Horizontal Lifelines – Methods and Pitfalls

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Introduction

To a safety professional, it is shocking how often horizontal lifelines (HLLs) are offered as a means to abate fall hazards. In spite of the repeated warnings from OSHA, ANSI, and many safety professionals regarding the complexity of HLLs, employers often see them as an inexpensive method to solve a nagging fall protection problem.

However, it is a fact that HLLs are complex mechanical systems, and if they are not treated as such, the consequences can be fatal. This paper will address the complexity of HLLs and provide ideas for effectively using HLLs in the appropriate circumstances.

Problems and Solutions

A simple Google search for “horizontal lifeline system” results in hundreds of HLL “systems” offered for sale. The term “system” in this case often refers to the components that make up the horizontal lifeline, such as the rope, connectors, in-line shock absorber, etc. The use of the word “system” is often misunderstood and confused with OSHA’s and ANSI’s “part of a complete fall arrest system.” The HLLs offered for sale, or any HLL for that matter, are only one component of a complete fall arrest system, which also must include analysis of the supporting structure, training and procedures for using the equipment, as well as rescue methods. Already the complexity of HLLs becomes apparent.

To understand why HLLs are so prevalent, it’s worth looking at what problems people are attempting to solve. HLLs are typically chosen when relatively long distances (more than 30 feet) must be covered with little or no overhead structure in between. At first glance, they seem to be a logical solution when motion in a linear horizontal direction is required, such as when working on a bridge crane runway or on top of a tractor-trailer. As shown in Exhibit 1, HLL systems that are supported from a lower beam using a stanchion are common on construction sites. These systems appear to offer a simple solution to the problem of having no overhead structure that can be used to support alternate fall protection methods.

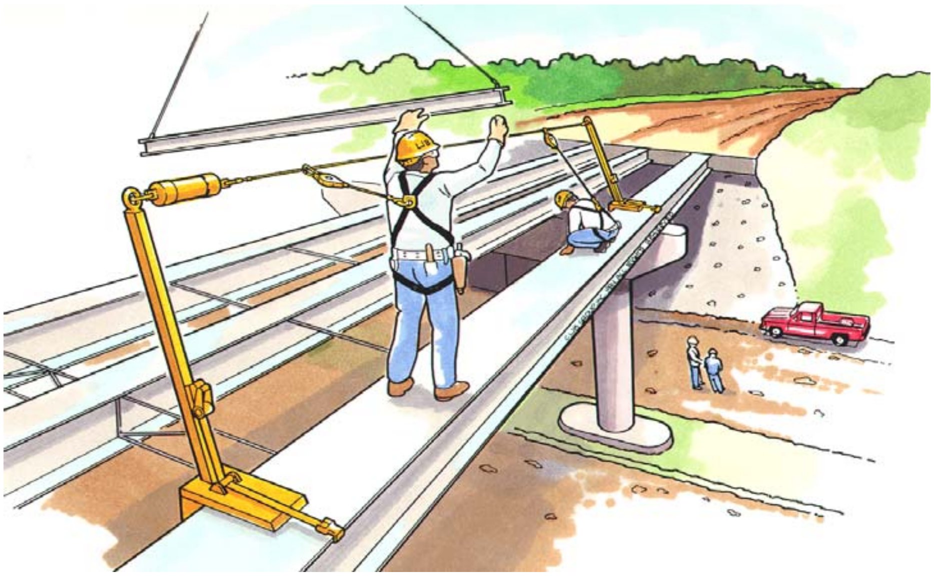

Exhibit 1 – This drawing represents a typical construction site HLL.

However, many HLLs are installed without regard to the tremendously high forces the cable puts on the upright stanchion and supporting structure. As will be described later in this paper, cable tension in the range of 10,000 lbs. is not difficult to generate. Most structures are not designed to support these types of forces in addition to normal dead, wind and snow loads. Therefore, the need for additional reinforcing should be factored into the decision to use an HLL. One way to reduce the end anchorage load is to allow the cable to deflect more in the event of a fall. However, when compared to a rigid monorail type fall arrest system, HLLs already deflect significantly. Many times, they are used in situations where there is inadequate clearance to the ground or a lower obstruction.

Another problem that HLLs seem to solve is that of cost. It's true that many of the HLL systems offered are relatively inexpensive compared to other hazard abatement options. Systems that connect directly to the supporting structure often come with adjustable brackets so that no additional fabrication would seem necessary. Installation labor, too, seems to be simply stringing the cable between two points, and drawing it tight, further supporting the idea that HLLs are a low cost option. However, when one considers the cost of structural reinforcing, installation cost of HLLs begins to approach, or even exceed, that of a monorail beam system. Add in the recurring costs of training, inspection, and maintenance, and any personal protective equipment solution loses much of its cost advantage.

Finally, HLLs are often chosen where aesthetics are important, such as on the roof of an historic building. In these cases, the slim profile of the cable is less obtrusive than other abatement options such as perimeter guardrail.

The sad truth of why HLLs may be so prevalent is that their apparent benefits of low cost, easy installation, and unobtrusive appearance make the idea of doing *something* easier to tolerate, rather than the alternative of doing *nothing*. Many people believe that doing something is better than doing nothing when it comes to fall protection. But if an improperly selected and installed HLL would fail to protect the employee relying on it, a false sense of security is the only result.

OSHA

OSHA regulations on fall protection are performance specifications that only occasionally indicate what method should be used to abate a fall hazard. In the case of HLLs, OSHA gives a few important guidelines. The most significant requirement set forth by OSHA is that HLLs must be "designed, installed, and used under the supervision of a Qualified Person." To a non-safety professional, this statement is misunderstood. Although not explicitly stated, many people (including the author) interpret OSHA's definition of a Qualified Person to consist of two parts: an engineering part and a safety part. Many people assume that any structural engineer can design an HLL. But a structural engineer without an understanding of the safety component might use improper loads, overlook critical clearance issues, or fail to plan for rescue. On the other hand, safety professionals who try to apply an off-the-shelf HLL system might very well attach the system to an inadequate supporting structure, failing to anticipate the high loads generated by the cable.

Proprietary HLLs

As mentioned previously, the word "system" is often incorrectly applied to the description of a horizontal lifeline. ANSI Z359.1 uses the phrase "Horizontal Lifeline Subsystem" to more accurately describe the physical components of the HLL between the end anchorages. A typical HLL configuration is shown below in Exhibit 2. In its simplest form, an HLL consists of cable with a means to connect it to a suitable end anchorage, plus a method to establish an initial sag or pretension, usually a turnbuckle.[1] An inline energy absorber is often used to reduce the overall end anchorage forces at the expense of increased cable deflection.

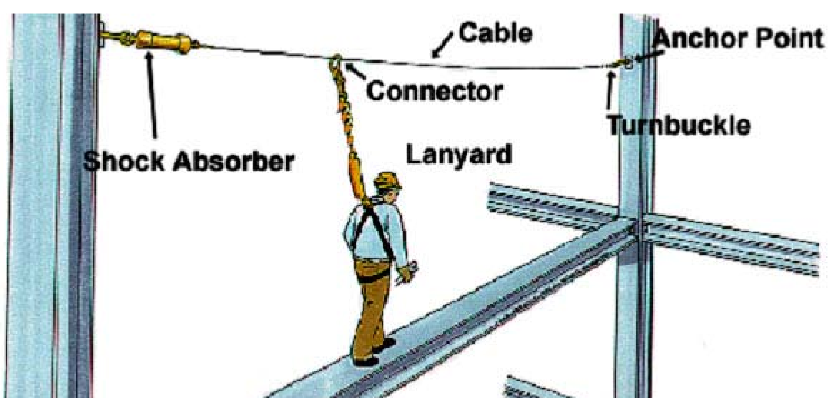

Exhibit 2 – This drawing represents a typical HLL configuration.

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[1] For the purposes of this paper, the terms cable, wire rope, rope and synthetic rope are used interchangeably to describe the line component of the horizontal lifeline. It should be noted that the behavior of these different types of lines can be different.

Such a simple HLL could be of the “home-built” variety, where a suitable wire rope is connected to the end anchors using clipped eye terminations. Alternatively, a proprietary HLL may be used. For the less experienced, the proprietary systems offer the benefit of having the rope, terminations, and energy absorber chosen for them. For those who are experienced at sifting through the wide selection of rope types and termination methods, a proprietary system might still be selected when intermediate supports or an inline energy absorber are required to help reduce the cable forces. Many propriety systems offer intermediate support brackets and compatible carriers that permit a user to pass through the support without disconnection from the cable.

The use of a proprietary system, however, does not eliminate the need for a Qualified Person. While some manufacturers offer full system design, including analysis of the structure to which the HLL is attached, many leave that critical step up to the buyer. Furthermore, a Qualified Person can assist the buyer in selecting the appropriate proprietary system by establishing performance criteria that can be used to evaluate the offers from several manufacturers. In the public arena, this facilitates the requirement that multiple proposals be obtained. This method was applied successfully when designing safety systems for numerous government buildings of a Midwestern state. The Qualified Person established criteria such as maximum end anchorage loads, maximum total fall distance, and other parameters that permitted proposals from several manufacturers to be fairly evaluated next to custom-built HLLs built from off-the-shelf components. The Qualified Person in this case also established proper rescue procedures and general training materials, that, when combined with the system-specific training provided by the HLL supplier, constituted a complete fall arrest system.

Influence of Design Parameters

HLLs are complex in part due to the non-linear analysis required to evaluate them. In a linear analysis, such as for a simple I-beam, it’s a straightforward matter to calculate the deflection resulting from a given load. Doubling the load results in twice the deflection. However, for an HLL, doubling the load does *not* necessarily mean double the deflection. This non-linear behavior means that one cannot easily predict the influence of changing a design parameter. The examples below, summarized in Table 1, help to illustrate this point.

<u>HLL Span</u>

Most of the time, the overall span is a fixed requirement. Determining the area where fall protection coverage is needed is one of the first steps when selecting the abatement method. However, situations may arise where there are options as to what structure will be used for anchorage. For example, the HLL may only be needed for a 20-foot portion of a bay in a manufacturing plant. Intermediate framing, between typical column lines that are at 80-foot centers, may provide the necessary coverage. But, since intermediate framing is less substantial than the framing on the column lines, reinforcing may be required to ensure adequate structural support. For a common HLL arrangement, the end anchorage force and total vertical fall clearance required for the 20-foot span is 6,040 lbs. and 10’-10”, respectively.[2] Changing the total span to 80 feet while holding all the other parameters constant would change the end

[2] These results are for a specific set of design parameters and do not necessarily apply to every 20-foot span HLL.

anchorage force and total vertical fall clearance required to 6,420 lbs. and 14'-2". If the additional 3'-4" of clearance is not available, then reinforcing the structure to support the shorter span may be the best option.

Number of intermediate supports

Let's assume that coverage for the entire 80 feet is required in the above example. One option is to use a single span with no intermediate supports. However, what if the end anchorage forces were higher than the structure could support? One option would be to use intermediate supports between the end anchors. Again, the effect is not linear, so predicting the exact behavior on a particular system is not trivial. Changing from a single-span system to a two-span system does not generally result in halving the end anchorage force. In general, though, keeping everything else constant while changing the number of intermediate supports will tend to decrease the end anchorage force, sometimes significantly. In the above example, adding one intermediate support in the center of the 80-foot span would reduce the end anchorage force to 4,970 lbs., while decreasing the clearance required to 12'-10". Changing it to a four-span system results in 3,830 lbs. of end anchorage force and 11'-9" of clearance required. As can be seen with this simple example, the load reduction can be significant (from 6,420 lbs. down to 3,830 lbs.) with a similar reduction in clearance required. The trade off is the requirement for an intermediate structure of adequate strength, plus the added cost of the intermediate support brackets.

Use of an inline energy absorber

The calculations above were based on the assumption that no inline energy absorber was used. But what if one were to use a proprietary energy absorber in the system? Each manufacturer's energy absorber yields different results, but in general they all function by allowing added length to the system when subjected to load and dissipating energy. The net result is an increase of the total clearance required with a simultaneous decrease in end anchorage force. Continuing with the examples above, adding a typical energy absorber to the single span, 20-foot long system reduces the end anchorage force from 6,040 lbs. to 3,800 lbs.—a 37% reduction. The total clearance required increases from 10'-10" to 11'-9". The force reduction is not always so dramatic. In the 80-foot long, four-span system described above, the addition of an energy absorber changes the end anchorage force only 19%, from 3,830 lbs. to 3,090 lbs. and adds only 6" to the 11'-9" of clearance required. The reason for this result is that the system without the energy absorber is already quite flexible, as opposed to the 20-foot span system which is quite stiff by comparison.

Other less obvious parameters can also have significant affect on HLL behavior. In general, anything that affects the system stiffness or its ability to stretch under load needs to be considered when evaluating an HLL. Cable type and size are such parameters, where not only is it important to understand the differences between wire and synthetic material, but also in the elastic qualities of the various types of wire ropes common in HLLs. End anchorage stiffness, initial cable tension, end connector type, and changes in temperature also contribute to the total system stiffness. Each variable should be accounted for during design.

Total system span	Number of spans	Inline Energy Absorber?	End anchor force	Total Clearance Required
20 feet	1	No	6,040 lbs.	10’-10”
80 feet	1	No	6,420 lbs.	14’-2”
80 feet	2	No	4,970 lbs.	12’-10”
80 feet	4	No	3,830 lbs.	11’-9”
20 feet	1	Yes	3,800 lbs.	11’-9”
80 feet	4	Yes	3.090 lbs.	12’-5”

Table 1: This table summarizes the examples used to illustrate design variables.

The magnitude of the clearance required for an HLL often surprises people who look only at the benefits of HLLs. These same people also underestimate the substantial end anchorage forces that must be supported. But, aside from these two issues, other important concerns must be addressed prior to implementing an HLL-based fall hazard abatement. One such concern is that of rescue. OSHA requires that employers ensure that self rescue is possible or provide for the prompt rescue of fallen employees. Still, some proactive employers require that a rescue plan be in place prior to starting any work at heights. It should be noted that any time a worker connects to a fall arrest system, there is an inherent assumption that he will fall. Otherwise, why is the system needed? For a worker using a self-retracting lanyard connected to a rigid beam, the notion of relying only on self-rescue is not advisable, but at least it is plausible. But, for an HLL, where the cable has deflected significantly from the starting point, the fallen worker may be suspended several feet below any structure that he can use to perform self-rescue.

Another result of the significant cable deflection is the possibility that the fall of one worker would pull a second worker over. Even those who argue that the system is strong enough and has sufficient fall clearance would acknowledge that even an arrested fall may result in some injury, such as striking the working surface on the way down or trauma caused by suspending in a harness. Therefore, when a situation arises where an abatement method must protect multiple users simultaneously, a form of abatement other than an HLL may be better suited.

Careless implementation of HLL “look-alikes” should also be avoided unless great control over their use can be maintained. “Look-alikes” are cable systems that are intended for purposes other than fall arrest HLLs, such as perimeter guardrail at a building construction site, or a travel restraint system at a roof edge. These “look-alikes” could easily be taken to be fall arrest HLL systems and inappropriately used, with dire consequences.

HLLs, properly implemented, do have their place in the fall protection industry. While these photos should not be construed as an endorsement of any particular proprietary system, they provide examples of the proper use of HLLs. Exhibits 3 and 4 show an HLL system that protects workers near the edge of a roof. Exhibit 5 illustrates how HLL systems can be effective at providing continuous fall protection around corners. Exhibit 6 shows the minimal impact that HLL systems have on the aesthetics of a building. Barely visible from the ground, the HLL system mounted near the ridge of the roof protects workers performing various maintenance tasks.

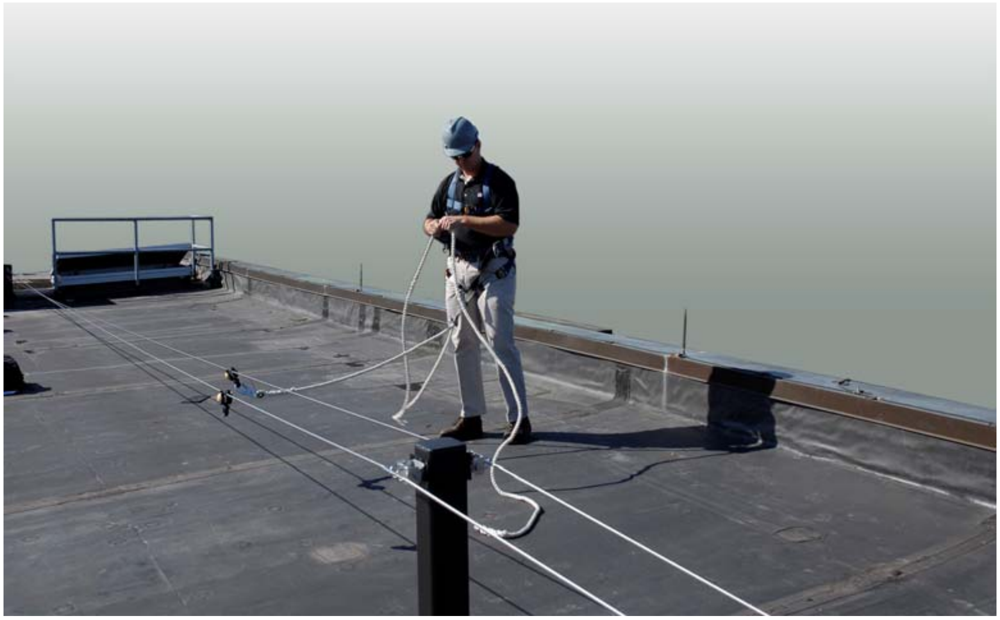

Exhibit 3 - This HLL system protects workers near the roof edge.

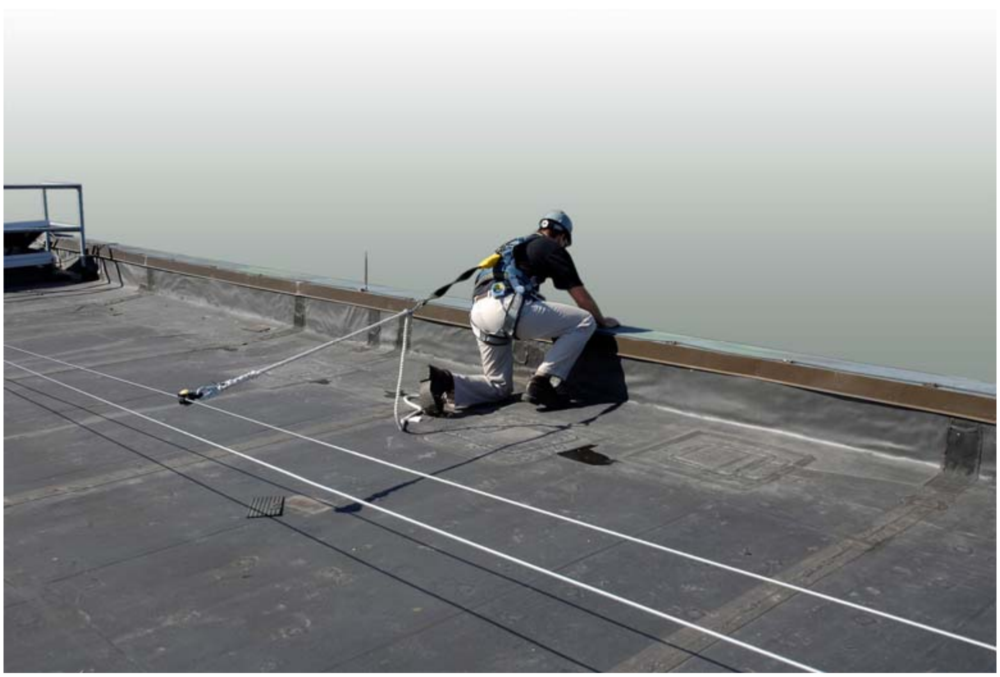

Exhibit 4 - This HLL system protects workers performing tasks at the roof edge.

Exhibit 5 – This photograph illustrates how HLL systems can be effective at providing continuous fall protection around corners.

Exhibit 6 – This photograph illustrates the minimal impact that HLL systems have on the aesthetics of a building.

Conclusion

Despite their pitfalls related to design, rescue, inspection, and a host of other hurdles that must be overcome, HLLs will likely continue to be a common solution to fall protection issues. As the owner, user, or designer of an HLL system, it is important to be able to recognize the pitfalls and to know when and how to use HLLs effectively.