CODE OF PRACTICE COP 22/2002

Wire rope suspension systems

A code of practice for services installers

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Supported by

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Wire rope suspension is increasingly being used for mounting building services components in commercial, public sector and industrial buildings. There are major advantages of flexible positioning and installation productivity benefits compared to traditional systems that have been highlighted in BSRIA reports[1]. To help ensure that wire rope suspension systems are being appropriately specified, installed and maintained such that long-term safety is guaranteed, BSRIA has produced this Code of Practice. This covers the selection, specification, installation, commissioning and subsequent inspection and testing of fixings and suspensions systems. As well as the Code of Practice, a training presentation for installers has been produced on CD. This illustrates examples of correct installation and commissioning procedures and was produced in conjunction with manufacturers.

1.1 BACKGROUND

Building services – both in terms of plant items and distribution systems such as pipework, ductwork and cabling – are currently positioned within buildings using a range of methods and materials. The majority of services are suspended from above using support systems comprising three major components; the fixing which is attached to the building structure, the suspension element itself, (the length of which can be adjusted to position the service at the right height), and the attachment or sling that is attached to or around the service.

Traditionally the suspension element has been a rigid component, usually threaded rod. While this is usually in tension, it also provides some resistance to compressive forces, helping to ensure the rigidity of an installation. Wire rope suspension elements are only strong when under tension and provide no resistance to compressive or bending loads, although careful design (for example setting wires at angles) can usually provide suitable restraint. In addition, most threaded rod systems (fixings, threaded rod and associated fittings) are significantly over specified for most applications, allowing considerable freedom of installation methods. Wire rope systems tend to be more closely specified against the design load and could be overstressed if incorrectly installed. However the time taken for installation is dramatically reduced compared to that for threaded rods, significantly reducing installation costs.

The other significant difference is that where threaded rods are usually mounted vertically, wire rope systems can easily be installed at an angle. This significantly increases the range of suspension points that can be used. However it has other effects, such as an increased load on fixings, which must be accounted for in the design (see Section 2.3).

1.2 SCOPE

Wire rope suspension can be used to support a very wide range of loads and objects. This publication deals with applications within the following criteria:

- Internal or semi-internal applications (not external)
- metal wire rope suspension (not rods or plastic ropes)
- moderate loadings (up to 1 tonne working load per suspension point)
- static fixed length permanent or semi-permanent suspension (no lifting).

Almost any piece of building services equipment could be suspended using wire ropes, such as:

- Fan coils and air handling units
- radiant heating and cooling emitters (radiant tubes, radiant panels, chilled beams)
- cable trays
- ceiling grids
- luminaires and lighting systems
- ductwork
- trunking
- busbars
- pipework
- large signs and indicator displays
- decorative objects.

2.1 THE DESIGN PROCESS

The steps in a typical design process are shown below. Not all the steps will be formally laid down on paper for all installations, but most of these issues will have to be considered at least informally at some stage, possibly by the installer:

- **Objectives and Specification:** What needs to be suspended and where?
- **Constraints:** Gather information on loads and design constraints (such as corrosive atmosphere, fire rating requirements, type of building structure).
- **Select the suspension system:** Not necessarily wire ropes.
- **Select configuration type:** Choose spacing and positions of suspension assemblies.
- **Select safety margins and redundancy limits:** Decide on appropriate safety factors.
- **Select system components:** Choose suitable components.
- **Risk assessment and design review:** Assess the hazards posed by the suspended load and the risk to those nearby. Check that the finished design meets the objectives, and amend if necessary.
- **Proceed with the project**.

Some of these steps may need to be reviewed more than once as the design progresses.

2.2 OBJECTIVES AND CONSTRAINTS

Before the design of a suspension system commences, the suspension requirements - and the constraints imposed by the building structure and operating environment - need to be understood by the designer.

Information about the suspended load will be required. For a simple run of services, all that may be needed is the weight per metre and any limits on maximum support spacings. For complex items of plant, the dimensions, weight, centre of gravity, and suspension attachment points may need to be known.

Consideration should be given to the kind of loads that may be applied to the suspension system. Although most loads in building services applications are static, some equipment may create brief dynamic loads, especially during start-up. Pipework, for example, can undergo a shock loading when pumps are suddenly started or stopped.

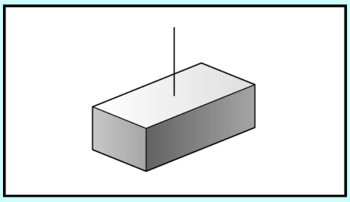
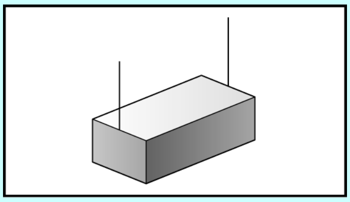
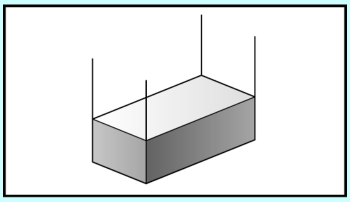
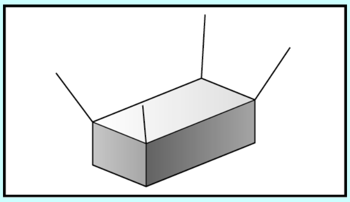
Other constraints will be the supporting structure and operating environment of the building. The materials and permissible fixing points should be identified. Any environmental constraints should be identified, such as a corrosive atmosphere (see Section 3.13).

2.3 CONFIGURATIONS AND APPLIED LOADS

There is a wide range of possible suspension configurations. Selection will depend on the particular circumstances of each installation, depending on such issues as the overall load, the position of suitable fixing points on the supporting structure and the attachment options for the item being suspended. Designers will be seeking to provide the simplest and quickest configuration to install, while meeting the requirements for load stability and easy access, as well as any requirement for redundancy should a part of the suspension system fail.

How some of these requirements apply to isolated loads may be seen in the table below:

Table 1: Suspension configurations.

	**Single wire** • Simple to install • No redundancy • No resistance to lateral or rotating forces
	**Two wire** • Some resistance to lateral loads
	**Four wire** • Improved redundancy • Resistant to rotational loads
	**Splayed four wire** • Increased resistance to lateral loads • Greater tension in wires

A suspension system designer is seeking to reach a compromise between a number of requirements, and there will not be a single correct configuration for any particular suspension requirement.

To assist in choosing a configuration, there are some sources of industry guidance on the suspension of different services. Most such sources (such as HVCA *DW144*[2] or the *CIBSE Guide B*[3]) do not yet specifically cover wire rope systems, so designers may have to interpret recommendations made for threaded rod systems.

Calculating loads

Once a configuration has been selected, the system designer must calculate the loads on each fixing and wire rope to ensure that suitably strong components are specified and that the building structure can withstand the intended loads. To calculate these loads the weight of the services to be installed must be known. Manufacturers will usually be able to supply information on the weight of plant items and the weight per metre of items such as pipes and ductwork. Designers should check that these weights reflect loads during operation, in particular that the weight of pipes and relevant plant are given when full of water, not in their dry condition.

Angled ropes

The majority of conventional suspension systems have vertical suspension elements, and as such fixings and suspension elements are subjected to purely tensile loads in a vertical direction. One of the advantages of using wire rope systems is that the rope can easily be installed at an angle, to allow for different anchor points for fixings. However when taking advantage of this feature, designers must take into account the fact that this will apply shear loads to fixings, and will increase the total load on the fixing and wire. The effect of using wire ropes at an angle is demonstrated in Figure 1 and Table 2 below.

Figure 1: The effect of rope angle on rope and fixing load.

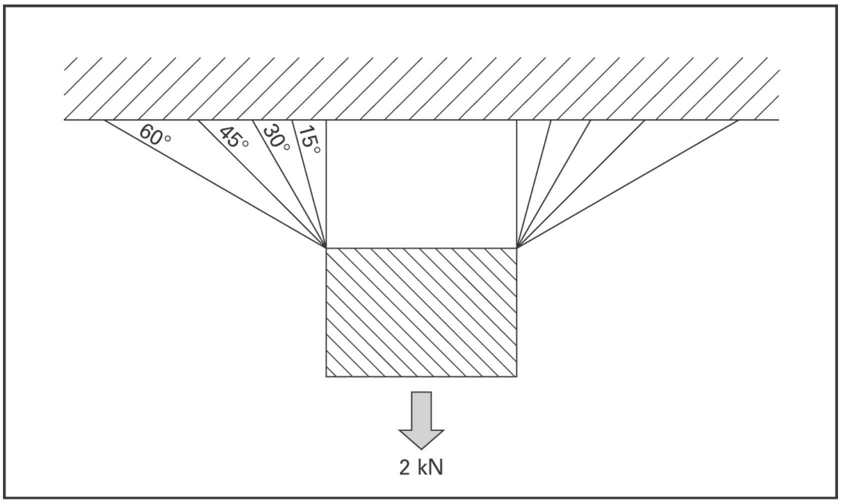


Table 2: Effect of rope angle on rope and fixing load.

	Loading of each wire and fixing		
Angle from the vertical	Vertical load	Lateral load	Total load
0°	1·00 kN	0·00 kN	1·00 kN
15°	1·00 kN	0·27 kN	1·04 kN
30°	1·00 kN	0·58 kN	1·15 kN
45°	1·00 kN	1·00 kN	1·41 kN
60°	1·00 kN	1·73 kN	2·00 kN

The magnitude of the increased loads is relatively simple to calculate, and specifying ropes of sufficient strength should not cause problems. Fixing requirements may be more complex to determine, as the strength of the fixing may vary as the angle of the applied load varies. Some fixings are strongest in shear while others best resist tensile loads. If an angled load is resolved into its horizontal and vertical components, it is not enough to simply compare these resolved loads with the manufacturers recommended tensile and shear loads as the fixing capacity may still be exceeded. Most manufacturers give simple equations for checking the safety condition for combined loads.

Safety margins and system redundancy

Once a suspension system configuration has been selected, suitable components will need to be chosen (see Section 3). Components are given a rated safe working load (see Section 3.1) and in many applications it will be acceptable to design a system that operates at or just slightly below that rating. However there may be circumstances where the risk of failure requires that the suspension system needs to be able to cope with higher than expected loads, or the failure of an element of the suspension system. To cope with excess loads, a suitable safety margin may be applied when selecting components, so that even under exceptional conditions, safe working loads are not exceeded.

If a suspension system can sustain the failure of a suspension element and successfully transfer the load to other adjacent anchor points, the system is said to provide redundancy. The more failures of individual elements a suspension system can sustain, the greater the degree of redundancy. The degree of redundancy required will depend on the risk (see Section 2.4) posed by the failure of the system.

It should be remembered that the integrity of a suspension system and load does not depend purely on the strength of the suspension system, but also on the stiffness and strength of the supported load. Stiff loads will tend to successfully transfer loads to a number of adjacent suspension assemblies, while more flexible loads will transfer the load to the adjacent suspension assembly only, or collapse entirely. So producing a redundant system may not simply be a matter of applying suitable safety margins, but may also require extra suspension points, or reinforcement of the load.

For light loads, in the order of 1 kN per anchor point (100 kg vertically suspended load), redundancy can usually be assumed if the load can be transferred to two adjacent fixings in the case of linear systems or three adjacent fixings in the case of bi-directional systems. For higher loads a full assessment may be required taking account of the stiffness of the supported structure.

A full risk assessment (see Section 2.4) cannot be carried out until the design is complete, but a preliminary assessment of the type of load and the possible consequences of failure will assist in selecting an appropriate strategy.

2.4 RISK ASSESSMENT

While wire rope suspension is as safe (or indeed safer than) other forms of suspension, hazards can be created through poor design or installation. The initial hazard is to those installing the system, from such dangers as falling while working at high level, or being hit by a dropped load, tools or a suspension system component. Once installed, future failure of a system component poses a hazard to the people and property below the suspended load.

While all construction professionals will be aware of the use of risk assessments during the construction process, they also need to consider and minimise the risk and consequences of future failures.

This section concentrates on the long term dangers posed by suspension systems to those living and working under them once installed. More information on risk analysis for the installation process can be found in Section 4.1; however, designers should bear in mind how their choices affect installation tasks, and therefore the risk to installers.

Assessment of long term risk

The majority of suspension systems in buildings will not require a specialised risk assessment, where the risk can be assumed to be small. If however an initial assessment indicates a greater degree of risk, a full formal risk assessment may be advisable.

The risk assessment will need to consider a number of issues:

- What can fail?
- What are the potential causes of failure?
- What are the consequences of failure?

Risk management

Risk management is the process of implementing the recommendations of the risk assessment to reduce the risk of injury or damage to an acceptable level. There are three main approaches to this:

- Remove the hazard: Does the service need to be suspended at this location?
- Reduce exposure to the hazard: If the hazard cannot be removed, then it may be possible to limit access to the area beneath the system, exposing as few people as possible to the hazard.
- Reduce the likelihood of failure: Use a stronger suspension system, or increase the number of suspension assemblies to increase redundancy.

2.5 LEGISLATION

Permanent wire rope suspension systems are not covered by any specific legislation[1] or guidance. However, the safety of buildings during construction and afterwards are covered by a number of pieces of legislation:

[1] Temporary suspension arrangements are covered by the *Lifting Operations and Lifting Equipment Regulations* 1998. These regulations impose stringent requirements for the training of personnel and the testing and periodic inspection of lifting equipment.

- The *Health and Safety etc at Work Act* 1974 and subsidiary regulations
- The *Construction (Design and Management) Regulations 1994*
- The *Construction Products Directive*
- The *Building Regulations* and specifically the *Approved Documents*.

The *Health and Safety at Work Act* places a general duty on employers to consider the safety of employees and others who may be affected by work activities. It is applicable to the construction phase, subsequent maintenance activities and the safety of future occupants of the building.

The *CDM Regulations* place a duty on construction managers to plan a safe method of construction and undertake a risk assessment of the proposed construction activity and the safety of the design.

The *Construction Products Directive* calls for the testing and certification of products used in the construction industry, including provisions for CE marking where appropriate, however at the time of writing there is no agreed standard for the testing of suspension systems such as wire rope.

Certain system components, such as the fixings or the wire, may have their own CE mark or other test approvals. CE marking is essentially an indication that the product is fit for purpose and may be sold throughout Europe. It does not mean that it will necessarily comply with local building regulations in each country. Products can be certified against a CEN standard or by means of a European Technical Approval (ETA). The nominated body for technical approvals in the UK is the British Board of Agrément.

The *Building Regulations Approved Documents* (and their equivalents in Scotland, Northern Ireland etc) states that:

"*Any building work to which a requirement of the Regulations applies must, in accordance with Regulation 7 be carried out with proper materials and in a workmanlike manner. You may show that you have complied with this requirement in a number of ways, for example by following an appropriate British Standard or British Board of Agrément Certificate or by the appropriate use of a product bearing a CE mark as defined in the Construction Products Directive (89/106/EEC).*"

In the absence of other more specific guidance there is an Approved Document on *Materials and Workmanship*[4].

The growth in the use of wire ropes for suspending building services has been driven by the productivity benefits[1] of the system. These were in turn made possible by the development of new components allowing the quick and easy fastening of wire ropes, and their ready availability as kits with pre-cut lengths of wire rope. While this section deals with a range of wire rope components, application guidance focuses on the use of such kits, as they are the most widely used within the industry.

Where ropes and other components are sourced from different suppliers it is essential to ensure that they are compatible. Mismatched components may not achieve claimed safe working loads and could result in premature failure.

3.1 COMPONENT LOAD LIMITS

An important part of designing a suspension system is to ensure that the components can safely take the loads that will be applied. However, a single component may well have a confusing array of differing load descriptions, depending on the application and the purpose of a particular type of load limit.

The ultimate tensile strength (UTS) of a component is that load at which it physically fails. Manufacturers will give the design ultimate tensile strength for a particular component type – since they expect all their products to meet this standard, the actual ultimate tensile strength of an individual specimen will normally be above this.

Proof testing may be carried out on individual components by the manufacturer, or on part or the whole suspension system by the installer. The proof load in a manufacturer's tests will typically be up to 50% of the design ultimate tensile strength. Installer tests will usually be in the range 1·25 to 1·5 times the load that is expected on the component or system.

The safe working load (SWL) or working load limit (WLL), is the maximum load that the supplier states the component or system should be routinely used for. This may be calculated in a number of ways, but is typically between a quarter and a fifth of the design ultimate tensile strength. This helps provide a margin for any inconsistencies in installation, and normal degradation of the component over its installed life.

All of these ratings may then be altered (usually decreased) depending on the application of the component. Components with a fire rating may have their standard safe working load reduced to ensure they provide adequate strength under extreme conditions (certified loading data is available from some fixings manufacturers for different exposure times under conditions of standard fire curves).

Designers must ensure they know what loads they are applying to components and the conditions they are expected to operate in, and if necessary check their suitability with the manufacturer.

3.2 WIRE ROPE COMPONENTS

Wire ropes

Wire ropes are built up from individual wires. Various types of wire can be used; the most common are mild steel (plain and galvanized) and stainless steel. A number of wires together form a strand, and several strands will be twisted together to form a rope. Characteristics like fatigue resistance and resistance to abrasion are directly affected by the design of strands. In most strands with two or more layers of wires, inner layers support outer layers in such a manner that all wires may slide and adjust freely when the rope bends. As a general rule, a rope that has strands made up of a few large wires will be more abrasion resistant and less fatigue resistant than a rope of the same size made up of strands with many smaller wires.

Wire rope manufacturers and suppliers will be able to advise on the gauge and type of rope required. Most wire rope used in the UK will be compliant with *BS 302*[5,6], and compliance and test certificates can usually be obtained from the supplier. Alternatively, where the rope is supplied as a component of a suspension system, the supplier may give an overall rating for all the components of the system.

Rope termination

Some way of attaching the wire rope to other pieces of equipment such as fixings or the suspended building services components will be required. This may be through a device or clamp directly gripping the rope, or the rope may be looped to form an eye that may be placed over suitable attachment points.

An eye may be formed in a rope in a number of ways. As with conventional fibre ropes, the rope may be spliced, where the wires at the end of the rope are unwound, the rope looped over, and the wires then woven back into the body of the rope. This is relatively rare and unlikely to be relevant in these applications. Most commonly, a ferrule will be crimped around the adjacent lengths of rope (see Figure 2). The eye may be a soft eye, simply formed of the loop of rope, or a thimble may be inserted, to ensure that the eye is held open and retains its shape.

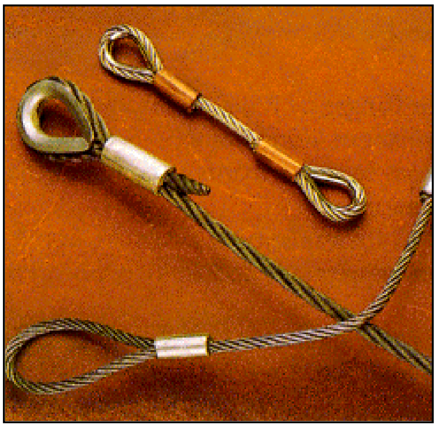


Figure 2: Wire rope eyes.

The recent rapid uptake of wire rope suspension in construction has partly been driven by the introduction of new components that allow the quick and easy formation of wire rope eyes without the need for additional tools. These allow wire ropes to be installed, wrapped around lifting points or entire components and then locked into position. They are commonly supplied as a kit, consisting of a length of wire rope with a preformed eye, the rope grip, and an unlocking tool to allow adjustment of the clip once installed (see Figure 3).

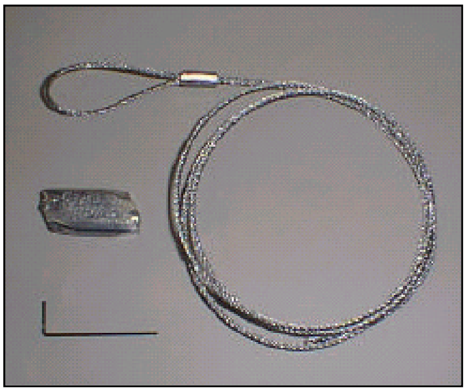


Figure 3: Wire rope kit.

Joining ropes

Some wire rope grips intended to be used to form an eye in a rope can be used to join two separate lengths, but if they are not designed for this application then there is a risk of failure. Ideally, a wire rope of the correct length should be obtained, but where this is not possible designers and installers must ensure they are using joining methods approved by the component manufacturer.

3.3 ATTACHMENT TO THE BUILDING STRUCTURE

There may be a number of ways of attaching the suspension system to the supporting structure. As well as the traditional use of construction fixings, wire ropes can add another option, where the rope is simply looped round a structural element of the building (see Section3.4), without a fixing in the accepted sense.

The major factors to be considered in selecting the attachment method are:

- type of structure
- base material
- applied load
- application dimensions
- temperature ranges
- corrosion conditions
- attachment configurations.

Table 3 identifies the most common fixings for different base materials. This table is not intended to be comprehensive, and a great deal of additional information may be obtained from manufacturers and from bodies such as the Construction Fixings Association, which produces a range of guidance notes, including *Anchor Selection*[7] and *Anchor installation*[8].

Table 3: Common fixings for a range of materials.

Building structure	Other factors	Suggested fixing types
Exposed steel work	Access to wrap rope around structural element (may be purlin or channel-fixed between sections)	Direct attachment using wire-rope loop (or indirect attachment into channel itself using adaptor)
	No access to wrap rope around structural element	Clamps and clips
		Powder actuated fixing of special clips
		Toggle inserted through hole drilled in horizontal flange
Solid concrete	Suitable for powder actuated fixings (site tests may be required to check)	Powder actuated fixings (pre-drilled in preference to non-drilled)
	Not suitable for powder actuated fixings (site tests may be required to check)	Drilled in fixings
Hollowcore concrete		Drilled fixings – Rubber expander or socket anchor with flared end.
Profiled roofing	Not open to elements	Toggle inserted through drilled hole
Composite decking	Profile suitable for wedge nuts	Wedge nuts
	Plain profile	Powder actuated fixing of special clips
		Drilled fixings

Where any doubt exists as to the suitability of a particular type or size of fixing then the manufacturer's advice should be sought. It may prove necessary to carry out suitability tests to determine if a fixing is suitable for the intended purpose. Suitability testing is covered in Section 5.1.

3.4 FIXING TO STEELWORK

Steel structures provide the obvious point of attachment for suspending services via wire rope.

Direct attachment

Where possible, the simplest method of attaching a wire rope is simply to wrap the rope around a suitable element of the building structure. The free end of the wire is passed round the structural element and then either fed through a pre-formed eye in the wire to form a noose around the support, or clamped. Its use is therefore dependent only on access around the section being available and the supporting element being in a suitable position. This method is typically applicable to steel framed sheds, where the roof purlins are exposed (see Figure 4). Where structural sections are not suitably positioned, or run in the wrong direction, then channels may be fitted between them and the wire rope loop attached using a suitable adaptor.

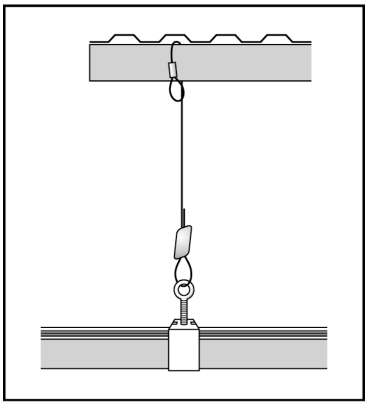
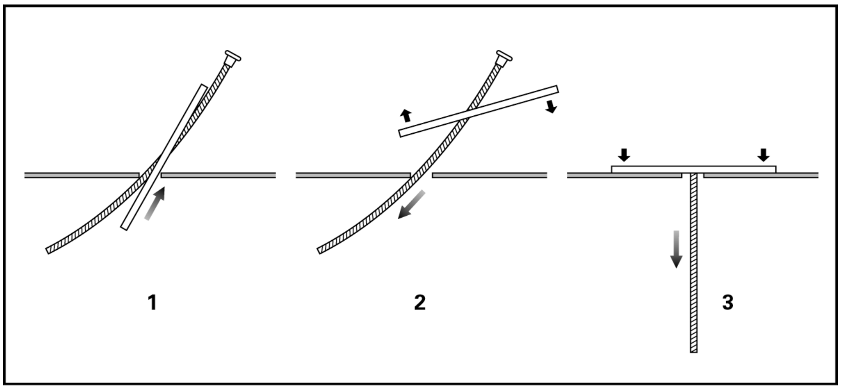


Figure 4: Attachment to purlin.

Designers must check that the structural element is strong enough to support the load and that it is suitable for this use. In most cases, the additional load from the services will not add substantially to the structural loads already supported. However some structures may not be suitable for the point loads applied by wrapping a wire around them. For example, a light 'C' section angle may undergo some deformation under such a load, and the designer will have to decide what degree of deformation is acceptable. Wire rope can normally be wrapped around structural beams without requiring corner protection. However for large loads or sharp edges, corner saddles or other protection may be desirable to prevent damage to the wire or support. If in doubt check with the manufacturer.

If the supporting element is horizontal, (see Figure 5) and the wire will be at right angles to the element (but not necessarily vertical) then the wire can be looped around without further restraint. For use on elements at other orientations, or where the wire is not at right angles, measures must be taken to ensure the loop cannot slip along the support, altering the height of the load and the load distribution. Such measures would include placing a collar or clamp to stop movement of the loop, or attaching a fixing bracket for the rope to be looped through.

Figure 5: Toggle fixing in horizontal steel flange.



Clamps and clips

A variety of clamps and clips are available (an example is shown in Figure 6). The configuration chosen will depend on the section to be attached to and the load to be supported. They are generally only capable of supporting light loads. Although the holes in clips have apparently sharp edges, for the relatively light loads commonly applied to such clips, good quality wire rope will not suffer. If in doubt, check with the manufacturer.

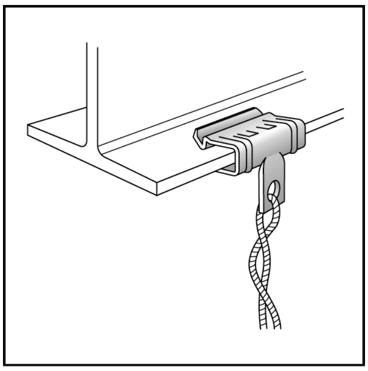


Figure 6: This is a screwed clamp with integral eye and caddy-type clip.

Powder-actuated fixings to steelwork
The use of this technique depends on various factors:

- Steel thickness: Typically greater than 5 mm. Ideal is 10 – 12 mm for normal structural steelwork.
- Steel strength
- Flexibility of the steel section
- Fixings should not be made too close to the edge of steel sections.

3.5 FIXING TO SOLID CONCRETE

The nature of concrete means that the most cost-effective fixing technique, powder-actuated fixings applied directly and without pre-drilling-may not always work as satisfactorily as required because the aggregates close to the surface are likely to cause deflection of the nails. Pre-drilling using special drill bits usually overcomes this problem, and is the preferred technique.

Powder-actuated fixings are usually viable only where a significant number of fixings is needed. Also some contractors do not want to establish the necessary administrative systems for the training and certification of operators. In these cases drilled fixings become the best option.

Reinforcing bars and pre-stressing elements
Many concrete structures will contain reinforcing bars or pre-stressing bars or cables. Cutting or damaging these elements can significantly affect the strength of a structure (this is particularly true for pre-stressed structures). Ideally, the depth of cover above such elements should be known, and a fixing with a suitably shallow embedment depth selected.

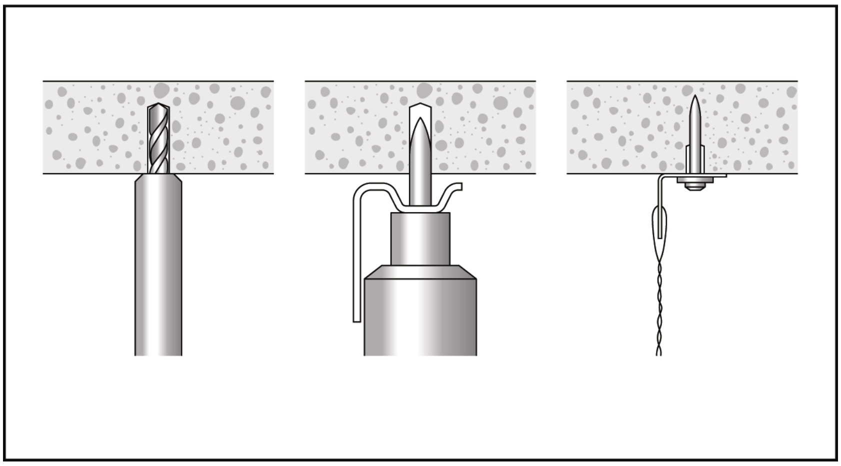
For reinforced structures, if reinforcement is hit the fixing should be relocated. Alternatively, the reinforcement may be cut with the permission of the structural engineer, (see Section 4.6).

Powder-actuated fixings to concrete
Factors governing this application include:

- type and size of the aggregates in the concrete
- compressive strength of the concrete.

Site trials are always required in concrete applications. The fact that these fixings will be made into the undersides of concrete where aggregates may be concentrated means there is a possibility of failures. If tests show this to be significant, then a technique of pre-drilling should be used (see Figure 8). This method is very reliable compared with powder actuated fixings without pre-drilling. Some manufacturers have developed systems for this technique. Although the pre-drilling adds a cost the improved reliability means fewer failed fixings to be remade so overall costs may be comparable.

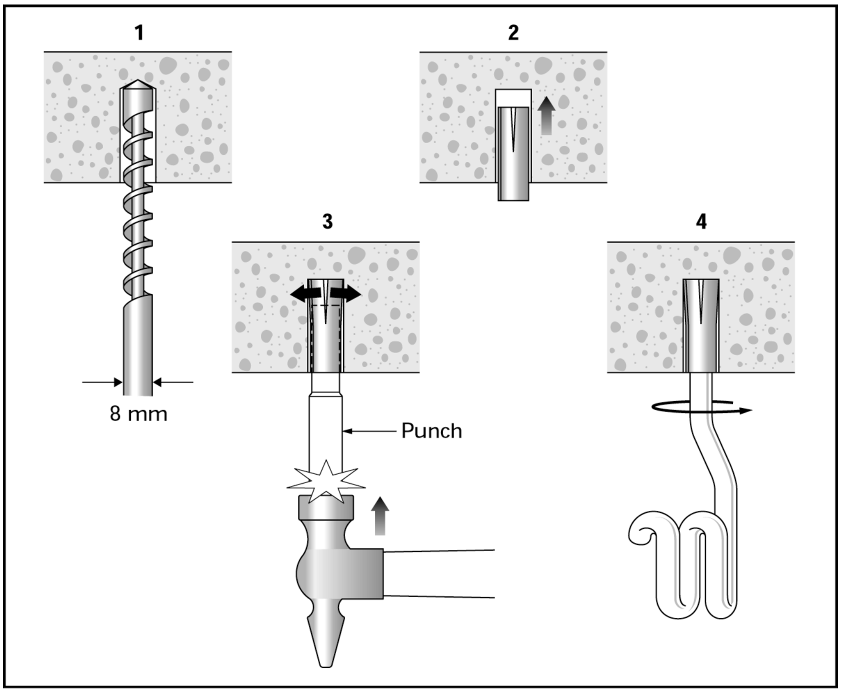
Figure 7: System of pre-drilling for use in concrete with special clips.



Drilled fixings

Hammer set socket anchors (otherwise known as drop-in anchors) are low cost anchors traditionally used for suspension of services. Full holding power of the anchor is assured only if the correct setting method is fully implemented as shown below. The anchor is usually set using a punch and club hammer but some manufacturers offer setting adaptors for use in hammer drilling machines. These speed up setting and ensure optimum expansion. May be used with an open coil attachment, (see Figure 8). M6 and M8 versions require 8 mm and 10 mm hole diameters respectively drilled typically 25 mm and 30 mm deep. They are relatively strong and, due to the shallow embedment depth, should avoid hitting rebar.

Figure 8: Socket anchor installation using special punch and club hammer or adaptor in drilling machine.



Wire hangers, (expansion anchors with integral eyes see Figure 9) are not used as commonly as socket anchors but overall the installed cost is likely to be similar as it comes complete and installation is very quick. The drill bit size (6 mm) is smaller but the hole depth is greater (40 mm). The only setting tool required is a claw hammer. The wire hanger has the added benefit that it expands automatically so will support the load even if not set correctly and is therefore inherently safe. In common with other eye-type fixings it does require the wire to be pulled as tight as possible after attachment to minimise sag when the load is applied. It is therefore best suited to light loads.

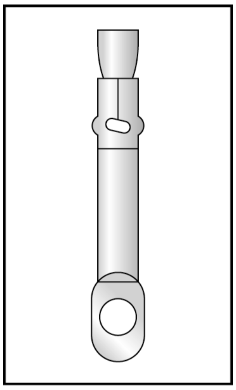
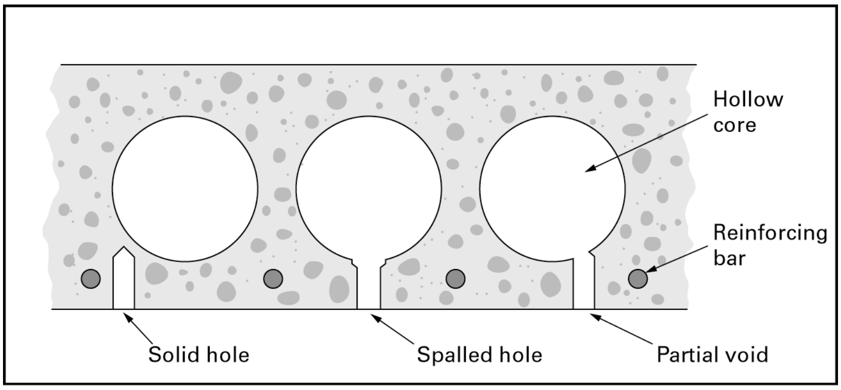


Figure 9: Wire hangers.

3.6 FIXING TO HOLLOWCORE CONCRETE

Hollowcore concrete sections (see Figure 10) are frequently used in modern construction and require fixings which can work in solid concrete, hollow sections or partial voids. See Section 3.5 for comments regarding pre-stressed and reinforced concrete sections.

Figure 10: Section through hollowcore concrete showing different hole conditions.



Hammer-set socket anchor with flared end

This is a version of the traditional drop-in anchor developed to locate flush with the surface the concrete irrespective of the hole depth. For the shallow embedment depths involved with these applications, (25 mm for M6 and 30 mm for M8), the anchor will expand satisfactorily even if the hole is drilled coincident with the core as shown above. This type of anchor should be used with open coil attachments or other threaded adaptors (see Figure 11).

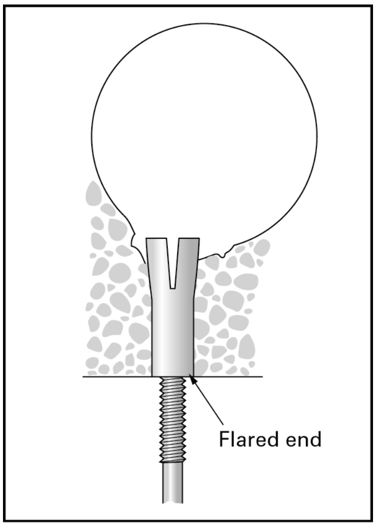
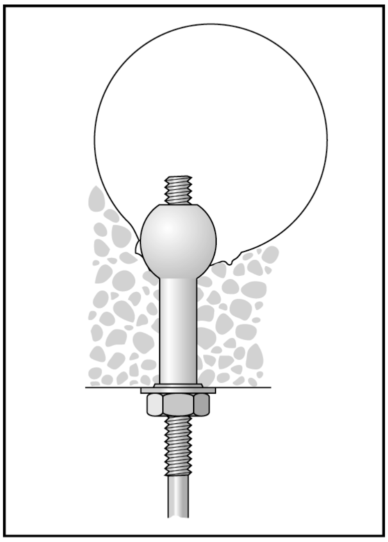


Figure 11: Hammer-set socket-anchor with flared end for use in hollowcore concrete.

Rubber expansion anchor



A rubber expansion anchor is a rubber expanding sleeve which works in solid materials, in a cavity or partial void. Figure 12 shows its use in a hollowcore floor slab where the drilled hole has broken through into the hollowcore. The device is for use with threaded adaptors or an open coil attachment (not fully shown) with a nut and washer to expand the sleeve.

Figure 12: Rubber expansion-anchor with flared end for use in hollowcore concrete.

3.7 FIXING TO COMPOSITE DECKING

Wedge nuts

If the profiled decking which forms the permanent shuttering of the decking has suitable wedge profiles, then wedge nuts are the most economical solution (see Figure 13). Wedge profiles within the sheeting vary, so care must be taken to choose a suitable wedge nut. Wedge nuts also vary in design and strength; ask the manufacturer for performance data. Fixing strength also depends on the type of aggregate used in the construction and on adequate concrete placement and vibration. Wedge nuts working in composite construction made using light weight aggregate concrete will be weaker than with normal weight concrete. For all these reasons site tests are recommended before confirming design loads (see Section 5.1).

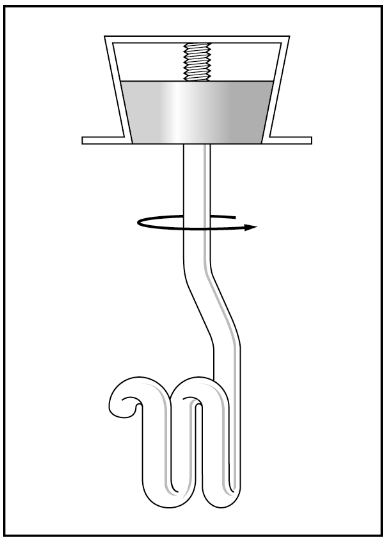


Figure 13: A wedge nut used with an open coil attachment.

Powder-actuated fixings to composite decking.

When no suitable profile exists then powder-actuated fixings directly into the ceiling are a reliable method. Pre-drilling is not required, the steel profile and lightweight aggregate typical of most composite construction minimises deflection of the nails. Strength may not be as high as with normal weight concrete (See also Figure 7).

Factors governing this application include:

- The type of concrete above the decking
- type and size of aggregates in the concrete.

Concrete used in composite decking is usually made from lightweight aggregate and as such poses no problems for powder-actuated fixings, although the reduction in holding capacity means test fixings should be carried out to determine allowable loads (see Section 5.1).

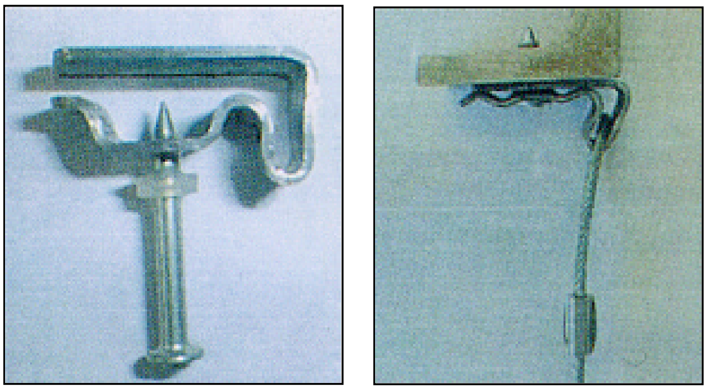
3.8 POWDER-ACTUATED FIXINGS

Powder-actuated fixings (sometimes referred to as shot-fired fixings) are an economical solution to the attachment of wire ropes to several types of ceiling construction if certain application parameters are met.

Common to all such uses is the need for all operators who install powder-actuated fastenings to be trained and certified in the correct use of the particular tool and accessories for the application in question.

Irrespective of base structure the most common technique is to fix a special clip that will have the loop of the wire rope already located in it (see Figure 14). The type of clip must be chosen to suit the application. Pre-drilled or non-predrilled application techniques require different clips (see Section 4.5).

Figure 14: Special clip for powder-actuated fixing to steel section.



Trial fixings are recommended for all new applications to ensure the particular application is feasible and the correct fastener shank length and cartridge strength are used. Fixing manufacturers will usually assist in trial fixings, if requested.

3.9 CONNECTION BETWEEN WIRE ROPE AND THE FIXING

A number of methods are available to link the wire rope to the fixing attached to the building structure. It should be noted that the use of open hooks is not recommended as the loop may jump off the hook during installation.

Fixings with internal threads

One aspect common to all internally threaded fixings (such as wedge nuts and socket anchors) is the need to ensure sufficient engagement of the mating threads. This is easily checked by counting turns, at least 10 full turns will give enough engagement.

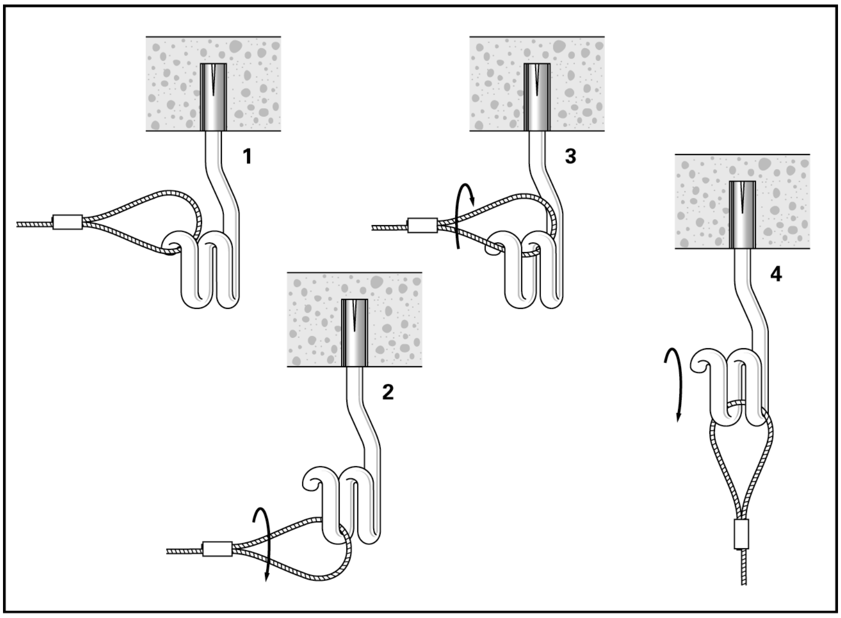
There are three possible connection methods:

- Open coil attachment (sometimes known as a Pigtail)
- directly threaded swaged end
- adaptor with integral eye (see Page 20).

Open coil attachment

The open coil attachment method (see Figure 15) has the benefit of allowing the loop to locate directly on the coils meaning there will be no settlement when the load is applied. The loop should be engaged over two coils.

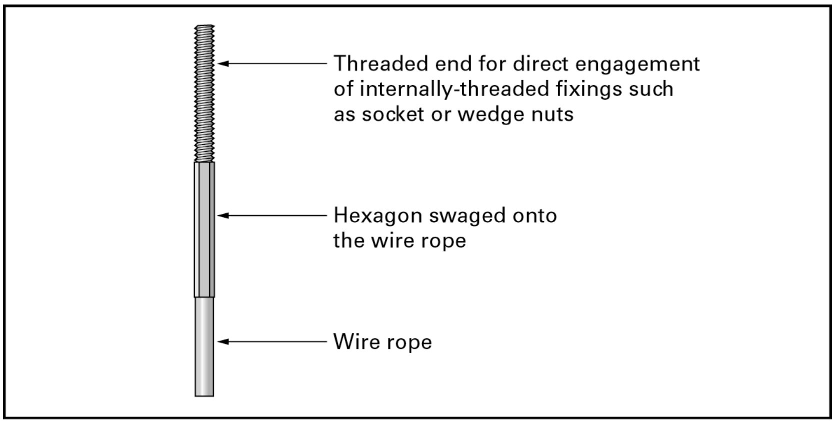
Figure 15: Open coil attachment for use with internally threaded fixing loop engaged over two coils.



Directly threaded swaged end

The directly threaded swaged end method (see Figure 16) has the benefit of cheapness and providing a direct linkage of the wire rope with the fixing. Installers must ensure that the swaged end is screwed into the fixing before attaching the rope to the load.

Figure 16: Threaded swaged end on wire rope.



Adaptor with integral eye
Some fixings may have an integral eye (see Figure 17 and Figure 18). The free end of the wire rope is fed through the eye and then through the loop of the rope. The wire rope must then be pulled tight to minimise the deformation that will occur when the wire rope is loaded.

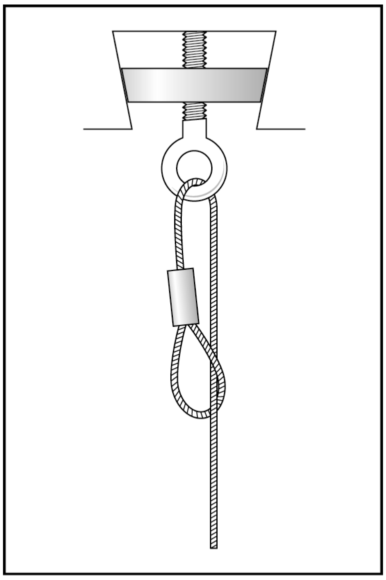
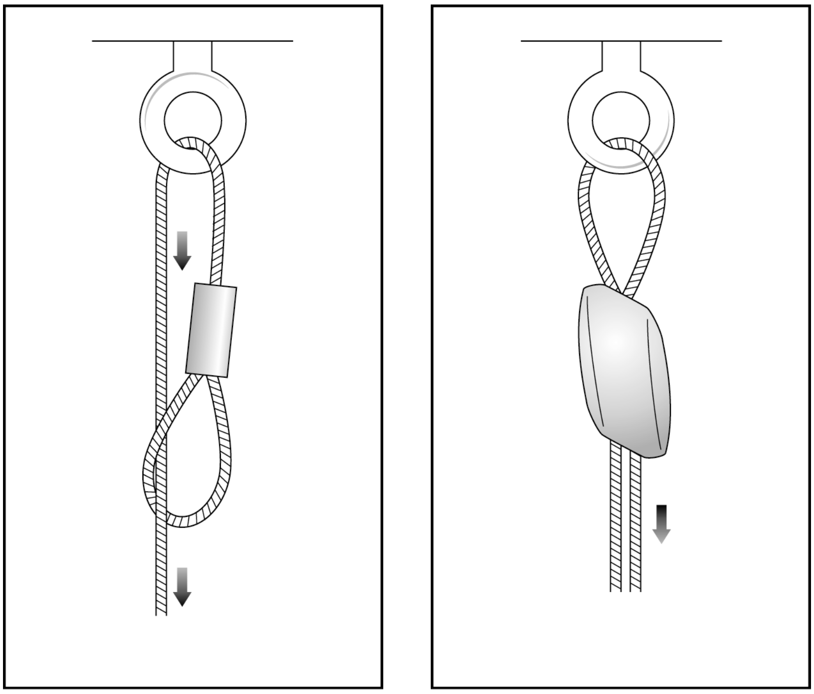


Figure 17: Eye adaptor shown in use with wedge nuts.

Figure 18: Reeved wire rope.



Through eye with loop at the top

Through eye with gripping adjuster at the top

3.10 TYPICAL SAFE WORKING LOADS

The values in Table 4 indicate the approximate relative capacities of the different systems. They are guide values only, and users must refer to manufacturer data for specific components. In any system the capacity is limited by the component with the lowest value.

Table 4: Typical safe working loads for common fixings.

Fixing type	Typical range of safe working loads (kg)	Site tests advised?
Wire rope - (capacity relates to diameter)	10 - 325	
Toggle end fixing on wire (capacity matches wire)	10 – 90	
Open coil attachment M6	90	
Open coil attachment M8	150	
Clamp for steelwork	45 - 300	
Clips for steelwork	60 - 90	
Powder-actuated fixing to steelwork (10 mm)	200 (approximate)	✓
Powder-actuated fixing to concrete – non drilled	40 (very approximate)	✓
Powder-actuated fixing to concrete – pre-drilled	90 (very approximate)	✓
Powder-actuated fixing to composite decking	Depends on concrete type	✓
Drilled fixings into solid concrete (30 N/mm²)		
Socket anchor M6	200 - 300	
Socket anchor M8	300 - 400	
Ceiling hanger	80 - 200	
Rubber expansion anchor	Depends on base material	✓
Wedge nuts M10	(200 approximate)	✓

3.11 ATTACHMENT TO SUSPENDED SERVICES

Where the wire is used to support a pipe or duct it is common practice to loop the free end around the service and re-attach to the standing wire with a clip or clamp. This provides the opportunity for adjustment of the suspension height. The alternative is to pass the free end of the wire around the service and back through a pre-prepared loop first with subsequent attachment to the structure.

There are three issues to be aware of with this approach. First, the wire can only be fitted in the plane that is perpendicular to the axis of a horizontal pipe or duct, otherwise it may slip. Second, there will be limited resistance to rotation. Finally, sharp corners on rectangular ducts should be avoided (fitting corner saddles will alleviate this problem, see Section 3.14).

For discrete plant items, eyebolts or other adaptors will normally be fitted to the casing for easy attachment. Note that if it is intended to suspend the item using angled wires, for example where there is no suspension point vertically above, then the strength of the casing may need to be considered.

3.12 FIRE PROTECTION

Some applications may require that the suspension system provides a degree of fire protection, either to ensure the continued operation of safety critical services, or simply to ensure that there is sufficient time for occupants to escape before there is a risk of overhead services collapsing. Requirements vary, and specifiers need to ensure that all components of the suspension system meet the relevant regulations.

3.13 CORROSION ISSUES

The possibility of corrosion needs to be taken into account. Fixings in particular will often form a vital element in the system and may be more susceptible to corrosion effects due to their relative size. Within the fixings industry, and the approvals systems that serve it, it is accepted that normal zinc plated (five microns) carbon steel components are suitable only for long-term use in dry internal conditions (typically $< 50\%$ RH).

At higher humidities a higher level of corrosion resistance is necessary. Hot dip galvanising is regarded as satisfactory for non-condensing conditions where the required design life is medium term, say in the order of 10 years. For external applications and high humidity environments with a design life of 50 years then stainless steel is normally required.

There are also some special applications, such as the suspension of ceilings or services within the roof space of swimming pools, where the conditions of elevated temperatures and chlorine in the atmosphere lead to the condition known as stress corrosion cracking. In this case even Grade A4 stainless steel is unsatisfactory and special materials must be employed. Typical guidance in this case is to use organically-coated carbon-steel materials, but the coating must be complete. Alternatively, special alloys of stainless steel, with higher percentages of chromium, nickel and molybdenum than are present in grade A4, may be used. Threaded rod and some fixings are available in this special material.

3.14 APPLICATION-SPECIFIC ISSUES

Lighting and electrical

Where metal suspension systems are used to support electrical services, it is possible that their components will need to be earthed. Contractors should check with a qualified electrical engineer to ensure they are meeting the relevant safety regulations.

Ductwork

Ductwork is usually well suited to direct suspension with wire rope systems. Care must be taken with rectangular ductwork, as the sharp radius of the corner may damage the wire rope, and on thin-walled ductwork, the cable may cut into the duct. To spread the load and increase the bend radius of the rope, some manufacturers are producing corner saddles to overcome these problems.

Pipework

Designers must make sure that they have accounted for the weight of the suspended pipes, including the contents when full.

To avoid cooling the suspension element and inducing condensation on it, chilled water pipework is usually suspended by a bracket incorporating a layer of insulation. Similar measures should be taken when using wire ropes in order to reduce the risk of corrosion.

3.15 DESIGN INTEGRATION ISSUES

Most building structures will be easily capable of supporting the services required without problems, as long as sufficient attachment points are provided to spread the load evenly. However where complex and extensive services are required, checks should be made to ensure that the additional loading, and penetration of the structure by fixings, does not compromise the load-bearing ability of the structure.

Certain construction choices can make the installation of suspension systems significantly quicker and simpler. One of these is cast-in-channel, where a channel can be cast into concrete decking during construction to provide an attachment point for suspension systems. This technique has to be designed in at the earliest time and is sometimes dependent on accurate positioning at the formwork stage. Many engineers prefer cast-in fixings over post-drilled as a matter of principle due to a perception of improved reliability.

Fixings can be easily located into the channel using special locking plates that are inserted into the channel and turned through 90° to locate against the lips of the channel. They offer a good variation of position in one direction and many fixing points can be provided over an area using this method. Loads are usually applied purely in tension, perpendicular to the fixing, so angled wire ropes should be used with care.

Problems on site sometimes arise if channels or slots have been incorrectly located. Very occasionally failures have occurred when the means by which the system gains its anchorage to the concrete has not been correctly installed. For instance some systems have tangs projecting from the back of the channel that, because of location problems in relation to reinforcement, have been flattened before concrete pouring. This problem is rare and some engineers prefer the relative reliability of cast-in fixings.

3.16 RETROFIT ISSUES

Retrofitting of suspended services may involve the modification of existing services, the complete replacement of existing services, or the complete installation of systems. A survey will need to determine whether the structure can take the proposed load and type of fixing that is most appropriate.

The amount of investigation required will depend on the age of the building, the quality of the existing information and the scale of the proposed retrofit. In relatively modern buildings, where a simple extension or replacement of services is planned using the same techniques as during the original installation, minimal checks will need to be carried out. Where large loads are proposed for older buildings, checks may include a structural survey and suitability tests for fixings.

3.17 DESIGN FOR INSPECTION AND MAINTENANCE

The designer should consider the likely future requirements for inspection and maintenance of both the suspended services, and of the suspension system itself.

For service *in situ*, installers must ensure that the suspension system does not obstruct access panels or controls. In the event of a severe failure, an item of plant may need to be removed and replaced. Designers need to make sure that the minimum of adjacent services will be disrupted during this process.

The major reason for the increase in the use of wire rope suspension systems is a significant reduction in installation times compared to traditional threaded-rod systems[1]. Wire rope systems are simple to use, and certainly no more complex than traditional suspension systems. The major areas of concern are the same as for threaded rod and other suspension systems - the correct installation of fixings, and the safe positioning of the load.

4.1 SAFETY AND RISK ASSESSMENT

Work on construction sites is covered by a number of different pieces of Health and Safety Legislation, including the following:

- The *Health and Safety etc at Work Act* 1974 and subsidiary regulations
- The *Construction (Design and Management) Regulations* 1994
- The *Construction Products Directive*
- The *Building Regulations* and specifically the *Approved Documents*.

More details on these regulations can be found in Section 2.5.

These regulations require the production of method statements and risk assessments for many of the procedures involved in installing suspended services. In particular, the dangers posed by working at high level, and the lifting of services to their installation position, will need to be addressed.

4.2 TRAINING OF INSTALLERS

As noted at the beginning of this section, wire rope suspension systems are easy to use. However training and familiarisation with the components and systems being used is still of vital importance. It not only contributes to health and safety on site, but also ensures that the systems are used to their full effectiveness, maximising the time and cost savings. All manufacturers should provide information on the safe and effective use of their products, and some will also assist with on site training if requested.

4.3 STORAGE AND HANDLING

While wire ropes and their fittings are relatively robust components, they can be damaged if mishandled or inappropriately stored. Storage conditions should be dry and clean to prevent the conditions for corrosion occurring, and to ensure the wire ropes do not pick up any contaminants that might interfere with the fittings gripping them securely.

If a rope needs to be shortened, then it is important that the correct cutting tools are used. These help prevent the rope from being crushed and flattened, and help ensure that the rope can still be easily passed through fittings.

4.4 DIRECT ATTACHMENT TO BUILDING STRUCTURE

Direct attachment of a wire rope to a building's structure is simple, but there are a few points that installers should note.

Make sure that the rope is being attached to the correct structural element – in a crowded roof space, the wrong component could be selected and it may not be suitable for the load.

The positioning of the rope should be checked. Unless additional collars or clamps are being used the supporting element should be horizontal, and the wire at right angles to the support (but not necessarily vertical) to ensure the wire loop doesn't slip along the support.

When attaching the rope by wrapping it around a support and threading it back through a small eye on the end of the rope, the free end of the rope should be pulled through to make the loop around the support as small as possible. This will prevent the loop slipping when it is placed under load.

4.5 INSTALLATION OF FIXINGS

One issue common to all types of fixing is that manufacturers' instructions must always be followed exactly. Failure to do so may reduce the load-carrying ability of the fixing.

Where fixing techniques are new to a contractor, and it is likely that this new technique will be adopted on many future installations, then it is wise to arrange for the manufacturer to train all operatives in the correct installation methods for the new technique. Manufacturers will provide method statements for incorporation in CDM documentation.

Key aspects of installation are summarised below for the most popular fixings.

Safety
The following guidelines are in addition to instructions already covered in contractors' safety policies.

- Always wear appropriate eye protection to *BS 2092 Grade 1 for Drilling or for Fixing Powder Actuated Fastenings*[9]
- always wear ear protection when fixing powder-actuated fastenings and when drilling for long periods or in a confined space
- always wear a dust mask when drilling overhead
- always ensure tools are in a safe condition
- always keep tools and small items safe when working at height.

Drilled fixings
It is assumed that fixings will be installed vertically upwards using small diameter holes drilled into ceiling structures. For this reason hole cleaning receives less emphasis than it would do if fixings were to be made horizontally or vertically down.

The installation procedures are:

1. Drill hole to correct diameter and depth
2. insert the fixing using the correct tools as supplied by the manufacturer, for example setting punch in the case of deformation controlled (drop in) socket anchors
3. set fixings using the manufacturer's setting procedure
4. tighten to the manufacturer's recommended installation torque, where appropriate.

More detail on installation methods is covered in the Construction Fixings Association Guidance Note *Anchor Installation*[8].

Powder-actuated fixings
Installation of powder-actuated fixings must only be carried out by operatives who have been trained in the correct procedures and who possess the appropriate certificates.

Aspects that will be covered in such training should include:

- Safety procedures
- identification of suitable base materials
- correct choice of fastening including penetration length
- appreciation of edge and spacing limits
- tool operation
- procedure for trial fixings prior to the installation proper to check penetration depth and establish cartridge strength
- procedure for installation.

This will include the procedures for pre-drilling that is recommended for all installations into concrete (not composite decking).

Where there is a need to verify the strength of powder-actuated fastenings to ensure they meet the requirements of the specification, most manufacturers will carry out on-site tests to determine the performance.

4.6 LOCATION OF FIXINGS

The location of fixings is dependent on the relation between the units being supported and the available supporting structures. This must be decided by responsible persons within the company responsible for the installation.

Ideally fixings should be located directly above the suspension point. If this is not possible then the suitability of the fixing to accept loads at the angle involved should be checked with the manufacturer.

The positioning of drilled-in fixings in concrete must respect limitations regarding edge and spacing distances as published by the fixing manufacturer.

Hitting reinforcement in concrete.
The thickness of concrete cover above reinforcement is typically 25 mm for internal situations and 40 mm externally. It is therefore likely that reinforcement will be hit from time to time. It can best be avoided by choosing a fixing with a shallow embedment, provided it gives sufficient holding power.

There are two options when reinforcement is struck:

- Move the fixing location: This is the preferred option. The new hole should be drilled a distance from the aborted hole of at least twice the depth of the aborted hole. The aborted hole should be filled with a strong non-shrink grout.

- Drill through the rebar: This option should only be contemplated if the above option1 is not practical and only with permission from the responsible structural engineer. Special rebar cutters, suitable for use in conventional SDS+ drilling machines, are available from some fixing manufacturers; otherwise diamond drilling is necessary. Hand held rigs are available.

4.7 INSTALLATION OF LOADS

Loads must be safely raised to the installation position, and the suspension system attached and tensioned. Small loads may be lifted into position manually (See *Manual Handling Operations Regulations*[10]), but larger items will require the use of equipment such as a block and tackle, mechanical scissors lifts, or mobile plant such as cranes and forklift trucks. The use of such devices must comply with the requirements of the *Lifting Operations and Lifting Equipment Regulations 1998*[11].

Most wire rope suspension systems are not suitable for use as part of a lifting system and should not be used as such. Slight adjustment of position may be permissible provided that safe working load on individual wires and fixings is not exceeded.

Once the load is positioned, the wire ropes should be attached and then tensioned. It is important that tension is applied gradually in turn to the individual ropes supporting an item. If only one of a number of ropes is tensioned, it may be carrying far more than its design load, possibly above the safe working load.

Most manufacturers can back up their claims for component performance with a range of test data if required. This may involve random sampling of a batch of components to check the ultimate tensile strength, or proof-testing of all components. However, the manufacturer may still carry out site tests for a number of reasons, such as suitability tests, proof tests, or testing a component or system for an unusual use.

This section concentrates on site testing of fixings, but the methods may be adapted to other components if required. Fixings are the components that are most likely to require some form of testing as they form the interface between the building and the suspension system. This is where there is most room for variation, either due to uncertainties about the base material or differences in installation methods. Suitable procedures are given in more detail in a guidance note – *Procedure for site testing construction fixings*[12] published by the Construction Fixings Association. Tests should always be carried out by a competent person.

5.1 SUITABILITY TESTS

These tests are carried out when the manufacturer of the fixing under consideration has no test data to prove the suitability of the fixing in a particular base material, or when suitability is known but no performance data is available. This may be the case when the strength of the base material is unknown.

The requirements of such tests can be summarised as follows:

- Tests to be carried out in the base material of the job prior to installation of the actual fixings but in areas remote from those where actual fixings will be located
- fixings to be loaded to failure
- number of tests: drilled fixings (at least three)
- powder-actuated fastenings (at least 10)
- reaction loads to be spaced well away from the fixing
- permissible loads to be calculated according to the manufacturer's recommended procedure or to the recommendations of the CFA *Guidance Note*: *Procedure for site testing construction fixings*[12].

Suitability tests are usually only carried out in the tensile direction; shear capacity being determined by the material strength of the fixing. The manufacturer should be consulted if the applied load is at an angle, as this is a combination of tension and shear.

5.2 PROOF TESTS

Proof tests are carried out in order to ensure that installation procedures have been correctly followed. Proof tests are always carried out in tension only.

In this case the requirements can be summarised as follows:

- Tests to be carried out on actual fixings to be used in the contract after installation of the fixings and before attachment of the services

- Fixings to be loaded to a proof load with respect to the design load (between 1·25 and 1·5 times the design load is recommended)
- The number of tests depends on the number of fixings in the project. Between 2·5% and 5% of the total is typical, but at least three should be tested on small jobs. For large projects a reducing percentage may be tested as long as initial tests are satisfactory. For example 5% for the first half of the job then 2·5% thereafter
- Reaction loads to be spaced well away from the fixing itself see the CFA *Guidance Note*: *Procedure for site testing construction fixings*[12].

Tests on powder-actuated fastenings.
While not written specifically with powder actuated fastenings in mind, the general requirements of the CFA *Guidance Note*: *Procedure for site testing construction fixings*[12], published by the Construction Fixings Association, should still be followed.

A range of information concerning the installed suspension systems may need to be retained by the designer and installer as well as being forwarded to the client as part of the handover documentation. Such information can help resolve contractual disputes, and may assist the client if alterations to the building are required at a later date. Some specific types of information are discussed below. For general information on handover requirements see BSRIA TN 15/95: *Handover Information for Building Services*[13].

Design assumptions
Suspension systems may carry significant loads, and in turn exert such loads on the building structure. Where formal stress calculations were deemed necessary, these records should be kept by the installer and designer, as well as being forwarded to the client. These can assist where modifications to the building and its services are being considered.

Test results
Tests may have been suitably carried out prior to installation, or proof tests to ensure correct installation. Records of both are of value and must be retained for future reference.

Documentation of installed components
Full details of the manufacturers of the suspension system components should be included, along with any installation and maintenance guides.

7.1 INSPECTION

There is currently no specific requirement to inspect suspension systems in buildings on a regular basis. However, given the increasing awareness of the consequential costs of system failure it may be considered appropriate to institute periodic inspections in high-risk areas. Certainly, the condition of the suspension system should be checked when routine inspection of, or work on, the suspended services themselves is carried out. Such checks should include the following points:

- The load on the fixings and suspension system has not increased (for example by the installation of extra services) beyond the design load
- The wire rope is not cut, frayed, twisted, deformed or showing signs of corrosion. No objects are deflecting the rope
- Fixings and other fittings show no sign of corrosion or physical damage
- No lubricants or paints have been applied to the wire and fittings, unless this is in accordance with the manufacturers guidance
- All ropes are evenly tensioned.

7.2 MAINTENANCE AND REPLACEMENT

If damage to the suspension system is found, then the cause of the damage should be identified so that action can be taken to prevent it recurring. If replacement of a wire or fitting is necessary, the load should be supported from below, the new components fitted, and the suspension system retensioned as in installation (see Section 4.7). Simply removing the damaged wire without providing support may overload the remaining suspension elements, and could lead to failure.

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2 HVCA, *Specification for Sheet metal Ductwork, DW/144,* HVCA, 1998, ISBN 0903783274

3 *CIBSE Guide, Volume B – Installation and Equipment Data*. CIBSE, 1986, ISBN 0 900953 30 6

4 The *Building Regulations 2000, Materials and Workmanship*, Approved Document to support regulation 7 - 1999 Edition, amended 2000, The Stationary Office, ISBN 0-11-753482-X

5 BSI, *Stranded Steel Wire Ropes. Part 1: Specification for General Requirements,* BS 302-1:1987, British Standards Institution, 1987

6 *BS 302-2:1987, Stranded Steel Wire Ropes. Part 2: Specification for Ropes for General Purposes*

7 *Anchor Selection,* The Construction Fixings Association, 1995

8 *Anchor Installation,* The Construction Fixings Association, 1996

9 *BS 2092 Grade 1 for Drilling or for Fixing Powder Actuated Fastenings*

10 *The Manual Handling Operations Regulations,* HMSO, 1992, ISBN 0 11 025920 3

11 *Lifting Operations and Lifting Equipment Regulations,* 1998

12 *Procedure for Site Testing Construction Fixings*, The Construction Fixings Association, 1994

13 De Saulles T, *Handover Information for Building Services*, TN15/95, BSRIA, 1995, ISBN 0860224163