Design of Fall Arrest Systems: A Review of the Current Issues in the Singapore Construction Industry

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Abstract

Falling from height is one of the leading causes of occupational fatalities in the construction industry of most countries, including Singapore. Despite significant effort by the Singapore Government and the industry, the number of deaths arising from falling from height accidents continues to remain unacceptably high in Singapore. Note that between 2007 and June 2011, 95 workers were killed in Singapore due to falling from height accidents. Since eliminating falling from height hazards and use of engineering controls are frequently impractical, it is common for workers to rely on fall arrest systems for protection while working at height. However, the use of fall arrest systems does not necessarily translate to lower risk of falling from height accidents. Based on the authors’ experience, some of the fall arrest systems utilised in Singapore were not adequately designed. This paper reviews the common safety issues with fall arrest systems used in the industry. International standards were referenced to facilitate discussion of local designs of fall arrest systems. Recommendations to improve the design of fall arrest systems will be provided. Two key recommendations were provided: (1) develop a local standard to provide guidance for design and evaluation of fall arrest systems, and (2) training programmes should be developed to train safety and engineering professionals on fall arrest systems.

Keywords

Work-at-height, design, fall arrest, fall protection, fall from height, personal protective equipment.

INTRODUCTION

Due to the dynamic nature of the construction industry, workers frequently have to use active fall protection systems to protect against falling from height. The Canadian Standards Association (CSA) (2004) defines active fall protection systems as, “a means of providing fall protection that requires workers to take specific actions including wearing (and otherwise using) personal fall protection equipment and following prescribed procedures”. Examples of active fall protection systems commonly used in the construction industry include travel restraint and fall arrest systems. Travel restraints prevent workers from reaching unprotected edges or openings. Fall arrest systems arrest workers that falls from height, preventing them from hitting the ground or obstacles. Active fall protection system is generally made up of components like full body harness, energy absorbers, ropes, lanyards and karabiners.

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Even though active fall protection systems are the last resort in the hierarchy of control measures they should be carefully designed to ensure their effectiveness. This is especially important in the case of the construction industry where falling from height is a major concern in a lot of countries (Adam et al., 2009; Chan et al., 2008; Chi et al., 2005; Workplace Safety and Health Council, 2012). Unlike the North Americans where there are design codes for active fall protection systems (American National Standards Institute & American Society for Safety Engineers, 2009; Canadian Standards Association, 2004), Singapore does not have similar design codes. The lack of a design code can potentially cause active fall protection systems to be inadequately designed and thus expose workers to unnecessary risk. It is also noted that, in contrast to North America, there is no legal requirements for active fall protection systems to be designed and endorsed by a professional engineer (PE).

This paper presents the preliminary results and findings of a small scale online survey designed to identify gaps in the evaluation and design of fall arrest systems in the Singapore construction industry. The paper also proposes recommendations to address the identified gaps.

RESEARCH METHOD

ONLINE SURVEY

The objective of the online survey was to gather the following information:
1. types of active fall arrest systems used
2. level of Professional Engineers’ involvement
3. scope and criteria used in evaluation of fall arrest systems
4. how fall arrest systems are being evaluated without a Professional Engineer

To encourage participation, the questionnaire only required about 10 to 15 minutes of response time. A draft of the questionnaire was sent to a technical expert, Greg Small, who was a member of the CSA Z259 Committee and the Technical Sub Committee of ANSI Z359.6, Z359.16 and Z359.17, for his comments. Based on his input, the questionnaire was revised before a pilot run of the online survey was conducted for a trial group of 10 respondents. The pilot run was successfully completed with no further input for improvements received.

The link to the online survey was sent to a total of 119 safety and health professionals, project managers, consultants, trainers and supervisors that have experience in fall arrest systems. These respondents were identified through the authors’ personal network in the local industry. At the time of writing, a total of 61 responses were received. This included the 10 respondents who participated in the pilot run. Out of the 61 responses, 43 indicated that they work in the construction industry. This paper only reports the findings in relation to the construction industry, i.e. only the 43 responses were considered in this paper. As the online survey was also freely circulated by the respondents identified by the authors, the actual response rate could not be readily determined.

About 80 percent of the respondents were workplace safety and health professionals, such as safety supervisors, coordinators, officers and managers, with the rest working as managers, engineers, consultants and supervisors. With reference to Table 1, more than half of the respondents worked in organisations employing more than 200 employees.
Table 1. Size of Respondents’ Companies

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>percent of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 500</td>
<td>30</td>
</tr>
<tr>
<td>201 - 500</td>
<td>25</td>
</tr>
<tr>
<td>101 - 200</td>
<td>13</td>
</tr>
<tr>
<td>51 - 100</td>
<td>13</td>
</tr>
<tr>
<td>26 - 50</td>
<td>18</td>
</tr>
<tr>
<td>1 - 25</td>
<td>2</td>
</tr>
</tbody>
</table>

REVIEW OF ENGINEERING CALCULATIONS

Respondents were also asked to indicate if they are willing to share PE endorsements and calculations of fall arrest systems. As a result, six PE endorsements and calculations were collected. In the absence of relevant Singapore standards, the Canadian Standards Association (CSA) Z259.16 (2004) standard was used to assess the six PE endorsements and calculations.

RESULTS AND FINDINGS

The following sections discuss the key results and findings of the online survey.

TYPES OF FALL ARREST SYSTEMS USED

*Non-manufactured fall arrest systems were more commonly used than manufactured systems*

Manufactured fall arrest system refers to a complete system designed by a manufacturer. In contrast, non-manufactured system refers to a system that is not designed by a manufacturer but may or may not be designed by a Professional Engineer. Non-manufactured systems are usually assembled from separate fall arrest system components and can be from different manufacturers. These systems are more vulnerable to component incompatibility and require more considerations to ensure effectiveness of the system.
Table 2 shows the types of fall arrest systems used by the respondents. As respondents were allowed to select more than one category, the columns and rows do not add up to 100 percent. It is observed that more than 50 percent of the respondents use non-manufactured horizontal lifelines and 36 percent use non-manufactured vertical lifelines.
Table 2. Types of Fall Arrest Systems Used

<table>
<thead>
<tr>
<th>Type of fall arrest system used</th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal lifeline system</td>
<td></td>
</tr>
<tr>
<td>Non-manufactured</td>
<td>51</td>
</tr>
<tr>
<td>Manufactured</td>
<td>26</td>
</tr>
<tr>
<td>Vertical lifeline system</td>
<td></td>
</tr>
<tr>
<td>Non-manufactured</td>
<td>36</td>
</tr>
<tr>
<td>Manufactured</td>
<td>26</td>
</tr>
<tr>
<td>Temporary anchors for lanyards or self-retracting lifelines</td>
<td></td>
</tr>
<tr>
<td>Non-manufactured</td>
<td>28</td>
</tr>
<tr>
<td>Manufactured</td>
<td>26</td>
</tr>
<tr>
<td>Fixed anchors for lanyards or self-retracting lifelines</td>
<td></td>
</tr>
<tr>
<td>Non-manufactured</td>
<td>21</td>
</tr>
<tr>
<td>Manufactured</td>
<td>26</td>
</tr>
</tbody>
</table>

PROFESSIONAL ENGINEERS’ ENDORSEMENT AND ENGINEERING CALCULATIONS

3 out of 5 fall arrest systems were endorsed by a Professional Engineer.

64 percent of the respondents had the whole or some part of their fall arrest systems endorsed by a Professional Engineer. However, the scope of the evaluation and endorsement was found to be inadequate when benchmarked against CSA Z259.16 (2004). The inadequacies are highlighted as follows.

Fall clearance was generally not considered or not accurately assessed.

CSA Z359.16 (2004) defines clearance as the distance from a specified reference point, such as the working platform or the anchorage of a fall arrest system, to the highest obstruction that a worker might encounter in a fall. Not ensuring that there is sufficient clearance may result in a worker getting injured or killed from collision with an obstruction or the ground in the fall path.

Fall clearance is one of the safety criteria in the CSA Z259.16 (2004) to be assessed but was only considered by 8 percent of the Professional Engineers who endorsed the systems. Almost 80 percent of the respondents relied on the information provided by the manufacturer to assess fall clearance, without the involvement of any Professional Engineer. 13 percent of the respondents did not consider fall clearances formally.

Of the six PE endorsements collected, none correctly evaluated the clearance. For example, in one of the endorsements the personal energy absorber extension was not factored into the calculations. The endorsements also did not indicate the performance requirements nor the specifications of the fall arrest system equipment components that are compatible with the design.

No specialized training required of Professional Engineers endorsing fall arrest systems.

None of the respondents indicated that the Professional Engineers engaged by them have specialised training in design or evaluation of fall arrest systems. It seemed that respondents were satisfied as long as it was a registered Professional Engineer who endorsed the fall arrest system and did not evaluate their competency in the subject matter.

This complacency was reflected in the minority of endorsements collected that consisted only of a statement that the Professional Engineer certified the fall arrest system structurally safe and sound without any engineering calculations.
Engineering calculations generally did not indicate standards referenced

While 83.3 percent of the PE endorsements were based on engineering calculations, almost 90 percent of the respondents had no idea what standards these calculations were based on.

Only 2 of the respondents indicated that the engineering calculations that they received were based on the ANSI Z359.6 (American National Standards Institute & American Society for Safety Engineers, 2009). It is noted that the CSA Z259.16 and AS/NZ1891.4 (Standards Australia/Standards New Zealand, 2009) were not used by the respondents. None of the engineering calculations that claimed to be based on ANSI Z259.6 were made available for verification of conformance.

It was also noted that in one of the engineering calculations samples collected, reference for horizontal lifeline anchorage and fall arrest system was made to the ANSI Z359.2 Minimum Requirements for a Comprehensive Managed Fall Protection Program instead of a more relevant standards such as ANSI Z259.6 (2009) or ANSI Z259.1 (2007).

FALL ARREST SYSTEMS WITHOUT PROFESSIONAL ENGINEER ENDORSEMENT

High reliance on manufacturers’ instructions to assess anchorage strengths

Manufactured fall arrest systems and some engineered fall arrest systems include guidelines about the required strength of the anchorages, but the users are expected to verify the strength of anchorages.

Most of the respondents (79 percent) assessed the anchorages based on the written guidelines by the manufacturer or the engineer who designed the system. The remainder did not formally assess the strength of the anchorages.

High reliance on manufacturers’ instructions to assess fall clearance

Table 3 shows how respondents assessed fall clearances in their workplaces without engaging Professional Engineers.

Table 3. Assessment of Fall Clearance of Fall Arrest Systems (Not Endorsed by Professional Engineer)

<table>
<thead>
<tr>
<th>percent of respondents</th>
<th>percent</th>
<th>Using non-manufactured systems</th>
<th>Using manufactured systems</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on manufacturer's guidelines</td>
<td>33</td>
<td>88</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Do not consider formally</td>
<td>17</td>
<td>12</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>50</td>
<td>--</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

For non-manufactured systems, one-third of the respondents indicated that they based their fall clearance assessment on manufacturer’s guidelines, and 17 percent did not consider fall clearance formally. In contrast, for manufactured systems, almost all the respondents relied on the manufacturer’s guidelines with a minority not considering fall clearances formally. Since non-manufactured systems are assembled from different sources, there is probably a lack of readily available documentation to guide the users on fall clearance. The remaining 50 percent of the respondents that used non-manufactured systems provided comments like: "only work very high, seldom have to worry about
clearance”, “consider clearance as required” and “use standard formula to calculate clearance height”. The comments indicate that the users have a sense of the importance of fall clearance and are dealing with the issue.

High reliance on Workplace Safety and Health Officers (WSHO) to ensure that fall arrest systems are safe for use

Table shows the approaches adopted by respondents, without the involvement of a Professional Engineer, to ensure their fall arrest systems were safe for use. There was a high reliance (72 percent) on workplace safety and health officers (WSHO) and supervisors, but these personnel may not be trained in fall arrest systems.

In the case of non-manufactured systems, which typically required more evaluation, half of the respondents relied on WSHOs trained in fall arrest systems to ensure that the non-manufactured systems were safe for use, but some depended on untrained workers.

Table 4. Respondents’ Approach in Ensuring Fall Arrest Systems (Not Endorsed by Professional Engineer) are Safe for Use

<table>
<thead>
<tr>
<th>Dependent on</th>
<th>Using non-manufactured systems</th>
<th>Using manufactured systems</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSHO / Supervisors - trained</td>
<td>50</td>
<td>38</td>
<td>43</td>
</tr>
<tr>
<td>WSHO / Supervisors – not trained</td>
<td>17</td>
<td>38</td>
<td>29</td>
</tr>
<tr>
<td>Workers – trained</td>
<td>--</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Workers – not trained</td>
<td>17</td>
<td>--</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>17</td>
<td>13</td>
<td>7</td>
</tr>
</tbody>
</table>

DISCUSSION AND RECOMMENDATIONS

QUALIFIED PERSON

From the survey findings, not all the horizontal lifelines or anchorages were designed by a “qualified person”. Even when the fall arrest systems were endorsed by Professional Engineers, they seemed to lack the expertise in design of fall arrest system. Currently, there is no clear definition of what a “qualified person” means in Singapore. In the United States, the OSHA CFR 1926.502 (Occupational Safety and Health Administration) requires horizontal lifelines and anchorages for personal fall arrest systems to be designed and installed under the supervision of a qualified person. Qualified means one who, by possession of a recognized degree, certificate, or professional standing, or by extensive knowledge, training, and experience, has successfully demonstrated his/her ability to solve or resolve problems related to the subject matter, the work, or the project. Similar regulations can be found in Canada. To support the regulations, there are detailed design codes (Z259.16 and Z359.6) to provide guidance on design of active fall protection systems. There are also courses in North America (Canada and the U.S.) that trains engineers on the design of active fall protection systems.

Based on the survey results, Professional Engineers that designed the fall arrest systems in Singapore seemed to have focused their evaluation on the structural aspects of the fall arrest systems. They did not evaluate or failed to adequately evaluate other aspects like fall clearance and maximum arrest force transmitted to the worker. These are critical aspects in established design codes (Z259.16 and Z359.6) that must be evaluated to ensure the safety of users of fall arrest systems in the event of fall and the Professional
Engineers had failed to demonstrate their knowledge or ability in this. The authors believe that there is a lack of qualified persons in Singapore to design fall arrest systems and there is an urgent need to build up a pool of such qualified persons.

USER COMPETENCY AND ATTITUDE

Due to a general lack of competency or complacency, the respondents (typically end users of the fall arrest systems) were not able to identify the inadequacy of the Professional Engineers’ (PE) endorsements. It appears that respondents are willing to accept endorsements without detailed engineering calculations. Even if there are calculations to support the PE's endorsement, the respondents were generally not aware of what relevant standards the calculations were based on. Respondents seemed satisfied as long as a registered Professional Engineer endorsed the system.

The lack of regulation and the general lack of awareness of fall arrest systems design in the industry probably attributed to the respondents’ complacency.

COMPLIANCE WITH MANUFACTURERS’ GUIDELINES

For fall arrest systems without Professional Engineer’s endorsement, respondents relied heavily on manufacturer’s guidelines and information provided to assess anchorages and fall clearances. However, manufacturer’s guidelines are usually generic in nature and not site specific. Employers must take active steps to reduce the risk of workers using fall arrest systems by seeking further advice from manufacturers or suitable experts on site specific issues.

Even though significant portion of the respondents indicated that they rely on the manufacturer’s guidelines, they might not be able to comply with the manufacturer’s guidelines due to work constraints. For example, a manufacturer’s website (n.d.) stated this instructions for the use of a lanyard with energy absorber: “Connect the lanyard’s connector to the structural anchorage point of resistance min. 10kN (Refer to EN795) placed above the user.” The manufacturer’s products are commonly used in Singapore, but to the authors’ knowledge, in actual usage the lanyards are usually not connected to an anchorage with a minimum strength of 10kN. This observation is supported by examining the Professional Engineer’s calculations collected as part of this study. None of the anchorages in the Professional Engineers’ designs had a minimum strength of 10kN.

SAFETY PROFESSIONALS

In the absence of Professional Engineer’s involvement, respondents indicated that their organisations relied mainly on Workplace Safety and Health Officers (WSHOs) and supervisors to ensure the fall arrest systems were safe for use. This means that the anchorages and fall clearances were probably assessed by WSHOs and supervisors. However, given the lack of coverage in this aspect in the current Curriculum Development Advisory (Workplace Safety and Health Council, 2010a, 2010b) for supervisors and in the national competency standards for WSHOs, it is unlikely that the WSHOs and supervisors have the necessary expertise and competency to evaluate fall arrest systems. It would be unsafe to WSHOs and supervisors to take on this burden of responsibility.

It is the authors’ experience that the WSHOs and supervisors, in turn, rely on the salespersons of fall arrest equipment for advice. This is often the case in the course of a purchase, when the salespersons are conveniently consulted for “free advice”. Although it can be assumed that these salespersons have received some training and are also likely to be more familiar with the equipment and systems that they represent, but they are clearly not qualified to provide advice on design parameters and safety criteria in a
professional capacity. It is complacent and unwise for WSHOs and supervisors to assume that the salespersons’ advice equates or supersedes the manufacturers’ instructions.

RECOMMENDATIONS

The authors believe that there is a very significant lack of competency in fall arrest systems in end-users, safety professionals and Professional Engineers in Singapore. Compared to the past, where failure to use fall arrest system is the common problem in Singapore, there is now a wider acceptance of fall arrest system due to improved safety culture and enforcement. However, the authors are concerned that with a high dependency on non-manufactured systems and a lack of proper design, the greater usage of fall arrest systems might actually be more dangerous. Workers might be under the false impression that they are protected, when they are not.

1. Develop local standards and guidance

It is recommended that local design standards be developed to guide the industry and its safety and engineering professionals. The local design standards can be based on established overseas standards but it needs to be contextualized to local environment. That includes taking into consideration of the fall arrest equipment used, existing relevant Singapore Standards, workplace safety and health legislation, profile of the workforce, existing business and operating processes, and the existing roles of safety and engineering professionals.

This contextualization is critical to the success of a local design standard. Adopting an established overseas standard without contextualization, will not be effective in ensuring the performance required of fall arrest systems. For example, the safety criteria in CSA Z259.16 (2004) are based on the performance standards of fall arrest equipment components certified to applicable CSA Z259 standards. But the fall arrest equipment used in Singapore can be certified to different standards and performance criteria, including its own Singapore Standards. Thus, any overseas standard used as a reference has to be reviewed and modified by a group of local experts as per the standards setting procedure of Spring Singapore. The local fall arrest system design standard should take the mandatory permit-to-work system into consideration. The standard should specify clear design parameters and safety criteria to facilitate assessment and approval of permit-to-work onsite.

It is also worthwhile to develop a set of guidance on the roles and responsibilities of all stakeholders in the design and usage of fall arrest systems. The guidance should provide guidelines on responsibilities for design, approval, installation, provision of compatible equipment, inspection and review of fall arrest systems.

2. Develop competency framework and training programmes

Having a local design standard for fall arrest systems is insufficient in closing the current competency gap. To improve the overall standard of fall arrest systems, there is a need to increase the competency of industry stakeholders and end-users, so that they can demand for the right level of service from engineers and safety professionals. Accordingly, a pool of qualified and competent persons will have to be trained to implement the design standard and suitable government inspectors must be competent enough to review fall arrest and inspect.

The authors are aware of an on-going tender by the Ministry of Manpower to develop a competency framework and training programmes for work-at-height. The current effort is commendable and timely. However, the current tender did not consider the fall protection
competency of engineers and other relevant professionals (such as design for safety coordinator and architects). It is recommended that the on-going effort to develop a competency framework for work-at-height be expanded to include engineers and other professionals.

CONCLUSION

A small scale survey was conducted to understand the current status of design of fall arrest systems in Singapore. A number of actual Professional Engineers’ designs of fall arrest systems were also collected. Coupled with the experiences of the authors, several findings and recommendations were provided. The key finding is that in the absence of a Singapore standard for design of fall arrest systems, fall arrest systems can be inadequately designed and installed. The paper also identified the competency gaps in engineering and safety professionals that need to be closed. End-users of fall arrest systems need to increase their knowledge in fall arrest systems to ensure that the systems that they are using are effective.

It is proposed that a local standard be developed to provide guidance in design and evaluation of fall arrest system. To support the implementation of the local standard, training programmes should be developed to educate safety and engineering professionals and to build a pool of qualified persons and subject matter experts.

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REFERENCES


