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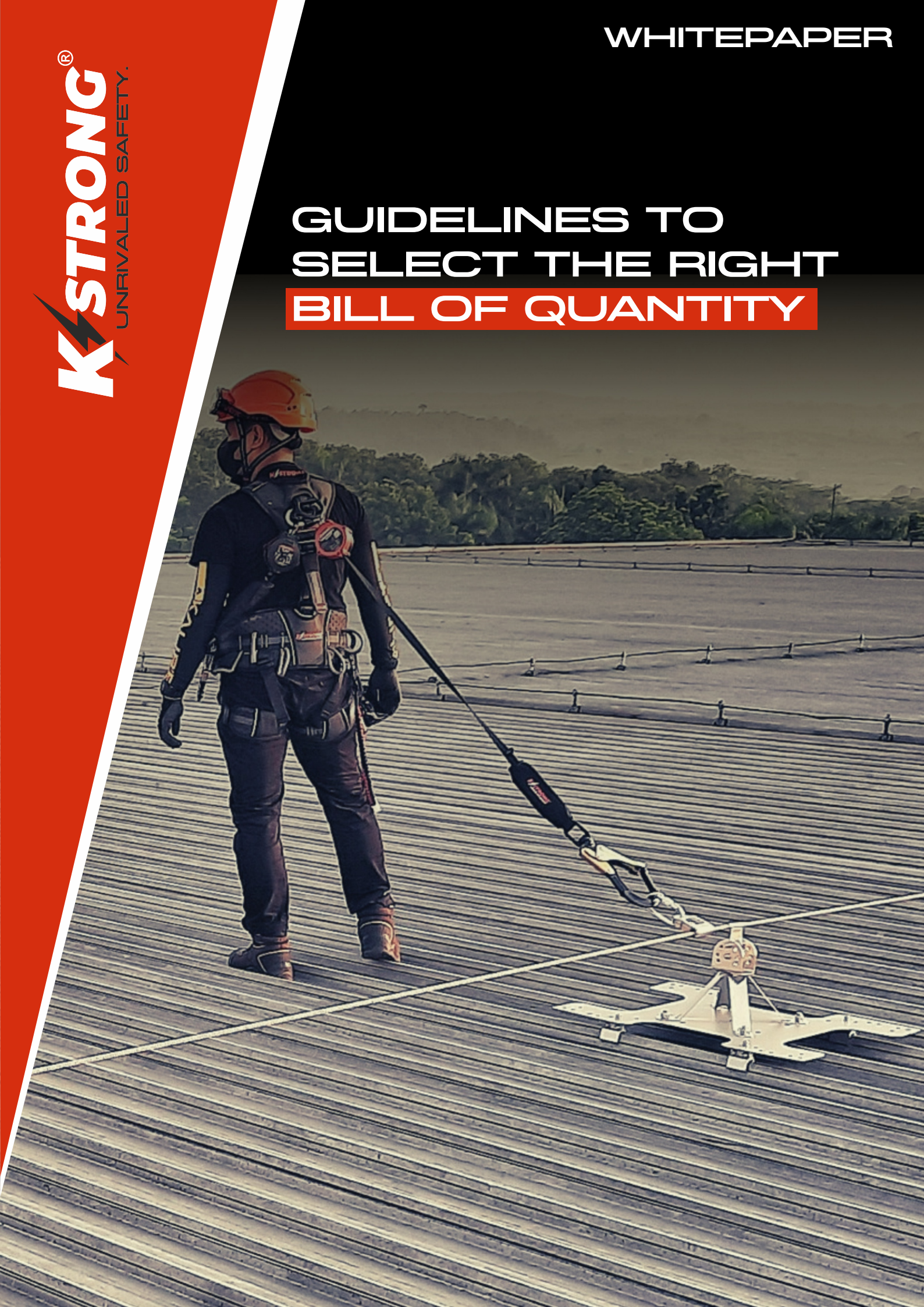
WHITEPAPER

GUIDELINES TO SELECT THE RIGHT BILL OF QUANTITY



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Foreword

The fixed lifeline systems are engineered lifelines which needs to be carefully designed by engineers considering various parameters linked to site conditions, correct bill of quantity (BOQ), environmental conditions, strength of receiving structure, fall clearance, number of users, certification etc. An oversight in any of these critical parameters may lead to the failure of system and may result in serious injury or death, which may impact the reputation of the manufacturer, distributor and installer.

Selecting the right components for a lifeline, factors affecting forces in a lifeline and the fall arrest distance generated after a fall in different site conditions need to be understood by installers.

Scope

This paper talks about guidelines that must be followed by engineers while selecting the BOQ for the lifelines. An attempt is made to explain the engineering behind the forces generated and deflection in a lifeline and the need to select specific components i.e. shock absorber, intermediates, anchorage post, wire cable, etc. in ensuring that the lifeline is compatible to site situation and structure.

Introduction

The horizontal lifeline system needs to be designed to ensure the least impact on the user as well as the receiving structure. This is necessary since the receiving structure may sometimes be very weak like 0.5mm thin roof sheets. In such cases, high forces at the end anchorage may result in the failure of the structure. Thus contrary to common perception, a lifeline is engineered to ensure each component absorbs shock and divides the force evenly.

Another important factor is fall arrest distance. If the fall arrest distance is high, the user may hit a structure below and get injured.

Requirements of the European Standards

Horizontal Lifelines are certified to EN 795:2012 Type C (for one user) and further tested to TS 16415:2013 if multiple users intend to use the lifeline (4 users in our case). The lifeline needs to be engineered to meet the following conditions of the standards.

4.2.3.2	Specific requirements – Type C anchor dynamic strength & integrity test	The maximum load measured at the extremity anchor during all dynamic strength and integrity tests should not exceed 50% of the minimum breaking strength of the flexible anchor line.
4.2.3.3	Specific requirements - Type C dynamic strength and integrity test	The values at the extremities and the maximum dynamic deflection of the anchor line does not vary by more than ±20% of that predicted

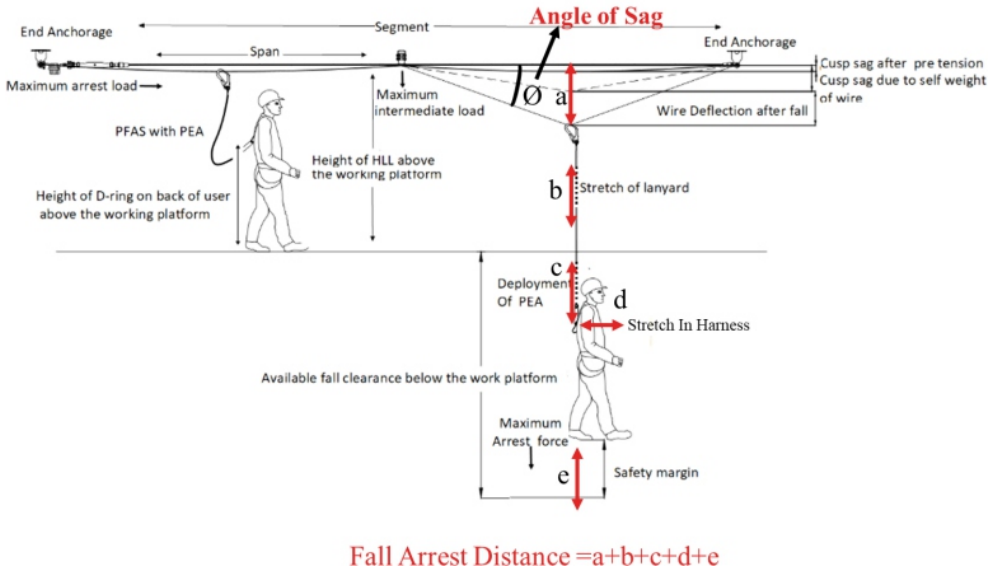
The Basics and Test Methods of EN 795:2012 Type C and TS 16415:2013

The size of the lifeline is different at each site. The distance between the intermediate posts may also vary .The lifelines can be installed with or without corners and can be used by one or multiple users. It is impossible to test a lifeline in all sizes and with different orientations, factoring corners, distance between intermediates and number of users .

To solve this intense challenge, EN 795 published dynamic strength and integrity tests, in its latest edition of EN795:2012. However, EN 795 addresses only one user, thus in 2013 a technical sheet TS 16415 was added to EN795:2012, which covers test parameters of dynamic strength and integrity tests for multiple users .

The Challenge

The Engineering of a Lifeline



Force Amplification at the Extremity in an Event of a Fall

During a fall, the wire rope sags. If the sag angle is less than 30 degrees, the force exerted by the user on the end extremity is amplified. For example, 15 degrees sag creates a force 2 times the force exerted at the center by the user, and a 5 degree sag creates a force as high as 6 times the force exerted at the center. The high force amplification may damage the structure and the fall may not be arrested.

High sag angles will reduce force amplification at the extremities; however, they will increase the fall distance and the user may hit a structure below (please see the drawing above). Thus, we need a balance between force amplification and fall distance.

When the user falls, the harness stretches, the lanyard elongates, the shock absorber deploys and there is deflection in the lifeline. All these contribute to the fall distance which we need to minimize as much as possible and also to reduce force amplification which is inversely proportional to the deflection of lifeline .

An engineering software helps to perform complex calculations to predict and control the forces at extremity and deflection in the lifeline. KStrong Compass software is a cloud based mobile application which helps the user to predict the forces at the extremity and deflection in the lifeline. KStrong Compass also helps in inspection of the lifeline systems and maintains inspection records for 20 years .

Factors Affecting Shock Absorption in a Lifeline

In an engineered lifeline system, all the components of the lifeline contribute towards shock absorption. Let us talk about each component and understand how shock is absorbed.

Shock Absorber

The shock absorber is the heart of the system and provides flexibility in the selection of components of the lifeline system. It consists of a SS 316 coil which deforms in an event of a fall. The energy used in the deformation contributes to shock absorption and results in a reduction in forces on the structure and the user.

Wire Rope

The wire rope is stretched in an event of a fall. Part of the fall energy is used for stretching in the wire rope thus reducing the forces on the structure. 7x19 construction provides the highest elongation while 1x19 the least.

Shock Absorbing Post (Extremity, Corners and Intermediates)

The posts for roof sheets on the pre-engineered buildings are designed to deform and absorb the energy generated by the fall. The table below describes different kinds of roof posts to suit a variety of roof profiles.

Roof Post	Image	How the Post Absorbs Energy
Extremity / Intermediate Post for Trapezoidal Roof Extremity / Intermediate Post for Standing Seam / Kliplok Roof	 For Trapezoidal Roof Sheets  For Standing Seam Roof Sheets  For Kliplok Roof Sheets	The cross arms and the base plates of the posts are designed to deform, thus absorbing a high amount of fall energy. **Compatible Roof Sheets** Two variants are available: Trapezoidal / Custom Orb Roof Sheets Standing Seam / Kliplok Roof Sheets

Extremity Post for Trapezoidal Roof Sheets
AFA935410

Standing Seam Extremity Post
AFA935156

Broad Standing Seam Extremity Post
AFA935156BS

Kliplok Extremity Post
AFA935168

Intermediate Post for Trapezoidal Roof Sheets
AFA935420

Intermediate Post for Standing Seam
AFA935157

Broad Intermediate Post for Standing Seam
AFA935157BS

Intermediate Post For Kliplok
AFA935169

Corner Post for Trapezoidal Roof Sheets
AFA935430
(60), (90), (120) Degrees

Corner Post For Standing Seam Roof
AFA935171
(60), (90), (120) Degrees

Broad Corner Post For Standing Seam
AFA935171BS
(60), (90), (120) Degrees

Corner Bend Post For Kliplok
AFA935185
(60), (90), (120) Degrees

Variable Corner Bend Post for Trapezoidal Roof
AFA935430(CB)

Corner Bend Post For Standing Seam Roof
AFA935171(CB)

Corner Bend Post for Standing Seam Roof
AFA935171BS(CB)

Corner Bend Post For Kliplok Roof
AFA935185(CB)

Roof Post	Image	How the post absorb energy
Corners For trapezoidal roof sheets For Standing Seam Roof/Kliplok Roof	 For Trapezoidal roof sheets  For Standing Seam roof sheets  For Kliplok roof sheets	Corners are provided with 3 shock absorbing supports which deform in an event of a fall , thus providing the much needed shock absorption. The corners are installed on the base plates of the respective posts.

Intermediates

The intermediates are mounted on the base plate of the post. It deforms in an event of a fall and absorb the fall energy. Thus the impact is not transferred to the roof sheet.

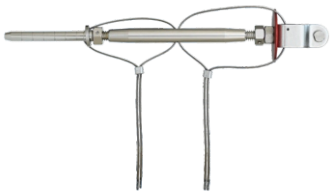
Factors Affecting Fall Distance

Wire Rope

The elongation of wire rope increases the fall arrest distance. The elongation in 7x19 wire is highest while the elongation in 1x19 is the lowest. Hence, if the fall arrest distance needs to be reduced, for example in an overhead lifeline for loading/unloading, then a 1x19 wire is recommended.


Pretension

The deflection in the lifeline is very low if the pretension is high. Normally, the pretension for a 15 meter span is 1kN. However, a tensioner capable of tensioning up to 5kN may be used if the span is longer than 15 meters or when a SRL is over 10 meters in an overhead application.



Shock Absorber

The shock absorber starts elongating at 1kN. Thus, if a very long span lifeline greater than 15 meters is required, or an SRL over 10 meters is used in an overhead system, then the standard coil type shock absorber is not suitable as it will keep on elongating when we tension the line above 1kN. The solution is an 18kN shock absorber which starts deploying only at a minimum force of 18kN and allows the line to be pretensioned at 5kN.


Long Span Horizontal Lifeline

- Lifelines installed overhead either using L posts, installed in concrete or using metal structures are economical if the number of intermediates is less. Increasing the span length in the lifeline will reduce the number of L posts and intermediates, however the sag of the lifeline after a fall may be very high and thus fall may not be arrested.

- A long span lifeline is required in a cement kiln which is around 70 meters and does not have limited options to install an intermediate. The solution is AFF4000(LS) long span horizontal lifeline which can be installed with a maximum of 35 meters span lengths without an intermediate.

- For a long span lifeline, the wire recommended is 8mm 1x19 wire which has the least elongation. In the long span system, you require two 5kN tensioners, allowing the pretension in the lifeline to be 5kN, ensuring the 18kN shock absorber does not deploy due to the high pretension of the lifeline. This combination allows the least amount of sag in the lifeline and thus reduces the fall arrest distance.

- By using the engineering calculation software, the lifeline can be calculated correctly ensuring that the correct system is used for the intended application.

Selection of the Right Components

Selection of right components is crucial for safety of the user. KStrong has a variety of specifically designed components ensuring the component is suitable for each type of structure. Selection of the wrong components may lead to failure of the lifelines and cause injury/death of the user. Thus selection of the wrong components for achieving a price advantage is immoral and not permitted. KStrong reserves the right to change the bill of quantity even after a quote has been submitted.

Wire Rope

The wire rope is available in 3 constructions and must be selected as per guidance below. KStrong may request channels to requote the correct bill of quantity if a wrong selection of wire rope construction is made.

1x19 construction. It must be selected when **using a long span lifeline.**
The 1x19 construction allows high strength and the least elongation, thus making it a perfect choice for long span lifelines. To reduce sag in a long span lifeline, we need to provide high pretension. However, the high pretension will result in higher fall arrest forces at the extremity and in the system. The breaking strength of 1x19 wire is 44kN as compared to 34kN for 7x19 construction. Thus, selection of a 7x19 or 7x7 wire may result in failure of the wire.

Installing a lifeline at a height greater than 3 meters from the working platform and using an SRL greater than 10 meters.
When the user starts moving on an elevated horizontal platform while connected to an overhead lifeline through an SRL ,the forces are exerted in two directions: vertical and horizontal. The vertical forces will extract the cable from the SRL, while the horizontal forces would move the SRL over the lifeline. In case the horizontal forces are less, the SRL will stay in its place and the wire will keep on extracting, thus creating a swing hazard since the SRL is not overhead. This issue will be amplified as we extract more wire and the user is further away from the lifeline.

Thus, the pretension in the lifeline should be high enough to avoid extra sag due to the weight of the SRL, so that the traveller moves freely on the wire rope with the least amount of friction.

Installing a Lifeline for Electric Overhead Traveling (EOT) Cranes
When the user is walking on the long travel of an EOT crane, a fall may occur. However, the fall may be arrested by the lifeline installed along the long travel. The fall would create a heavy sag in the lifeline resulting in a higher fall arrest distance. The user may sustain injury due to hitting the structure / bus bar below. To reduce the fall arrest distance, we can provide higher pretension in the wire rope. Selection of 1x19 wire rope construction is crucial to withstand high fall arrest forces due to higher pretension.

7x19 /7x7 Wire Rope Construction
It must be selected when **using lifelines for over the roof applications.**
Roof sheets are weak and we need to protect them by reducing the forces generated in the lifeline. The 7x19 wire provides highest elongation and thus absorbs a lot of fall arrest energy resulting in to high shock absorption and transmits very little forces to the roof posts.

Over the head applications for loading/unloading for spans more than 15 meters or when an SRL longer than 10 meters is used.

Note1: 1x19 wire rope construction may be used if the fall clearance is very low and the goal is to reduce fall arrest distance.
Note2: Cable termination using U-bolts and thimbles is not allowed in horizontal lifelines as per EN 795.

Shock Absorber

The AFF112100 coil type shock absorber starts deforming at 1kN, thus providing a very high shock absorption. However the elongation is very high and hence the fall arrest distance is higher. The coil type shock absorber is suitable for over the roof lifeline to protect weak roof sheets by providing high shock absorption.

The coil type shock absorbers may also be used on overhead lifelines with short span between 5 to 15 meters using 10-meter SRL's.

Long Span Shock Absorber AFF114112 is used for long span lifelines where the goal is to provide high pretension in the lifelines for the following reasons:

- To reduce the wire deflection in an event of a fall in a long span (up to 35 meters lifeline) thus, reducing the fall arrest distance specially in situations wherein the fall clearance is low.
- To be used with all SRL's above 10 meters which helps reduce the sag due to its weight.

Posts

Kindly refer to the excel sheet below to select the right posts for different receiving structures.
https://kstrong.com/asia/wp-content/uploads/sites/3/roof-post-guide.xlsx

Fabrication

KStrong has developed posts for almost every type of structure. These posts are certified to EN 795 Type A and tested in the worst-case scenarios. KStrong strongly recommends use of certified posts in the lifelines since fabricating posts at site may result in failure of the structure. In case a fabrication is necessary, it should be done in consultation with a KStrong Engineer.

Travellers

AFF119025 & AFF119000

AFF119028 & AFF119100

AFF119025 and AFF119000 travelers are suitable for wall and over the roof lifelines.

AFF119000 traveler is supplied with wheels, reducing the friction while traveling on a wire rope. Suitable for SRL's up to 6 meter for over the head applications.

AFF119028 must be used when the SRL is over 6 meters.

AFF119028 traveler has been designed with extra large wheels fitted with bearings to reduce friction during horizontal movement. This "must" be used if the overhead lifeline is higher than 3 meters from the elevated horizontal platform and the SRL required is greater than 6 meters.

Conclusion

To protect the user and structure from damage, it is important to select the right components in an engineered lifeline system. It is important that the end user or engineer follows the manufacturer's instructions in selecting the right components to avoid failure of lifelines in its intended use and prevent injury/loss of precious life.

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