Published in September 2012 by the Workplace Safety and Health Council in collaboration with the Ministry of Manpower.

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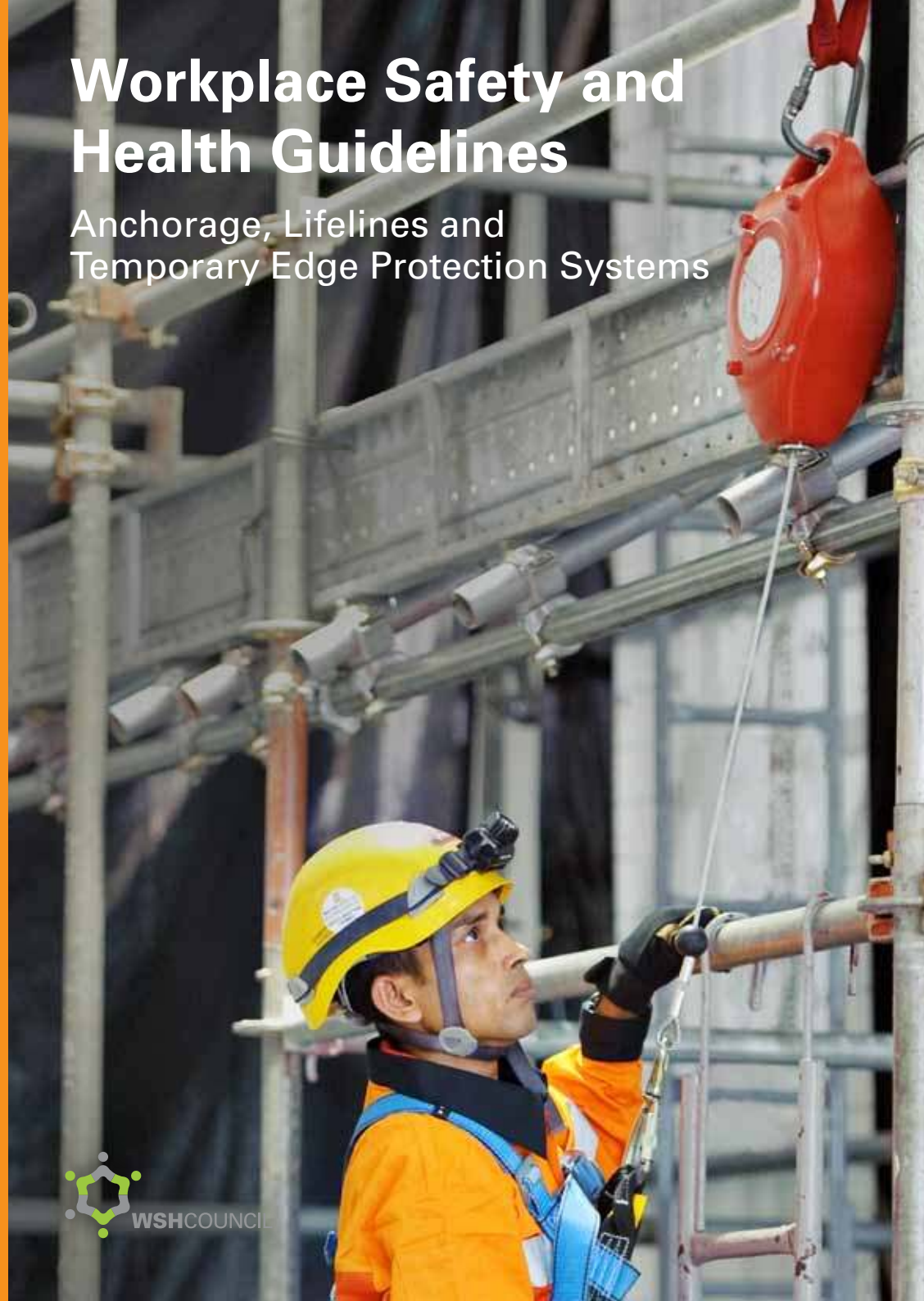
Workplace Safety and Health Guidelines

Anchorage, Lifelines and Temporary Edge Protection Systems



Year of issue: 2012

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1. Introduction

Falls from heights (FFH) is one of the largest causes of death and injury in the workplace. It is therefore essential that measures are taken to protect workers against the risks of falling from heights.

This guide is developed to help employers and workers who are involved in working at heights to better understand the application of anchorage, lifelines and temporary edge protection as a means of fall prevention.

It is important to note that risk assessment needs to be carried out prior to any work at heights (WAH) activities. Whenever possible, eliminate or substitute any WAH activities. Using temporary edge protection systems (such as guardrails) shall be the first option in designing any fall prevention systems. The use of anchorages and lifelines, with proper personal protective equipment (PPE) shall come second if the option of having temporary edge protection is not feasible.

1.1 What this Guide is About

This guide is relevant for WAH activities. It contains salient points on proper application of temporary edge protection to prevent a fall; and correct anchorages and lifelines to arrest a fall during an accident.

This guide also includes two sections of the structural categories (i.e., ISO tanks and formworks) where the understanding of fall preventions systems (such as having correct anchorage and lifelines) can be applied. After reading this guide, the user should be able to:

- understand anchors or anchor points and their applications;
- understand lifelines and their applications;
- understand temporary edge protection systems and their applications;
- identify correct applications of anchorages and lifelines for formworks; and
- identify correct applications of anchorages and lifelines when working on top of ISO tanks.

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,

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

which incorporates an anchor point or several anchor points.

- 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. Anchors

A high proportion of falls in workplaces occur either due to unavailability of proper anchor points or failure of anchors. Therefore, anchors and anchors 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.

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.

Figure 3: Example of an expanding socket type of eyebolt anchor.

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.

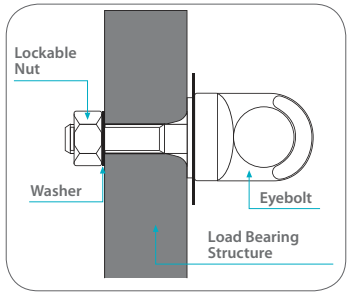


Figure 4: Example of a through-type anchor.

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.

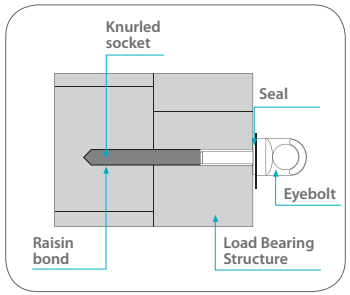


Figure 5: Example of chemically bonded anchor.

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)[1] 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[2].

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.

[1]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.*
[2]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.*

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)

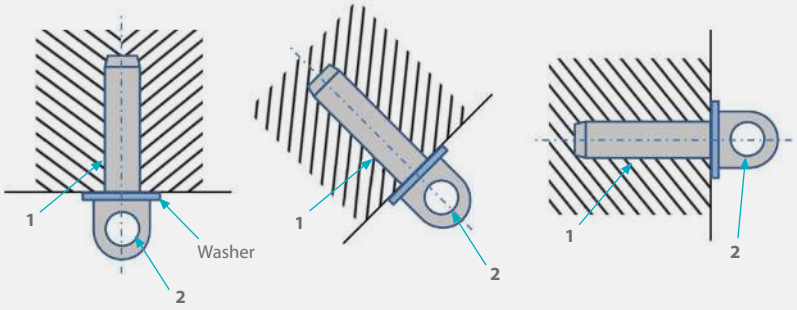
It is important to ensure that the design and surveying of the installation of anchors shall be carried out by a competent person.

2.4 Anchor Devices

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*.

Class A1

These are designed to be secured to vertical, inclined and horizontal surfaces. For example, walls, columns and eyebolts.

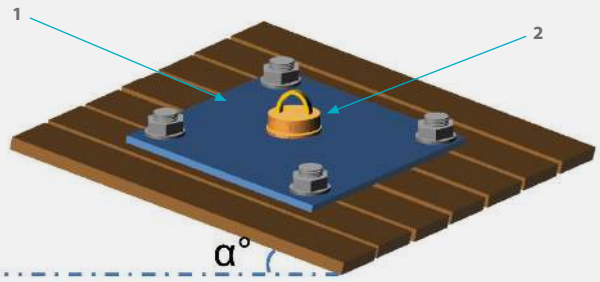


Vertical Inclined Horizontal

No	Items
1	Structural Anchor
2	Anchor Point
1 + 2 = Anchor device	

Class A2

These are designed to be secured to inclined roofs.

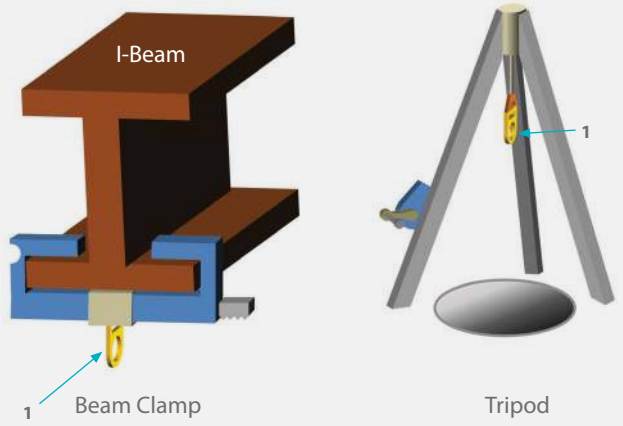


Inclined Roof

No	Items
1	Structural Anchor
2	Anchor Point
1 + 2 = Anchor device	

Class B

These are transportable temporary anchor devices. For example, a tripod over a confined space, a beam clamp or an anchor sling.

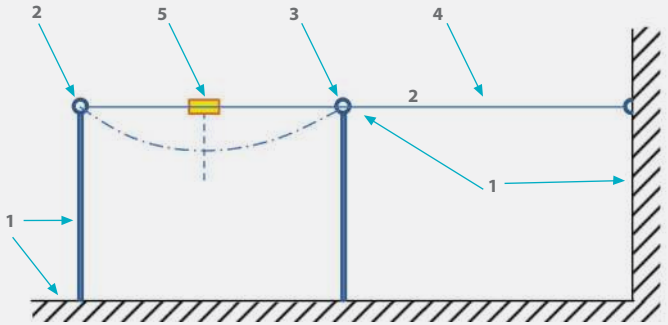


Beam Clamp Tripod

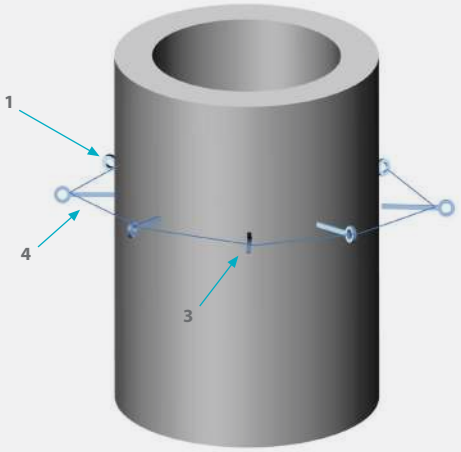
No	Items
1	Anchor Point

Class C

These are designed for use with horizontal flexible lifelines.



(a) Example of Roof Lifeline Installation

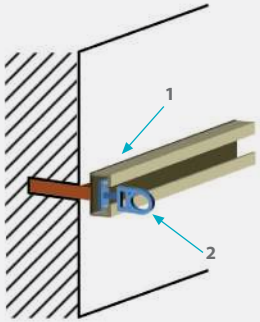


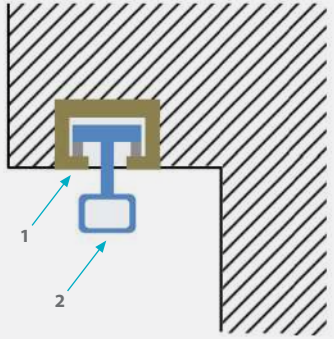
(b) Example of Chimney Lifeline Installation

No	Items
1	Structure
2	Extremity Structural Anchor
3	Intermediate Structural Anchor
4	Lifeline
5	Mobile Anchor Point

Class D

These are designed for use with horizontal rigid lifelines. For example, rails.

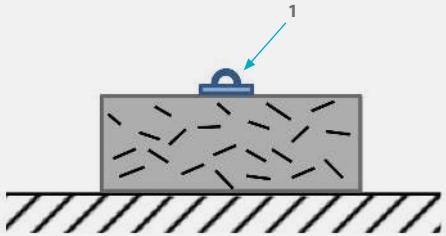




No	Items
1	Anchor Rail
2	Mobile Anchor Point

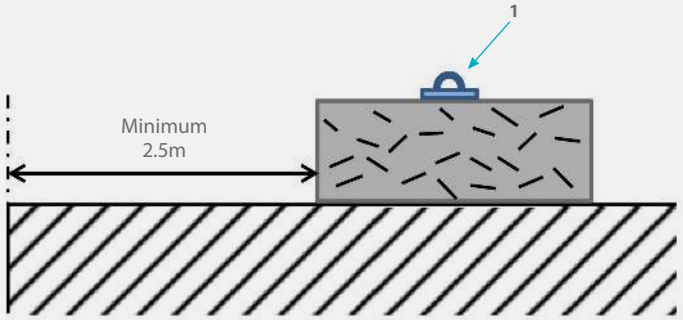
Class E

These are dead weight anchors for use on horizontal surfaces.



No	Items
1	Anchor Point

Note: It is critical to take note that dead weight anchor devices shall not be used where the distance to the edge of the roof is less than 2.5m.



Limit of distance to roof edge for deadweight anchor devices

Table 1: Classes of anchor devices.

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.

Figure 7: Excessive looping of an anchor sling should be avoided (unless otherwise stated in manufacturer's manual).

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;
- scaffolding;
- light fixtures;
- conduit or plumbing;
- ductwork or pipe vents;
- C-clamps;
- wiring harnesses;
- rebar (except for positioning during formwork);
- another lanyard;
- roof stacks, vents, fans or chimney;
- TV antennas; and
- any point which does not meet the structural requirements.

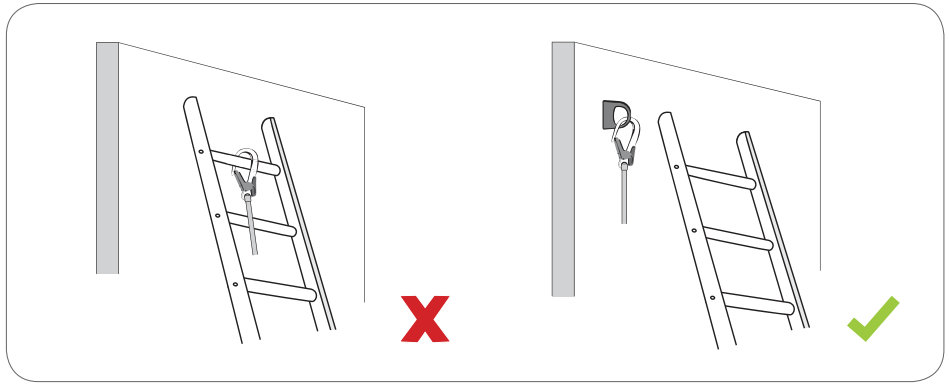


Figure 8: Fall prevention systems should not be connected directly to portable ladders that are leaned against any structures for the purpose of access. It should be connected to a proper anchorage adjacent to the ladder. A connection to a portable ladder should only be made if the top of the ladder is properly secured and the system tested by a competent person.

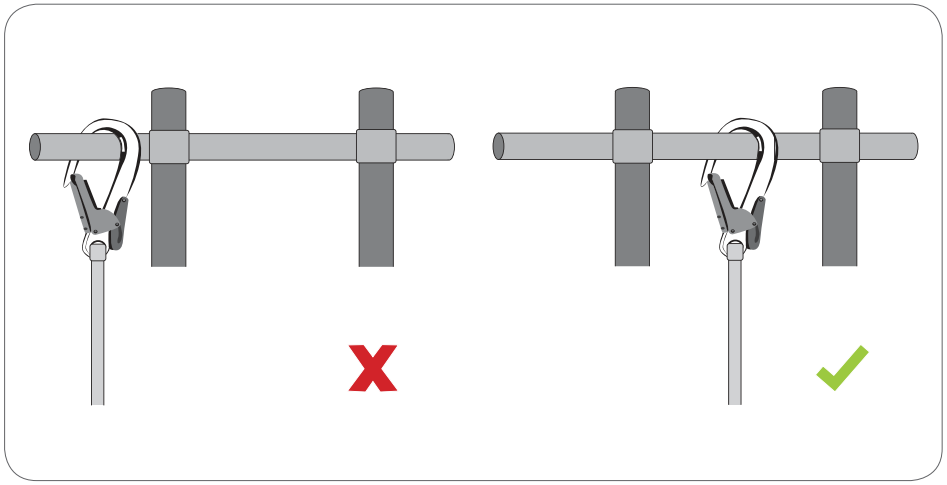


Figure 9: Fall prevention systems should not be connected to any open ended beams or cantilevers, as an initial fall arrest can cause the connection to slip off the open end of the beam or cantilever. Connections to beams and cantilevers should only be made between supports of which the structural strength has been determined and approved by a competent person.

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).

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.

2.8 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*.

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.

2.9 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 instruction 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.

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.

3.1 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.

3.2 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.

Types of Fall Arrest Systems	Lifelines (Conforming) Standards
Guided type fall arrester and a rigid vertical lifeline	SS 528 : Part 4 : 2006 Personal fall-arrest systems: Vertical rails and vertical lifelines incorporating in a sliding-type fall arrester
Guided type fall arrester and a flexible vertical lifeline	
System based horizontal flexible lifeline	SS 570 : 2011 Personal protective equipment for protection against falls from a height - single point anchor devices and flexible horizontal lifeline systems
System based horizontal rigid lifeline	

Table 2: Recommended lifelines for different fall arrest systems.

Textile lifelines used for fall arrest systems should be as follows:

- 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;*
- hawser-laid polyamide ropes conforming to *ISO 1140 : 2012 - Fibre ropes -- Polyamide--3-, 4-, 8- and 12- strand ropes; and*
- hawser-laid polyester ropes conforming to *ISO 1141 : 2012 - Fibre ropes -- Polyester--3-, 4-, 8 - and 12- strand ropes*.

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* for hawser-laid polyamide ropes or *ISO 1141 : 2012 - Fibre ropes -- Polyester--3-, 4-, 8 - and 12- strand ropes* for hawser-laid polyester 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 kernmantel ropes.*

Types of Tied Knots	Strength Reduction
Bowline	26% to 45%
Double figure-of-eight	23% to 34%

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

Figure 11: **Two different knot tying methods commonly used in industry, "bowline" (left) and "figure-of-eight on a bight".**

Note
The lower and upper values relate to the strength reductions due to the conditions of the knots been tied to "well dressed" or "poorly dressed" respectively. This refers to the arrangement of the layers or rope in the knots and its neatness.

As a rule of thumb, a 50% reduction in strength due to the knot should be allowed to give an adequate margin to cover a worst case situation.

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.

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.

Guided type fall arrestors

Hand ascender (left), chest ascender and descender

Figure 12: **Different types of lifeline devices.**

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):

Figure 13: Permanent VLL.

Design Criteria

- 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):

Figure 14: Temporary VLL.

Design Criteria

- 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.

Design Criteria
• Capable of being fastened to a ladder or structure by a number of brackets at intervals as per recommended by the manufacturer. • 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. • Able to prevent unintentional separation of the sliding-type fall arrester from the rail. • 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.

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^{o} .

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:

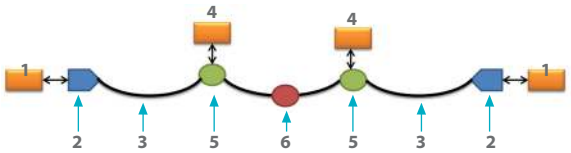
- 12kN downward force being applied at right angles to the axis of the line; and in the direction of the fall arrest; and
- a force in line with the flexible HLL with at least two times the maximum line arrest load.

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



Items	Descriptions
1	End anchor
2	End anchor connector
3	Horizontal lifeline
4	Intermediate anchor
5	Intermediate anchor connector
6	Mobile attachment device

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.

Figure 17: Example of wire rope lifeline.

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.

Figure 18: Example of webbing lifeline.

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.

Figure 19: Example of fibre rope lifeline.

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.

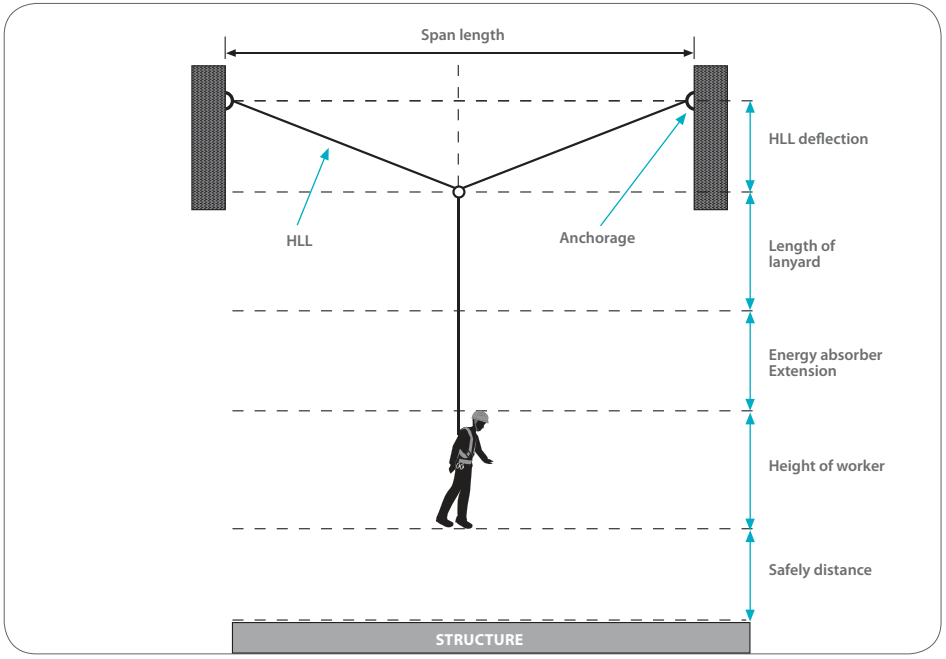


Figure 20: Example of minimum clearance height for a HLL (with lifeline deflection taken into account).

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.

Figure 21: Example of SRLs.

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.

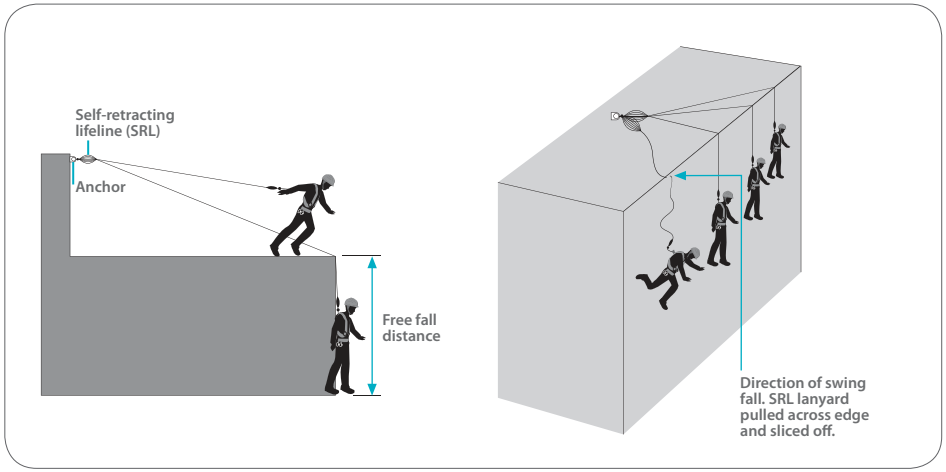


Figure 22: Dangers of using a SRL in the horizontal plane.

- Great care must be taken into account when the SRL is used in situations where the lifeline has to pass or trail 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

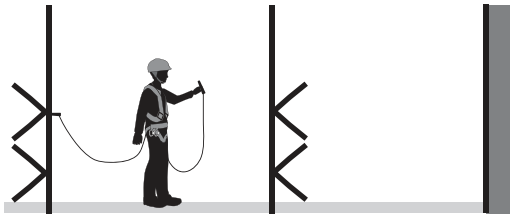
Lifelines (VLLs, HLLs or SRLs) should be acquired through reliable sources or suppliers. All lifelines shall be of good construction manufactured in conformance to recognised international standards and come with a COC.

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

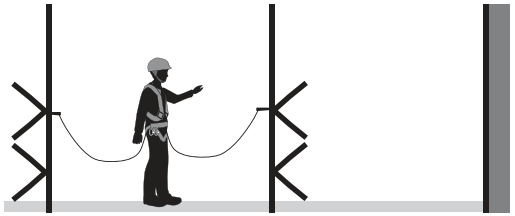
- **Ease of Use**
  The type of work to be carried out may affect the suitability of the type of system. Where possible, the least cumbersome one should be chosen. If the system hinders the user from carrying out the work too greatly, the users may end up choosing to disengage themselves from the lifeline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

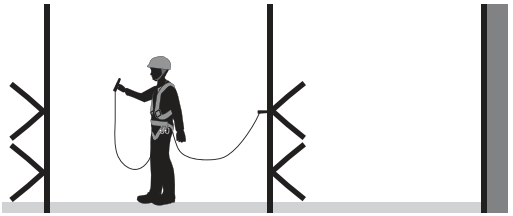
Where it is necessary for a user to switch between lifelines, the second lanyard must be connected to the next lifeline before the connection to the previous lifeline is disengaged. This is known as 100% tie-off.



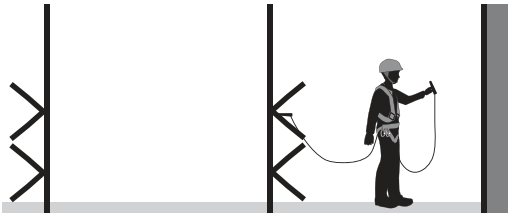
While being anchored, proceed to anchor the second lanyard to the secondary anchor position.



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:

Ultraviolet light	Long exposure to the sun will damage and deteriorate the life of synthetic lifelines. For outdoor usage, UV-resistant lifelines should be considered.
Sparks or flame	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.
Temperature	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.
Chemicals	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.
Marking or dying	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.
Friction and abrasion	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.
Storage	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.

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;
- discolouration;
- 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).

4. Temporary Edge Protection Systems

Temporary edge protection system is a set of components intended to protect the workers from the possibility of falling to a lower level from any exposed edges or open sides. Those who install the selected temporary edge protection system must also be protected from falling by using the correct means of fall arresting system.

In the past, "tube and fitting" scaffold components were used, supplemented with safety nets, fencing and tensioned wires. In recent years, purpose-made components are manufactured or assembled by WAH specialist companies; most of them are proprietary. Refer to Appendix B on the types of temporary edge protection systems commonly seen in the industry.

In general, a temporary edge protection system should make up of the following components:

- principal guardrail (top rail element);
- intermediate guardrail (mid rail element between principal guardrail and working surface);
- intermediate protection (protection barriers formed between the principal guardrail and the working surface. For example, fencing structures or safety net); and
- toeboard (bottom up-stand element on the working surface).

The dimensions requirements for a temporary edge protection system are:

- principal guardrail or top guardrail shall be at least 1.0 m above the working surface;
- any vertical gap between the protection components shall not exceed 600 mm; and
- toeboard shall not be less than 90 mm above the working surface to be effective in stopping objects from falling both over and under them.

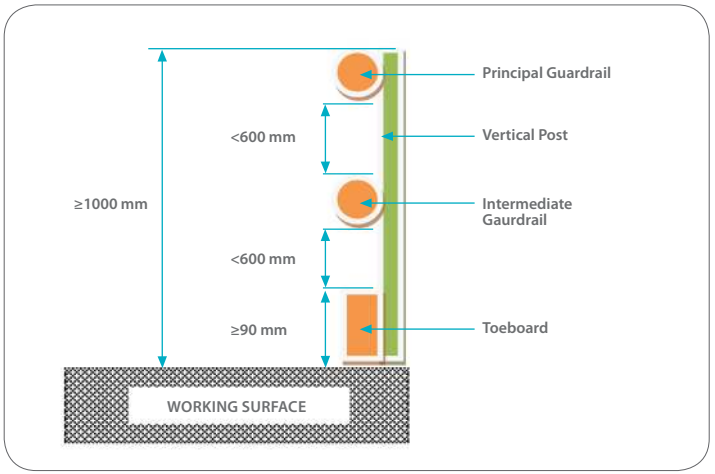


Figure 24: Dimension requirements for a temporary edge protection system.

4.1 Criteria in Selecting and Installing a Suitable Temporary Edge Protection System

In selecting a system for temporary edge protection, the following factors should be considered:

- type and nature of work;
- means of access and egress;
- method of erection of edge protection systems;
- usage;
- dismantling procedures; and
- rescue means and procedures.

A temporary edge protection system that can be installed without the need for a worker to perform WAH should be the priority choice and consideration. When erected, the system should not harm or endanger a worker, for example, cut by sharp edges and hit by protruding structures.

4.2 Three Classes of Temporary Edge Protection Systems

All designs of edge protection systems should follow one of the following class systems and refer to *BS EN 13374 : 2004 Temporary edge protection systems - Product spefication test methods for details of testing requirements.*

4.2.1 Class A System

Class A System is designed to withstand to static loads only, based on the requirements to:

- support a worker leaning onto the protection element or provide a handhold when walking beside it; and
- arrest the fall of a worker who is walking or possibility of falling towards the protection.

Limitation of Class A System

It should not be used if the working surface is more than 10°.

Static Loading for Class A System

Table 8 shows the design static loads to be supported for Class A:

General	Each edge protection components (except toe-boards) shall be designed to withstand 0.3kN applied to guardrails and posts perpendicular to the plane of the system.
Toeboard	Toeboard shall be designed to withstand 0.2kN at the most onerous position
Loads Parallel to the Guard-rail	Each edge protection (and its components) shall withstand a horizontal force of 0.2kN at the most onerous point
Accidental Loading	Any guard-rail/ toe-board shall be capable of resisting a downwards (± 10°) point load of 1.25kN, on a length of 100 mm.
Elastic Deflection	The elastic deflection shall not be greater than 55 mm.
Wind	The wind velocity pressure shall be taken as 0.6 kN/ m2.

Table 8: Design static loads to be supported for Class A.

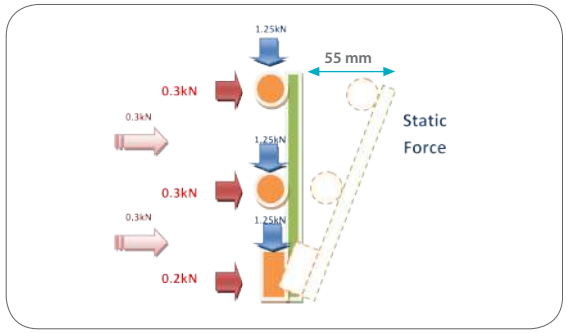


Figure 25: Static loading requirements for Class A system.

4.2.2 Class B System

Class B System (commonly used on roof pitches) is designed to withstand static loads and low dynamic forces only, based on the following requirements to:

- support a worker leaning onto the protection element or provide a handhold when walking beside it;
- arrest a worker who is walking or possibility of falling towards the protection; and
- arrest a falling worker who slides down a slope.

Limitations of Class B System

Class B may be used only if the angle of the working surface from the horizontal is less than:

- 30° (without any limitation of the falling height); or
- 60° (where the falling height is less than 2.0 m).

Static and Dynamic Loading for Class B System
The static loading for Class B is similar to Class A system.

For the dynamic loading capability of Class B system, it shall be able to absorb a kinetic energy of 1.1kJ (anywhere along the protection up to 200 mm height above working surface) and 0.5kJ at any higher parts.

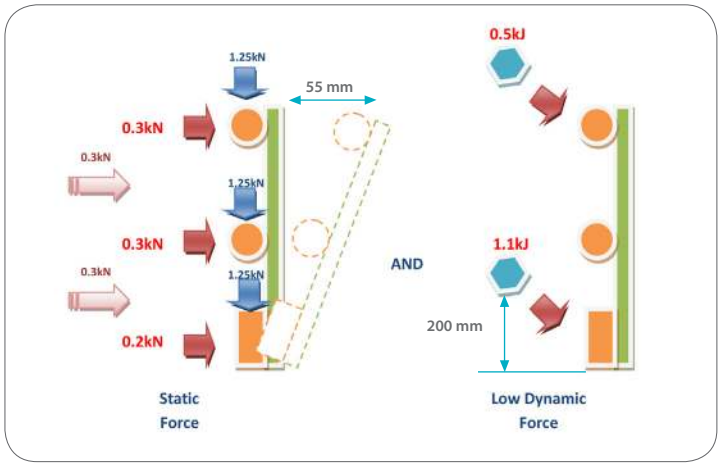


Figure 26: Loading requirements for Class B system.

4.2.3 Class C System

Class C system is designed to withstand high dynamic forces based on the requirements to arrest a falling worker sliding down a steeply slope surface.

Limitation of Class C System
Class C system may be used only if the angle of the working surface from the horizontal is between:

- 30º and 45º (without any limitation of the falling height); or
- 45º and 60º (where the falling height is less than 5.0 m).

High Dynamic Loading for Class C System
In general, Class C system shall be able to absorb a kinetic energy of 2.2kJ (anywhere along the protection up to 200 mm height above working surface).

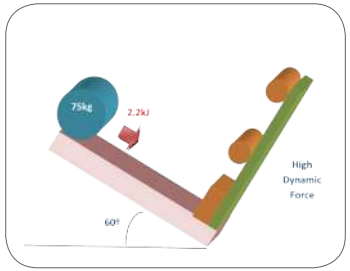


Figure 27: Loading requirements for Class C system.

4.3 Materials

Materials used for construction of temporary edge protection systems shall be sufficiently robust and durable to withstand normal working conditions. The materials shall also be free from any impurities and defects that may affect their satisfactory use.

Materials being used for construction of temporary edge protection systems shall adhere to the recommendations from the international standards as listed in Table 9.

Materials	International Codes and Standards
Steel	BS EN 12811 - 2 : 2004 Temporary works equipment information on materials prEN 74 - 1 : 2002 Couplers, spigot pins and baseplates for use in falseworks and scaffolds - Part1: Couplers for tubes - Requirements and test procedures
Aluminium	prEN 74 - 1 : 2002 Couplers, spigot pins and baseplates for use in falseworks and scaffolds - Part1: Couplers for tubes - Requirements and test procedures
Timber	BS EN 338 : 2009 Structural timber. Strength classes Note: ii. If protective coating is being applied on timber, it shall not prevent the detection/ discovery of material defects. iii. If plywood is to be used, it shall have at least 5 plies and shall have a minimum 9mm thickness. It shall have good climate durability condition.

Table 9: Standards for materials used for construction of temporary edge protection systems.

4.4 Markings

All purpose made components such as principal guardrails, intermediate guardrails, intermediate protection (e.g., fencing), posts, toeboards and counterweights shall be marked.

The following markings shall be clearly visible and arranged in a manner that it will remain legible for the service life of the product:

- types of edge protection systems (i.e., Class A, B or C) and its standards number;
- manufacturer or supplier's name and identification;
- year and month of manufactured date;
- serial number; and
- their weight in kilograms if counterweights are used.

4.5 Different Types of Temporary Edge Protections

4.5.1 Full Scaffolding

Full scaffolding combines an eaves-level scaffold access platform with edge protection. It is well suited for the following types of roofing work:

- accessing the workplace (e.g., roof);
- carrying out slating and tiling works;
- delivering materials to required locations;
- manual handling heavy or large components along the roof; and
- working on steep roof pitches.

Guardrails (with toe-boards) add protection on the outside of the access way to prevent people and materials falling from the inside edge.

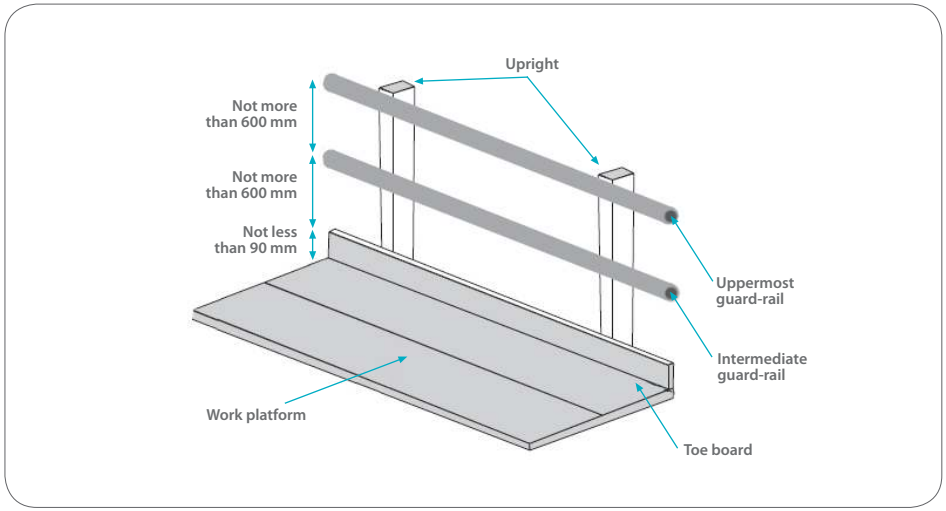


Figure 28: Example of full scaffolding for edge protection on roofing work.

4.5.2 Ground Supported Edge Protection

This type of edge protection is erected from the ground to the required height using tubes to prevent users from falling off eaves or open sides. The design shall include a safe means of access.

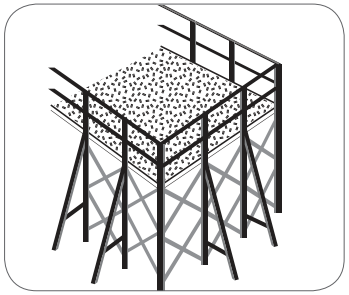


Figure 29: Example of ground supported edge protection.

4.5.3 Edge Protection off the Structure

This is the most suitable type of edge protection for use on new steel structures. Edge protection uprights are secured into prefabricated brackets or sockets on the structural steel work. The guardrail system, whenever possible, should be attached to the structural steel work component at ground level. The structure should be of sufficient strength and rigidity to resist foreseeable forces exerted on the guardrail system.

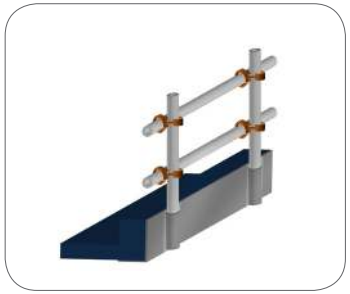


Figure 30: Example of edge protection off the structure.

4.5.4 Parapet Edge Protection

Parapet edge protection design can be applied, with consideration given to the suitability of the structure and how materials can be located and accessed.

Figure 31: Example of parapet edge protection design.

4.6 Use of Proprietary Systems

Where it is intended to use proprietary temporary edge protection systems, the usage should be discussed with the manufacturer who supplies it. The manufacturer should be made aware of the following information:

- situation in which the system is to be used (e.g., whether or not the site is exposed and any significant topographic feature likely to affect the wind speed and direction);
- thickness of the slab (e.g., when clamped to the edge of a concrete slab);
- width of the flanges (e.g., when clamped to steel beams);
- slope of the roof (e.g., when used on a sloping roof);
- whether the system will be modified (e.g., fixing debris nets or advertising banners to it); and
- whether work will be carried out at the edge of the roof (e.g., some sections may need to be removed temporarily).

5. Case Application One: Anchorage and Lifelines for ISO Tanks

A tank container (also known as "ISO container tank") is defined as a vessel for bulk transport of liquid and powder that fits within the corner dimensions of the familiar box-like international shipping container.

Falling off from the top of tank containers can cause serious or even fatal injuries. This section is intended to help contractors and workers who are involved working on top of tank containers to mitigate the danger of falling from heights by implementing appropriate fall prevention systems such as having proper anchorage and lifelines.

Figure 32: Example of a tank container.

5.1 Accessing top of ISO tanks using ladders

A common method of accessing to the top of the ISO tanks is through the use of in-built ladders.

The process of climbing and maneuvering on top of the ISO tank has a risk of falling from heights, especially if no fall prevention measures have been implemented.

Figure 33: ISO tanks with in-built ladders.

5.2 Alternative Access and Fall Prevention Approaches

Locating a suitable and secured anchorage point may be difficult on an ISO tank because there are several designs (e.g., "frame tank" or a "beam tank") available in the market.

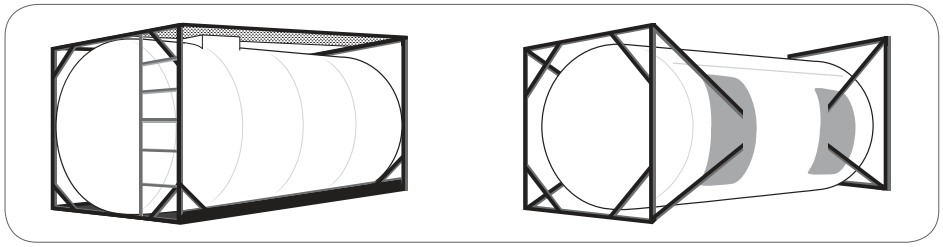


Figure 34: A "frame tank" (left) and a "beam tank".

Some of the recommended alternative anchorage and access solutions are listed below for reference (See Figures 35 to 40).

5.2.1 Anchorage and Lifeline Structural Systems

If access platforms and structures are not available, a drive-in or portable anchorage and lifeline structural system should be provided for workers to protect themselves before ascending the ISO tanks.

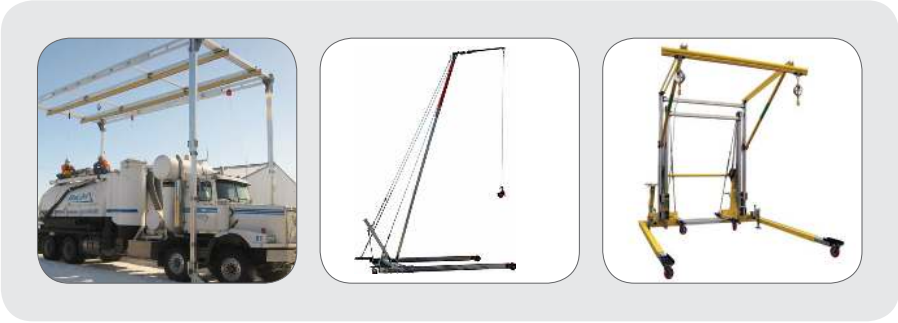


Figure 35: Portable anchorage and lifeline structural systems.

Figure 36: Drive-in anchorage and lifeline structural system.

5.2.2 Mobile Fall Arrest Anchorage Pole Systems

Some proprietary mobile fall arrest systems are also available to quickly engage and disengage all ISO type container corner castings without the use of tools.

Figure 37: Examples showing portable anchorage and lifeline pole systems.

5.2.3 Fall Prevention Systems from Top of ISO Tanks

There are existing proprietary devices in the market to cater for fall prevention and assist the user in making the transition between the ladder and the walkway.

Figure 38: A proprietary TRAM system by Standfast Corp.

5.2.4 Access Structures and Platforms

Accessing the top of ISO tanks can be done safely with the use of appropriate proprietary access platforms and structures.

Figure 39: ISO tanks access structural platform.

Figure 40: ISO tanks cage access platforms.

6. Case Application Two: Anchorage and Lifelines for Formworks

Formwork construction is another process that poses a risk of falling from heights as it usually involves WAH. It may also involve other associated risks such as structural collapse or struck by falling objects. Hence, workers involved in formwork incidents can be fatally or seriously injured.

This section recommends some forms of anchorage and lifeline systems commonly used in the context of formworks.

6.1 Common Use Anchors for Formwork

6.1.1 Strap Anchors

Strap anchors provide versatility and options for anchorage points while performing anchorage on formwork rebars. They can be looped over rebars and removed when no longer necessary.

Strap anchors can also be poured over with concrete and left in during construction. Anti-chafe sleeves can be used to maintain the integrity of the strap. Once no longer needed, the strap can be cut out of the concrete and removed.

Figure 41: Example of a strap anchor.

6.1.2 Cast-in Rebar Anchors

A cast-in rebar anchor is another type of anchorage for workers working on formwork. These types of anchorage must be designed and certified by a Professional Engineer before use.

6.1.3 Expandable Bolt Anchors

Anchors can be added to cured concrete. Anchors with expandable bolts can be placed in holes that have been drilled into the concrete for formwork.

Figure 42: Example of an expandable bolt used in concrete (cut-away view).

6.2 Work Positioning Device Systems

Work positioning device systems are a form of personal fall prevention during formwork construction for working on and placing rebars, provided the primary mean of access platform is inaccessible. It allows a worker to work on vertical surfaces with both hands free.

The work positioning lanyard or snaphook system device should not be relied upon alone to arrest a fall, as its energy absorbing capacity might be insufficient. Hence, it is important for the user to also be connected to a safety backup personal fall prevention system.

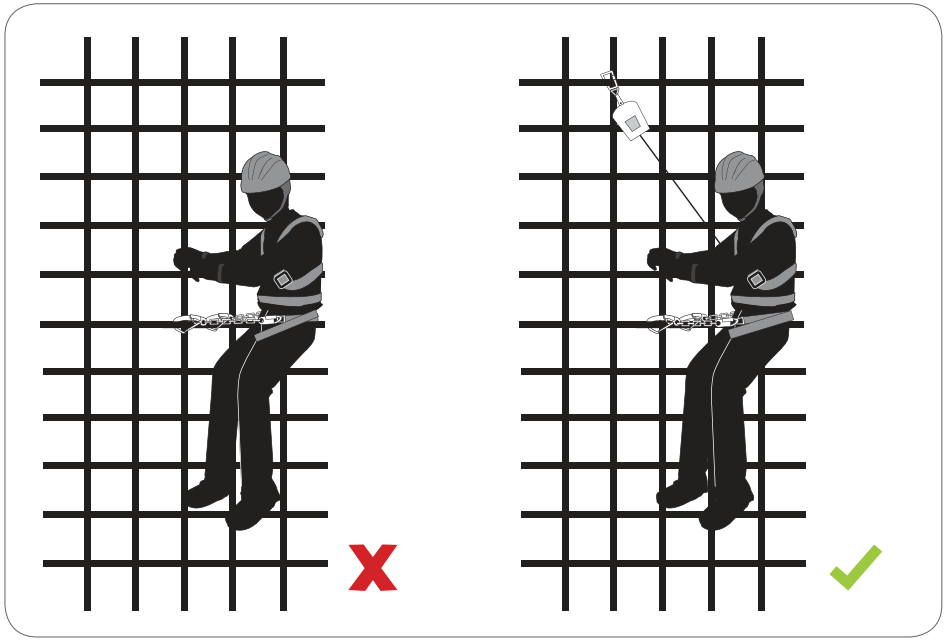


Figure 43: Example of work positioning device system (when working on rebar) without any personal fall arrest system (left) and example of a work positioning device system with a personal fall arrest system being incorporated.

7. 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 1492 - 1 : 2000 + A1 : 2008 Textile slings. Safety. Flat woven webbing slings made of man-made fibres for general purpose use
- 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

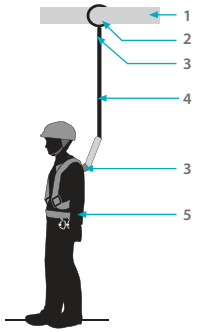
- BS 7985 : 2009 Code of practice for the use of rope access methods for industrial purposes
- BS 8437 : 2005 Code of practice for selection, use and maintenance of personal fall prevention systems and equipment for use in the workplace
- BS EN 13374 : 2004 Temporary edge protection systems. Product specification, test methods
- ISO 1140 : 2004 Fibre ropes - Polyamide - 3-, 4 -, 8 - and 12 - strand ropes
- ISO 1141 : 2004 Fibre ropes - Polyester - 3-, 4 -, 8 - and 12 -strand ropes
- ISO 10333 - 4 : 2002 Personal fall-arrest systems - Part 4: Vertical rails and vertical lifelines incorporating a sliding-type fall arrester
- ISO 14567 : 1999 Personal protective equipment for protection against falls from a height - Single-point anchor devices
- ISO 22159 : 2007 Personal equipment for protection against falls - Descending devices
- ISO 22846 - 1 : 2003 Personal equipment for protection against falls - Rope access systems - Part 1: Fundamental principles for a system of work

8. Acknowledgements

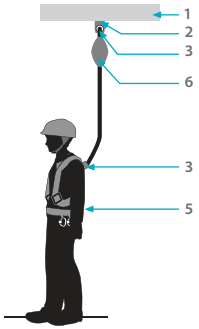
We acknowledge Asretec Pte. Ltd., Capital Safety Group Asia Pte. Ltd., Ferramenta, Flexible Lifeline Systems, QMT Industrial & Safety Pte. Ltd., and Standfast Corp for their assistance in providing the images used in this guideline.

Appendix A

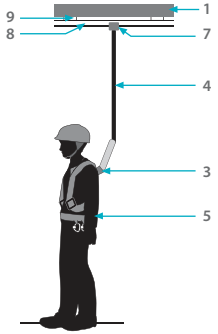
Different Types of Fall Arrest Systems (with Different Anchorages)



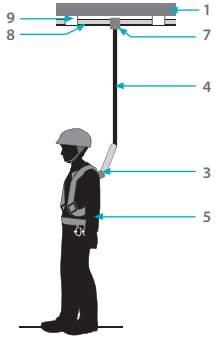
a) Fall arrest system based on an energy absorbing lanyard



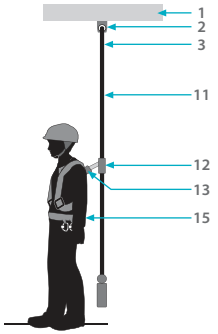
b) Fall arrest system based on a Self Retracting lifelines (SRL)



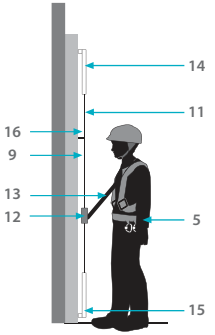
c) Fall arrest system based on a rigid horizontal lifeline



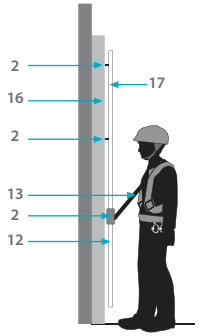
d) Fall arrest system based on a flexible horizontal lifeline



e) Fall arrest system based on a flexible vertical lifeline with an upper anchor



f) Fall arrest system based on a flexible vertical Lifeline with an upper and a lower anchor



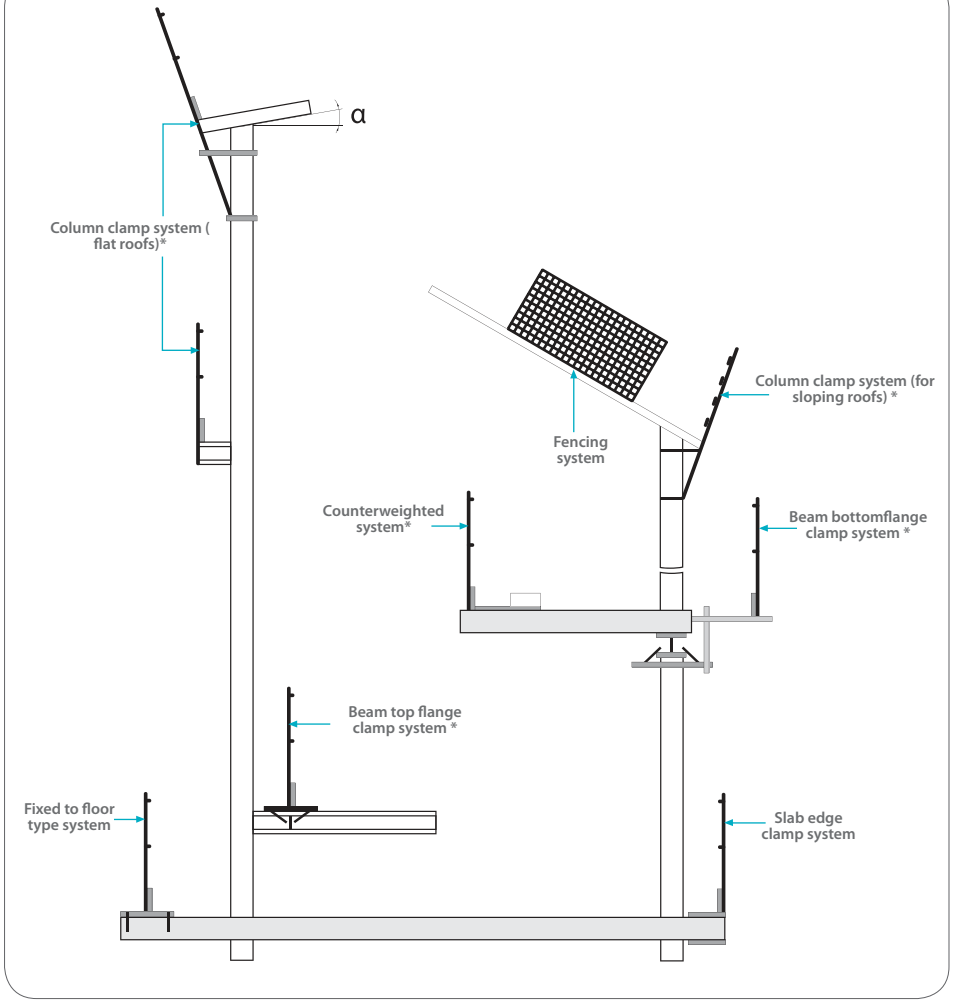
g) Fall arrest system based on a rigid vertical lifeline

No	Key
1	Workplace Structure
2	Anchor
3	Connector
4	Energy absorbing landyard
5	Full body harness worn by user
6	Self retracting lifeline
7	Traveller
8	Rigid horizontal lifeline

9	Immediate anchor
10	Flexible horizontal lifeline
11	Flexible vertical lifeline
12	Guided type fall arrester
13	Short connecting lanyard
14	Upper Anchor
15	Lower Anchor
16	Permanently installed ladder
17	Rigid vertical lifeline

Appendix B

Different Types of Temporary Edge Protection Systems



* Adapted for use on roofs (as edge protection)