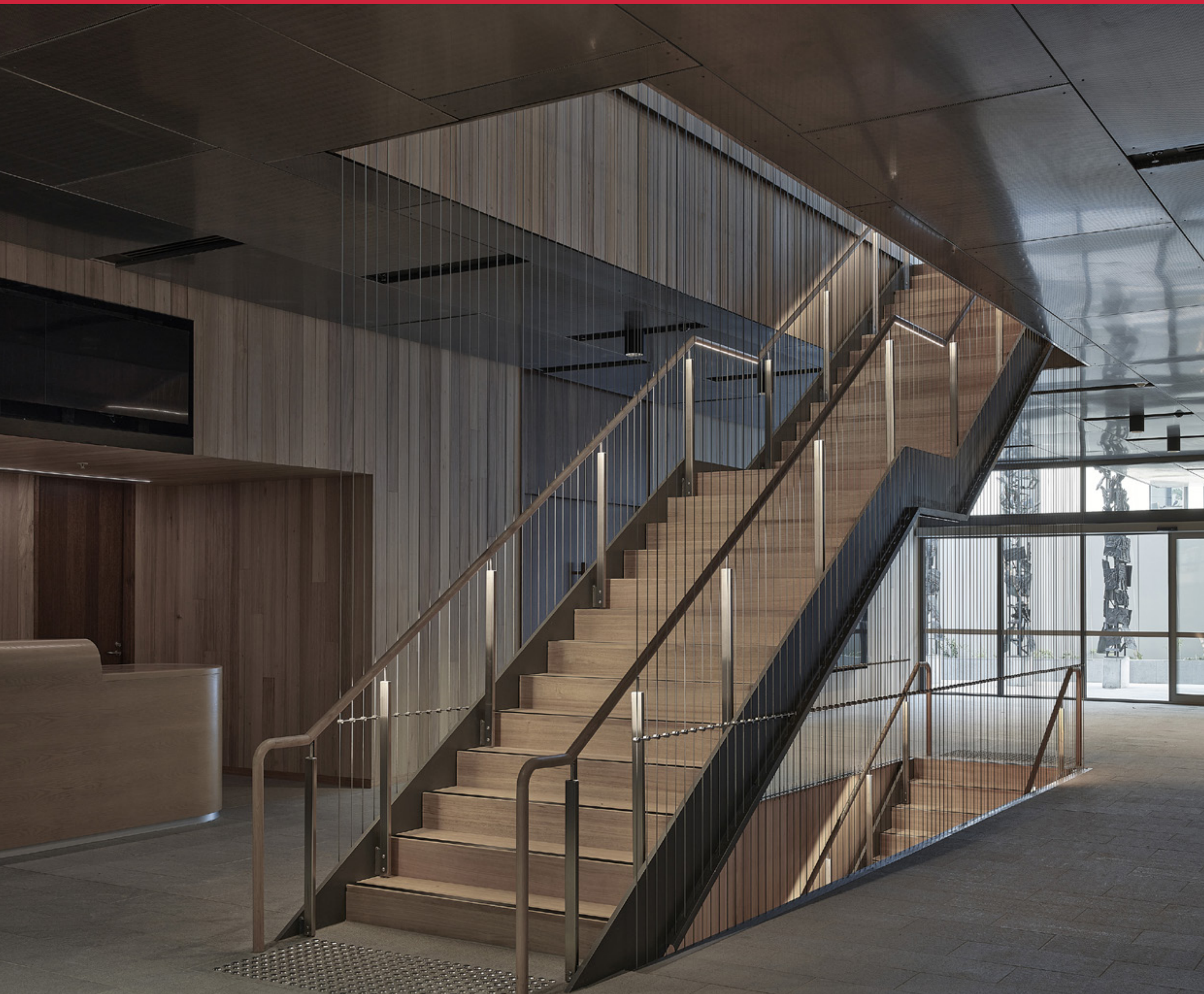
Vertical Cable Safety Barriers

PRINCIPLES FOR GOOD DESIGN



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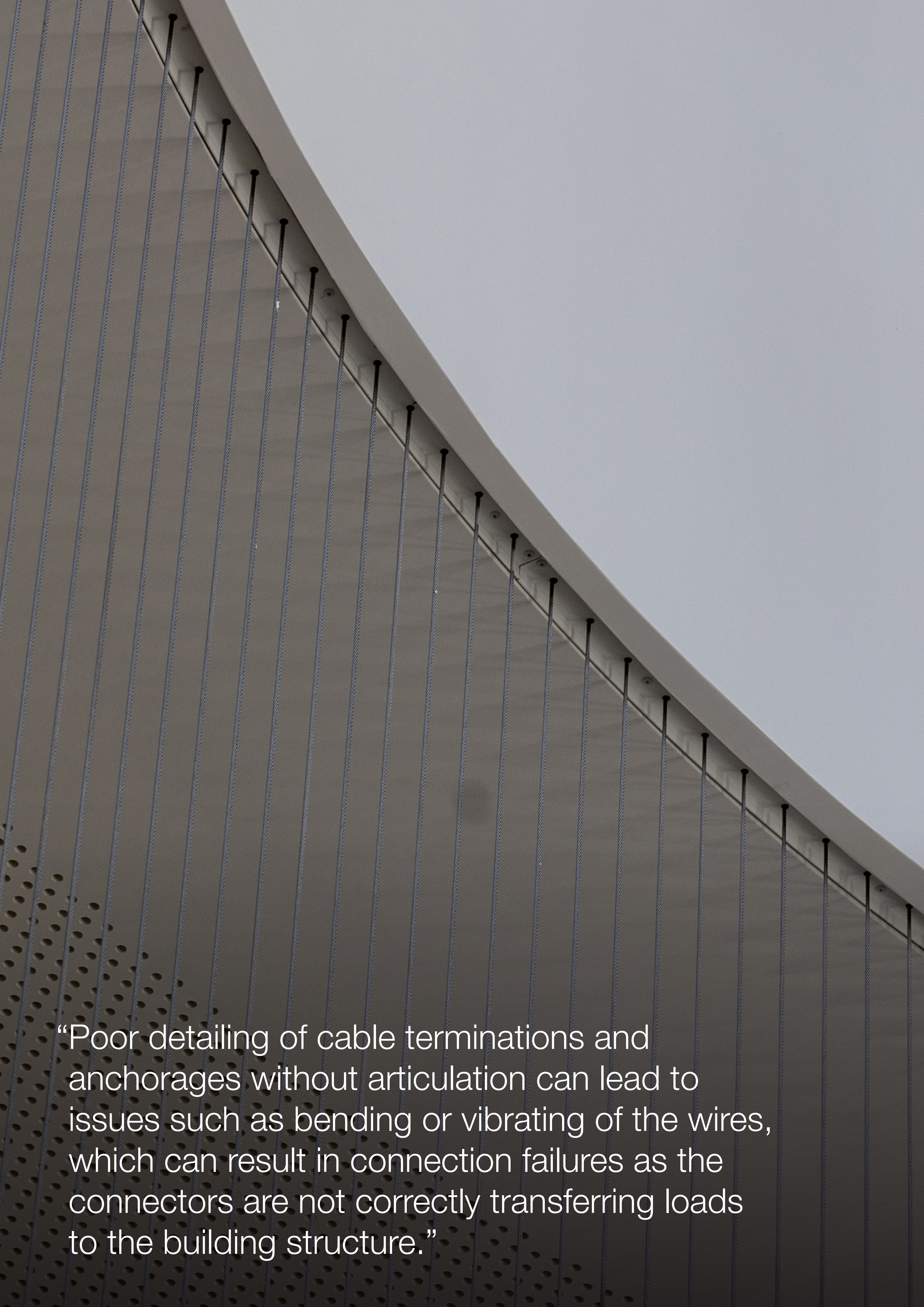

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Introduction

A barrier made of tensioned, vertical stainless-steel cables offers a bold yet minimalist solution for enclosing an atrium, void, balcony, stair, or other elevated space. A vertical cable safety barrier of this kind offers maximum transparency, space utilisation and protection from falls, which has made it an increasingly popular solution for modern commercial spaces.

The primary concern when putting in vertical cable barriers for the upper levels of any building is safety to avoid falls and other accidents. While the National Construction Code (NCC) provides some guidance on the design of safety barriers through the balustrade “deemed to satisfy” conditions, it does not provide the full picture, leaving the specification of components like cable connections to structural engineers.

The design of tensioned stainless-steel cable barriers is a specialist field, and it requires experience and technical knowledge to understand how the cables themselves should be designed to mate effectively with and transfer the cable loads to the building structure. Without the right experience, specifications may be created that result in tensioned cable barriers that may not meet the required design life of the building and could fail when they see a load event at the design capacity.

Barriers that are designed and installed without full consideration of factors like cable behaviour, the importance of connections, and so on can be problematic. Depending on the application, the consequences can render a barrier non-compliant or create a space that is unsafe for users. A barrier could even be deemed compliant without meeting good design principles, meaning it may not perform as expected over its service life.

In this whitepaper, we discuss the proper design and specification of vertical floor-to-ceiling cable safety barriers, with a special focus on the importance of articulated cable end fittings.

Articulated vs. non-articulated connections

A vertical cable barrier consists of a series of tensioned cables connected to the floor and ceiling, serving as a guard to eliminate the risk of a person falling from the edge of a raised floor level. The system relies on the tension and spacing of the cables to limit cable deflection and prevent a person or object from falling through the barrier. Each cable will have independent connections to an anchor at both ends.

End connections are critical to cable life and integrity of the barrier. Articulated connections accommodate movements in the cable system, reducing or eliminating bending at the cable attachment point. Poor detailing of cable terminations and anchorages without articulation can lead to issues such as bending or vibrating of the wires, which can result in connection failures as the connectors are not correctly transferring loads to the building structure.

If non-articulating cable end fittings are to be employed, all project stakeholders must be aware of their limitations and prepare adequately for their use. Once installed, barrier cables that do not articulate at the connections must be regularly and vigilantly inspected for any bending. While a bent cable end termination may still be secured at the base, it has failed and would not satisfy NCC verification tests, potentially allowing for the penetration of the barrier.

Designers and project stakeholders must recognise this risk and plan for a regular cable maintenance and inspection program that is pro-active and involves the immediate replacement of any bent cables. These costs should be considered in the life cycle of the barrier.

Other common issues with cable barriers

A designer's inexperience with cable behavior and performance can often lead to cable failures. This goes hand-in-hand with a lack of understanding as to what causes cable bending of the terminations and how that can lead to failure. It only takes one failed cable to render an entire barrier structure non-compliant.

The practice of cutting costs by allowing sub-contractors and builders to attempt to manufacture cables themselves without the required machinery and dies that are essential to achieve the required performance is another issue. Fabricators often fail to appreciate the importance of the "swaging process" (pressing end fittings onto the wire) to ensure cables achieve their design loads and often ignore the manufacturer's guidance when it comes to cable manufacture.

Another common mistake is improper consideration of environmental conditions and incorrect selection of material grades. The use of materials that are not fit to withstand the environmental conditions of the installation site or dissimilar metals without proper isolation will increase the likelihood of corrosion and eventual failure of the system. Additionally, poor maintenance can also contribute to degradation and compromise the integrity of the system.

There is help available – where to find design guidance

When designing and constructing a vertical cable barrier system, it is not enough to check that the cable complies with the NCC. If a designer solely relies on the NCC verification procedures and uses cheap end fittings with non-articulating connections that bend under design loads, the integrity of cables may be compromised and vulnerable to premature failure. The designer must also refer to the relevant international codes and standards, listed below, to create a barrier that will be successful and compliant for years to come.

The relevant NCC "Deemed to Satisfy" (DtS) provisions that set out design requirements for wire balustrades are also applicable for vertical cable barriers and are a good starting point. Take, for example, the DtS provisions in Part 11.3.6 of the ABCB Housing Provisions, "Construction of Wire Barriers", which detail the requirements of cables for barriers in terms of wire diameter, construction, spacings, wire tensions and permissible deflections, but importantly, only where cables are less than 2500 mm in length.

Where cables (vertical or horizontal) exceed 2500 mm in length, the DtS provisions do not apply. In this instance, the cables need to be individually engineered using first principles and, in some instances, verified with applicable cone testing to ensure they remain within permissible cable deflection limits for barrier compliance. If cable deflections exceed limits, tensions can be increased, but this risks the imposition of significant loads on slabs and soffits at the cable ends. The introduction of horizontal rods or cables at balustrade height clamps vertical cables in position without excessive additional cable loads on mating structures.

There is no Australian standard that may be used to define vertical cable barriers in the design of lightweight tensioned structures or cable structures. For further guidance and good practice, we can turn to Eurocode 3 Part 1-11: Design of Structures with Tension Components, or to ASCE19-16 Structural Applications of Steel Cables for Buildings, which require designers to consider and design for the loads imposed at the cable end, among other criteria.

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Applying Eurocode 3 Part 1-11 and ASCE19-16

Eurocode 3 Part 1-11 and ASCE19-16 offer guidance on how cables should be connected to ensure that bending and fatigue, two issues leading to cable failures, are reduced at the cable connections. These codes and standards require that swaged end fittings be used to ensure that no systematic bending occurs at these connections, something ignored by many in the industry on the basis of cost.

The codes say that tension components in cables should comply with the following criteria:

- strength and ductility of the cable system and its terminations;
- fatigue resistance due to axial load fluctuation, bending stresses, angular deviations caused by catenary effects, wind forces and erection imperfections;
- stable condition of axial stiffness of the cable system by guaranteed pre-stretching; and
- protection of cable and anchorages against corrosion; and
- resistance to fretting at any contact between steel parts.

In practice, not all these are relevant to cable barriers, but good practice suggests that designers should be aware of these and understand if any of these criteria are applicable to cable barriers.

Of more specific relevance to cables used in barriers, the codes also say that the terminations and anchorages of tensioned cables should be designed such that:

- the ultimate resistance of the tension component would be reached before any yielding or other permanent deformation of the anchoring or any bearing elements would occur (this advice is very relevant to cable barriers as any individual cable or connection must be able to meet the design load and resist any permanent deformation or bending as a consequence of a load event, such as somebody falling against a cable);
- sufficient articulation is provided in the anchorage to allow unrestricted movement of the cable under load and to cater for manufacturing and erection imperfections (this is also very relevant for cable barriers ensuring the minimisation of bending under the applied load above);
- their fatigue resistance exceeds that of the components;
- facilities for adjustment of the component length are provided to meet the requirements for preload, geometrical tolerances, and so on; and
- the tension components can be replaced.

Cable behaviour and performance

The installed cables may be compliant with the size and spacing requirements of the NCC, and the structure certified to the relevant sections of AS1170.1 governing barrier design, but the cables could still be lacking in terms of performance and durability if they are not specified with the application and installation context in mind.

In selecting the right structural cable, it is important to determine the specific requirements of the application and to match these with the properties of the cable that will perform best. Ensuring the specified cable has the appropriate yield and ultimate strength characteristics is an obvious starting point. Vertical cable barriers require cables of minimal stretch and maximum stiffness to resist cable deflection and the passage of objects through the cables under lateral loads. A good specification will have considered cable construction (such as 1x19 strand) and selected the appropriate construction to match the application.

Articulated connection options

The ability of the vertical barrier cable to move freely under load is most critical at the bottom of the cable (balustrade height and below), where people can make contact with feet or have hands pushing and applying lateral loads that force cables to move. If a cable receives a decent enough blow (i.e., point load on a single cable) and there is no provision for it to move freely, then the fitting can bend, potentially beyond its plastic limits. It then stays bent, has effectively failed, and therefore must be replaced.

To prevent bending and fatigue when a point load is applied, cable end connectors must be able to articulate and offer rotational freedom. Ronstan, a global leader in tensile cable structures, offers all the articulating options below, enabling the vertical barrier cable to move freely under load.

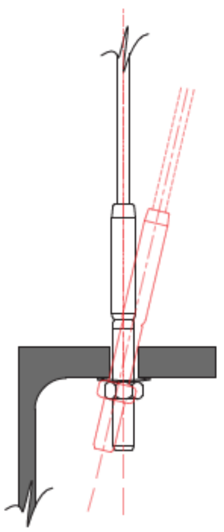

Figure A. Belleville Washer

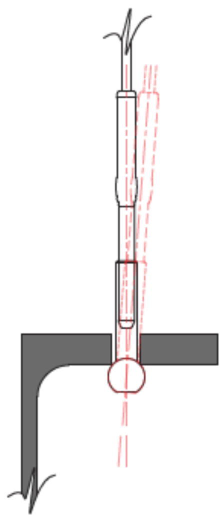

Figure B. Ball Fittings

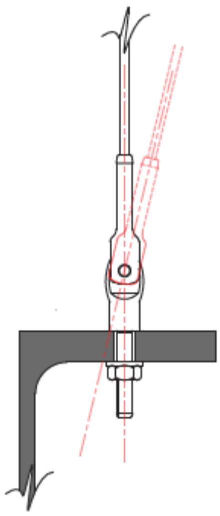

Figure C. Pinned Connections

Life cycle and maintenance

A thorough consideration of the needs of the cables and components used in vertical cable barriers and use of articulated connections will ensure cable performance and longevity. Where deemed appropriate, and under no circumstances should cost be the driving factor, non-articulating connections can be used. However, this can occur only where there is broad acknowledgement across all project stakeholders, designer, builder and client, that in the event a cable end connection does bend, it is understood that the cable has failed and requires immediate replacement.

In the event a design team chooses this option, a full maintenance, inspection and cable replacement program must be considered as a life cycle cost up front. It should be recognised that these cable defects are often very difficult to spot, and cables are challenging to replace given that their fittings are usually concealed and mostly at height.

About Ronstan Tensile Architecture

Ronstan has been setting the standard for tensile cable structures since 1988. As a world-leading cable manufacturer, designer and builder of cable structures, Ronstan understands how cables stretch and can define the loads and forces in the cable system, keeping the barrier solution buildable and compliant through common sense and practical design suggestions.

Structural designs reflect consideration of all cable needs and standards in addition to simply meeting NCC and Australian standards like AS 1170.1. This meticulous design is combined with Ronstan's proven tensile cable products, such as ACS3 stainless steel vertical cables and Carl Stahl I-SYS®, to help designers create lasting and beautiful cable barrier solutions.

All information provided correct as of November 2023

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