CO-CONSTRUCT

Services Co-ordination with Structural Beams

Guidance for a defect-free interface

By Sally Mitchell, Martin Heywood, and Glenn Hawkins

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What is Co-Construct?

Co-Construct is a network of five leading construction research and information organisations - Concrete Society, BSRIA, CIRIA, TRADA and SCI - who are working together to produce a single point of communication for construction professionals.

BSRIA covers all aspects of mechanical and electrical services in buildings, including heating, air conditioning, and ventilation. Its services to industry include information, collaborative research, consultancy, testing and certification. It also has a worldwide market research and intelligence group, and offers hire calibration and sale of instruments to the industry.

The **Construction Industry Research and Information Association** (CIRIA) works with the construction industry to develop and implement best practice, leading to better performance. CIRIA's independence and wide membership base makes it uniquely placed to bring together all parties with an interest in improving performance.

The Concrete Society is renowned for providing impartial information and technical reports on concrete specification and best practice. The Society operates an independent advisory service and offers networking through its regions and clubs.

The Steel Construction Institute (SCI) is an independent, international, member-based organisation with a mission to develop and promote the effective use of steel in construction. SCI specialises in providing advanced internet-based solutions for the construction industry.

TRADA provides timber information, research and consultancy for the construction industry. The fully confidential range of expert services extends from strategic planning and market analysis through to product development, technical advice, training and publications.

For more information on Co-Construct visit www.construction.co.uk.

Services Co-ordination with Structural Beams

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An Interface Engineering Publication 2

What are Interface Engineering Publications?

Interface Engineering Publications (IEP) are a series of guides that aim to bridge the gaps in technical knowledge at the interfaces between construction packages. The publications involve reformating existing professional knowledge, developed independently by Co-Construct members, into a single source of guidance.

The objective of IEPs are to reduce failures on site, to create greater understanding of shared processes by clients, designers and contractors, and to improve construction quality and the in-use performance of building systems.

Services Co-ordination with Structural Beams was jointly researched, edited and produced by BSRIA and The Steel Construction Institute in order to provide comprehensive guidance in a single publication. All the information has been drawn from current research and existing publications, and cross-referenced with the latest regulatory requirements.

For more information on Co-Construct visit www.construction.co.uk.

CO-CONSTRUCT

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Introduction

The office boom of the early 1980s led to many innovations: facade engineering, myriad forms of air conditioning, and many new designs of steel structures. Trendsetting developers discovered that the choice of structural beam had a fundamental effect on the efficiency and speed of construction. By running services through holes in structural beams – and designing those beams with services distribution in mind – developers were able to reduce storey heights, increase lettable area, and save on the cost of the external envelope.

However, real reductions in capital cost only accrue from properly co-ordinated design, where the structure and services are designed in harmony, and where the policy of integration is followed through to installation. For less well co-ordinated projects, the theoretical savings can be more than wiped out by lack of detailed co-ordination. The resulting problems can only be solved through costly improvisation by site contractors.

This guide, the second in a series called Interface Engineering Publications, aims to provide guidance on the best ways to engineer the interface between structural design and services distribution. BSRIA and The Steel Construction Institute (SCI) have pooled their technical knowledge to provide structural and services engineers with consistent, interlocking advice.

The publication largely contains material repackaged from existing BSRIA and SCI guidance. Details of the original publications, relevant European and British Standards and other references for further reading are provided at the end of this publication.

Much of the guidance in this publication concentrates on the technical aspects of a well co-ordinated design. It argues that structural engineers must invite their services colleagues to take part in option analysis, to design the beam openings to cater for the favoured services systems, and to help resolve the inevitable conflicts that occur in ceiling voids. The risk from not doing so will be increased time or cost overruns during installation, largely caused by the need to adapt ductwork and pipework, and to provide additional fittings required to make services go together.

The key message is that structural design must not be carried out in isolation from the design of the building services. All parties to the design process should make it clear to the client – and the client's representatives – that savings will only be achieved if services are installed so they will perform properly, and in a manner that enables them to be maintained.

Roderic Bunn, BSRIA
Martin Heywood, The Steel Construction Institute

December 2003

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Advice about the mechanical engineering requirements of running services through structural beams will be found in blue-tinted boxes. Comments marked by 🟧 link to structural sections listed under *see also*. Comments marked by ◩ denote a link common to both specialisms.

Advice about the structural requirements of running services through structural beams will be found in yellow-tinted boxes. Comments marked by 🟦 link to mechanical engineering sections listed under *see also*. Comments marked by ◩ denote a link common to both specialisms.

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☐ Essential mechanical engineering messages from the guide

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Early design decisions

Building structure is often designed between the client, the architect and the structural engineer, but the services engineer also has a key role to play. If savings in construction materials and installation cost are to be achieved, along with a well integrated services installation, then the structural engineer must obtain guidance from the building services engineer on the dimensional nature of the proposed services design, and the preferred routes of those services.

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First steps in design

Early on in the design of a building, the structural engineer and architect have to make important decisions regarding the layout of the structural frame. Although the total cost of the structural steelwork in a typical commercial building is less than 10% of the total capital cost, these decisions can have a significant effect on building whole-life cost.

The design of the steel frame should be considered as part of the overall building design. When selecting a beam and column layout, the structural engineer needs to take account of the present and future requirements for unobstructed floor space, the type of floor system to be used, the effect of the structural layout on the overall building height, the proposed layout of the building services, and the level of flexibility required, such as cutting additional services risers. 1

Beam span and layout

The structural engineer should aim for long span solutions in order to minimise the number of columns and maximise the unobstructed floor space. This provides flexibility for the design of the internal layout and allows for future changes of use.

The exact span between the columns should be selected to suit the architectural grid, so that the locations of the structural members coincide with the spacing of the partitions, ceilings and, in some cases, fixed items of furniture. The architectural grid typically has intervals of 0·6 m, in which case suitable beam spans would be 3·6 m, 6·0 m, 7·2 m, 9·0 m etc.

Having decided on the column locations, the structural engineer must then decide on the arrangement of primary and secondary beams to transfer the loads from the floor to the columns (figure 1).

The use of secondary beams is often necessary because the spacing of the columns usually exceeds the maximum span of the floor decking units.

🟦 **Mechanical engineering issues**

🟨 **Structural issues**

Storey height

It is often advantageous to reduce storey height in order to minimise the cost of the cladding, or to comply with planning restrictions on the overall height of the building. This requires the careful selection of beam members and consideration of services integration into the structure.

2 If the beams are arranged such that the secondary beams span further than the primary beams (figure 1), it is sometimes possible to use primary and secondary beams of a similar depth. This approach minimises the depth of the steelwork, but might prevent the services from being passed through the beam webs, resulting in a need for a separate services zone beneath the beams.

If a beam layout is chosen that requires deep primary beams and shallow secondary beams, the depth of the steelwork will be greater, but it should be possible to pass services through the webs of the primary beams and under the secondary beams. The minimum storey height does not therefore always correspond to the minimum beam depth.

Integrating the building services

The services engineer has the choice of passing the services beneath the beams in a separate services zone, or locating them within the depth of the beams. It is essential that the building services engineer and structural engineer discuss the options early on in the design process and work closely to arrive at the best integrated solution.

3 If it is decided to pass the services through the beam webs, the services engineer must provide data on the number, size and spacing of the required holes so that the beams can be fabricated accordingly. Failure to do so could lead to expensive alterations on site.

Key structural watchpoints

☐ Although the total cost of the structural steelwork in a typical commercial building is less than 10% of the total capital cost of the building. The structural engineer can have a significant effect on the whole-life cost of the building

☐ Explain to the client that savings in installation time and cost will accrue from the structural and services engineers working together in an integrated approach

☐ Savings will accrue from matching the size and shape of the beam openings to the dimensional and performance requirements of the building services; standardisation should be a priority

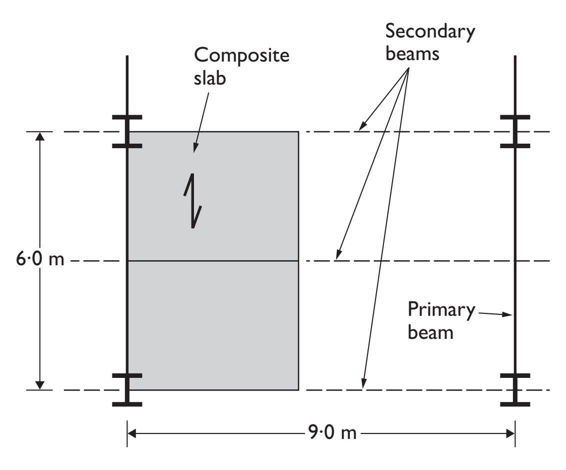

Figure 1: A typical layout for primary and secondary beams. ©The Steel Construction Institute (SCI). See also Figure 11, page 16.

See also

1 Services Detailed Design, page 16
2 Table 1, page 11
3 Figure 9, page 12

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A clients' guide to

Beam options 1

A full understanding of the different types of structural beam, and the services that can run through them, is necessary for a proper option-appraisal process. The choice of structural beam will be influenced by a range of construction issues, but when it comes to optimising the services distribution, every person involved in the design process needs to appreciate the cost and performance benefits of integrating the beam design with the services design.

Types of structural beam

Several different types of steel beam are used in building construction. These have specific attributes that aid the horizontal distribution of building services (figure 2). These beam types are generally classified as:

1 ☐ Universal beams or plate girders with web openings
2 ☐ Cellular beams
3 ☐ Castellated beams
4 ☐ Stub girders
☐ Tapered beams
5 ☐ Trusses or lattice girders

Isolated web openings

Where relatively few services are required to pass through the beam, isolated holes may be cut in the webs of beams.

Relatively large openings can usually be provided without the need for strengthening, provided that there is sufficient shear resistance in the remaining web. These holes will often be cut to meet the specific requirements of the building services.

While isolated, tailor-made openings might seem ideal to the building services designer, the option limits the future scope for alteration of the services layout, for example when the building is refurbished.

Cellular beams

Where the requirements for building services are uncertain, or likely to change during the life of the structure, the cellular beam may be a more versatile alternative to isolated web openings.

Cellular beams contain many regularly spaced circular holes along the entire length of the beam and are produced by specialist manufacturers in a range of depths (figure 3). They permit an aesthetically pleasing solution for situations where the beams are exposed, are structurally efficient and provide plenty of scope for future changes to the services layout.

Manufacturers provide a specialist design service for sizing the depths and hole sizes.

➧

Figure 3: Fabricated beams with circular and rectangular web openings.

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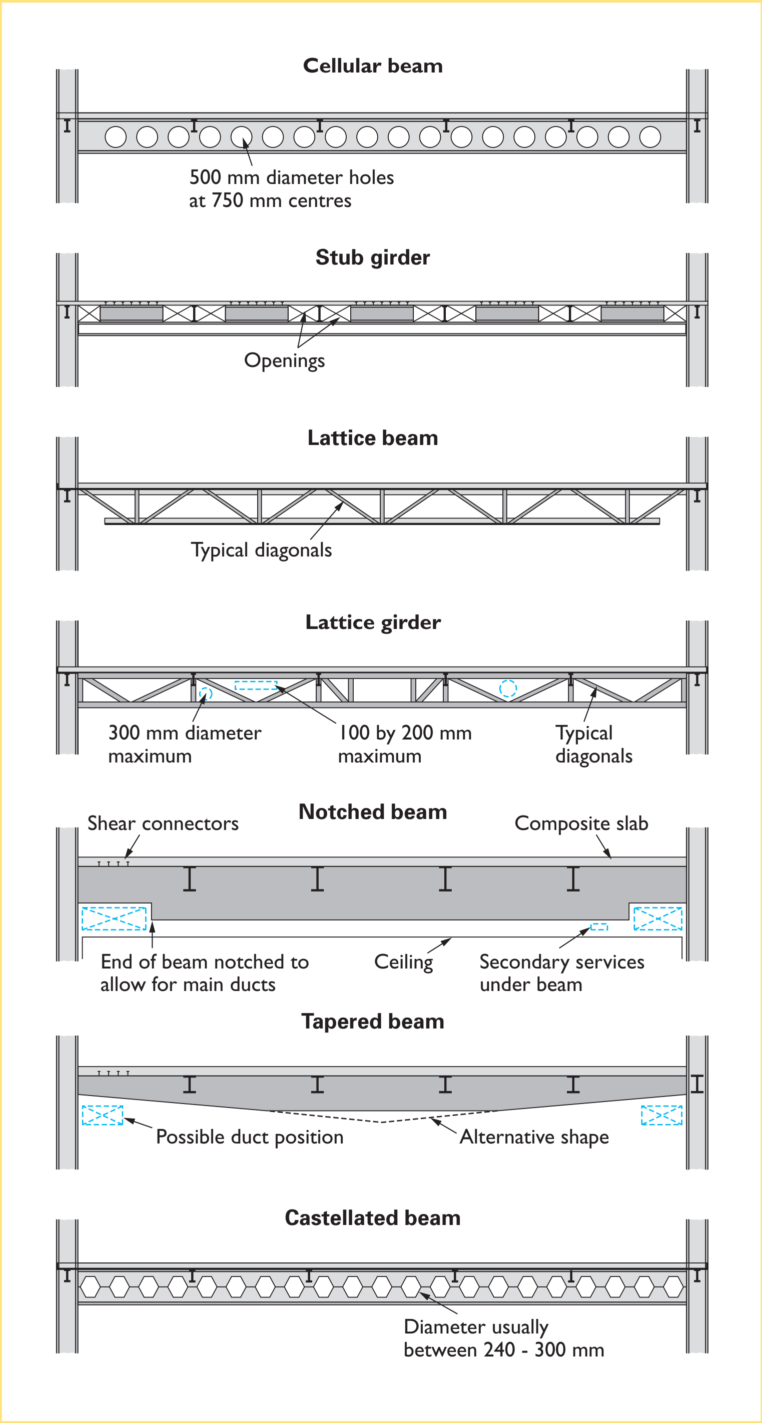
🟦 **Mechanical engineering issues**

🟨 **Structural issues**



6 ***Figure 2:*** Different types of steel beams suitable for integrating with building services. ©The Steel Construction Institute.

Key m&e watchpoints

- ☐ Designers should consider prioritising the design and installation of building services. For example:
  - ■ Sanitary drainage has very specific fall requirements
  - ■ More duct fittings will increase pressure losses, fan duty and running costs; the same is true of pipework fittings
  - ■ Moving installed cables to accommodate later services will incur re-installation costs
  - ■ Long sprinkler pipework runs will increase the required pump duty

- ☐ When sizing services to go through a beam aperture, the apertures must be large enough to allow for beam fire protection and insulation around the services (air handling ductwork can have insulation 25-75 mm thick) and to enable ease of installation

- ☐ Services such as hot water distribution pipework will expand when in use. Check that this expansion can be accommodated

See also

1 Glossary, page 32
2 Figure 11, page 16
3 Figure 12, page 18
4 Services Installation, page 24
5 Figure 4, page 8
6 Table 3, page 15

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A clients' guide to

Beam options 2

Castellated beams

A castellated beam is a beam with equally spaced hexagonal openings over all or most of its length (it is common to use infill plates at beam supports). The beam is formed by cutting a rolled-steel joist along the web in a zig-zag shape. The crests of the cuts are then welded together.

Although rarely used today in new construction, castellated beams have been used extensively in the past and will regularly be encountered by building services engineers working on refurbishment projects (figure 4).

Stub girders

A stub girder is a special form of Vierendeel girder, consisting of a universal column (UC) section as a bottom chord and a concrete slab as a top chord (figure 5).

Intermittent short lengths of a standard steel section, connected by shear studs to the concrete slab and welded to the bottom chord, act as vertical web members.

Tapered beams

As an alternative to rolled sections, fabricated steel sections produced from flat plate can be used. This provides the option of varying the depth of the beam along its length to produce a structurally more efficient solution.

Depth may be reduced at the ends of the beam, depending on the required shear resistance. This saves weight of steel, but more importantly, releases space below the beam for service distributions. Thus a reasonably-sized zone is created in which large services may be accommodated adjacent
1 to the columns. However, this can push main duct runs to the edge of the slab which will cause a conflict with perimeter air grilles, usually needed to ventilate cellular offices.

Lattice girders

2 The use of lattice girders (or trusses) for long spans is a well-established alternative to rolled or fabricated steel sections. Lattice girders can be manufactured from tees, angles or hollow sections and are usually welded

Figure 4: A typical castellated beam assembly, formed by cutting and re-welding standard universal beams. ©The Steel Construction Institute.

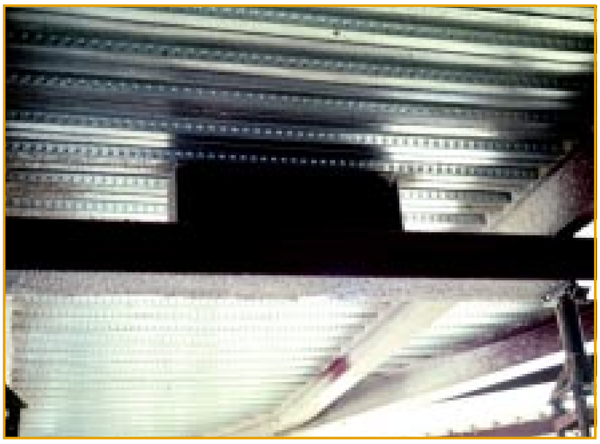

Figure 5: Stub girders consist of a universal column section as a bottom chord and a concrete slab as a top chord. ©The Steel Construction Institute.

🟦 **Mechanical engineering issues**

🟨 **Structural issues**

together (figure 6).

The spaces that are formed between the individual elements that make up the truss offer many opportunities for passing services through the beam, allowing flexibility in the layout of the building services and future alterations. However, the triangular shape of the opening means that the full width of the opening is only available for services at certain locations, restricting the size of the services that can be passed through the beam.

3 ***Figure 6:*** A typical lattice girder prior to the application of fire protection. ©BSRIA.

4 ***Figure 7:*** A standard universal beam cut with rectangular apertures. A symmetrical layout such as this gives wide scope for services distribution, though not necessarily optimal. Note the horizontal stiffeners above and below the openings. ©SCI.

Key structural watchpoints

☐ **Cellular beams:** Cellular beams feature regular rows of circular openings which offer flexible, (though not necessarily optimal) routes for services

☐ **Castellated beams:** More likely to be encountered on a refurbishment project, castellated steel sections feature regular rows of hexagonal apertures, but do not normally provide scope for different sizes and shapes of services

☐ **Stub girders:** Stub girders for good flexibility for services distribution, particularly for rectangular ductwork and in providing scope for future re-servicing

☐ **Tapered beams:** Tapered beams give the structural engineer the greatest freedom in the selection of section size. These beams may have straight tapers or be semi-tapered (figure 2), and aid the location of services at the beam ends

☐ **Lattice girders**: Lattice girders offer great opportunity for allowing services to pass through, although the full width of the opening is only available for services at particular locations

See also

1 Figure 24, page 29
2 Figure 16, page 25
3 Figure 16, page 25
4 Figure 12, page 18

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A clients' guide to

Building services options

There are various building services systems that traverse ceiling voids. The one thing they have in common is the need for space. Clients and structural engineers need to have an appreciation of the various systems and their basic characteristics. It is also important to understand how a decision made for structural reasons might affect the nature of the building services, and how those building services would be designed and installed as a consequence.

The technology

Mechanical services

Mechanical building services that commonly traverse ceiling voids include:

☐ Supply and extract ductwork serving a mechanical or full air conditioning system

☐ Heating and cooling pipework, and condensation pipework (serving from any ceiling-mounted cooling devices such as fan coils or direct expansion refrigerant coils)

☐ Fire suppression pipework; water-based for serving sprinklers, or gaseous pipework distribution for gas discharge systems

☐ Refrigerant pipework for variable flow refrigerant systems (VRF), and split systems comprising indoor and outdoor components

☐ Ancillary devices serving the above systems, including ductwork and pipework suspension systems hangers, valves on pipework, and access doors on ductwork.

Many of the latter affect space allocation and can influence the freedom of services distribution depending on the space available and the intensity of the servicing.

Electrical services

Electrical services include:

☐ Power cables

☐ Communications cabling for data communications and telephones

☐ Building management system signal cables, linking to in-ceiling devices such as thermostats, fan coils and luminaires

☐ Power cables for lighting

☐ Fire protection system cables

☐ Security cabling for closed circuit television, and access control entry systems

☐ Ancillary devices, such as cable tray, support mechanisms, and terminal devices such as building management system controllers.

The latter may not necessarily be integral to the unit to which the cables connect, and could impinge on space otherwise set aside for access to ductwork, for example.

Cables can be run on trays or in conduit where several cables need to follow the same path. Sometimes power cables are put in separate trays or conduit to the communications cables in order to prevent electrical interference. Although most power cables tend to run in the floor void, power will still be required in the ceiling void for lighting, and to power fan coils and associated controls.

Typical ceiling-mounted building services

The largest and most common types of building services are those serving a mechanical ventilation system or a full air conditioning system with terminal units. These fall into categories: centralised air systems, partially centralised air and water systems, and local system. Table 1 lists nominal dimensions.

Centralised systems involve constant volume or variable volume systems, each of which have specific ductwork and pipework requirements. Partially centralised systems include fan coils, chilled beams, chilled ceiling panels, and room-based heat pumps. Figure 8 illustrates some general requirements.

Constant volume systems provide tempered ventilation air at a fixed rate through ductwork to devices such as fan coils and chilled beams. These units handle the primary heating and cooling requirements of the space.

Variable air volume systems (often called VAV) are more complex. VAV is an air conditioning system where the ducted air not only provides room ventilation (at a variable rate depending on demands) but also handles space cooling and heating needs.

When the ventilation air is the cooling and heating medium, larger ductwork is required to cope with the peak air volumes. This can be a

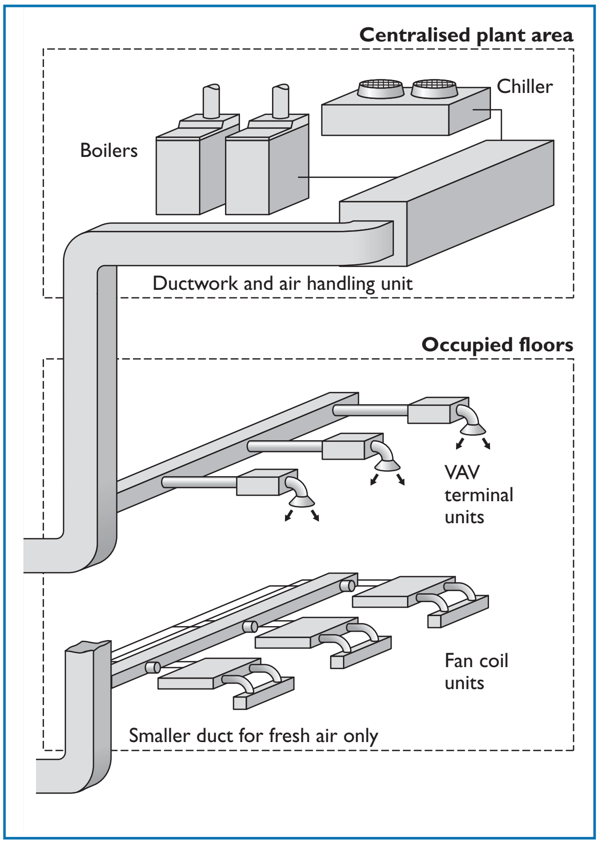

Figure 8: A schematic showing a centralised VAV system with a fan coil system. Fan coils require separate hydraulic circuits, and VAV systems are served by large primary ductwork with smaller secondary ducted connections to terminal units. ©BSRIA.

limiting factor when the ductwork is being threaded through beams.

Both constant volume and VAV systems need for good co-ordination with cellular beams. Poor co-ordination will prevent constant volume and VAV systems from delivering good ventilation and temperature control.

Local systems

Local systems are not served by centralised plant, and are mostly cooling devices serving specific zones in a building. Some recirculate room air without any fresh air makeup, others can be ducted to an air handling unit located elsewhere in the building.

Local systems include split air conditioning units (commonly called splits) and variable refrigerant flow systems (VRF). These devices are served by refrigerant pipework.

Key m&e watchpoints

☑ The services engineer should provide the structural engineer with basic dimensions of typical ceiling-void services to aid the choice of beam (Table 1).

☐ Refer to manufacturer's dimensional information and constantly revisit the space requirements

☐ Ensure that early consideration is given to the need to segregate electrical services from communications cabling

Table 1: Space needs of typical ceiling-void services. ©BSRIA.

	Approximate dimensions in millimetres		
System	*Length*	*Width*	*Depth*
VAV box	600	300	350 – 750
VRF unit			450
Fan coil unit	1000	500	450
Chilled beam (recessed)	350 – 450	Various	Various
Ducted air system			450
Drainage			10 – 25 per metre run
Soil and waste drainage			7 – 16 per metre run
Lighting			100 – 150 (plus access)

Note that the dimensions in Table 1 are nominal – accurate dimensions should be obtained from the preferred system suppliers.

See also

■ Figure 11, page 16

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Issues to address during

Services scheme design

The scheme design stage is where all parties in the design process will discuss the options. The choice of structural system will have a fundamental effect on floor to ceiling heights and ceiling void depth, and thereby the services installation. The services designer needs to make it very clear that any space savings will only be beneficial to the client if the services can be installed in a way that enables them to perform to specification, and be maintainable during operation.

Services information needed

Design inputs

☐ Architectural drawings for all zones
☐ Client brief and desired ventilation and/or air conditioning strategy
☐ Building orientation and shading
☐ Details of the structural frame and beams
☐ Space plan and layout
☐ Floor to ceiling heights
☐ Use and occupancy of spaces
☐ Desired internal design condition
☐ Internal zoning and building layout
☐ Locations of fire compartments, including the floor and ceiling voids
☐ Nominal zones for additional meeting rooms, communication rooms and kitchen areas that may require additional servicing.

The services engineer should obtain information on the total deflection of the structural beams before and after the services are installed (dead load and imposed loads).

Terminal unit issues

1 The actual size of any ductwork of terminal units will vary according to the number of units and the load imposed on the space it is serving. Sizes and connection layouts may also vary between different manufacturers for similar rated units. Figures for the amount of depth or clear space in a ceiling or floor void for various terminal units, derived from *BSRIA BG 14/2003 Rules of Thumb,* are:

☐ Variable air volume: 350–750 mm
☐ Variable refrigeration flow: 450 mm
☐ Recessed chilled beams: 350–450 mm
☐ Surface chilled beams: 250 mm
☐ Chilled ceilings: 250 mm
☐ Fan coils: 450 mm
☐ Ducted air system: 450 mm.

Advantages of circular ducts

One advantage of using circular duct instead of rectangular duct is the overall reduced system resistance which in turn has an affect on the fan size and associated installation/running costs. There are also other advantages to using circular ducts, such as being able to cut the duct lengths to size on site.

2 If a building has cellular beams, then square or circular or flat oval duct can be used. Circular duct will provide a lower resistance compared to a square duct through cellular beams, although insulation and fire protection will reduce the space available for the duct.

When designing duct services through composite beams there will be restrictions on the maximum duct size that can fit through the beam. This will obviously be influenced by the type of beam and the size/shape of the holes. With these constraints it is important to check the options available that will best suit the application.

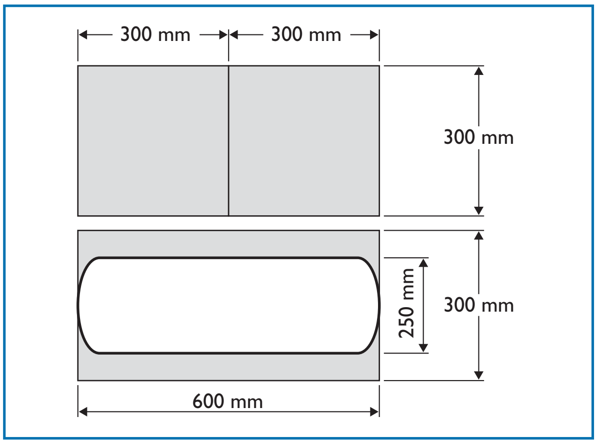

***Figure 9*:** If the beams in the building have rectangular holes, then flat oval ducts may be an option. Alternatively, a single rectangular duct or two square ducts (such as supply and extract) may be chosen depending on cost and availability.

If the services engineer believes this option would provide a cost and performance benefit for the client, then the structural engineer needs to be made aware of these benefits when the building structure is being designed. It may be possible to cut flat-oval apertures in the beams to cater for this services distribution.

🟦 **Mechanical engineering issues**

🟨 **Structural issues**

Deflection information needed

All beams deflect when loaded and an allowance must be made for such deflection when designing and installing building services.

Initially, the beam will deflect due to its self-weight and the weight of the concrete slab (the dead load). This loading is carried by the steel beam and the deflection will therefore be a function of the stiffness of the beam.

As this deflection occurs before the services are installed, services designers and contractors need to be aware that the beams through which their services pass might not be horizontal or at the same level along the length of the building at the time the services are installed.

In some cases, beams can be precambered to offset the effects of dead load. Where this is not possible, the services should be supported in a way that allows the levels to be adjusted.

The added load of the services will cause the beam to deflect further. With composite construction, the weight of the services will be resisted by the beam and slab acting together, and so the deflections are likely to be small.

Deflection also occurs in service due to imposed (live) loads from occupancy of the building and partitions, fixtures and fittings. *BS 5950-1: 2000 Structural use of steelwork in building* recommends limits for calculated deflections due to imposed loads (Table 2). For long span beams a maximum deflection of 60 mm is generally specified.

Where services are supported by beams, they should be able to withstand deflections equal to these limits. Where services pass freely through holes in beam apertures, there should be sufficient clearance between the edge of the hole and the service to allow for beam movement. Services designs must take into account the total deflection (dead load plus imposed loads).

Key structural watchpoints

✓

- ☐ An allowance must be made for beam deflection when building services are intended to pass through or under beams
- ☐ Deflection must be anticipated by both the structural and building services engineers to avoid costly re-routing and modification of services during installation
- ☐ Services engineers must provide the permissable degree of deviation between the centres of apertures in a series of perforated beams destined for a run of services

Table 2: *BS 5950-1: 2000* limits for calculated deflections due to imposed loads.

Category	**Deflection limit**
Cantilevers	Length/180
Beams carrying plaster or other brittle finish	Span/360
Other beams (except purlins and sheeting rails)	Span/200

Key m&e watchpoints

✓

- ☐ Obtain information on the deflection characteristics of the structural beams under pre-servicing and post-servicing conditions
- ☐ Services must be able to cope with the deflection of the total load on the structure (dead load and live loads)

See also

1 Table 1, page 11
2 Lindab further reading, page 30

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Issues to address during

Structural detailed design

The scheme design stage is where all parties in the design process will discuss the options. It is not unusual for the architect's design to have been already accepted by the client, leaving the engineers to propose solutions. It is vital that the specialists able to shed most light on co-ordination issues are involved in discussions: for structure that means the supplier of the cellular beams, and for services, the ventilation system suppliers and the ductwork contractor. This will necessitate early tendering.

Structural design issues

1 The following structural design information is required at the scheme design stage. All parties need to agree the consistent use of terminology.

Isolated web openings

When locating rectangular openings in the webs of composite beams, the following guidelines should be considered:

☐ Openings should not be located closer than two times the beam depth *D* from the support, or 10% of the span, whichever is greater.

☐ For uniformally loaded beams, the best location for any opening is between one fifth and one third of the span from a support.

☐ For beams subject to point loads, the best position of the openings depends on the relative importance of moment and shear along the beam, but normally openings are placed close to the mid-span.

☐ Rectangular openings should not be less than the beam depth (*D*) apart.

☐ Rectangular unstiffened openings should not generally be deeper than 0·6 *D*, nor longer than 1·5 *D*. The shear resistance and instability
2 of the web should be checked.

☐ Rectangular stiffened openings should not be deeper than 0·7 *D*, nor longer than 2·0 *D*.

☐ Stiffeners in the form of horizontal plates should be welded above and below the opening.

☐ Point loads should not be applied at less than *D* from the side of the adjacent beam opening.

Cellular and castellated beams

Castellated beams formed from structural sections have an overall depth *D* 50% greater than the parent beam. Standard castellations comprise hexagonal holes of maximum depth 0·67 *D* at 0·72 *D* centres.

For cellular beams, it is possible to have a wide range of opening and beam sizes (Table 3). Circular openings can be created with diameters of 0·6 to 0·8 times the final beam depth, and at spacings of 1·1 to 1·5 times the opening diameter. A typical span/depth ratio would be 20. As with castellated beams, the loss of the beam web reduces its bending and shear strength.

In some cases, openings may be enlarged by removing the web post separating two adjacent openings. This can be achieved in the middle third of the span, but additional stiffening is generally required.

A cellular beam may also be formed by welding together two sections. For composite beam design, where the concrete slab acts in compression, the top flange may be significantly smaller than the bottom flange.

A combination of different universal beam (UB) and universal column (UC) sections can reduce the weight of a beam by up to 30%, while providing the same composite stiffness as a solid beam of the same depth. The production process for cellular beams also allows the sections to be pre-cambered to overcome deflection problems.

Tapered beams

In the case of fabricated steel sections, the structural engineer has the greatest freedom in the selection of section size. These beams may have straight tapers, or alternatively be semi-tapered (uniform depth in the middle part of the span). A straight taper is simpler to fabricate and, in many cases, is the most economic shape. Typical tapered girders reduce to approximately half depth at the supports with a maximum taper angle of about 6^0. A vertical stiffener may be required at mid-span for deeper sections. A practical range of span/depth ratios is 15 to 25.

🟦 **Mechanical engineering issues**

🟨 **Structural issues**

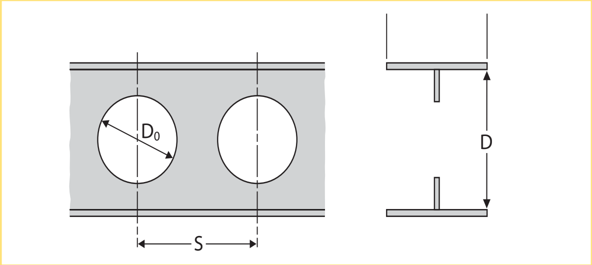


Figure 10: Geometry and notation for a cellular beam.

Table 3: Summary of typical gross opening sizes for efficiently designed long span composite beams incorporating services zones. ©The Steel Construction Institute.

Structural option	**Span/depth of primary beam ratio**[1]	**Opening size for beam span**	
		12 metres	*15 metres*
Composite beam with stiffened openings in low shear regions	25	2 @ 300 x 600	1 @ 400 x 1000 + 2 @ 350 x 700
	20	2 @ 400 x 800	1 @ 500 x 1200 + 2 @ 450 x 900
Composite beam with stiffened openings in high shear region	25	2 @ 250 x 450	4 @ 300 x 600
	20	2 @ 300 x 500	4 @ 375 x 750
Composite beam with notches at ends of beam	25	2 @ 250 x 450	2 @ 300 x 600
	20	2 @ 300 x 600	2 @ 375 x 600
Cellular beam	20	20 @ 350 diameter	22 @ 400 diameter
Castellated beam[2]	20	20 @ 240 diameter	20 @ 300 diameter
Stub girder	20	4 @ 300 x 900 + 4 @ 300 x 600	2 @ 400 x 1000 + 4 @ 400 x 700 + 4 @ 400 x 500
Tapered beam	20	2 @ 200 to 400 x 3000	2 @ 250 to 500 x 3000
Castellated beam[2]	20	20 @ 240 diameter	20 @ 300 diameter
Composite truss	17 for 12 m span or 20 for 15 m span	4 @ 400 diameter + 6 @ 250 diameter	4 @ 400 diameter + 6 @ 250 diameter + 1 @ 450 x 1000

Assumptions
Ceiling to floor zone: 1250 mm
Structural zone (beams and slab): 900 mm
Beam spacing: 6 m

[1] Depth is steel section depth. Slab depth (about 130 mm) to be added
[2] May be restricted to applications as long span secondary beams
[3] Structural zone deeper than 900 mm

Key structural watchpoints

✓

☐ Openings should not be located closer than two times the beam depth D from the support, or 10% of the span, whichever is greater

☐ Openings should not be less than the beam depth D apart

☐ Unstiffened openings should not generally be deeper than 0·6 D, nor longer than 1·5 D, and the shear resistance and instability of the web should be checked

☐ For cellular beams, circular openings can be created with diameters of 0·6 to 0·8 times the final beam depth, and at spacings of 1·1 to 1·5 times the opening diameter

See also

1 Glossary, page 31; Figure 2, page 7
2 Figure 12 page 18

Standards on page 30

Further reading on page 30

Glossary on page 32

Issues to address during

Services detailed design 1

Detailed design is a critical stage in determining how the services will pass through cellular or webbed beams. Detailed design must not only address functional requirements, co-ordination, and methods of fixing and fire protection, but also provide solutions that can be installed productively. This means a design that does not require an excess number of deviations from the drawings, and thereby additional fittings. Services designers should also consider the maintainability of their design solution.

Services design issues

General design information needed
Figures 10 and 11 shown on this and the following page represent a simplified diagram of a large, air conditioned open-plan office.

1 BSRIA AG1/2002 *Design Checks for HVAC*, lists the design information required for services instalaltions. With respect to the interface of services with structural beams, the designer should check the following:

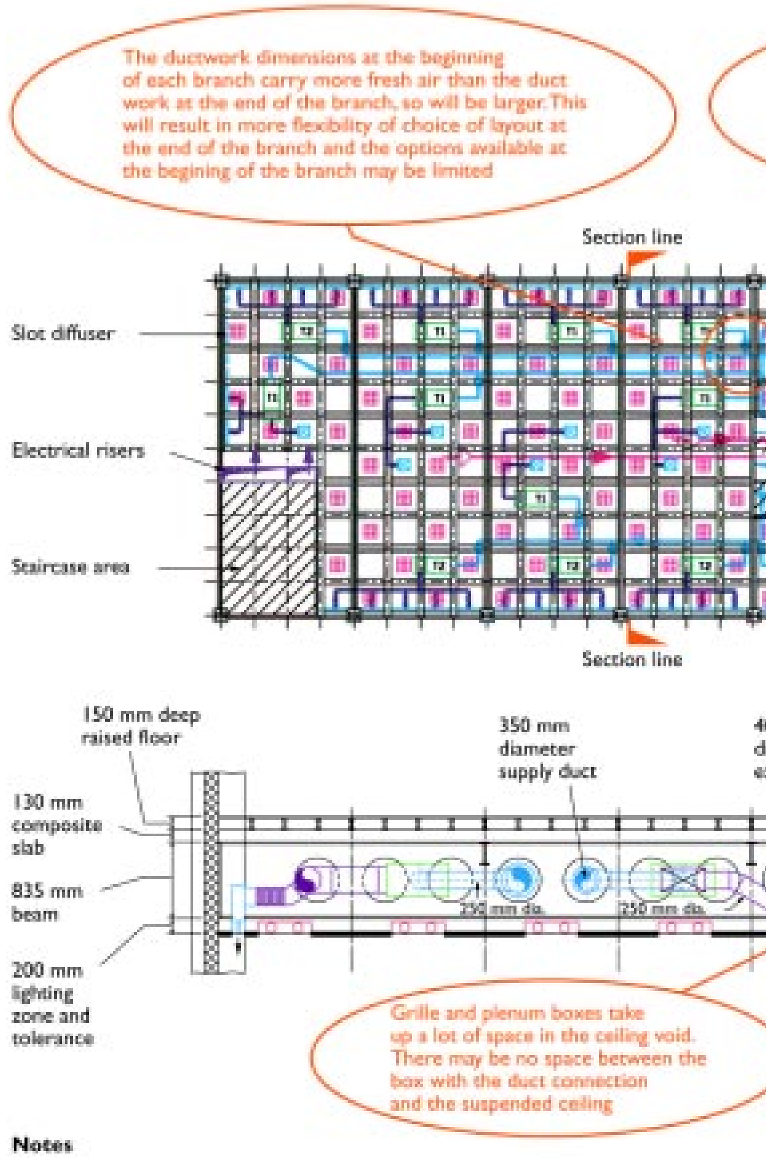
☐ Determine the acceptable noise levels in the occupied space
☐ Check whether the ceiling is to be sealed
☐ Check the return air path, for example whether via air handling light fittings, dedicated grilles or ceiling gaps
☐ For fan coils, check the position of drainage pipes used for condensate run-off
☐ Determine the relationships between the location of cellular beams and the location of internal partitions
☐ Agree grille positions in principle in anticipation of future cellular layout
☐ Determine the type and quality of acoustic treatment required for ductwork
2 ☐ Determine the fire protection system for the ducted and piped services
3 ☐ Identify the fire protection system for the structure, and the consequential reduction in aperture size for treated cellular beams.

Plant sizing issues

4 A pre-requisite for successful interface engineering between the structure and building services is that the services engineer supplies the structural engineer with basic dimensional characteristics of the key items of plant to be located in the ceiling void.

Details of associated horizontal distribution that may need to pass through the beams, such as ductwork, pipework and cabling, should

➧



Notes

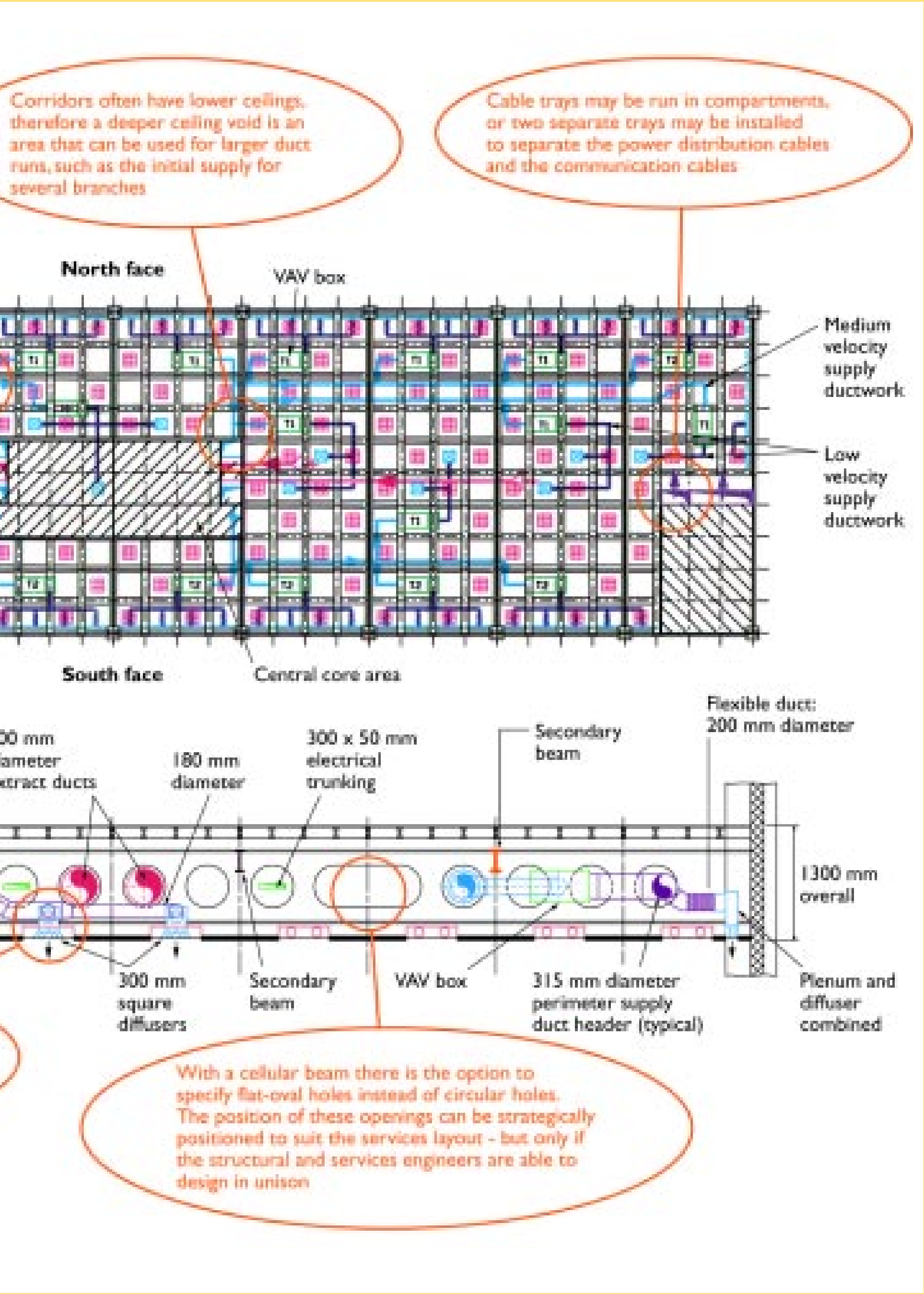
The apertures must be large enough to allow for services insulation, for the fire protection of the beam, and to enable the installation of the ductwork and pipework.

Extract path through light fitting and ceiling void into stub extract ductwork.

Figure 11: The detailed design issues for a variable air volume-type air conditioning syst
tight radius bends in ductwork, for example forced by the need to thread the ductwork
create air pressure and noise problems. Original diagram ©The Steel Construction Instit

🟦 **Mechanical engineering issues**

🟨 **Structural issues**



em interfaced with a cellular beam. Note that VAV systems are categorised as high pressure systems. Any k through the cellular beam and then to bend to a terminal unit located close to the beam, will inevitably tute.

Key m&e watchpoints

✓

☐ Ensure that the design caters for the position of drainage pipes used for condensate run-off

☐ Obtain details of the fire protection system for the structural elements

☐ Determine the reduction in beam opening as a consequence of the choice of structural fire protection system, and determine the centre point of each opening from the bottom of the slab

☐ Determine the precise dimensional details for acoustic treatment to ductwork destined to pass through a beam opening

Key structural watchpoints

✓

☐ Understand the true dimensional requirements for space-critical items such as ductwork, fan coils, vav boxes, and plenum boxes that will be located in the ceiling void

☐ Provide the services engineer with the details of the fire protection system for the beams
Ensure the space requirements for all horizontal services are clearly expressed in early design team discussions

See also

1 Glossary, page 31
2 Fire protection issues, page 22
3 Table 4, page 21
4 Table 1, page 11

Standards on page 30

Further reading on page 30

Glossary on page 31

Detailed design issues (continued)

also be provided. This information should be revisited once suppliers have been selected.

Ductwork sizing and selection issues

1 Ductwork layouts should be carefully considered to be as short as possible in order to account for physical constraints such as lift shafts, structural columns and beams, and to minimise tight bends. Ductwork layouts should be designed to reduce the need for builders' work, and to be as self-balancing as possible to reduce damper pressure drops.

Designers need to consider breakout noise and cross-talk, and take appropriate measures. Ideally, the layout should make best use of any attentuation inherent in the design concept.

Ductwork requirements

Ductwork insulation needs to be considered as early as possible. There are several penalties that can be suffered if inadequate attention is paid to insulation, such as:

2 ☐ The inability of the insulated service to fit in the beam aperture

3 ☐ The inability of separate services nominated to run together in a single beam aperture, forcing one or more of those services to deviate to another beam aperture or, worse, forced to run beneath a beam that has not been selected for that purpose.

4 The services design engineer also needs to know the details of the structural fire protection system specified by the structural engineer. Different forms of structural fire protection (such as boards and blankets) may significantly reduce the final size of the beam aperture. The overall diameter of insulated and fire protected services must be known before they designed to run through a beam.

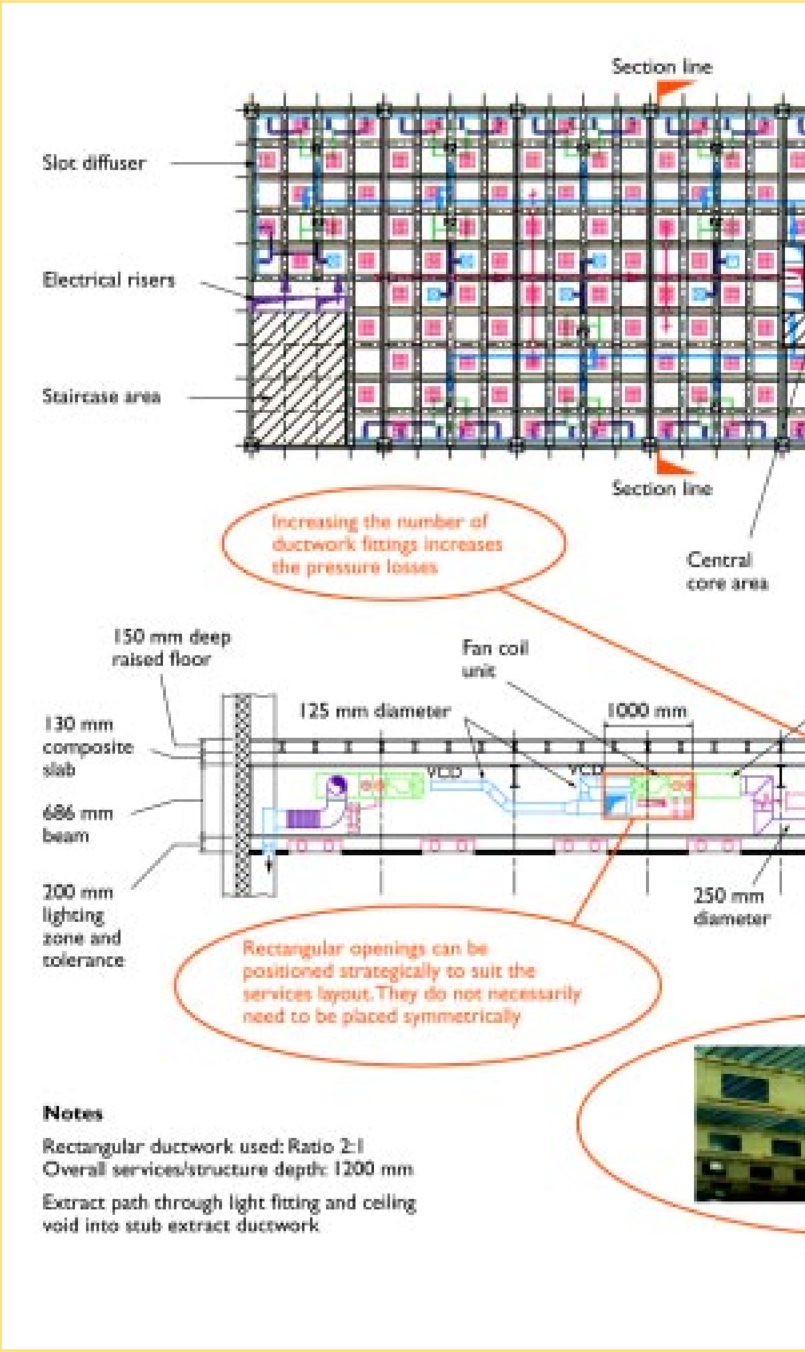
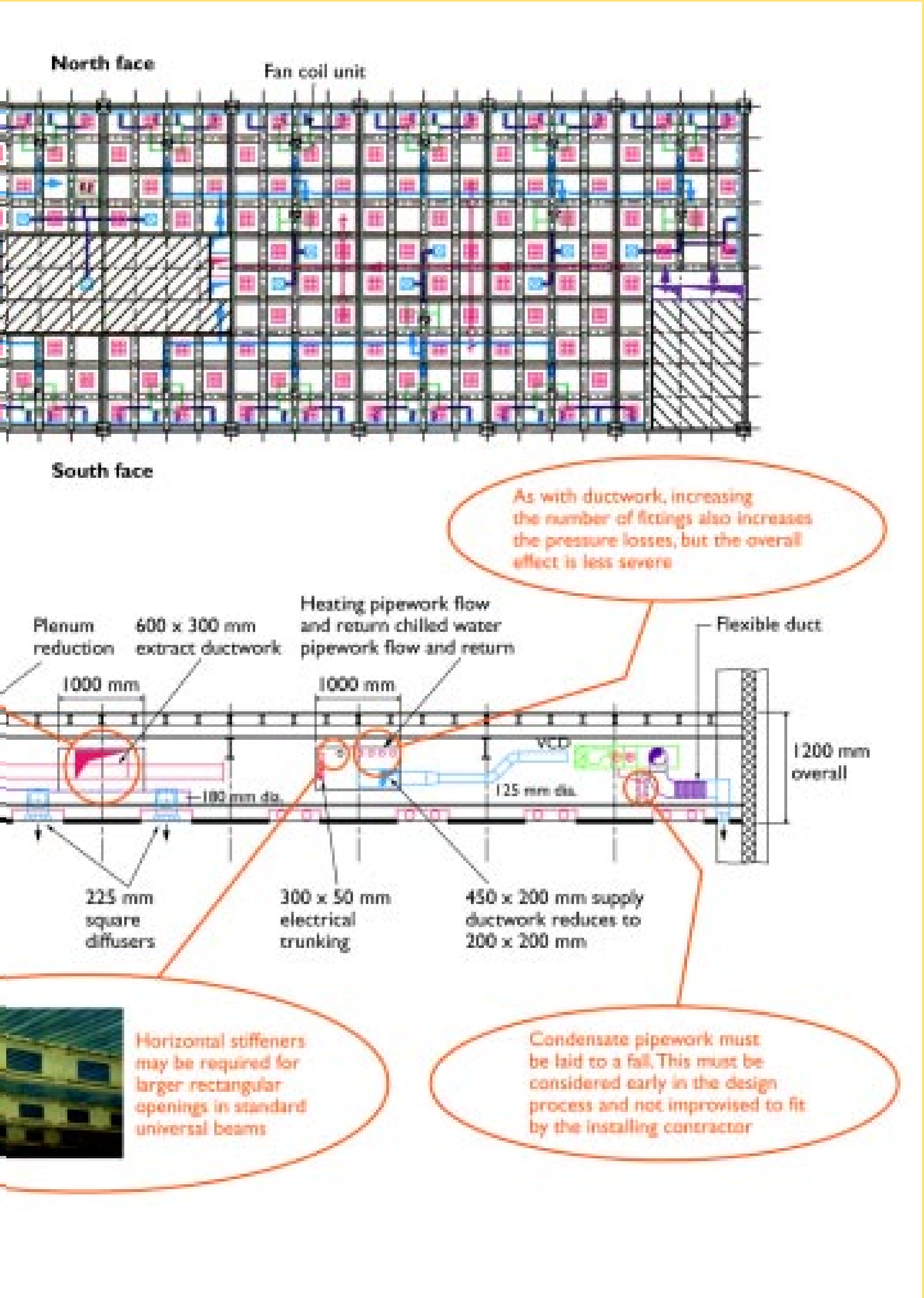


Figure 12: The detailed design issues for a fan-coil based air conditioning system interfaced thread the ductwork through the girder and then to bend to a terminal unit located Construction Institute.

🟦 **Mechanical engineering issues**

🟨 **Structural issues**



with a stub girder. Any tight radius bends in ductwork, for example forced by the need to close to the beam, will inevitably create air pressure and noise problems. Original diagram ©The Steel

Key m&e watchpoints

☐ Design ductwork layouts to reduce the need for builders' work, and ensure they are as self-balancing as possible to reduce damper pressure drops

☐ Obtain precise dimensional details from ductwork and pipework suppliers once they are known and revisit the space allocation

☐ Obtain full details of the structural fire protection system. Different forms of structural fire protection may significantly reduce the final size of the beam aperture

☐ The width of air risers (and hence width available for main floor branches) will determine the services height needed in the ceiling void, and the overall building height

See also

1 Figure 22, page 28
2 Figure 16, page 25
3 Figure 20, page 27
4 Structural fire protection, page 20

Standards on page 30

Further reading on page 30

Glossary on page 31

Issues to address for

Structural fire protection

Once the beams have been designed, any apertures cut for services distribution and the beams installed, the structural engineer's job is largely done. However, a good interface with services penetrations still depends on other factors such as the nature and quality of the beam fire protection. These factors, plus accurate dimensioning information, must be communicated and clearly shown on the detailed drawings to enable the high number of trade contractors to follow the co-ordination plan.

Structural design issues

The choice of castellated or lattice web beams may aid the horizontal distribution of services to the extent that it can equate to a significant saving in floor to ceiling heights. For a multi-storey building, this may equate to an extra floor of lettable area. It is crucial that all interface issues are made explicit on all design and installation drawings. Nowhere is this more important than in the choice of structural fire protection.

Cement or gypsum-based materials

The types of fire protection systems available can be classified into three main product groups: sprays, boards and intumescent coatings. A summary of the main factors affecting product selection in each of these three groups is given in Table 4.

Cement or gypsum-based materials containing mineral fibre, expanded vermiculite, expanded perlite and/or other lightweight aggregates or fillers, are generally the least expensive forms of fire protection. Mineral fibre-based materials are delivered dry to the spray head, where they are mixed with water and compressed air. Vermiculite or perlite sprays are usually premixed with water before being pumped to the spray head.

These fibre-based materials can provide up to 240 minutes fire resistance and are usually defined as being non-combustible in accordance with *BS 476-4*. While most materials are applied *in situ*, some may be applied to the steelwork before erection.

As long as the fire protection is applied to the steelwork before the services are installed, it should be possible to pass the pipes and ducts through the holes in the beam web without needing to take any special measures. However, as the range of thicknesses for cement or gypsum-based materials is between 10 mm and 75 mm, an allowance must be made for the material thickness when selecting the required hole size.

Boards and blankets

Blankets, semi-rigid and rigid boards are used as dry forms of fire protection installed *in situ* as either profile or boxed protection. Base materials include ceramic fibres, calcium silicate, rock fibre, gypsum and vermiculite. Most are only suitable for interior use or limited external exposure during construction.

Potential problems with loose fibres may be minimised by an outer sheathing of aluminium foil or similar, and by the use of taped joints.

Up to 240 minutes fire resistance can be provided, although longer fire resistance periods often require the use of multiple layers of boards. In that case the joints in the layers are staggered.

The difficulty of using board with regard to service integration is that the board must be cut to allow the services to pass through the beam, while maintaining proper protection of the steelwork. This is not a practical option for cellular beams or beams with multiple holes.

Intumescent coatings

Intumescent coating systems are classified as either thin film, which account for the vast majority of systems used in general construction, or thick film, sometimes referred to as mastics. The materials are reactive, swelling to many times their original thickness when exposed to fire, with the resultant char insulating the underlying steel substrate.

Thin film intumescent coating systems are applied either by airless spray, brush or roller.

Further guidance on the off-site application of intumescent coatings is given in the SCI publication, *Structural fire design: Off-site*

Table 4: Characteristics of fire protection systems. ©SCI.

	Sprayed cementitious or gypsum-based coatings	Boards and blankets	Intumescent coatings
Wet or dry	Wet	Mainly dry	Wet, thick film may be preformed
Cleanliness of application	Messy with protection required to adjacent surfaces	Relatively clean	Protection required to adjacent surfaces
Robustness	Can be brittle and vulnerable to mechanical damage. Some coatings unsuitable for use in plenum ceilings or in clean areas	Some rigid boards can be brittle and vulnerable to mechanical damage. Batts and blankets may require additional covering	Similar to that of paint systems. Thick film very tough and durable
Thickness range	10 – 75 mm	Boards: 6 – 100 mm Batts/blankets: 12 – 76 mm	Thin film: 0·3 – 6·5 mm Thick film: 2·0 – 32 mm
Maximum fire resistance	240 minutes	240 minutes	Thin film: 120 minutes Thick film: 240 minutes
Class O surface	Yes	Usually	Possibly

applied thin film intumescent coatings.

General guidance on the selection and use of intumescent coatings can be found in *BS 8202-2*. Guidance on the measurement of coating thickness can be found in an ASFP document, *On-site Measurement of Intumescent Coating Systems*. If intumescent coatings are used with cellular beams, specialist advice should be sought on the appropriate thickness.

Intumescent coatings offer advantages over the previous types of fire protection system. Compared with cementitious coatings, the coating thickness is relatively thin (0·3 mm to 6·5 mm for thin film) and should not have much effect on the selection of hole size.

Whether the coating is applied *in-situ* or off-site, the operation is not impaired in any way by the need to pass services through the beams. The presence of the coating will also not affect the installation of services. However, care must be taken to avoid damaging the coating during services installation.

Key structural watchpoints

☐ All interface issues should be made explicit on all design and installation drawings

☐ As the range of thicknesses for fire protection materials is between 1·0 mm and 75 mm, allowance must be made for material thickness when selecting the required hole size

☐ Cutting board-type fire protection to allow services to pass through beams is not a practical option for cellular beams or beams with multiple holes

☐ If intumescent coatings are used with cellular beams, specialist advice should be sought regarding appropriate thickness

Key m&e watchpoints

☐ Obtain full details of the structural fire protection system. Different forms of structural fire protection may significantly reduce the final size of the beam aperture

☐ Ensure that services contractors are aware that intumescent coatings can be damaged by careless installation

☐ Obtain specific thickness details of intumescent fire protection coatings if they are specified for use on cellular beams

☐ Obtain precise dimensions of the way fire boards will be fitted to the beams to ensure space for services runs are not compromised

See also

Figure 16, page 25

Standards on page 30

Further reading on page 30

Glossary on page 32

Issues to address for

Services and fire protection

The interface engineering of services with beams must take into account fire protection. Fibreboard-based fire protection for beams can reduce apertures by 40 mm all round, and this will reduce usable area by a similar figure if the services passing through the beam are to be thermally insulated. It is vital that these dimensions are known at the design stage, along with the specific locations of fire dampers. The Association for Specialist Fire Protection is working towards defining a set of agreed methodologies.

Fire protection issues

Good interface engineering should include the fire protection scheme for the beams, as well as the dimensional characteristics of thermal insulation for those services intended to interface with or pass through the beams.

1 If the dimensional characteristics of both forms of covering – along with spacing needs – are not considered early in the design co-ordination process, installers may find services will not fit through beam apertures, forcing pipework and ductwork to deviate laterally and/or horizontally. This can massively increase installation time and materials costs.

2 Furthermore, if these issues are factored into the design co-ordination process by the structural engineer, services designer and specialist contractors, it may reveal that a series of dimensionally identical holes in a cellular beam is not an optimal arrangement.

A more efficient services distribution may accrue from a series of circular, flat oval or square apertures co-ordinated to match the services distribution. The added cost in design time is likely to be recouped from a better co-ordinated, faster installed, and better performing services installation.

However, while pipework and ductwork can share a penetration, fire dampers should not, as it is important to allow the fire damper room for expansion. Other services running in the same aperture as the fire damper may hinder this expansion.

Integrating fire dampers

As there is no industry-agreed interface detail, for fire dampers with structural beams, fire dampers are regularly subject to improvisation by installing contractors (figure 13). The same is true for dampers installed on a ductwork spigot, where the duct is effectively part of the preceding fire zone.

Figures 14 shows an off-set fire damper installation appropriate for use adjacent to a fire separation, which could be modifed for use near to a structural beam. The basic approach is in accordance with *BS 476 Part 20, BS EN 1366-2* and *BS ISO 10294-1*.

It is rare for fire dampers to be required in large open-plan office areas where structural beams are most likely to interface with building services. It is also general practice not to create fire compartments in ceiling voids, for example where a void is used as a return air plenum.

While fire partitions will be the norm in core areas, the universal columns in these areas tend to be larger and connected by smaller transverse beams, enabling the services to run beneath rather than through those beams. The fire partitions will not necessarily be on the line of the structural beam, and any fire dampers are likely to be installed in or near the fire partitioning as shown in figure 14.

The Fire Damper Working Group of the Association for Specialist Fire Protection (ASFP) is working towards nationally applicable, tested and assessed fire damper installation methods. The subject is very complex and contentious, and as yet there is no industry-accepted method of locating fire dampers in structural beams.

In the event that a fire damper is required to be fitted direct to a structural beam, engineers should recognise that every component used to attach a fire damper to a beam – the face plate, expansion frame and fixing bolts – must be fire-rated equal to, or greater than, the fire damper and the fire protection applied by the specialist contractor.

Irrespective of the method chosen to mount the fire damper, the method must be presented to the local fire officer for comments and approval. Fixings into structural steelwork must be agreed with the structural engineer.

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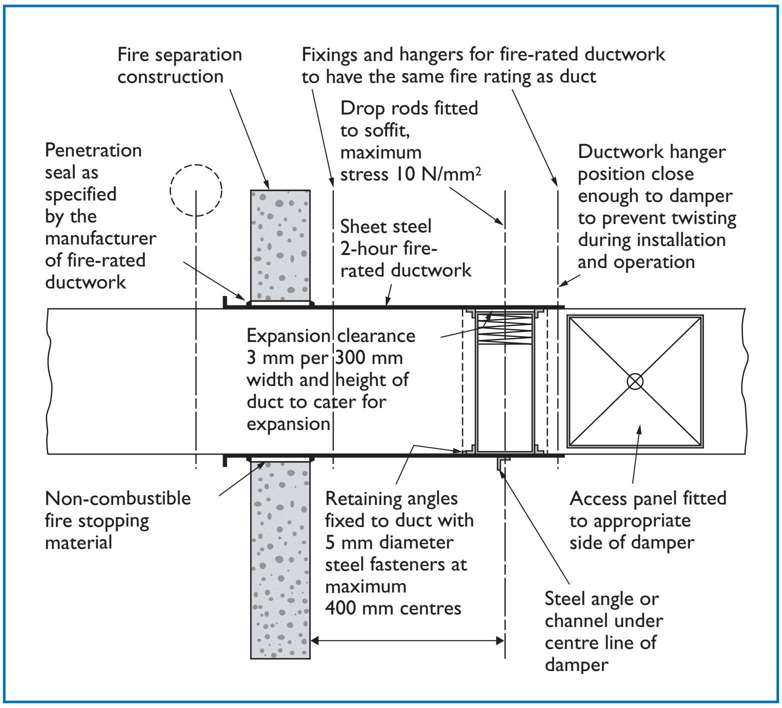
Figure 13: A fire damper suspended from a beam. Poor co-ordination forced the cutting of the beam fire protection system for Unistrut fixings – a typical improvisation by a services installer.



2 ***Figure 14:*** A fire/smoke damper set-off from a fire partition (potentially a structural beam). Reference: BSRIA Detail Drawings.

Key m&e watchpoints

- ☐ The m&e interface engineering should include details of the fire protection scheme for the beams, and the dimensional characteristics of that fire protection
- ☐ Services engineers should check that services will fit through fire protected beam apertures without the need for deviations
- ☐ Services engineers should establish whether the steelwork fire protection is to be contracted out to a specialist fire protection contractor, and determine the precise dimensional details of the steelwork fire protection
- ☐ All fire damper installation methods must be presented by the ductwork designers to the local fire officer for comment and approval
- ☐ All fixings onto the structural steelwork must be agreed with the structural engineer

See also

1 Figure 18, page 26
2 Figure 9, page 12

Standards on page 30

Further reading on page 30

Glossary on page 31

Issues to address during

Services installation I

Properly co-ordinated drawings are critical to ensuring a quality installation. Get it right, and the client will inherit cost-effective, well-installed, well performing and easily accessible services. Get it wrong, and the materials and labour overspend will adversely affect the speed, quality and profitability of the project. The sums involved will not be small: on city office projects contractors can overspend by £250 000 for additional fittings to cope with unforseen services deviations, plus a similar sum for lost productivity.

Key installation issues

By the time designers' drawings get to the contractors, the emphasis tends to be on the volume of services that need to be fitted into the ceiling void in a given time, rather than the location of vent, point, drain points, and potential points of leakage.

At the installation stage, good interface engineering should also concentrate on installing the services in a manner that will consume the least amount of operative hours on site, and create the least problems for subsequent operation and maintenance.

Unfortunately, the advice of the installing or specialist contractors is rarely sought at the stage when the designers are concentrating on system functional requirements, such as air movement and temperature. However, a successfully engineered interface is one that:

☐ facilitates the installation

☐ can be installed productively

☐ does not require too many fittings to deal with deviations.

Services running parallel to beams

1 It is important that the services design team understands the effects of running services in parallel to the beams. If the co-ordination process is carried out in two dimensions only, then it is possible that neither the plan nor the elevation drawings will reveal a co-ordination clash between pipework running parallel to a beam, and the circular ductwork running at 90° to the beam, and chosen specifically to take advantage of the circular passageways in a cellular beam.

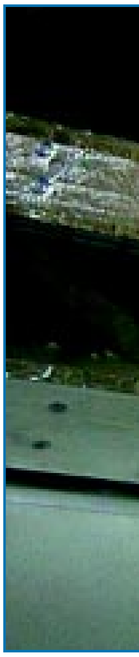
2 The cost to the client in terms of delays while pipework is reconfigured by the installing contractor could be better spent at the scheme design stage by nominating rectanglar holes in the beam, and then using more space-efficient flat oval ductwork.

Figure 15 shows a cellular beam in line with a lattice beam. Designers can be mislead into believing that the centres of the apertures in both beams may be assumed to be identical for each hole in the cellular beam, whereas the centre points of adjacent triangles in the lattice beam can be offset by up to 200 mm. The tolerances will be tighter once fire protection is applied.

Depth restrictions

3 The height available for services distribution is defined by the distance between the ceiling and the lowest of the beam apertures. In figure 22, between 40 and 60 mm of depth from the underside of the slab to the bottom face of the beam is effectively lost as a distribution zone.

This may be a crucial issue for distribution services that must be laid to a fall, and need to



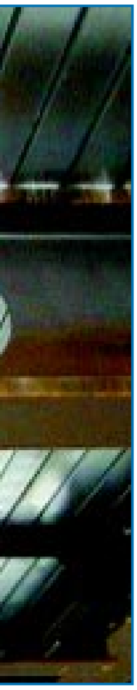
🟦 **Mechanical engineering issues**

🟨 **Structural issues**

start as high as they can in the ceiling plenum.

Figure 16 also shows a lattice beam enclosed by a fibreboard-based fire protection system of about 40 mm thickness. The board is fixed to the steelwork using adhesive, or spot-welded pins to which the foil-faced board is then attached.

4 With this kind of fire protection, the free area of beam that can accommodate services is vastly reduced – a factor that must be taken into account by the services designer at the detailed design stage.



Left, figure 15: A cellular beam in line with a lattice web beam. Designers can be misled into believing that the centres of the apertures in both beams will always be in line – they will not, a difference that may be greater once fire insulation is applied (see Figure 16). ©BSRIA.

Above, figure 16: A lattice beam enclosed by a fibreboard-based fire protection system. Note that the free area of the beam is now considerably reduced. ©BSRIA.

Key m&e watchpoints

✓

- ☐ Design should enable services to be installed in a manner that will consume the least amount of operative hours on site, and create the least problems for subsequent operation and maintenance
- ☐ Check that the chosen beam fire protection system will not reduce the free area of the beam aperture below that required for services
- ☐ Check the details of the installation method for the beam fire protection system to ensure design clearances for services will be maintained
- ☐ Pay particular attention to the relationship between the actual location of beam apertures and services (such as fan coil condensate pipework) that need to be laid to a fall
- ☐ Obtain the actual measurement of the distance between the soffit and the top edge of the lowest aperture in the beam. This will determine the true void area available for services distribution

See also

1 Figure 18, page 26
2 Figure 9, page 12
3 Figure 22, page 28
4 Table 4, page 21

Standards on page 30

Further reading on page 30

Glossary on page 31

Issues to address during

Services installation 2

Although the highly serviced installation shown in figure 17 appears at first glance to be well co-ordinated, closer inspection will reveal a high number of deviations both horizontally and vertically.

Some of these deviations could have been avoided had the beams been strategically equipped with different sizes and shapes of openings, such as flat oval or rectangular, more closely related to the location of services.

Here, the services designers have made the best use of what was made available, but a better co-ordinated installation could have resulted had the structural design provided holes in the beam in the shape, size, number and location required by the services engineer. That they haven't is probably evidence of a sequential (rather than integrated) design process between the structural and services engineers.

Figure 18 shows a problem created by a focus on services running through beams at the expense of those services running parallel to them. While the design team were correct to place the gravity pipework as high in the void as possible, more attention could have been paid to co-ordination to ensure that the fan-coil flow and return pipework did not have to deviate, creating the need for more fittings and the potential for higher flow resistance.

It is not unusual for the co-ordination of services to be done in two dimensions. If this is considered in plan view, the consequences will not be immediately obvious. In this case, had the design team been more strategic with the beam openings, flat oval ductwork could have been used instead of circular ductwork, enabling the pipework to maintain a clear run.

1 Figure 19 shows an example of how poorly co-ordinated services with cellular beams can lead to deviations and the creation of potential problems.

Here, the pipework contractor has been forced to run flow and return pipework beneath the beam. Having created a low point in the circuit, the contractor had to fit drain cocks. Not only could these valves interfere with the suspended ceiling, they could also clash with light fittings that may need a clear depth of 150 – 200 mm.

Figure 17: While this installation shows the integration of services with structure, deviations laterally and horizontally hint at a sequential rather than a truly integrated design process. ©BSRIA.

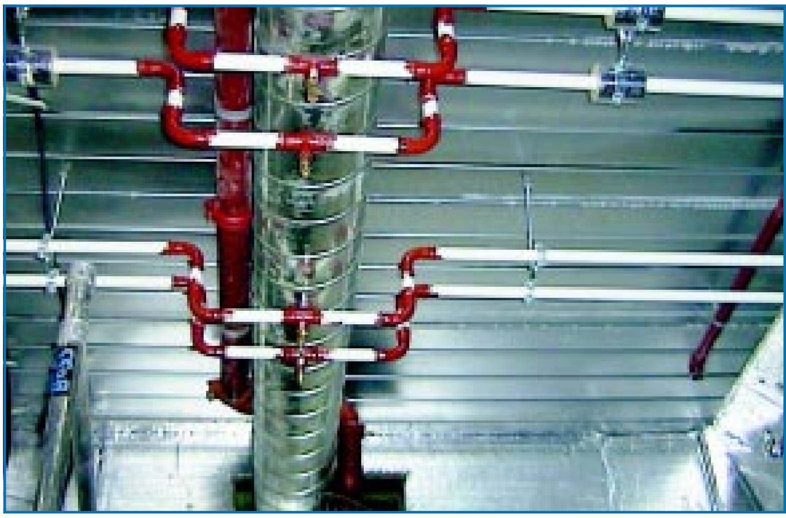


Figure 18: Poor services-to-beam interface engineering. Not only has the pipework been forced to deviate beneath the ductwork, but this is necessitated the labour-intensive fitting of joints and drain cocks. ©BSRIA.

2 Figure 20 shows pipework attached to a fan-coil unit. The white polymer pipework carries the condensate from the fan coil, and needs to be laid to a fall.

The requirements of this one item can

Figure 19: More poor services-to-beam interface engineering. The fitting of drain cocks and valves such as these could not only interfere with other services such as light fittings, they could be low enough to foul the suspended ceiling. ©BSRIA.

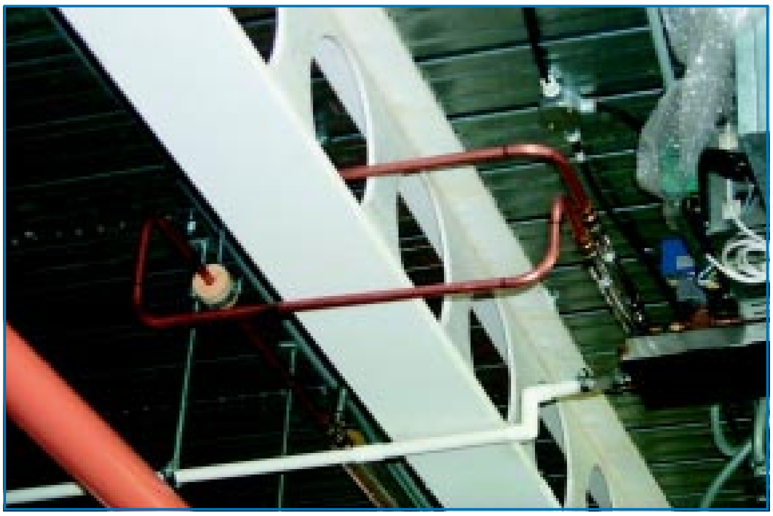


Figure 20: Poor interface engineering between a cellular beam and a fan-coil unit. The condensate pipework has been forced to deviate immediately after leaving the fan coil unit. More attention at the design stage could have avoided this problem. ©BSRIA.

drive the entire co-ordination process, but as can be seen, the close proximity of the fan coil to the beam – plus the inability to line up all the fan coil pipework with the openings in the beam – has forced the condensate pipework to deviate immediately. Forcing the condensate pipework to deviate so soon after leaving the fan coil unit may mean that the fall will be far shallower than is required to drain the condensate effectively.

Key m&e watchpoints

☐ Ensure that the space requirements for all horizontal services are clearly expressed in early design team discussions

☐ Refer to manufacturer's dimensional information and constantly revisit the space requirements

☐ Ensure that fan-coil flow and return pipework does not have to deviate, creating the need for more fittings and the potential for higher flow resistance.

☐ Be aware that apparently minor services systems, such as condensate pipework, can drive the entire co-ordination process and deserve equal attention in the design process

☐ Be aware that deviations in pipework can force the fitting of drainage cocks and valves that could subsequently compromise other services and the suspended ceiling

See also

1 Figure 11, page 16
2 Figure 12, page 18

Standards on page 30

Further reading on page 30

Glossary on page 31

Issues to address during

Services installation 3

Figure 21 shows the result of an installer's attempt to co-ordinate services with the beams shown in figure 15. In the foreground, flow and return pipework has had to deviate to pass through the cellular beam, and then deviate a second time to find a way through the lattice beam in the background and thence to a fan coil unit.

Deviations such as this require additional cut lengths of pipe and fittings, plus time to mark up, measure and cut the pipe, and extra time for installation. Once finished, each joint is then a potential leakage point.

Figure 22 shows evidence that once services have been run at one level, space may no longer be available for other services. Here, between 40 to 60 mm of depth has been lost by fixing cabling to the soffit, and then dropping it down so it can run through a beam aperture. Such practice can steal space from other services of greater priority.

As services deviate from the slab to penetrate the beam, additional fixing is required, which absorbs the installer's time. Alternatively, if the services are suspended from the soffit to achieve an uninterrupted, horizontal run through the beams, then the space above will be lost for distributing any other services. Designers and contractors need to collaborate to decide on the most space-effective and cost-effective approach.

Figure 23 shows a fan-coil unit with its rigid ventilation ductwork fed through the openings in a webbed beam. The relationship between the fan coil unit and the structural beam has created the need for a substantial amount of deviation pieces in the ductwork.

In this case, flexible or semi-rigid ductwork would have been a faster and more cost-effective installation, rather than the multiple measuring, marking, cutting and fitting activities required to make this solution work.

Such deviation in ductwork creates the potential for turbulence, noise, pressure drops and leakage. The advantages and disadvantages (such as less efficient airflow) of flexible ductwork need to be identified by the designer during the design process.

Figure 21: A contractor's attempt to co-ordinate services through a cellular beam and a lattice-web beam. Note the number of deviations necessary for the services to pass through the beams. ©BSRIA.

Figure 22: Between 40 to 60 mm of depth can be lost from the underside of the slab to the bottom face of a ceiling, adversely affecting the ability to run cabling horizontally. ©BSRIA.

Figure 24 shows an alternative to figure 22. Here the use of flexible ductwork made use of the cellular openings without the need for complicated and expensive on-site fabrication. However, although flexible ductwork can be easily threaded through cellular beams, a high number of duct bends can restrict airflow and create noise problems.

The headline message from these examples and those on preceding pages is that the choice of structural system used on the project has a fundamental effect on floor to ceiling

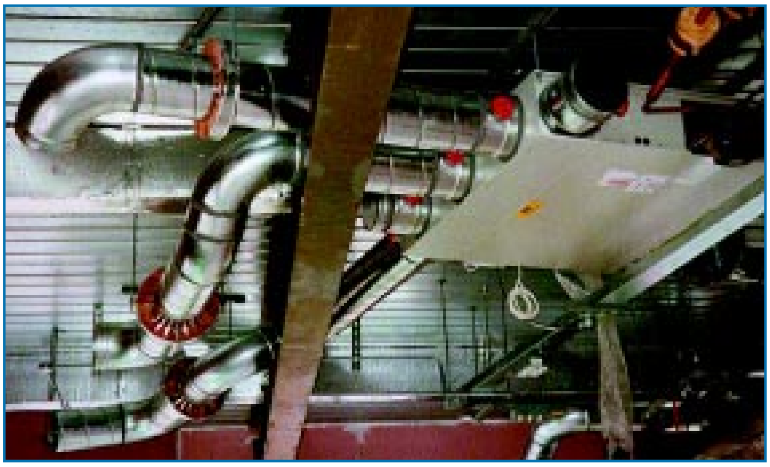


Figure 23: The use of rigid ventilation ductwork fed through beams can result in a high number of deviation pieces, all of which are labour-intensive to fabricate and fit, and as a consequence be a source of air leaks during building operation. ©BSRIA.

Figure 24: An uncontrolled number of bends in flexible ductwork will cause loss of self-balancing between diffusers, and added noise through the diffuser that gets more air. ©BSRIA.

heights and external envelope area. From a services fit-out perspective, the choice of structural system has a fundamental effect on the building services design.

In turn, the services design engineer needs to have a better appreciation of the effect that a design will have on the time taken to install the services by the contractors, and of the knock-on effects in terms of operation and maintenance of the building. This needs to be communicated to the client in the early stages of design.

Key m&e watchpoints

☐ Note that pipework and ductwork deviations require additional cut lengths of pipe and fittings which create potential leakage points.

☐ Discuss with the client the installation and performance benefits (and disadvantages) of using flexible ductwork as opposed to rigid ductwork

☐ Inform the client that savings from integrating services with structural beams will only be achieved if contractors and installers are not required to improvise the interfaces on site

See also

Key m&e watchpoints, page 7

Standards on page 30

Further reading on page 30

Glossary on page 31

Standards

Designers and contractors should always follow the guidance laid down in prevailing standards.

Mechanical engineering standards

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*BS 476 Part 20, 1999, Fire tests on building materials and structures. Method for determination of the fire resistance of elements of construction (general principles),*1987 ISBN 0580 158 977

BS EN 1366-2: 1999, Fire dampers, ISBN 0580 324 281

BS ISO 10294-1: 1996 Fire-resistance tests. Fire dampers for air distribution systems – test method. ISBN 0580 27523 X

BS EN 1366-2: 1999 Fire resistance tests for service installations – fire dampers ISBN 0580 32428 1

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Structural standards

BS 5950: Structural use of steelwork in building, Part 1: Code of practice for design. Rolled and welded sections BSI, 2001, ISBN 0 580 33239 X

BS 5950: Structural use of steelwork in building, Part 8: Code of practice for fire resistant design BSI, 1990, ISBN 0 580 18344 0

BS 6399: Loading for buildings Part 1: Code of practice for dead and imposed loads BSI, 1996, ISBN 0 580 26239 1

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The use of intumescent coatings for the fire protection of beams with circular web openings, AD 269, New Steel Construction, Vol. 11 No. 6, Nov/Dec 2003, SCI/BCSA, ISBN 0968 - 0098

Yandzio E, Dowling J J & Newman G M (editors), *Structural fire design: Off-site applied thin film intumescent coatings,* The Steel Construction Institute, 1996, ISBN 1 85942 038 9

Glossary

Building services terms

Building management system	A microprocessor-based system that is connected to devices in the ceiling void, such as fan coils, VAV boxes, terminal units, lighting, fire alarms and similar devices to enable remote monitoring and control.
Chilled beams/ceiling panel	A simple cooling device incorporating a chilled-water pipe and mounted in a ceiling void. It requires a ceiling void depth of about 300 mm. A chilled ceiling comprises a serpentine arrangement of pipework, fitted to a slim, perforated ceiling panel. It needs a shallow ceiling void of between 60 – 70 mm.
Condensation pipework unit	Pipework required to drain condensation from devices such as fan coils (*qv*). Condensation pipework needs to be laid to a fall across the ceiling void to enable the condensate to be drained.
Constant volume system	A simple system used to provide a fixed volume of tempered air in multi-zone buildings often associated with partially centralised air/water systems, such as fan coils (*qv*).
Fan coil unit	A device in the ceiling void which comprises a fan, heating coil, cooling coil and air filter, housed in a metal casing. The fan-coil unit is supplied with air from the main air supply ductwork. This air passes into a plenum chamber with multiple outlets for connection to one or more terminal devices (*qv*), plus connections for valves and controls
Fire damper	A device connecting two zones or sections of ductwork and designed to close under a fire or high heat condition, and rated to maintain its integrity for a pre-determined time, at or below a certain temperature.
Pressure drop	A term describing variations in air or water differential pressure caused by obstructions or constrictions to flow. Pressure drops can be caused by bends or in-line elements such as fire dampers (*qv*).
Terminal device	The final device at the end of a mechanical ventilation or air conditioning system. Its primary role is to supply and direct air into the occupied zone at the desired temperature and location. Terminal devices may be connected to a separate diffuser located in a suspended ceiling or in a raised floor.
Variable air volume (VAV)	An air-conditioning system consisting of centralised plant connected to supply air ductwork distributed in the ceiling void, which carries air at a given temperature to terminal devices (*qv*) called VAV boxes. These boxes regulate the amount of air entering the occupied space
Variable refrigerant flow (VRF)	An air-conditioning system requiring a ducted air supply, (insulated) pipework for refrigerant gases, and micro processor-based electronics to control the devices. The VRF units are normally housed in terminal devices (*qv*) called ceiling cassettes.

Glossary

Structural terms

Bending moment	The total bending effect at any section of a beam due to the self-weight and applied loading.
Castellated beam	A steel beam with regularly spaced hexagonal openings in the web, formed by cutting and re-welding a hot-rolled section.
Cellular beam	A steel beam with many regularly spaced circular holes in its web, formed by a proprietary fabrication process.
Composite beam	A steel beam supporting a concrete slab with a shear connection (usually studs) between the beam and slab, such that they act compositely together.
Intumescent coating	A coating applied to steel beams or columns that expands to many times its initial thickness when heated, thus providing an insulating layer to the steel.
Non-composite beam	A steel beam that acts alone and is not assisted by the concrete slab in carrying the load.
Primary beam	A structural member designed to transfer loads from the secondary beams to the columns.
Secondary beam	A structural member supporting the floor slab, spanning between columns or primary beams.
Shear resistance	The ability of a section to resist the shear forces acting on it.
Stub girder	Vierendeel girder consisting of a universal column section as a bottom chord, a concrete slab as a top chord and steel stubs as verticals.
Tapered beam	A beam in which the depth of the web varies along its length.
Truss girder	A triangulated frame built up wholly from members in tension and compression used as a beam.
Universal beam (UB)	A hot-rolled steel I section consisting of a web and two flanges of uniform thickness.
Universal column (UC)	A hot-rolled steel H section consisting of a web and two flanges of uniform thickness.
Vierendeel girder	After Professor Vierendeel. An open-web girder without diagonal members, but with rigid joints between the top and bottom chords and the verticals.