1. Introduction

2. Anchors
   2.1 Personal Fall Prevention System
   2.2 Attachment Types of Anchors
       2.2.1 Cast-In
       2.2.2 Expanding Socket
       2.2.3 Through-type
       2.2.4 Chemically Bonded
   2.3 Reliability and Strength of Anchors
       2.3.1 Obtaining a Safety Factor 2.0
       2.3.2 Sharing of Same Anchor
   2.4 Anchor Devices
   2.5 Anchor Slings
   2.6 Correct and Incorrect Anchor Points
   2.7 Procurement and Marking Specifications
   2.8 Test Certificate after Installation
   2.9 Usage and Maintenance of Anchor Devices

3. Lifelines
   3.1 Use of Lifelines at Angles
   3.2 Lifelines Conforming to International Standards
   3.3 Textile Lifelines
       3.3.1 Selection of Textile Lifelines
       3.3.2 Knots for Textile Lifelines
   3.4 Lifelines Devices
   3.5 Vertical Lifelines
       3.5.1 Permanent Vertical Lifeline
       3.5.2 Temporary Vertical Lifeline
   3.6 Vertical Rail
   3.7 Vertical Lifeline Materials and Construction
       3.7.1 Webbing and Fibre Ropes
       3.7.2 Wire Ropes
   3.8 Flexible Horizontal Lifeline System
   3.9 Flexible Horizontal Lifeline
       3.9.1 Wire Rope Lines
       3.9.2 Webbing Lines
       3.9.3 Fibre Rope Lines
   3.10 Minimum Clearance Height for Horizontal Lifelines
   3.11 Self-Retracting Lifelines
   3.12 Procurement and Selection of Lifelines
   3.13 Switching of Lifelines
   3.14 Factors Affecting the Conditions of Lifelines
   3.15 Inspection of Lifelines
   3.16 Flexible Horizontal Lifeline System Marking Specifications

4. References

5. Acknowledgements

Appendix A – Different types of Fall Arrest Systems (with Different Anchorages)
Appendix B – Different types of Temporary Edge Protection Systems
1. Introduction

Falls from heights (FFH) are one of the largest causes of serious and fatal injury in the Hong Kong construction industry. Thus it is essential that robust measures are implemented to protect workers from the risks of falling from heights.

This guide has been developed in order to help employers and workers who are working at heights to have a better understanding of the importance of the correct installation of anchorage points, lifelines and temporary edge protection as a means of fall prevention.

It must be noted that carrying out a detailed risk assessment prior to starting any work at heights (WAH) activities. As with any safe system of work the priority must always be to eliminate the hazard as far as reasonably practicable or substitute any WAH activities. The use of temporary edge protection systems (such as guardrails) should always be the first option in designing any fall prevention systems. The use of anchorages and lifelines, with proper personal protective equipment (PPE) should always been seen as the last least preferred option.
1.1 What is the relevance of this Guide

The guide is relevant for WAH activities. It contains relevant points pertaining to the proper application and installation of anchorages and lifelines to arrest a fall.

After studying this guide, a person should be able to:

• Have a clearer understanding of anchors, anchor points and their applications;
• Have a clearer understanding of lifelines and their applications;
• Be able to identify correct applications of anchorages and lifelines for various applications.

1.2 Terms and Definitions

• “Competent person”, refers to a person who has sufficient experience and training to perform the work to be carried out, and has passed such courses as the Commissioner may require for the work.
• An “anchor” is a fixture or place for the secure attachment of lifelines, lifelines or persons.
• An “anchor point” (also known as anchorage) is part of an anchor for other equipment in a personal fall prevention system to be attached to.
• An “anchor device” is an element or series of elements of a personal fall prevention system, which incorporates an anchor point or several anchor points.
2. Anchors

A high proportion of falls in workplaces occur either due to unavailability of proper anchor points or failure of anchors. Therefore, anchors and anchor points must be assessed for suitability and security prior to use.

Personal fall prevention equipment must be anchored securely when in use. Wherever possible, anchor points and anchors should always be positioned above the user. This is to ensure that the lifeline or lanyard is taut or has as little slack as possible. The positioning of anchors and anchor points should not be resting on sharp, rough edges or hot surfaces, as they are likely to be damaged, particularly those made from textiles which would fail under load.

Refer to Appendix A for a list of different types of fall arrest system with different anchorages.

Figure 1: An eyebolt (left) and steel beams are classified as anchors.

- A “structural anchor” is an element permanently secured to a structure, to which an anchor device or equipment for personal fall prevention can be attached.
- A “lifeline” is a flexible or rigid line connected at least at one end to a reliable anchor as a means of fall prevention.
- A “lifeline device” (also known as anchor line device) is a device which accompanies the user along a lifeline.
- A “traveller” is a lifeline device which travels in the broadly horizontal plane on a horizontal lifeline system and is intended to act as mobile anchor points.
- A “guided type fall arrester” is a lifeline device with a fall arrest and self-locking function. It travels along a vertical lifeline without requiring manual adjustment by the user, during upward or downward changes of position.
2.1 Personal Fall Prevention System Attachment

The personal fall prevention system may be attached to one of the following:

• a permanent structure or suitable features of a building (e.g., a welded eyebolt or a drilled hole in a steel beam);
• an anchor device that is specifically design-made (e.g., an eyebolt installed permanently or temporarily to a building or structure); or
• a feature of the building or structure (e.g., a structural column of which a lanyard, or anchor sling can be placed around).

2.2 Types of Anchors

There are many types of anchors, some are more suitable for use on certain construction materials than others. Four common types of anchors are listed below.

2.2.1 Cast-in

The anchor (or anchor device) is casted into the surface of the structure as it is being built; hence it is usable for solid concrete structures. This type of anchor requires the use of cross bars positioned perpendicularly behind reinforcing bars (also known as rebars) and a socket positioned behind the cross bar for the insertion of the eyebolt. The life expectancy of this type of anchor should be specified by the manufacturer.

Figure 2: Example of a cast-in eyebolt anchor.
2.2.2 Expanding Socket

An expanding socket type of anchor makes use of a steel socket which expands upon the installation of the eyebolt and will require drilled holes for installation.

2.2.3 Through-type

Through-type anchors utilise an eyebolt with an extended shank which runs through the material it is installed onto. The eyebolt is then held in place through the use of a back plate and either a locking nut or a threaded bush. Such anchors are ideal for use on thin structural members, such as on steel I-beams. However, these structural members must of sufficient material strength and material to support the anchor loads.

2.2.4 Chemically Bonded

Chemically bonded anchors consist of a socket that is held in place by use of a bonding resin. This type of anchor is generally not recommended for use in Singapore, due to the weather and possible reactions between the rainwater and the bonding resin. The manufacturer should specify the products’ applicability in relation to the local climate and life expectancy.

2.3 Reliability and Strength of Anchors

Anchors shall be reliable and have adequate strength and stability to withstand the dynamic and static forces that could be applied to them during a fall scenario.

Anchor devices should conform to SS 570 : 2011 Personal protective equipment for protection against falls from a height – Single point anchor devices and flexible horizontal lifeline systems. A safety factor of 2.0 should be used to calculate the required static strength of an anchor device in a personal fall prevention system. To arrest a fall for a single person use, an anchor device or anchor with a minimum static strength of 12kN (2,697 lbf) should be used. For illustration purpose, an anchorage should be able to support an average-size car (with an approximate weight of 1100kg to 1400kg).

Note

1 kN = 1000 N = 100 kgf
12 kN = 12,000 N = 1200 kgf

2.3.1 Obtaining a Safety Factor 2.0

A safety factor of 2.0 can be obtained in one of the recommended ways of using an anchor device by:

• re-positioning the anchor device in order to limit the free fall distance;
• procuring and using an anchor device with a higher static strength than the minimum specified; or
• incorporating an energy absorber into the personal fall prevention system, such that the impact force in the event of fall would be limited to 6kN (and this equipment is to be used with an anchor device).

2.3.2 Sharing of Same Anchor

When two or more users are to be connected to a single anchor (either independently or through a shared lifeline), it is important to account for the possibility that they could fall at the same time.

For two users sharing a single anchor, the minimum breaking strength is 12kN per person (with safety factor of 2.0) in the direction of loading in service. If more than two users are to be connected to the same anchor, the minimum breaking strength of the anchor needs to be increased by 2kN for each additional user.

For more information on obtaining a safety factor of 2.0, refer to SS570 : 2011 Personal protective equipment for protection against falls from a height – Single point anchor devices and flexible horizontal lifeline systems.

For more information on sharing of same anchor, refer to BS 8347 : 2005 Code of practice for selection, use and maintenance of personal fall prevention systems and equipment for use in the workplace.

Bill we need to see if this is acceptable in HK?
Thus, in order to maintain a safety factor of 2.0, the minimum static strength of a single anchor for two persons’, three persons’ and four persons’ use should be 24kN; 26kN and 28kN respectively.

### Note
1 anchor 1 user 12 kN (with a safety factor 2.0)
1 anchor 2 users 24 kN (with a safety factor 2.0)
1 anchor 3 users 24 kN + 2 kN = 26 kN (with a safety factor 2.0)
1 anchor 4 users 24 kN + 2 kN + 2 kN = 28 kN (with a safety factor 2.0)

It is important to ensure that the design and surveying of the installation of anchors shall be carried out by a competent person.

### 2.4 Anchor Devices

*Bill is there a BS for this?*

Table 1 shows the six classes of anchor devices as specified in SS 570 : 2011 Personal protective equipment for protection against falls from a height – Single point anchor devices and flexible horizontal lifeline systems.

<table>
<thead>
<tr>
<th>Class A1</th>
<th>These are designed to be secured to vertical, inclined and horizontal surfaces. For example, walls, columns and eyebolts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A2</td>
<td>These are designed to be secured to inclined roofs.</td>
</tr>
<tr>
<td>Class B</td>
<td>These are transportable temporary anchor devices. For example, a tripod over a confined space, a beam clamp or an anchor sling.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Structural Anchor</td>
</tr>
<tr>
<td>2</td>
<td>Anchor Point</td>
</tr>
<tr>
<td>1 + 2</td>
<td>Anchor device</td>
</tr>
</tbody>
</table>

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<tr>
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</table>

<table>
<thead>
<tr>
<th>No</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anchor Point</td>
</tr>
</tbody>
</table>
2.5 Anchor Slings

Anchor slings are designed to be wrapped around feature of a structure (e.g., steel beam).

Anchor slings made from textiles (e.g., webbing) should have a minimum breaking strength of 22kN while the minimum breaking strength of anchor slings made from wire rope or chain should be 15kN, in accordance to BS 8347:2005 Code of practice for selection, use and maintenance of personal fall prevention systems and equipment for use in the workplace.

Due to the weakening effect, the looping of anchor slings or other lanyards through themselves (known as “lark’s footing or “choking”) should be avoided unless they are designed to allow this.

![Figure 6: Example of an anchor sling.](image)

![Figure 7: Excessive looping of an anchor sling should be avoided (unless otherwise stated in manufacturer’s manual).](image)

2.6 Correct and Incorrect Anchor Points

Personal fall prevention systems should not be connected or tied-off to inadequate or improper anchor points. These could fail to provide the intended protection, and may result in fatalities.

When assessing by competent person on existing structural features or equipment for used as anchor points, avoid corners or edges that could cut, chafe, or abrade fall prevention components.

The following areas should never be used as anchor points unless the minimum structural requirements have being determined to be safe and approved by a competent person:

- standard guardrails;
- standard or balcony railings;
- ladders or rungs;
- light fixtures;
- conduit or plumbing;
- ductwork or pipe vents;
- C-clamps;
- wiring harnesses;
- another lanyard;
- roof stacks, vents, fans or chimney;
- TV antennas; and
- any point which does not meet the structural requirements.
8. Test Certificate after Installation
A test certificate shall be provided by the installer stating that the anchor devices (e.g., eyebolt) have been installed and tested in accordance to SS 570 : 2011 Personal protective equipment for protection against falls from a height – Single point anchor devices and flexible horizontal lifeline systems.

*Bill is there a BS for this?*

This certificate shall also include a warning against misuse of the anchor device and draw attention to the need to inspect the anchor device before each occasion of use.

9. Usage and Maintenance of Anchor Devices
Prior to using anchor devices or systems, they shall be inspected and checked manually in accordance with the manufacturer’s instructions for use.

Each anchor device and anchor system shall be fully examined at least once every year, in accordance with the manufacturer’s instructions, by a competent person authorised by the manufacturer.

2.7 Procurement and Marking Specifications

Anchors and anchor devices should be acquired through reliable suppliers and be of good construction and manufactured in conformance to recognised international standards. All anchors and anchor devices shall also come with “certified type-examination certificate” or “certificate of conformance” (COC).

*Bill we may need to change this COC bit?*

Each detachable component of an anchor system or anchor device shall be clearly marked out (using suitable methods not harmful on the material) with the following minimum identification markings:

- manufacturer or supplier’s name;
- manufacturer showing compliance to international standards
- manufacturer or supplier’s trade mark (or any means of original identification);
- manufacturer’s batch number or serial number of the component;
- manufacturer’s recommended breaking strength (kN) of the anchor, and
- manufacturer recommended maximum number of users per anchor.

Markings may also be incorporated in details with a label-tag being tagged along with the anchor devices to show the above intended information.
Anchor for lifelines

Special thanks to HILTI Hong Kong for their technical advice
Traditional method for lifeline anchor

Push-in anchor
綻爆 / 撞爆 / 平爆

Eye-bolt
羊眼圈
An incident occurred not long ago...

Case
What happened?
• Insulated air ductwork dropped together with push-in anchors from concrete ceiling

Why did that happen?
• Investigation revealed that the anchor sleeves had not expanded

How to fix?
• Sampling pull out test to installed anchors
• Workers are required to attend Installation card training
• Standardized and mechanized installation procedures to reduce human errors

How can it be prevented?
• Properly set anchor to achieve right sleeve expansion
• Change into other anchor types

Imagine this scenario on a lifeline..........
Anchor bolt holds things … they can also hold HUMAN LIVES!

3 key factors to consider…..

PRODUCT
is safe & reliable

DESIGN
it right

INSTALL
it right

Safety & Productivity
MECHANISMS OF ANCHOR IN DIFFERENT TYPES

**Friction- Expansion**

The anchor expands into the concrete and is kept by friction.

**Keying- Undercut**

At a certain point the anchor has a bigger diameter than the borehole itself.

**Keying- Screw type**

Screw in the anchor by mechanical device with undercutting mechanisms.

**Tension**
Basic Anchor Theory – Working Principles

Load – Displacement Curve

- **Rigid type anchors**
  - Displacement-controlled anchor
  - Adhesive anchor (e.g. HKD, HKV)

- **Follow-up expansion**
  - Torque-controlled anchor
  - Undercut anchor (e.g. HSL, HST-3, HSA, HDA, HSC)

- **Sudden pull-out when characteristic resistance is reached**

- **Further expansion happens when load exceeds characteristic resistance**

- **Factor of Safety (FOS)**

- Characteristic Resistance (Ultimate Resistance)
### SAFETY RELEVANCE FOR DIFFERENT ANCHORS

<table>
<thead>
<tr>
<th>Principle</th>
<th>Keying</th>
<th>Keying</th>
<th>Friction</th>
<th>Deformation controlled expansion anchor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
<td>Undercut anchor</td>
<td>Screw anchor</td>
<td>Torque controlled expansion anchor</td>
<td></td>
</tr>
<tr>
<td><strong>Safety Benefits</strong></td>
<td>✓ Highest safety relevance with high pull out (normal condition), displaced &amp; compressed concrete</td>
<td>✓ Highest safety relevance with medium pull out (normal condition), displaced &amp; compressed concrete</td>
<td>✓ Follow up expansion will happen while torquing/loading the anchor, to avoid sudden failure</td>
<td>✓ Short embedment depths to prevent rebar hit</td>
</tr>
<tr>
<td></td>
<td>✓ Approved for dynamic load application e.g. shock, fatigue, seismic</td>
<td>✓ Approved for dynamic load application e.g. seismic</td>
<td>✓ Low displacement</td>
<td>✓ Quick installation for multiple fastenings</td>
</tr>
<tr>
<td></td>
<td>✓ Minimal displacement</td>
<td>✓ Minimal displacement</td>
<td>✓ Follow up expansion)</td>
<td>✓ Follow up expansion)</td>
</tr>
<tr>
<td><strong>Common applications</strong></td>
<td>• Heavy-medium weigh equipment • High safety relevance fixings</td>
<td>• Medium weigh equipment • High safety relevance fixings</td>
<td>• General medium -duty fixings in (un-)cracked concrete</td>
<td>• Light-duty mechanical and electrical fixings</td>
</tr>
</tbody>
</table>

Undercut and torque controlled expansion anchor types are better options in terms of load sustainability and safety.
ANCHOR REQUIREMENTS FOR LIFELINES IN HONG KONG

**Strength tests for anchor devices**

Anchor devices shall meet the static strength and dynamic strength tests requirements under the BS EN795:1997 standard to ensure they possess sufficient strength for safe use.

**Table 1: Requirements of strength tests**

<table>
<thead>
<tr>
<th>Class</th>
<th>Test description and requirement</th>
<th>Test procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Static strength</td>
<td>According to clause 5.2.1 of BS EN795</td>
</tr>
<tr>
<td></td>
<td>Apply and maintain for 3 minutes 10kN force. Observe if the anchor device can hold the force</td>
<td></td>
</tr>
<tr>
<td>Dynamic strength</td>
<td>Secure one end of the test lanyard to the anchor device and the other end to a 100 kg mass. Allows the mass falls freely through 2.5 m. Observe if the mass is arrested</td>
<td>According to clause 5.3.2 of BS EN795</td>
</tr>
</tbody>
</table>

From OSHC, BS EN 795 requirements
ANCHOR DESIGN REQUIREMENTS FOR LIFELINES IN SG

2.3 Reliability and Strength of Anchors

Anchors shall be reliable and have adequate strength and stability to withstand the dynamic and static forces that could be applied to them during a fall scenario.

Anchor devices should conform to SS 570: 2011 Personal protective equipment for protection against falls from a height – Single point anchor devices and flexible horizontal lifeline systems. A safety factor of 2.0 should be used to calculate the required static strength of an anchor device in a personal fall prevention system. To arrest a fall for a single person use, an anchor device or anchor with a minimum static strength of 12 kN (2,697 lbf) should be used. For illustration purpose, an anchorage should be able to support an average-size car (with an approximate weight of 1100kg to 1400kg).

Note
1 kN = 1000 N = 100 kgf
12 kN = 12,000 N = 1200 kgf

Thus, in order to maintain a safety factor of 2.0, the minimum static strength of a single anchor for two persons; three persons’ and four persons’ use should be 24kN; 26kN and 28kN respectively.

Note
1 anchor → 1 user → 12 kN (with a safety factor 2.0)
1 anchor → 2 users → 24 kN (with a safety factor 2.0)
1 anchor → 3 users → 24 kN + 2 kN = 26 kN (with a safety factor 2.0)
1 anchor → 4 users → 24 kN + 2 kN + 2 kN = 28 kN (with a safety factor 2.0)
# DESIGN CONSIDERATION OF LIFELINES ANCHOR

<table>
<thead>
<tr>
<th>Consideration</th>
<th>What need to consider?</th>
<th>How to settle?</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic loading requirements</td>
<td>✓ 10~12kN SWL (HK and Singapore)</td>
<td>• Bigger sizes, M10 or above to take loading higher than 10kN SWL</td>
<td>• HST3</td>
</tr>
<tr>
<td></td>
<td>✓ Should clearly check from manufacturer’s manual</td>
<td>• Torque controlled /undercutting/ screw anchor to be selected</td>
<td>• HUS3</td>
</tr>
<tr>
<td></td>
<td>✓ Quality of concrete, old or new? Reduction factor from manufacturer’s manual</td>
<td>• Design manual for manufacture should be very detailed.</td>
<td>• HSC-I /A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Hilti technical manual</td>
</tr>
<tr>
<td>Directions of loadings</td>
<td>✓ Manual SWL value only for tension and shear</td>
<td>• Follow manufacturer’s manual to calculate combined load effect</td>
<td>• Detailed calculation submission to cater all load directions</td>
</tr>
<tr>
<td></td>
<td>✓ Should consider the combined load effect if there is inclination during loading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance of overloading for safety buffer</td>
<td>✓ Overloading of anchor would happen sometimes</td>
<td>• Select torque controlled anchor as it has follow-up expansion behavior while overloading</td>
<td>• HST3</td>
</tr>
<tr>
<td></td>
<td>✓ Behavior of anchors would be critical under this situation</td>
<td>• Undercutting / screw type anchor provide safe keying effect</td>
<td>• HUS3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• HSC-I/A</td>
</tr>
<tr>
<td>Life time of anchor</td>
<td>✓ Some anchor point may be reused for future purpose</td>
<td>• Select stainless steel anchor for future purpose</td>
<td>• HST3-R / HUS-IR / HUS-HR(stainless steel)</td>
</tr>
<tr>
<td></td>
<td>✓ Rusting may occur if abandoned anchor is reminded in concrete and affect building appearance</td>
<td>• Select removable anchor</td>
<td>• Screw anchor – HUS3 (removable)</td>
</tr>
</tbody>
</table>
## SUMMARY OF ANCHOR SELECTION FOR LIFELINES

<table>
<thead>
<tr>
<th>Model</th>
<th>Advantages</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>HST3 M10 or above</td>
<td>✓ Follow-up expansion during overloading, higher safety</td>
<td>• Need to equip with externally-threaded eye-bolt</td>
</tr>
<tr>
<td></td>
<td>✓ Common anchor type, easy to install</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Stainless steel version available</td>
<td></td>
</tr>
<tr>
<td>HSC-I M10 or above</td>
<td>✓ Undercutting mechanisms, higher safety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Internally-threaded option for common internally-threaded eye-bolt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Stainless steel version available</td>
<td></td>
</tr>
<tr>
<td>HUS3 10 or above</td>
<td>✓ Undercutting mechanisms, higher safety</td>
<td>• Only hex head is available for bigger sizes such as M10 above</td>
</tr>
<tr>
<td></td>
<td>✓ Totally removable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Stainless steel version available</td>
<td></td>
</tr>
</tbody>
</table>
3. Lifelines

Lifelines, provide links between the anchorage and the user which has an effective length that can be adjusted or altered by the use of a mobile lifeline device.

In general, lifelines should have the following characteristics:

- It should have a safe rating high enough to withstand forces or tension being generated in the event when it is in use; and
- It should not interfere with any other items of equipment (e.g., safety equipment or clothing) with which it is to be used.

If the lifeline is purchased as a system, it is important to note that a lifeline together with the anchor devices must be used as a system and each part should not be used independently as specified by the manufacturer. Components from different manufacturers should not be used together unless it is specified or advised by the manufacturer.

1. Use of Lifelines at Angles

Lifelines are type tested together with their lifeline devices either vertically or horizontally. If they are to be used at angles deviating from the vertical or horizontal, the manufacturer should be contacted for advice. When necessary, additional tests may be required to be carried out in the presence of a Professional Engineer (PE) to ensure integrity of the lifelines and anchor devices.

2. Lifelines Conforming to International Standards

For fall arrest systems, Table 2 shows a list of recommended lifelines conforming to international standards and should be used.

<table>
<thead>
<tr>
<th>Types of Fall Arrest Systems</th>
<th>Lifelines (Conforming) Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guided type fallarrester and a rigid vertical lifeline</td>
<td>SS 528 : Part 4 : 2006 Personal fall-arrest systems: Vertical rails and vertical lifelines incorporating in a sliding-type fall arrester</td>
</tr>
<tr>
<td>Guided type fall arrester and a flexible vertical lifeline</td>
<td>Bill is there a BS for this?</td>
</tr>
<tr>
<td>System based horizontal flexible lifeline</td>
<td>SS 570 : 2011 Personal protective equipment for protection against falls from a height - single point anchor devices and flexible horizontal lifeline systems</td>
</tr>
<tr>
<td>System based horizontal rigid lifeline</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Recommended lifelines for different fall arrest systems.

3.3 Textile Lifelines

3.3.1 Selection of Textile Lifelines

Different types of textile lifelines have different elongation characteristics. Therefore, great care is required in selecting the proper type to use.

In general, kernmantel ropes (conforming to BS EN 1891 : 1998, type A - Personal protective equipment for the prevention of falls from a height. Low stretch kernmantel ropes) are recommended for work positioning systems, other than rope access systems. If hawser-laid ropes are used as lifelines, those conforming to ISO 1140 : 2012 - Fibre ropes -- Polyamide--3-, 4-, 8- and 12- strand ropes; and ISO 1141 : 2012 - Fibre ropes -- Polyester-3-, 4-, 8- and 12- strand ropes are recommended.

Figure 10: Examples showing a kernmantel (left) and hawser-laid lifeline.

3.3.2 Knots for Textile Lifelines

Termination loops on textile rope lifelines are usually formed by splicing or sewing but they can also be formed by knots. Some lifelines come with knots already tied by the manufacturer. Otherwise, they can be tied by a competent person.

It is important to note that there can be subtle differences between one knot and another as these are created due to slight twists imparted during tying of the knots and even when they were tied by the same person. Therefore, it is essential that knots are only tied by the same competent person who has thorough knowledge of knots and knots tying techniques.

Knots should never be used to connect a safety lanyard to any anchor points. The tails of all knots should be at least 100mm long and the knots should never be tied in lifelines made from wire ropes.
The strength of a rope is reduced at a knot. Table 3 shows two examples of strength loss due to various methods of tying knots in a 10.5 mm low stretch rope conforming to BS EN 1891: 1998, type A - Personal protective equipment for the prevention of falls from a height. Low stretch kernmantle ropes.

<table>
<thead>
<tr>
<th>Types of Tied Knots</th>
<th>Strength Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowline</td>
<td>26% to 45%</td>
</tr>
<tr>
<td>Double figure-of-eight</td>
<td>23% to 34%</td>
</tr>
</tbody>
</table>

Table 3: Example of strength loss due to different methods of tying knots.

There are several types of lifelines devices used in fall prevention systems as listed below:

- length adjusters on manually adjustable lanyards for restraint systems;
- rope grabs for work positioning systems;
- travellers for horizontal lifeline systems (for either restraint or fall arrest systems);
- guided type fall arrestors for use with vertical lifelines for fall arrest systems; and
- ascender and descender devices for rope access systems.

Note
Lifeline devices are designed to lock automatically onto the lifeline when a force or load is suddenly applied, with the exception of traveller.

3.4 Lifelines Devices
Lifelines devices refer to a collective set of components which link users to lifelines. They allow users to travel alongside the lifeline during upwards, downwards and horizontal movement.
3.5 Vertical Lifelines

There are basically two types of vertical lifeline (VLL) designs which are classified as either permanent or temporary.

3.5.1 Permanent Vertical Lifeline
A permanent VLL is defined as a tensioned line which is permanently fastened to at least one position at its upper end, to act as a reliable anchor point.

Permanent VLLs shall comprise the following design criteria (see Table 4):

- Capable of being fastened to a ladder or structure at the upper and lower extremity. A number of brackets at intervals should be installed, if required, as per recommended by the manufacturer.
- Capable of being tensioned, once installed, as per recommended by the manufacturer.
- Allow the sliding-type fall arrester to be attached and detached at points along the lifeline, unless the sliding-type fall arrester is designed to be integrated as a whole system.
- Permit the movement of the sliding-type fall arrester in an upward or downward direction without impeding movement, especially at intermediate fastenings.
- Prevent unintentional separation of the fall arrester from the lifeline.

Table 4: Design criteria for permanent VLLs.

3.5.2 Temporary Vertical Lifeline
A temporary VLL is defined as a suspended line that is temporarily fastened at its upper extremity to an overhead anchoring point, to which a sliding-type fall arrester can be attached.

Temporary VLLs shall comprise the following design criteria (see Table 5):

- Capable of being fastened to an overhead anchoring point in accordance with the recommendation by the manufacturer.
- Able to allow the sliding-type fall arrester to be attached and detached at least at the lower extremity of the lifeline, unless the sliding-type fall arrester is designed to be integral.
- Allow the movement of the sliding-type fall arrester in an upward and downward direction, without impeding movement.
- Capable of being fitted with a tensioning weight or other stabilizing means at the lower extremity.
- Prevent unintentional separation of the fall arrester from the lifeline.

Table 5: Design criteria for temporary VLLs.
3.6 Vertical Rail
A vertical rail is defined as a rigid track that is permanently fastened by a number of brackets at intervals along its length to a fixed ladder or structure where a sliding-type fall arrester can be attached. Vertical rails shall have the following criteria in their design (see Table 6):

![Figure 15: Vertical rail.](image)

<table>
<thead>
<tr>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Capable of being fastened to a ladder or structure by a number of brackets at intervals as per recommended by the manufacturer.</td>
</tr>
<tr>
<td>• Allows the sliding-type fall arrester to be attached and detached at least at the two extremities of the rail length, unless the sliding-type fall arrester is designed to be integrated as a whole system.</td>
</tr>
<tr>
<td>• Able to prevent unintentional separation of the sliding-type fall arrester from the rail.</td>
</tr>
<tr>
<td>• Permit the movement of the sliding-type fall arrester in an upward or downward direction without impeding movement, especially at joints and at intermediate fastenings.</td>
</tr>
</tbody>
</table>

Table 6: Design criteria for vertical rails.

3.7 Vertical Lifeline Materials and Construction

3.7.1 Webbing and Fibre Ropes
Webbing, fibre ropes and sewing threads for lifelines shall be made from virgin filament or multi-filament synthetic fibres suitable for the intended use. The breaking strength of the synthetic fibres shall be at least 0.6 N/tex.

The number of strands of laid lifeline shall be at least three where three-strand polyamide lifelines shall comply with ISO 1140:2012 - Fibre ropes -- Polyamide--3-, 4-, 8- and 12-strand ropes and three-strand polyester lifelines with ISO 1141:2012 - Fibre ropes -- Polyester--3-, 4-, 8- and 12-strand ropes.

Braided rope lifelines shall comply with EN 892: Dynamic mountaineering Ropes (single rope) or EN 1891:1998, type A - Personal protective equipment for the prevention of falls from a height. Low stretch kernmantel ropes; and any equivalent material is acceptable.

Lifelines that are used in work carried out near welding, oxy-cutting stations or heat sources shall be protected by suitable means of heat protection.

3.7.2 Wire Ropes
To comply with SS 528: Part 4: 2006 Personal fall-arrest systems: Vertical rails and vertical lifelines incorporating a sliding-type arrester, the minimum diameter of wire rope material used in construction of a lifeline shall be 8 mm.

3.8 Flexible Horizontal Lifeline System
A flexible horizontal lifeline (HLL) system is a flexible lifeline supported by two or more anchors such that the slope of a straight line joining two adjacent anchors does not deviate from the horizontal by more than 15°.

![Bill is there a BS for wire rope?](image)

As outlined in SS 570:2011: Personal protective equipment for protection against falls from a height-single point anchor devices and flexible horizontal lifeline systems, the flexible HLL system shall limit the maximum arrest force being transmitted to the harness attachment point of the user's full body harness to 6kN. The system shall also ensure a minimum of 1.0 m post-fall clearance between the user and the ground, structure or any obstacles.

End anchor connectors of the flexible HLL system shall be designed to resist and to transfer to the end anchor at a minimum amount force:
- 12kN downward force being applied at right angles to the axis of the line; and in the direction of the fall arrest; and
- a force in line with the flexible HLL with at least two times the maximum line arrest load.

Intermediate anchor connectors, as with other similar hardware, shall not resist the flexible HLL from running freely through the aperture. It should not damage the flexible HLL during operation as well.

A mobile attachment device (e.g., traveller) shall not be easily removed by the user unintentionally during use, meaning it shall have at least two consecutive deliberate manual actions for removal. It shall resist a static force of 20kN in the direction of intended loading without breakage or deformation.

Some flexible HLL systems come with a lifeline energy absorber at one end. It shall be capable to resist a static force of at least two times the maximum arrest load; three times this load if the lifeline absorber is non-metallic in nature, developed from traceable test results for the particular configuration; and no less than 12kN in the direction of intended load force.

See Figure 16 for a list of typical HLL components.
3.9 Flexible Horizontal Lifeline

3.9.1 Wire Rope Lines
The finished wire assembly, including terminations, shall have a minimum static strength of at least twice the maximum arrest load in line developed from traceable test results for the particular configuration in which it is to be used.

3.9.2 Webbing Lines
The finished webbing assembly, including terminations, shall have a minimum static strength of at least three times the maximum arrest load in line developed from traceable test results for the particular configuration in which it is to be used.

3.9.3 Fibre Rope Lines
The finished fibre rope assembly, including terminations, shall have a static strength of at least three times the maximum arrest load in line developed from traceable test results for the particular configuration in which it is to be used.
All synthetic rope to be used as a flexible HLL constituent shall be made of virgin synthetic filament or multifilament synthetic fibres suitable for their intended use. Polypropylene shall not be used.

3.10 Minimum Clearance Height for Horizontal Lifelines
Different lifelines, made from various materials, have different mechanical properties such as yield strength, tensile strength and ductility.
The "stretch-ability" or elongation property of a lifeline has to be taken into account during the designing of any HLL system, as this will directly affect the lifeline’s deflection and minimum clearance distance.

<table>
<thead>
<tr>
<th>Items</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>End anchor</td>
</tr>
<tr>
<td>2</td>
<td>End anchor connector</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal lifeline</td>
</tr>
<tr>
<td>4</td>
<td>Intermediate anchor</td>
</tr>
<tr>
<td>5</td>
<td>Intermediate anchor connector</td>
</tr>
<tr>
<td>6</td>
<td>Mobile attachment device</td>
</tr>
</tbody>
</table>

Figure 16: HLL components.
There are generally three types of flexible HLLs.

3.9.1 Wire Rope Lines
The finished wire assembly, including terminations, shall have a minimum static strength of at least twice the maximum arrest load in line developed from traceable test results for the particular configuration in which it is to be used.

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The finished fibre rope assembly, including terminations, shall have a static strength of at least three times the maximum arrest load in line developed from traceable test results for the particular configuration in which it is to be used.

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Figure 17: Example of wire rope lifeline.

Figure 18: Example of webbing lifeline.

Figure 19: Example of fibre rope lifeline.
3.11 Self-Retracting Lifelines

A self-retracting lifeline (SRL), also known as a “self-retracting lanyard” or “yo-yo”, involves the use of a spring-loaded reel to reel in any excess length of lifeline, ensuring a shortest possible length of lifeline between the user and the reel. In the event of a fall, the SRL is rapidly pulled out on the reel and a braking mechanism is engaged to halt the fall of the user.

SRLs should not be knotted or clipped to shorten it and the user should ensure that the retractable lifeline runs directly from the housing to the harness attachment points (i.e., the lifeline should not pass beneath the armpits or between the legs whilst moving around or whilst stationary) as this could result in injury in the event of a fall.

To comply with SS 528 : Part3 : 2006 Personal fall-arrest systems: Self-retracting lifelines, SRLs shall lock and limit the arrest force to a maximum of 6kN. The breaking forces for SRLs with webbing based and fibre rope based lifelines are both 15kN; and wire rope based lifeline is 12kN.

It is often easy to misuse SRLs, causing them to fail in providing the intended protection from falls. Thus, it is important to follow the instructions of the manufacturer when using such systems.

The degree of safety of the SRL must be considered in the following situations:

• The SRL must not be used in the horizontal plane, unless the manufacturer had done testing in this direction, and has specifically permitted such usage;
• The SRL must not be attached on a HLL; unless the manufacturer had done testing in such a situation and has specifically permitted such usage.
• Great care must be taken into account when the SRL is used in situations where the lifeline has to pass over sharp edges such as a roof’s edge. The line may be weakened due to abrasion and this effect will be compounded by the movements of the lifeline due to the movements of the user.
• A lanyard (with or without energy absorber) must not be attached between the SRL and the harness as this may increase the fall distance.
• The SRL must not be allowed to extend beyond its normal working length as the linkages may not be of sufficient strength to withstand the forces generated during a fall.
• Tampering, modifying the SRL or joining more than one device together must not be allowed. The device may no longer function as intended with several SRLs being joined together.
• Attachment of more than one user to each SRL must not be allowed, as overloading may occur.
• Reusing of a SRL that had previously arrested a fall must not be allowed and should be withdrawn from usage.
• Rapid retraction of the lifeline must not be allowed as this may result in jamming or failure due to the rapid spooling of the lifeline.

3.12 Procurement and Selection of Lifelines

Lifelines (VLLs, HLLs or SRLs) should be acquired through reliable sources or suppliers. All lifelines shall be of good construction manufactured in conformance to recognised international standards and come with a COC.

When deciding on the compatibility, type and positioning of lifelines, the following factors need to be considered:

• Ease of Use
  The type of work to be carried out may affect the suitability of the type of system. Where possible, the least cumbersome one should be chosen. If the system hinders the user from carrying out the work too greatly, the users may end up choosing to disengage themselves from the lifeline and carry out the work unprotected.

• Length of Service
  The system should match the expected term of use. Using a fibre rope lifeline for long-term or permanently, may put users at risk. Due to long-term environmental exposure, the lifeline may weaken and be unable to withstand the forces generated during a fall. The user should refer to the manufacturer’s manual for indication and advice on the length of service for a particular brand of lifelines or lifeline systems.

• Conditions
  Should there be potential exposure to substances such as corrosive substances, high temperatures or harsh weather, the type of lifeline used would need to be suitable for use under such conditions.

• Adequate Coverage
  It is important to provide sufficient coverage for users performing work while anchored to the lifeline. In the event of a fall, inadequate coverage may result either in users disengaging themselves from the lifeline or “swing back” collisions.
3.13 Switching of Lifelines
Where it is necessary for a user to switch between lifelines, the second lanyard must be connected to the next lifeline before the connection to the previous lifeline is disengaged. This is known as 100% clip-on.

While being anchored, proceed to anchor the second lanyard to the secondary anchor position.

Return back to the initial position.

Once the second lanyard is securely anchored, proceed to remove the first lanyard from the initial position.

Proceed to the next stage while maintaining 100% tie-off.

Figure 23: Example of a 100% tie-off by ensuring continuous connection to the structure or lifelines through the use of two energy absorbing lanyards in relay.

3.14 Factors Affecting the Conditions of Lifelines
Table 7 shows some of the factors that will deteriorate the life and usability conditions of the lifelines:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description and Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet light</td>
<td>Long exposure to the sun will damage and deteriorate the life of synthetic lifelines. For outdoor usage, UV-resistant lifelines should be considered.</td>
</tr>
<tr>
<td>Sparks or flame</td>
<td>Hot works (e.g., welding or flame cutting) could burn, melt, cut, or otherwise damage a lifeline. Flame resistant lifelines should be used to provide appropriate fall prevention where sparks or flame may be encountered.</td>
</tr>
<tr>
<td>Temperature</td>
<td>Extreme heat (such as from machinery) or cold could weaken, damage and cause brittleness in some lifelines. Lifelines should be chosen to ensure that the material could withstand to the most extreme conditions expected.</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Exposure to chemicals could burn or degrade a lifeline at a fast rate. Chemical resistant lifelines should be considered to ensure that they will resist any chemicals encountered on the job.</td>
</tr>
<tr>
<td>Marking or dying</td>
<td>Only dyes approved by the manufacturer can be used to mark lifelines; as most conventional dyes contain acids which can result in the weakening of the lifeline.</td>
</tr>
<tr>
<td>Friction and abrasion</td>
<td>Sliding movements would cause wear and tear (due to friction and abrasion) to the lifelines when in contact with sharp or rough surfaces. Protection means of using wood softeners or rubber mats could be used at contact points or surfaces to prevent wear and tear.</td>
</tr>
<tr>
<td>Storage</td>
<td>Lifelines should be stored separately in a cool and sheltered area. They should never be stored where hazards such as sharp objects, chemicals, or gasoline are present.</td>
</tr>
</tbody>
</table>

Table 7: Factors affecting conditions of lifelines.
3.15 Inspection of Lifelines
If the lifelines are left at the site of usage, they must be inspected on a daily basis or before each time they are used by a competent person.

If any of the following is found, the lifeline is unsafe and must be withdrawn from usage.

- tears or cuts (broken or loose strands);
- glazing of surface (heat damage);
- varied strand size or shape;
- decreased elasticity (stiffness) or presence of lumps;
- discoloration;
- lack of proper termination;
- unclear or missing identification or inspection labels; or
- connecting hardware is damaged or in poor condition (e.g., unable to lock).

3.16 Flexible Horizontal Lifeline System Marking Specifications
The flexible HLL system equipments shall be indelibly marked or permanently labelled in the language of the country; and with the following minimum identification markings:

- manufacturer’s name, address and contact information;
- year of manufacture;
- manufacturer’s recommended maximum number of users;
- batch number or serial number (if applicable);
- standards number
- pictogram(for indication that users shall read the information supplied by the manufacturer).
Considerations

System hierarchy:

**Fall Restraint**

Fall restraint is the preferred approach to fall protection — it prevents you from falling and from suffering possible injury from the fall arrest system. Work restraint is a technique which uses PPE to prevent a person from entering an area of where a risk of fall from height exists.

**Work Positioning**

Work Positioning is a technique for supporting a person while working by means of PPE in tension, in such a way as to prevent a fall.

**Fall Arrest**

Fall arrest is an approach which makes use of items of PPE to stop a falling person under safe conditions. This means that if a worker is in a position such that if he loses control he will fall, he is required to use PPE to limit both the distance and force of that fall.
A rigid system is preferable to a wire rope system.

The height of the anchorage point for SWR lifelines must be selected to ensure safe clearance in the event of a fall, and this point shall be strong enough to withstand a force of not less than **2275 kg** — Bill we need to make sure that all quoted forces/weights etc are uniform and as per HK legislation/standards/codes or if non existent refer to relevant BS.
Wire Rope Life Lines

L_max

Steel wire rope

Controlled Deflection

Anchorage

Middle support
Before Fall  |  After Fall  | Anchorage

Static line deflection
Length of Lanyard
Energy Absorber Extension
Height of worker
Safety clearance

1.0m  
1.5m  
1.7m  
1.8m  
2.0m  

= 8.0m  
or  
= 6.2m (Without shock absorber)
Pre-installation

- Ensure persons involved in the SWR and clip installation fully understand the installation procedure.
- Select and inspect correct size of SWR (8mm, 10mm, or 12mm) and clips for the lifelines.
- The size of SWR clip must match the size of steel wire rope, e.g. SWR size 10mm must be matched by 10mm size clip.

<table>
<thead>
<tr>
<th>Rope Diameter (mm)</th>
<th>Effective Number of Clips</th>
<th>Min. Clip Spacing (mm)</th>
<th>Controlled Deflection (d)</th>
<th>Max Spacing ($L_{max}$) of Anchor Point</th>
<th>Max Number of Person between anchor points (100kg/P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 mm</td>
<td>4</td>
<td>48 mm</td>
<td>500 mm</td>
<td>2930 mm</td>
<td>2</td>
</tr>
<tr>
<td>10 mm</td>
<td>4</td>
<td>60 mm</td>
<td>500 mm</td>
<td>3066 mm</td>
<td>3</td>
</tr>
<tr>
<td>12 mm</td>
<td>4</td>
<td>72 mm</td>
<td>500 mm</td>
<td>3336 mm</td>
<td>4</td>
</tr>
</tbody>
</table>

Bill we may need to Delete these figures
As HK doesn’t allow More than one person To clip on?
SWR Installation

SWR Dead End (Red)

SWR Live End (Blue)

U-bolt Treads

U-bolt

Saddle

Nuts

SWR Safety Loop

Effective Clips

Min. Clip Spacing (MS) = SWR Diameter X 6

Inspection Clip

(Red) SWR Dead End

SWR Live End (Blue)
SWR Installation

TURNBUCKLE

(1) JIS TYPE TURNBUCKLE
(2) OPEN BODY TURNBUCKLE E/E H/H E/H
(3) OPEN BODY TURNBUCKLE JAW/JAW
(4) "US" TYPE E/E
(5) "US" TYPE JAW/JAW
Examples of incorrect installation
SWR installation

**Wrong**

*Do not* secure Steel Wire Rope by knots

**Correct**
SWR installation

X WRONG

✓ CORRECT

Correct joining of Steel Wire Rope
SWR installation

- Not in equal distance as per 6 X SWR Diameter

- Dead end clip placed very near to dead end tip

- Wrong placement of saddles and U-bolts of the clips

- Not in equal distance as per 6 X SWR Diameter
SWR installation

No safety loop. SWR may have been placed under stress

X WRONG

✓ CORRECT
Rule of thumb

NEVER SADDLE A DEAD HORSE
4. Acknowledgements

- HILTI
- Mr. Gilbert Reyes

5. References

- Workplace Safety and Health Act
- Workplace Safety and Health (Construction) Regulations 2007
- Workplace Safety and Health (Scaffold) Regulations 2011
- Workplace Safety and Health (Risk Management) Regulations
- Code of Practice for Working Safely at Height
- Code of Practice for WSH Risk Management
- SS 528 Part 1 : 2006 Personal fall-arrest systems – Full body harness
- SS 528 Part 2 : 2006 Personal fall-arrest systems – Lanyards and energy absorbers
- SS 528 Part 3 : 2006 Personal fall-arrest systems – Self-retracting lifelines
- SS 528 Part 4 : 2006 Personal fall-arrest systems – Vertical rails and vertical lifelines incorporating a sliding-type fall arrester
- SS 528 Part 5 : 2006 Personal fall-arrest systems – Connectors with self-closing and self-locking gates
- SS 528 Part 6 : 2006 Personal fall-arrest systems – System performance test
- SS 570 : 2011 Personal protective equipment for protection against falls from a height – Single point anchor devices and flexible horizontal lifeline systems
- BS EN 341 : 2011 Personal fall prevention equipment. Descender devices for rescue
- BS EN 353 - 1 : 2002 Personal protective equipment against falls from a height. Guided type fall arresters including a rigid lifeline
- BS EN 353 - 2 : 2002 Personal protective equipment against falls from a height. Guided type fall arresters including a flexible lifeline
- BS EN 354 : 2010 Personal fall prevention equipment. Lanyards
- BS EN 355 : 2002 Personal protective equipment against falls from a height. Energy absorbers
- BS EN 360 : 2002 Personal protective equipment against falls from a height. Retractable type fall arresters
- BS EN 361 : 2002 Personal protective equipment against falls from a height. Full body harnesses
- BS EN 362 : 2004 Personal protective equipment against falls from a height. Connectors
- BS EN 795 : 1997 Protection against falls from a height. Anchor devices. Requirements and testing
- BS EN 1891 : 1998 Personal protective equipment for the prevention of falls from a height. Low stretch kernmantel ropes
- BS 7883 : 2005 Code of practice for the design, selection, installation, use and maintenance of anchor devices conforming to BS EN 795