et al. (2005) conducted a survey to investigate safety practices employed by Michigan roofing contractors. Based on BLS data, Fredericks et al. found that fall accidents accounted for 26% of all injuries sustained in the roofing industry, but that falls accounted for 75% of all fatal cases in the roofing industry. Results of the study showed that the most prevalent sources of injuries were motion/positioning (31%), slips/trips (22%) and tools/machinery (22%), while slipping was the primary event leading to falls (59%). Roofing workers spent 61% of the workday on roofs. Regarding the height, 44% of the respondents said their workers operated at heights from 10 to 12 feet, while 22% of the companies worked at heights from 21 to 30 ft. The survey results also showed that

52% of the respondents said that 11 to 30 feet distance was the most common distance traveled for a manual carry.

Singh (2000) conducted interviews with construction company managers and roofing workers in the Hawaiian Islands to identify the most appropriate fall protection systems. Interview results showed that construction managers (CMs) and workers agreed that PFAS are the most common fall protection method used and that 75% of the workers used PFAS. Workers stated that they used PFAS mostly during roof sheathing. Workers also thought that PFAS is the best fall protection system to be used during truss installation. In addition, 42% of the workers thought that PFASs are the preferred method of fall protection for roof slopes from 4:12 to 8:12 pitch, while both workers and CMs agreed that PFASs are the primary fall protection system for roof slopes above 8:12 pitch (Singh 2000). Duncan and Bennett (1991) stated that active systems of fall protection, such as PFASs, provide better protection than passive systems.

Huang and Hinze (2003) found that 13.5% of worker falls involving roofing were due to insufficient or lack of personal protective equipment (PPE), while 11.5% were due to the removal (to make them inoperative) of safety devices. About 33% of the fall accidents were caused by human misjudgment of a hazardous situation. A typical scenario would be when workers do not tie-off their full body harnesses when working at elevations or they unhook a body harness to move to a different location. Researchers agree that fall prevention is a more effective method than fall protection (Holt 2001, Singh 2000, Huang and Hinze 2003). PFASs, such as full body harnesses, should be used for fall prevention. OSHA regulations state that only properly tied-off body harnesses are qualified as PFASs for fall protection (OSHA 1998 in Huang and Hinze, 2003).

### **3. RESEARCH APPROACH**

Falls have obviously continued to constitute a disproportionate percentage of all construction worker deaths. While others have examined some aspects of construction worker deaths attributed to falls, this study had as its focus those fall fatalities that involved or should have involved personal fall arrest systems. Personal fall arrest systems consist of safety harnesses, lanyards and an anchorage device. The lanyard is a device that essentially connects the worker's safety harness to an anchorage device. When the term "personal fall arrest system" is used, it is assumed that all three components are being addressed.

This study was conducted by examining OSHA data that was generated through the investigation of construction fatality cases. These data included 10, 598 fatalities that were investigated between 1990 and the first half of 2004. These investigation reports contain various types of coded information related to the fatality (account number, date of occurrence, time of occurrence, gender of victim, age of victim, cause of the accident, and a narrative description of the accident itself). In this study, the information of primary interest was contained in the narrative description.

The narrative descriptions were examined with the focus being on those aspects of the accident that pertained to the victim's personal fall arrest system. While the other coded information was considered in this study, it was determined that this additional information was of limited value for this effort. Additionally, some of this information was also available in the narrative descriptions as well. With a specific focus on the use of personal fall arrest systems, many fall fatalities were not considered. Examples of those fall cases not examined further in this study were those in which workers fell from scaffolding that was installed improperly, from ladders, through floor openings, and through skylights. Cases involving workers who fell because guardrails were removed were also not included in this investigation. Instances of workers falling from roofs and unprotected edges were also not considered in this study if the narrative description did not specifically mention the use of personal fall arrest systems, especially the use of a safety harness.

A total of 184 construction worker fatalities were identified in which some aspect of personal fall arrest systems were mentioned in the narrative description. These incidents were examined to determine the root causes as far as the use of personal fall arrest systems were concerned.

#### **4. RESULTS**

Each of the fatality cases were examined to determine the nature of the cause of the fatality with particular focus on the role that was played by the personal fall arrest system. Cases were not considered applicable if the use of the personal fall arrest system did not play a crucial role in the accident itself. For example, if a worker was wearing a harness at the time of making contact with electric wiring, the harness itself was not considered to have played a significant role in the incident.

Through the examination of the different fatality cases, it was determined that the underlying causes could be categorized into common groups of related factors. These different causal factors will be described. To help understand the nature of the incidents, some of the narrative descriptions will be provided. Some of these descriptions had extraneous information removed, but the essence of the factors related to the incidents has remained intact. Information that was not included might include descriptions of the nature of the bodily damage incurred by the fatality victims.

##### **No Harness worn**

Several of the fatality fall cases involved workers who were not wearing safety harnesses at the time of the fall incident. There was insufficient information provided in most cases to determine if the workers had the personal fall arrest systems provided and they simply did not use it for the task being performed or if such personal protective equipment was not provided to the workers. The following cases are typical of the cases where no personal fall arrest systems were being utilized by the fall victims.

- Employee #1, an iron worker, was standing 23 feet above the ground on a six-inch wide steel truss receiving bundles of metal roof decking material. He was not protected from falling by nets, a safety harness, or any other means. When employee #1 took a step backward, he apparently miss-stepped, and fell 23 feet. He landed on his head and shoulders and was killed.
- Employee #1 and employee #2 were working on the roof of the building approximately 27 feet high. Employee #1 was placing a stringer at the edge of the building when suddenly he lost his balance and fell to the ground. He was not wearing a body harness and was killed by the fall.

### **Lanyard unhooked**

A number of the fall incidents took place where personal fall arrest systems were provided to the workers. These were typically instances in which workers were wearing safety harnesses and they had previously been tied off to an anchorage connector. In some cases there were no clear explanations why the worker unhooked the lanyard. It might be surmised in some cases that the workers unhooked the lanyards to move to different work locations, but this could not be verified in most instances because of the lack of witnesses. The second case below may be construed to be one in which the worker was moving to a different location, but this is not clear as the worker was using a retractable lanyard that offered mobility while being tied off.

- An ironworker was setting bridging on bar joists and fell approximately 27 feet from an I-beam. The victim was initially observed by co-workers as wearing a safety harness and being tied-off with a lanyard to a static line. For some unknown reason, he unhooked the lanyard. The victim landed face/chest first to a small mound of clay/sand material. He died two weeks later from his injuries.
- Ironworker installing roof decking on a flat roof disconnected his self-retracting lanyard from his harness and was walking on the decking. He stepped onto a piece of decking that did not properly overlap a bar joist. The piece of decking slipped off the bar joist and the employee fell 34 feet to his death.

### **Harness improperly worn**

When personal fall arrest systems are employed it is imperative that they are used properly. Furthermore, these systems should not be altered in any way. Some of the fatality cases included instances in which workers were equipped with the personal fall arrest systems, but for some reason they were not worn properly. As shown in the following incident description, the worker failed to secure the leg straps resulting in the worker falling free from the harness during the fall. In the second case, the harness was modified so that there were no leg straps on the harness. These practices, and others similar them, proved to be unfortunate and fatal errors.

- An employee was 265 feet high working on a communications tower installing co-ax cable when he fell from the tower. He was wearing a body harness with a shock absorbing lanyard and a positioning strap at the time of the accident. His harness leg straps were not buckled and his lanyard did not show any signs of being exposed to fall impact forces.
- The ironworker fell approximately 80 feet and died after having gone to the top of the southeast corner column of a building. Witnesses stated that he had been working with the raising gang crew and had climbed the (12 ft.) ladder which did not go all the way to the top of the 15 ft high column. He then climbed up on top of the column to unbolt a large lifting lug from the top of the column. The crane swung free with the lug attached without incident. After that, there was no direct witness account as to whether he fell from the column or from the ladder. The ladder was observed to be defective (too flexible due to wear), was too short for the task, and could not sit square against the column due to the shape of the column. A fall protection harness which was being worn by him was missing the leg straps.

### **Removed Harness**

The proper use of personal fall arrest systems should adequately protect workers from fall injuries. Such systems are to be used at all times when workers are at risk of sustaining falls. There were instances when workers were at elevation and, for no known reason, removed their safety harnesses. Other fall victims apparently removed their harnesses when relocating to other work areas. The following are typical of such cases.

- Employee #1 was part of a six-member crew that was installing new felt and shingles on an existing apartment building roof. The crew was installing felt on the roof while employee #1 was marking the felt with chalk. When employee #1's coworker stopped to refill the chalk container, employee #1 removed his safety harness. He fell from the gable end of the roof and was killed.
- An employee removed his safety harness and stepped out of an aerial lift onto a building. He subsequently fell 25 feet to his death.

### **Lanyard Broke**

Personal fall arrest systems must be kept in good condition to ensure the safety of workers who rely on them. If personal fall arrest systems deteriorate over time, they must be replaced. Incidents were noted where the lanyards failed, generally for no apparent reason. Possibly the quality of the lanyards had deteriorated with age and through extensive use.

- Employee #1 was killed when he fell while installing steel roof trusses at a height of about 20 feet. He was wearing a safety harness with the lanyard properly attached to a point having the required load carrying strength. The lanyard, a rip-

stitch shock-absorbing type, broke before the rip-stitch shock absorber functioned. The victim struck steel floor joists that had been installed at the floor level.

- Two steel workers were laying a sheet of decking when apparently one employee slipped and fell. Apparently his lanyard broke (possibly cut by the sharp edge of the decking) and the victim fell 38 feet to his death onto the concrete floor below.

### **Not 100% tie off**

To ensure the safety of their employees, some companies implement policies in which workers at elevation are to be tied off at all times. This is only possible with the use of twin-leg lanyards. With twin-leg lanyards, workers can be tied off 100% of the time, even when relocating positions. This is done by having both legs of the lanyard attached. One leg is unhooked and the worker then moves in the direction of the next position. When the worker extends the lanyard that is still hooked, the worker attaches the loose leg of the lanyard and unhooks the other leg. In this way, the worker is never in an at-risk condition. With single-leg lanyards, workers are always at risk whenever the lanyard is unhooked. Anything less than 100% tie-off places workers at risk. As demonstrated in the following cases, workers are at risk whenever a single-leg lanyard is unhooked or when both legs of a twin-leg lanyard are unhooked.

- An employee was working 30ft above the ground when he unhooked his safety harness while changing positions. He lost his balance and fell to the ground. His injuries were fatal.
- A steel worker was connecting a steel beam at the highest point of the new building being built. He was in the center of the building when he fell twenty eight feet to the ground. The worker was wearing a full body harness with twin-leg lanyards. The worker unsnapped his lanyard from the attachment point, and reached out to disconnect a steel choker used to set the beam in place when the fall occurred.

### **Malfunction of personal fall arrest system components**

Personal fall arrest systems, when functioning properly, should provide adequate protection to workers when working at elevation. A few instances have been noted where workers have fallen while utilizing personal fall arrest systems, but where a component of the system failed. One commonly-known problem is that lanyard hooks, that are designed to withstand 5,000 pounds of static force, should not be subjected to side-loading. The hooks are not designed to withstand a side-loading force. Unfortunately, unusual circumstances can arise in which such side-loading might occur. This requires diligence on the part of workers to ensure that such conditions do not occur.

Retractable lanyards provide a means by which workers can walk freely while remaining secured to an anchorage point. Depending on the type of retractable device, workers can move from ten to twenty feet (approximately three to six meters) from the anchorage

point. This is a valuable feature as the worker is not in a position of tripping over the lanyard as it constantly retracts when slack is introduced into it. It is only when the worker falls or introduces a sudden acceleration force on the lanyard that the retractable device locks up and does not allow the lanyard length to be extended. The second case below describes an instance where one such device failed.

- Employees were installing sheet metal decking on the 3<sup>rd</sup> level of a steel structure. Employee #1 was placing short sections (16') of decking over 3 joists. As he progressed with this task, he kicked the last sheet placed to make it fall into place and interlock with the previously laid sheet. The sheet slipped away from the 3<sup>rd</sup> joist and the employee started falling through to the lower level. At the time of this event, the victim was wearing a full body harness and was tied-off to a retractable cable block about 15'-18' away. As he fell, somehow the cable hook came undone/slipped out of the "d" ring attached to the body harness. The block had been recently purchased and put into service just a couple of days before the event. The victim fell approximately 36 feet to his death.
- An employee fell 60 feet while decking a metal roof. The employee was wearing a full body harness and a self-retracting lanyard, however, the lanyard did not activate until he had fallen 29 feet. At that time the self retracting lanyard cable broke and the employee fell another 31 feet.

### **Tied off but killed**

In most instances, when personal fall arrest systems are properly maintained and utilized, adequate fall protection will be ensured. It is imperative that the work conditions also be fully evaluated. The personal fall arrest system should restrict a worker's fall to no more than six feet (approximately 1.8 meters). This does mean that the personal fall arrest system does not prevent falls from occurring, but they are designed to restrict the distance that workers fall. Rather than falling to the ground or to a lower level, a worker with a properly-employed personal fall arrest system will only fall a short distance, generally without sustaining any injuries. The following example is one that demonstrates the need to carefully evaluate the work conditions before setting up a work task with a personal fall arrest system.

- The deceased was involved in connecting a steel beam approximately 15 feet above the ground. He was on the beam, and was wearing appropriate personal fall protection equipment. After completing his connections, he stood, and then fell from the beam. His harness and lanyard limited his fall to approximately three feet, and prevented him from falling to the ground. Unfortunately, the lanyard caused him to swing into the support column, and to strike his head.

### **Structure Collapsed**

Instances where entire structures fail are rare, but such events offer little means of avoiding injury to those working on the structure. Structures must be properly secured

prior to placing workers in vulnerable situations. To ensure the structural stability of structures, some redundancy in the support system appears necessary. The following incident gives the details of an unfortunate event in which workers were complying with the proper use of personal fall arrest systems, but the entire structure failed.

- Three employees were in the process of installing purlins or scattering them on the frame of the engineered building under construction. All of the workers agreed they heard a loud "pop" and the frame lines of the structure started to collapse. The three workers were wearing personal fall protection (harnesses) but the anchor posts and cable collapsed with the structure. The individuals fell at least 30 feet to the concrete slab or the gravel railroad bed located inside the structure. Two workers were hospitalized and one worker died as a result of injuries sustained. One of the surviving employees suffered severe permanent injuries, and the other sustained moderately severe injuries.

### **Role of Roof Anchors**

Of all fall fatalities, perhaps the location of greatest concern relates to work performed on roofs. The roofs of particular interest are those that are sloped. Most sloped roofs occur in residential construction. Perhaps the significance of roofs is not that surprising when it is realized that approximately two million new homes are constructed each year in the United States during strong economic periods. In addition, workers are exposed to falls from existing houses when they perform repairs and when they apply new roofing materials.

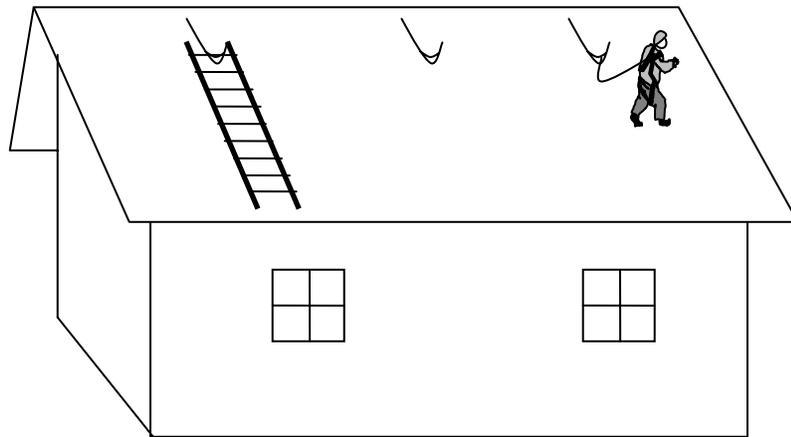
With the high number of construction worker deaths that occur due to falls from sloped roofs, one might assume that there are no effective means by which construction workers can be protected on sloped roofs. This is often the general consensus; however, there are several methods by which workers on roofs can be afforded protection from falls. Perhaps the most effective method is to have workers on sloped roofs tied off to roof anchors, devices that are affixed to the roof structure. Roof anchors should be capable of supporting 5,000 pounds (nearly 2300 kilograms) of static force, according to the Occupational Safety and Health Administration regulations.

Despite the fact that roof anchors are commercially available, the use of roof anchors is not extensive in the U.S. construction industry. In addition, in the few instances when roof anchors are employed, they are generally removed or covered with roofing materials at the conclusion of the construction effort. This renders the anchors unavailable for use by roof maintenance and repair workers or any other workers who may have occasion to be on these roofs.

If conditions do not change in the way that roofing work is done, the construction industry is destined to continue to have significant numbers of worker deaths due to falls from roofs. Perhaps the primary question that remains unanswered is why the employers of roofing workers do not fully comply with the OSHA regulations to prevent worker injuries and deaths.

An examination of roofing practices observed in Europe provides some revealing information about providing for worker fall protection. These consist of permanent devices that are attached to many European buildings that have sloped roofs. These devices appear as hooks that are generally located slightly below the pitch of the roof. On roofs with clay tile or slate tiles, the hooks are used to support a ladder that has one of its top rungs supported by the hook (see Figure 2). The ladder takes the weight of a worker on a clay tile or a slate roof and distributes it over a broader area of the roof. This prevents the worker's weight from actually breaking any of the rigid or brittle roofing tiles or shingles. On long roofs, additional hooks will be located further down the slope from the upper hooks. Such hooks have been noted on roofs with slopes considerably over 45 degrees and with roof slopes as little as 4:12 pitch.

In Germany, these hooks were noted on roofs of buildings that were under construction and they have been noted on roofs of buildings that were considerably older than a hundred years. Thus, the practice of incorporating these hooks in the roofs has been around for scores of years. The above description mentioned the use of the roof hooks on clay tile and slate tile roofs; however, similar hooks were noted on roofs with asphalt shingles. Thus, the purpose of the hooks is not purely for worker weight distribution on rigid tile roofs (see Figure 2).



**Figure 2. Example of permanent hooks on roofs for fall protection**

It is worth mentioning that the hooks are used for other purposes than to support ladders. One system consists of ropes being attached to a series of rollers that are supported from the hooks. These rollers can be adjusted so that the system can be moved up and down along the roof. A plank would then be used to span between the two frames or rollers. This would then provide a working surface for workers who could reach virtually any part of the roof with the use of the system.

## 5. CONCLUSIONS

In the construction industry in the United States, falls account for over 36 percent of the construction worker fatalities. Falls can take place from any point of elevation whether from ladders, scaffolding, unprotected edges, floor openings, roofs, or some other elevated location. This research has examined the role of personal fall arrest systems in providing for the safety of workers at elevation. Specifically, the study examined instances in which a flaw was noted in the employment of personal fall arrest systems. From this information, it is apparent that many fatalities could be avoided if workers would adhere to proper practices in the use and maintenance of the protective fall equipment. Most fall fatalities involving personal fall arrest systems occurred because workers were not provided with the equipment, the workers failed to wear the equipment, the workers removed the safety devices, the workers or others altered the equipment, or the system did not provide 100% fall protection.

From this information, it can be concluded that when other means of fall protection are not provided that the proper employment of personal fall arrest systems by workers at elevation would eliminate most fall deaths. It is also evident that in some instances, the workers do not use personal fall arrest systems because suitable anchorage points were not provided. Whenever personal fall arrest systems are employed, failure to fully assess the overall jobsite conditions can also result in mishaps.

## 6. RECOMMENDATIONS

The review of the various fall fatalities provides clear evidence of the general nature of circumstances in which worker fall deaths occur. From this information it quickly becomes apparent that employers must provide their employees with personal fall arrest systems, devise clear policies on the proper employment of the personal fall arrest systems, fully train all of their employees in the safe use of personal fall arrest systems, and enforce compliance with the fall protection policies.

Because of the importance of having adequate anchorage connectors, employers should carefully evaluate jobsite conditions before workers are placed at risk at elevation. This includes planning the locations of anchorage connectors. When practical, this should be done during the design phase of projects.

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