SFS

Fall Protection Whitepaper

Fragile roof design trends and the impact on specifying fall protection systems.

March 2022

The building envelope specialist

We strive for continuous improvement and innovation – always in close collaboration with our customers, colleagues and suppliers. We want to be successful together, improve all the time, see where the technological limits are and drive them forward. SFS creates value with advanced fixing and rainscreen subframe systems for the building envelope. As the leading specialist in this application we offer the highest possible expertise.

Together with our partners we invent new products and services for our shared success.

Contents

Introduction

Why Fall Protection

Where roof access is essential or unavoidable, fall protection systems are required to help meet health and safety best practice.

They either prevent falls in the first instance, by providing restraint, or they minimise the distance of any fall through fall arrest. Manufacturers have also developed software programmes to help in the identification of the fall protection system for the roof situation. Indeed SFS have created the SFS ConnectSuite® of online tools that incorporates one of these identification tools called SFS Fall Protection Visualizer →.

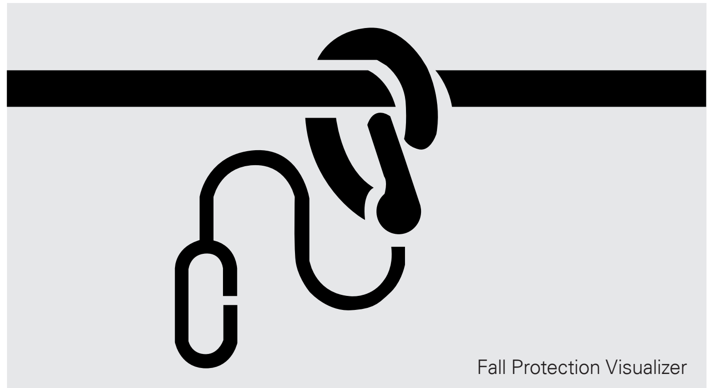
Restraint should always be the default, but the factors that influence roof access design, and which determine whether fall arrest is needed, can be complex.

In the event that the worst case occurs and a person falls from a roof, the arresting action exerts substantial forces on the roof build-up to which the fall protection system is attached. Many life line solutions exert forces of 10 kN or more back to the roof structure.

We have seen an increasing desire from designers and specifiers to understand these forces. More importantly, they are seeking to understand the relationship between the minimum forces exerted and the strength of the roof structure.

The missing link of this relationship, this interaction, between the minimum forces exerted and the forces the roof can withstand, is the subject of this document.

In order to gain that understanding, it's first necessary to have an appreciation for the critical aspects of roof build-ups. If the factors influencing roof access design are complex, then no less complex are the performance characteristics that a modern roof build-up must deliver while also keeping costs under control.



Fall Protection Visualizer

The opening section of this document looks at trends in roof design, and how those trends have begun to have unintended consequences for the provision of fall protection systems.

The focus then switches to fall protection systems themselves: the health and safety requirements behind them, the types of system and how they're fixed, and relevant standards.

With all that in mind, the final section then looks at some of the compatibility issues arising out of the roof design trends discussed and the challenges they pose when needing to incorporate a fall protection system.

By highlighting these compatibility issues, the aim is to give designers and specifiers the awareness they need to confidently allow for the inclusion of fall protection systems when making roof specification decisions - and ensure that both the roof and the fall protection can perform as needed once the building is in service.

Design trends in roofing

Performance requirement of roofs

A roof serves many more functions than simply providing shelter to building occupants. It plays a significant role in creating a safe and comfortable building for occupants - first and foremost through compliance with national building regulations, and then in contributing to any voluntary certification schemes such as BREEAM.

As the range of functions and uses to which a roof can be put has increased, so the design criteria for roofs have become more complex. Fundamental regulatory requirements that must be met include structural safety, resistance to moisture, fire safety, acoustic performance, effective drainage and thermal efficiency.

Thermal efficiency is just one part of a broader set of sustainability criteria that a roof can be designed to meet. Providing wildlife habitats, creating a sustainable drainage system or allowing for the installation of solar panels are other factors that might need to be considered.

Roofs generally require regular inspections and maintenance. Alongside that, roof spaces have also been adopted as areas for plant and equipment, which itself requires regular access for inspection and servicing.

This section looks in more detail at the inherent need to balance different performance demands, helping to put all of the various aspects of roof design into context before considering what fall protection systems are and how they are incorporated into roof build-ups.

Design trends in roofing

Optimising roofs

Performance and sustainability are, of course, key drivers in design and construction generally, as well for roofs specifically. Ever present alongside them, however, is cost.

Economic considerations remain a decisive factor in the acceptance of roof specifications, especially when resource availability and material shortages are a seemingly ever-present risk. Long-term thinking in the form of payback periods and lifetime costs still tends to take a back seat to getting upfront costs as low as possible.

Construction product manufacturers aim to design components that are lighter, thinner and/or quicker to install, promising to make specification easier and reduce obstacles for contractors installing them. The supply chain, meanwhile, looks to offer components as cheaply as possible, promising functional equivalence at lower prices.

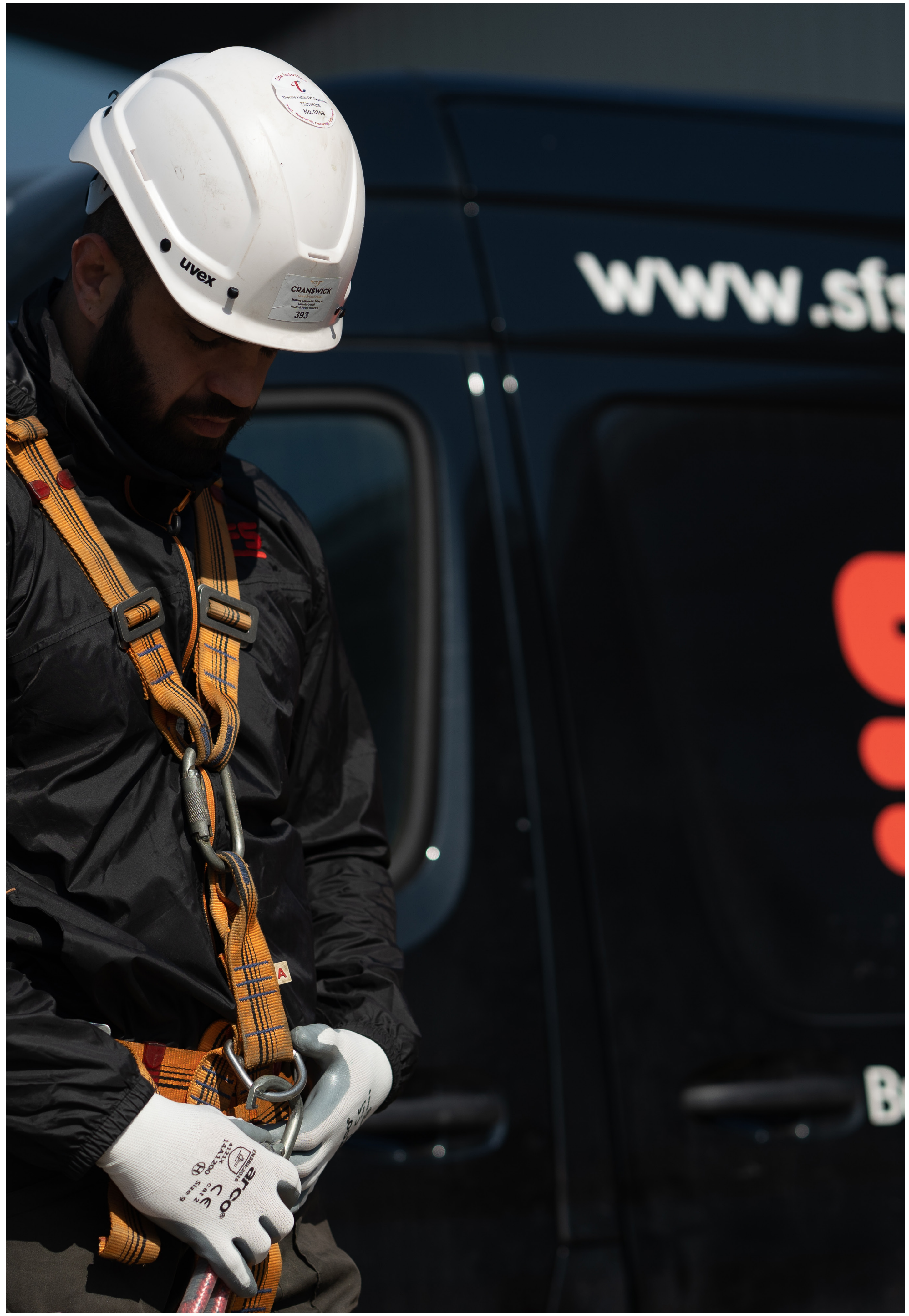
None of this is new, necessarily. But when thinking about trends, optimisation also feeds into matters of sustainable construction. Achieving the same levels of performance (be it structural, thermal, fire safety or something else) while using less raw material overall is desirable from a resource consumption point of view.

Examples of the kind of optimisation we're discussing here include the following:

- Changing concrete specifications to achieve thinner roof decks and use less material overall.
- Specifying hollowcore concrete planks with minimum concrete cover over the air voids in the centre of the panel.
- Seeking to reduce metal deck thickness from 0.7mm to 0.6mm, or even 0.5mm.
- Composite roof decks, such as those featuring a steel liner tray with concrete pour over, designed to achieve structural requirements while minimising volumes.

Optimising roof designs is an understandable and, in some respects, entirely necessary trend in roof design. Issues start to arise, though, when optimisation decisions are made without due consideration for the potential knock-on effects - such as the impact on specifying and installing fall protection systems.

It speaks to a limited understanding of both the minimum forces that a fall protection system might exert on a roof if called into action, and of the strength of the roof as designed. When the link between these two related aspects is not taken into account as part of design and specification, it can have consequences that we'll look at in more detail later in the document.



Design trends in roofing

Increased roof build–up depths

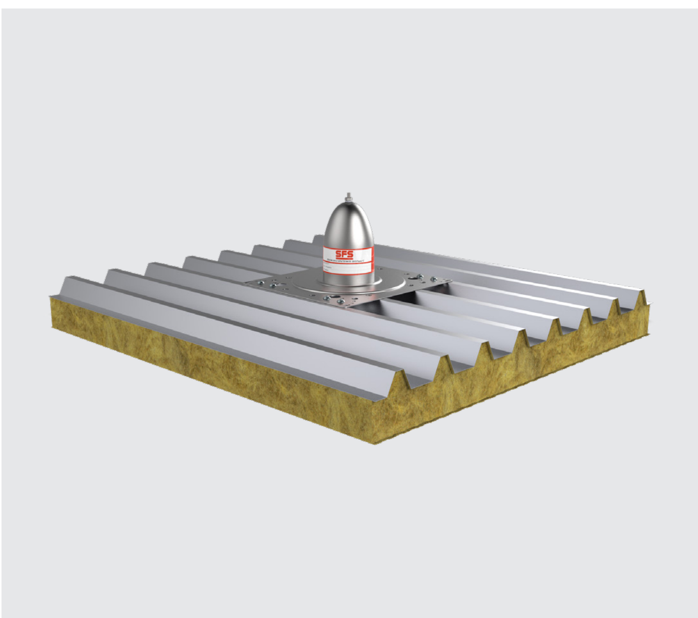
While roof decks are generally getting thinner and lighter, the range and depth of the build-ups and systems that they must support is increasing.

So far we have acknowledged that a roof design must balance all of the different performance criteria it's expected to meet. But the reality is that thermal performance often takes precedence over other requirements. Even if other requirements are not compromised in the process of accommodating the insulation thicknesses required to meet project U-values, the design tends to be led by thermal efficiency considerations.

Where thermal insulation is concerned, achieving lower U-values is a case of diminishing returns. That means it's necessary to add more and more insulation for smaller and smaller incremental gains.

Depending on the type of roof construction and the chosen insulation solution (e.g. PIR, XPS, EPS or stone mineral wool, among others), it could require upwards of 400mm of insulation to achieve a U-value as low as 0.10 W/m2K. Not all roof build-ups need to achieve a U-value that low, but it is an indication of what may be required.

It is becoming more common to see built-up metal roofs where the spacer system has a depth of 400mm.



The lateral load exerted due to a fall from the roof creates a cantilever effect on the fixing that makes it likely the roof could compromised at little over 9 kN. Remember that in the introduction to this document, we mentioned that many life line solutions exert forces of 10 kN or more on the roof structure.

For many roofs, thermal insulation is the thickest component of the system installed on the deck. However, an increasing number of roofs feature additional components and finishes that add to the overall depth. Some warm roofs feature ballast as a finish, while inverted flat roof constructions depend on ballast to help secure the insulation. For the latter, the ballast must achieve a minimum coverage to resist wind uplift. Access to a ballasted roof is required in order to check the ballast and ensure that it's providing the required coverage.

Green roof finishes can be installed over a waterproofed roof system, and can serve as the ballast to an inverted flat roof. The depth of a green roof finish varies depending on the type of planting and the growing medium required to support it. Some green roofs can be left to develop into a biodiverse habitat, but others require access for maintenance purposes.

Blue roof systems sit on top of a waterproofed roof. They feature a void former, in which rainwater can collect during periods of extreme weather. The flow of water from the system is attenuated, allowing the collected water to drain gradually and consistently over a maximum period of 24 hours.

The aim of a blue roof is to avoid storm drainage in urban environments being overwhelmed during heavy rainfall. Access to a blue roof is essential in order to inspect gulleys and generally ensure that the roof is performing as intended.

Design trends in roofing

Lack of detail in fall protection system specification

When roof design is led by a focus on certain performance requirements - and, as discussed, thermal efficiency in particular - **it can lead to other elements or components being forgotten or neglected.**

This is not necessarily intentional. But when a roof build-up has been finalised and the specification simply says something like, "Fall protection system by others", the designer is leaving it to somebody else to find a solution for the roof that has been designed. In some cases, that solution might not exist.

It is not always the case that a fall protection system is left for others to specify, whether through vague specification or complete omission.

In cases where a fall protection system is specified, it's not uncommon for a proprietary system to be named but in a way that is meant generically. Generic terms are 'roof safety system' or 'horizontal life line'. Stating anything else is either making a specification or naming a particular manufacturer.

When such a situation occurs, the specifier is asking that a fall protection system be included, but is unintentionally narrowing the choice. It is similar to someone saying a Hoover is required when they really mean that any suitable vacuum cleaner would be acceptable.

Where such a situation occurs, there is no guarantee that the manufacturer whose system has been named can offer a suitable solution, or that their best solution is the best one for the roof in question. The person responsible for sourcing the system may look for an equivalent, but if the named system is not the optimum choice for the project then nor is an equivalent selection likely to be.

Design trends in roofing

Summary

Designers and specifiers should be seeking a greater understanding of the forces that act on a roof if a fall protection system has to be relied upon. Before understanding those forces, however, it's necessary to look at the broader picture of roof design and fall protection specification.

Roof structures are generally getting thinner and lighter, while the depth of roof systems installed on those structures is increasing. The biggest driver of this increase is thermal performance, and the thickness of insulation required to achieve necessary U-values.

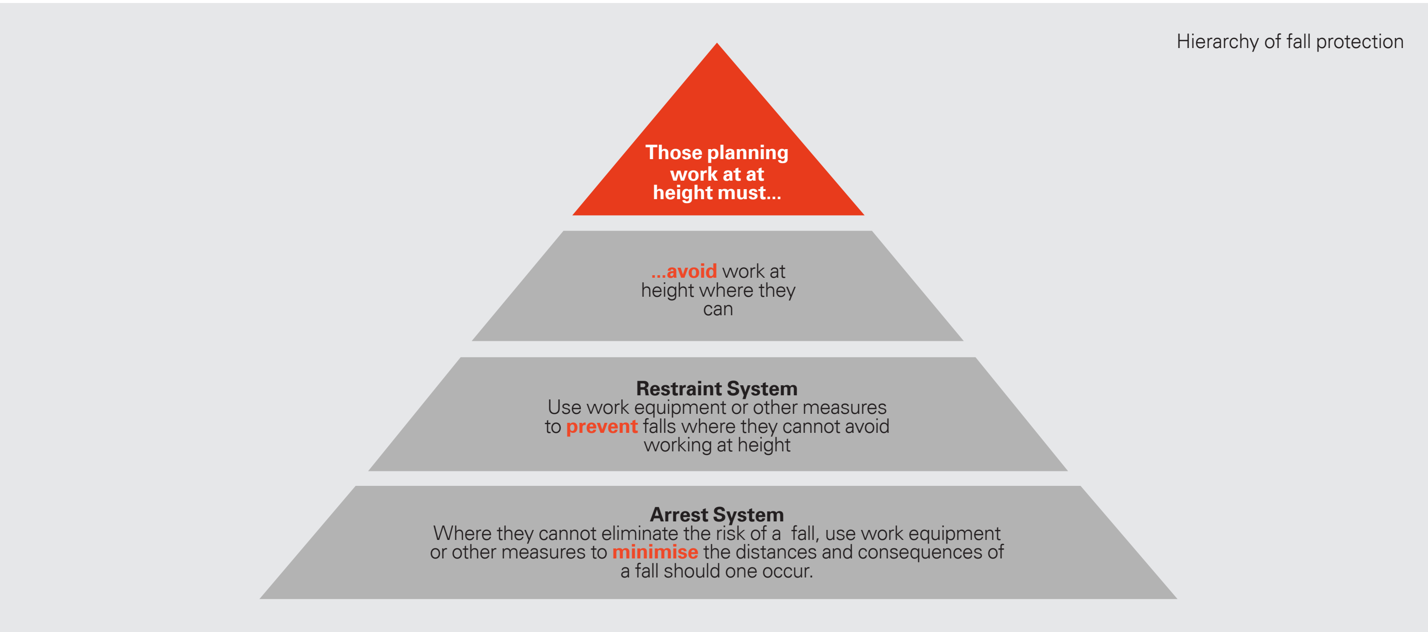
There is also the issue of whether fall protection systems are being specified with the roof design in mind - and, in some cases, whether they are being specified at all. To ensure the best outcomes, roof design and fall protection system specification need to go hand-in-hand. Leaving fall protection for others to deal with risks compromising the ability of the roof to achieve all of its performance goals.

Information about application testing of fall protection systems should be available to customers, although only a draft standard currently exists. The market leading fall protection system manufacturer has promoted an acceptance of only product-based testing standards, which they have acknowledged has created a problem.

We'll look at this issue, together with an overview of fall protection, in the next section, before concluding with a look at the possible consequences of the design trends discussed in this section.

Fall protection systems – an overview

Hierarchy of fall protection



Health and safety protocols for roof access and working at height are based on a clear hierarchy, defined by Regulation 6 of the Work at Height Regulations.

First and foremost, work at height should be avoided wherever possible.

If working at height cannot be avoided then work equipment or other measures should prevent the risk of a fall occurring. A system can only be classed as a restraint system when there is no possibility of a fall.

Where there is potential for a fall, the system is classed as an arrest system. Rather than preventing a fall, the equipment or other measures are designed to minimise the distances and consequences of a fall, should one occur.

All systems must be capable of arresting a fall under the definitions of ‘foreseeable misuse’ given in EN 795:2012 (for single user systems) and CEN/TS 16415:2013 (for multi-user systems). However, it is best practice to keep a user in restraint to prevent any possibility of a fall occurring. Restraint systems should be the preferred option, with arrest options offered only as a last resort.

System designers should be competent and always follow this hierarchy of fall protection. When considering a safe system design, the designer must understand the requirements of the user and the need for roof access. The safest method should be prioritised, without the prejudice of a cost saving.

Safe work at height is implemented long before anybody can actually get on a roof, through proper implementation of the Construction Design and Management (CDM) regulations. Building designers and specifiers should be actively looking to eliminate or minimise working at height risks from the outset of a project. When it finally becomes necessary to design a fall protection system as part of the works, the system designer is hopefully building upon the good planning of the Principal Designer.

More information on safe system design - including different design considerations, the range of components that make up the system, and fall clearances - is available in the SFS Fall Protection Application Guide →.

Fall protection systems – an overview

System types and terminology

There are two broad categories for fall protection options: collective or personal. As the names suggest, the former is designed to provide general protection, while the latter is focused on each individual user of a system.


Personal fall protection


Collective fall protection

For multiple people, collective fall protection is typically centred on restraint solutions, such as providing guardrails around the building edge or fragile roof areas, or installing covers over rooflights to prevent people from falling through them.

While there are collective fall arrest options available, collective fall protection is generally characterised by creating a solution that needs to cover every eventuality. It is an acknowledgement that roof access is necessary and possibly frequent, and possibly by a wide range of users all with different knowledge and understanding of the risks of being on a roof.

Collective solutions tend to be preferred on older, flat roofed buildings, where the nature of the existing roof construction imposes restrictions on the retrofitting of a new fall protection system. Another consideration is that, above a certain threshold height, collective fall protection is not recommended - leaving personal fall protection as the only option.

The most popular form of **personal fall protection** is flexible safety lines. As per EN 795:2012, personal fall protection can provide both restraint and arrest within the same system - it is the needs of the individual roof that determines whether arrest forms part of the solution.

Personal solutions can include rail fix solutions instead of flexible lines, but these have limitations including transportation to site, handling, lack of flexibility when multiple users are operating on the system, and the need to form corners and profiles on site.

For the avoidance of doubt, this document is centred on personal fall protection and flexible safety lines (also known as horizontal lifelines). Having covered the hierarchy of fall protection at the start of this section, we can consider what restraint and arrest means in terms of flexible line solutions.

Fall restraint
The safety line dictates and guides the user’s path, restricting what they can access and thereby keeping them away from possible falls.

The typical setback from the roof edge, fragile area or other fall risk is 2.3m, based on a lanyard length of 2m. Training for users is minimal, and appropriate planning and design of the system should minimise the need for a rescue plan. This, combined with the restriction on the user’s movement, is what makes safety lines such a popular solution, compared to the limitations of a rail fix system.

The system design must take into account the possibility of varying distances, with the shortest necessary line length preferred before considering variable or multiple lanyards.

Fall arrest
Should a fall occur, the post fixed to the roof, and to which the safety line is attached, can be subjected to extreme forces, depending on the fall factor. As a result, systems designed to provide arrest must be backed up by published calculations that are applicable to the roof substrate.

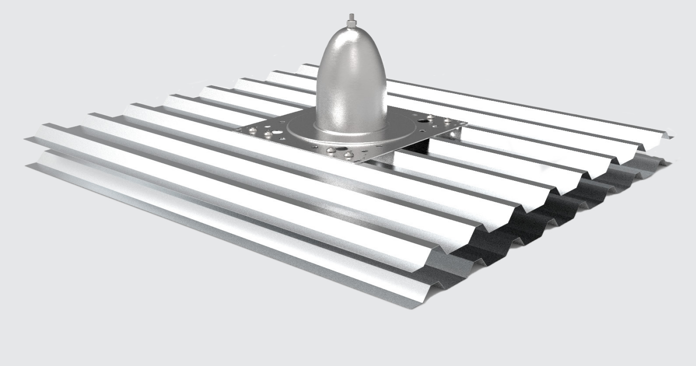
Where a system is designed to provide fall arrest, specialist user training is required, with a potential requirement for additional personal protective equipment (PPE) as well. A rescue plan is required in the event that a fall occurs, which is something that is often overlooked when considering system design.

Fall protection systems – an overview

Fixing flexible safety line systems

A typical flexible safety line comprises a series of post modules which are secured to the roof by a base plate. The type of fixing depends on the nature of the roof build-up. To help with identifying the right system for the right roof structure SFS has created a Fall Protection Visualizer tool →.

On a **metal roof/sandwich panel** structure, the base plate is fixed by rivets to the crown of the panels. This is a relatively speedy method of fixing and allows solutions to be installed quickly on large roofs with significant system lengths.



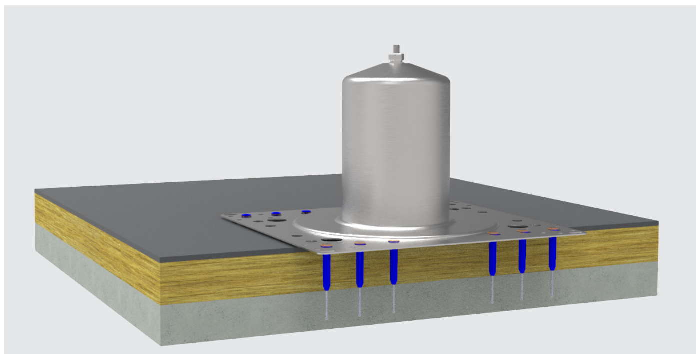
Base plate fixed to twin skin metal roof by rivets

Built-up on site (BUOS) roof constructions feature a metal deck, sub-frame structure and outer metal cover profile. Sub-frame heights are increasing to meet thermal performance requirements, requiring longer fixings to secure the system to the metal deck.

There are three main types of deck for **flat roof** build-ups: concrete, metal and timber. Composite deck constructions, featuring a steel liner tray with concrete cover (mentioned in the first section of this document), are also available. The base plate fixings, which vary depending on the deck, must penetrate the complete roof system (waterproofing, insulation, and air and vapour control layer) to achieve a secure fixing into the structural deck.

Aside from adequately securing the fall protection system to the roof, the challenge with flat roof fixings is three-fold:

- Limit the risk of water ingress from external sources.
- Limit the risk of interstitial condensation due to moisture vapour passing into the roof system from the interior, particularly where fasteners penetrate the deck.
- Limit the potential of thermal bridging, and therefore excess heat loss, through the insulation layer.



Base plate fixed to flat roof concrete deck by sleeve and fasteners

The overall aim, therefore, is to keep penetration of the flat roof deck to a minimum.

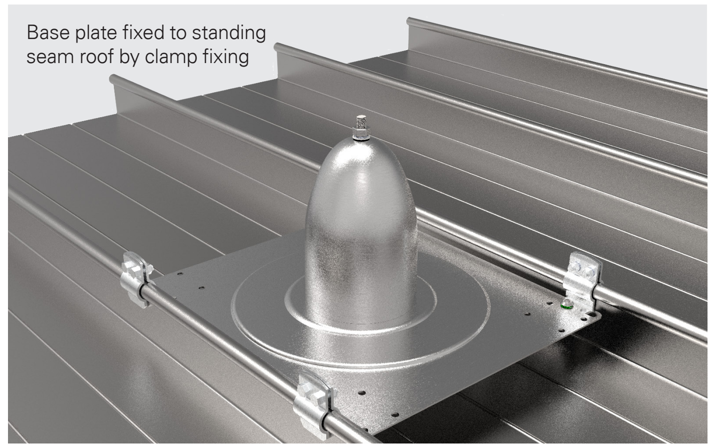
Fall protection systems – an overview

Fixing flexible safety line systems

The overall aim, therefore, is to keep penetration of the flat roof deck to a minimum.

For **standing seam roofs**, penetration of the outer metal skin has to be avoided. This rules out the use of rivets, and so a clamp fixing is used instead. Because standing seam roofs don't have the same mechanical strength as other mechanically fixed roof systems, they cannot sustain the same loads. So where the performance of a fall protection system cannot be established via application based testing, there should be a degree of scepticism about whether the two systems are compatible

This is only a brief summary of roof types and some of the fixing considerations for fall protection systems. A key to successful fall protection specification is to engage on the issue from an early stage of the project, speaking to a manufacturer and understanding how different roof design options might impact on the eventual system specification.



Base plate fixed to standing seam roof by clamp fixing

Early engagement should help to ensure the compatibility between roof structure and fall protection system that is so crucial to a successful installation. A fall protection system is considered primarily for its ability to save a life, but it must also protect the roof structure when a fall exerts a force back onto it. Without this protection, the solution can be viewed only as incompatible.

Fall protection systems – an overview

Standards and testing

An important aspect of engaging with a manufacturer is understanding the scope of testing that they carry out on their **systems** and being confident that potential solutions meet relevant standards.

EN 795:2012 Personal fall protection. Anchor devices is a European Standard that specifies performance requirements and test methods for single-use anchor devices. It is this standard that requires anchor devices intended for restraint to also be capable of arresting a fall in the event of **'foreseeable misuse'**.

However, as EN 795:2012 is a product-based standard (rather than an application-based one, which we'll discuss shortly), it is possible to meet its foreseeable misuse requirements even if the roof type/application will actually struggle to handle the forces that a fall would exert on the structure. This introduces a level of risk that many specifiers will not be aware of when they believe they are specifying a compliant fall protection system.

A separate technical specification, CEN TS 16415:2013, recognises that horizontal lifelines often need to accommodate more than one user. It sets out that anchor devices complying with EN 795:2012 must be tested to simulate a minimum of two users falling simultaneously.

A standard that is currently drafted but not yet formally published is **prEN 17235:2018 Permanent anchor devices and safety hooks**. It requires fall protection manufacturers to test their systems as part of complete roof applications, and measure the performance achieved with each construction type. The current lack of adoption of the draft standard is a challenge for the fall protection industry. By 2023, it is expected that EN 795 will be updated to remove permanently attached solutions from its scope.

This will represent an even greater challenge for specifiers looking to understand how a fall protection system integrates with different roof construction types. Some manufacturers are already working to the draft standard because it increases the amount of information available and the amount of confidence in how a fall protection system will behave should it be called upon to arrest a fall.

Without the formal publication of this draft standard, the industry will be faced with having **no test standard** for permanently attached anchor devices.

Unintended consequences of roof design trends

For the specification and installation of fall protection systems

Protecting lives and protecting the roof system
Early lifeline systems, produced in the 1980s, were labour intensive and costly to install. Due to the way they attached to the building structure, significant weatherproofing was required. Over time, that weatherproofing inevitably broke down, so frequent maintenance was also required.

The first post designs featured no shock absorbing elements. The roof bore the brunt of any fall, usually resulting in significant damage to the roof.

In the 2000s, roof anchors featuring shock absorbing elements were introduced. The shock absorbing element reduced the loads imposed on the base plate fixings/fasteners in the event of a fall. In turn, the potential for damage to the roof finish, or even the roof structure, was also reduced.

You can read more about the development of lifeline systems in the SFS Fall Protection Systems brochure →.

A lifeline system on its own does not save the life of a roof operative who suffers a fall. The PPE worn by the operative is essential to avoiding injury or loss of life. Of course, one does not work without the other, but the point is that a lifeline system is not just ensuring health and safety.

It is also protecting the roof build-up from damage, allowing the building to continue functioning normally. A damaged roof risks weather ingress, or compromises the performance of other components in the build-up, potentially leading to other long-term failures of the roof that could compromise safety or the integrity of the building fabric in their own way.

The trends outlined at the start of this document are again changing the relationship between the roof and the lifeline system anchors.

Unintended consequences of roof design trends

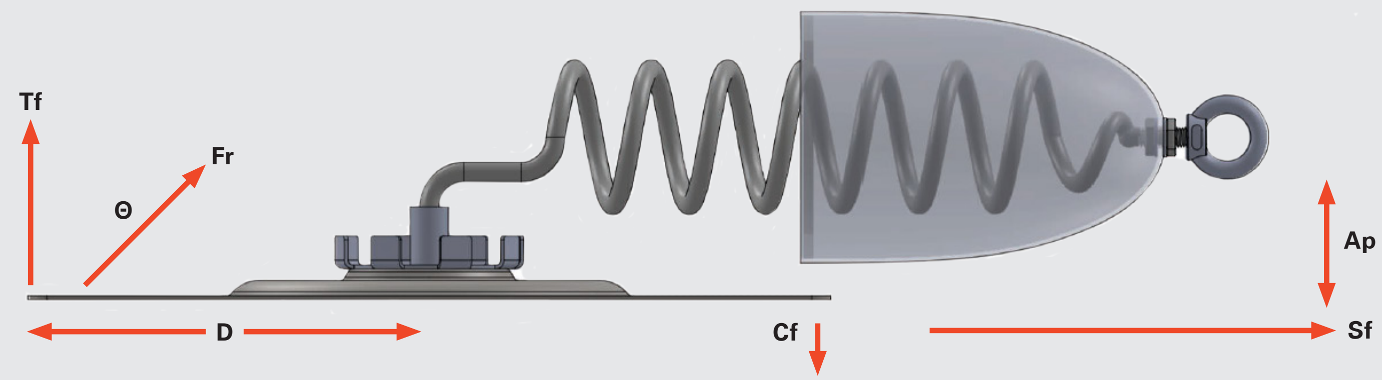
For the specification and installation of fall protection systems

Limitations of roof design and fixing method
We started by looking at some of the ways in which roof structures are being optimised to make them cheaper and/or less resource-intensive. One of the unintended consequences of this drive for efficiency is that it becomes harder to secure roof anchors to the deck or structure.

Where metal decks are made thinner, or the strength of concrete is reduced, the deck is not able to support as much load. Since the loads imposed by a fall from height are transferred to the fixings, the effectiveness of the fall protection system is reduced.

At the same time, the increasing depth of roof build-ups adds further complication to the equation. Longer fixings become necessary, creating a cantilever that cannot tolerate as much load being imposed on it.

When the aim of the fall protection system design is to reduce the forces that act back to the roof, reducing the system's capacity to bear loads through the roof design is detrimental and risks compromising the roof in the event of a fall occurring.



Ap = 50 mm
Wl = 6kN peak working load
Cf = compressive force on the fastenings
Θ = resultant angle
D = distance between centre of base plate and furthest fixing
Tf = tensile force on the fixings
Sf = shear force
Fr = resultant force

Where a hollowcore concrete deck is specified and a fixing penetrates the concrete over one of the air voids, the fixing tends to 'blow through' the already thin layer of concrete. There is a loss of material around the bottom of the fixing, effectively making the depth of concrete even thinner, and providing even less support to the fixing.

Along similar lines, concrete-poured steel liner trays can feature as little as 60mm of concrete. To avoid penetrating the liner tray it is necessary to use shorter fixings, which again reduces the overall load the fixing can bear.

Unintended consequences of roof design trends

For the specification and installation of fall protection systems

The need for a compatibility standard
With that in mind, it is more important than ever to understand how a fall protection system interacts with a specific roof type/structure.

EN 795:2012 is a product standard. Any manufacturer of fall protection anchors can pass it, but the results of testing to the standard say nothing about compatibility between the anchor and a specific roof construction.

Nor is it a harmonised standard, meaning manufacturers cannot affix a CE mark to their products that comply with it.

The draft standard **prEN 17235:2018** seeks to address both of these issues. Testing to this standard takes into account the roof application rather than the product alone, and manufacturers would be able to use the CE mark to demonstrate conformity.

Conclusion

Every single roof is different in its combination of performance characteristics and therefore roof design requirements. As a result, there are countless combinations of structural design, roof build-up and finish, and fall protection system.

This document cannot say what fall protection system you should specify if you have one scenario, or what alternative solution would be appropriate if you chose to adopt another scenario instead. What it can do is raise awareness of the issues surrounding fall protections systems and how they interact with roof build-ups.

Compromising health and safety is not an option when roof access is unavoidable. If the nature of a project means that a certain insulation thickness is required and a certain fall protection system is necessary, then the roof deck has to be able to support that system.

At the same time, fall protection systems must also be capable of protecting the roof. The system might be seen as a solution for saving a life, but if it cannot protect the roof as well then the solution has to be seen as incompatible.

People want to use less concrete or thinner metal decks, and we support those aims generally. But we have also started to see evidence that people are aware of some of the potential consequences of that decision-making. Structural Engineers are often asking about fixing choices and the load-bearing capability. To aid responsible specification, therefore, we feel that discussion needs to be brought to a wider audience. With wider awareness comes greater confidence to seek technical back-up fro tection manufacturers.

Specifiers can and should question manufacturers to ensure a full understanding of the issue, and to obtain evidence that the fall protection system will work in conjunction with the proposed roof construction. And by evidence, we mean adequate test reports that detail the roof build-up and give the result of performance testing.

Leaning on EN 795:2012 alone is **not enough**, and does not give the security of knowing that your roof design can accommodate the right fall protection system to meet the access needs.

About SFS Fall Protection systems

Since its launch SFS has evolved its fall protection system by developing an extensive knowledge of fastener solutions for roofing. The range of applications extends to industrial pitched metal roofs, built-up flat roofs, and vertical and overhead applications.

SOTER® II is an optimum shock absorbing element and base-plate that features load-limiting technology. While many life line solutions allow forces of 10 kN or more to be exerted on the roof structure, SOTER® II is engineered to reduce deployment loads to the roof structure, keeping the force exerted to below 6 kN.

In addition, the post is modular, allowing it to be removed after deployment without disturbing the roof make-up.

The system is manufactured using stainless steel and typically features 60% recycled content. It delivers a durable and low maintenance solution that is fully recyclable at the end of its life.

Find out more →.

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