

# LOOK OUT FOR THOSE SQUARE HOLES!

## *Recent developments in fire protection of steel beams with web openings*

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Recent releases of information from the Association of Specialist Fire Protection (ASFP) and the Steel Construction Institute (SCI), suggest that clients, designers and risk assessment writers must pay special attention to new guidance that draws attention to the possibility of lower limiting temperature for steel beams in fire. This implies a need for thicker fire protection systems, but if the guidance is ignored they may all end up stuck in the proverbial square hole.

### The trends

We have witnessed a variety of innovative deployments of steel elements when used as the structure in buildings. Much of the activity has been targeted at reducing the storey height, whilst retaining all the facilities that make a contemporary building tick for the widest range of potential occupants. In short, an extra storey in a fixed height of building usually means better return on the capital investment.

In recent years, the provision and use of beams with a wide variety of apertures, or openings in the web of the steel, has seen steady and increasing growth. The web openings of old were invariably provided as substantial castellated hexagonal openings. Nowadays, we are seeing beams with circular, rectangular and elongated circular or lozenge shaped openings. The resulting 'cellular beam' is approximately 40 to 60% deeper than its parent rolled steel section, but the exact finished depth, cell opening diameter and cell spacing, are very flexible.

Manufacturers may claim that the cellular beam has up to 250% better section properties than its parent section. The manufacturing technology allows beams with elongated openings, pre-cambered beams, curved roof beams and even tapered beams. Some cellular beams are made from welded plates, whilst others are made by special profile cutting/welding of the parent steel web. There could be slight differences in the inside corner details, dependent on the manufacturing process. Asymmetric cellular beams are also available, such that the top and bottom tees are profiled from different sized parent steel sections.

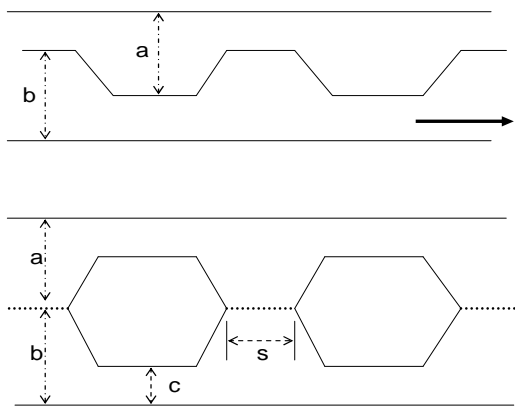
The overall end result is that clients can benefit from greater clear beam spans with less columns and improved flexibility for use of the space. In some cases, the size of the cellular steel beam can be increased and optimised for the most cost effective fire protection solution.

Importantly, the web openings provide a useful conduit for the routing of services through buildings within the depth of the beam. At the same time, the lower weight of the steel frame may contribute toward producing further savings elsewhere, e.g., in the cost of foundations.

### New challenges

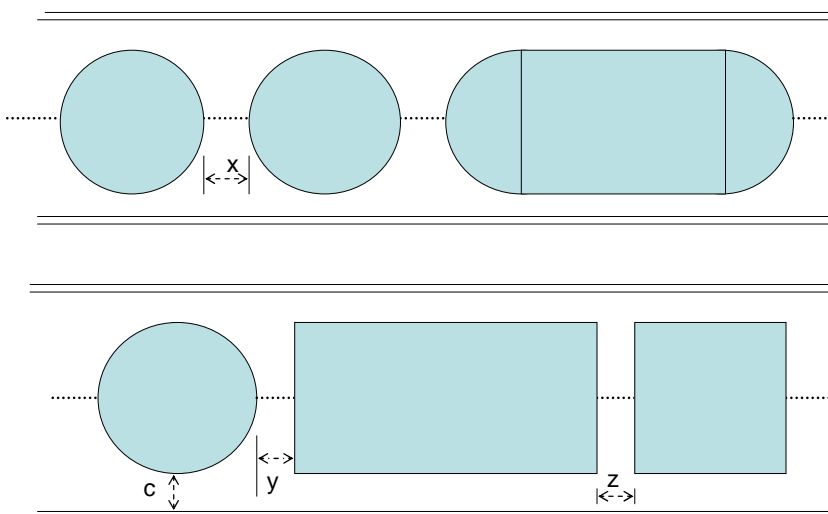
Figure 1 illustrates how a universal beam may be cut to enable each half to be repositioned before rewelding the both parts together again, such that the depth of the new castellated beam is  $[a + b]$ . The spacing[s] between apertures is governed by the dimension of the top chord of the aperture. The dimensions 's' and 'c' are fundamental to the strength of the steel section.

Fig 1. Example of manufacture of castellated beam



In Figure 2, circular cellular apertures are shown, spaced at distance 'x'. This pattern can be regularly repeated along the length of a beam, but circles can be joined to form elongated shapes, or interchanged with rectangular apertures, or mixtures of all three types as illustrated in the site photographs. The space between apertures may vary considerably to give dimensions 'x' or 'y' or 'z', but its important to note that the residual web post zone can vary substantially – and this may well be the weakest part of the beam in fire, rather than the bottom flange.

Fig 2. Various cellular apertures



## Fire protection of steel beams

Under normal circumstances, for universal beams and columns, the fire protection requirements will primarily depend on the fire protection period required and the Section Factor of the steelwork in question, where

*Section Factor ( $m^{-1}$ ) =  $A/V$  where  $A$  is the area of the steel exposed to fire, and  $V$  is the volume of steel*

This assumes that the steel has constant cross section along its length. Clearly, this is not the case when castellated or cellular beam structures are concerned. So designers need to take stock of the potential effect of these structural and dimensional issues on the limiting temperature of the beam in fire. More than one mechanism of failure could occur.

The SCI has proposed (adopted by the ASFP) that the Section Factor of cellular beams is calculated in a new way as follows:

*Section Factor ( $m^{-1}$ ) = 1400 / t where t = the thickness in mm of the lower steel web.*

Some ASFP members (manufacturers of reactive intumescent fire protection systems) have carried out sufficient fire tests to have created product-specific-models with the SCI to determine the critical, or limiting temperatures, of the beams with circular openings, bearing due consideration to the key dimensions and static/dynamic load. This information can be combined with the product-specific performance of a named reactive fire protection system, to determine the fire protection thickness required for a given fire resistance period for cellular beams with circular openings.

The available evidence suggests simpler modelling with non-reactive fire protection systems. Its worth noting that the fire testing and assessment of steel cellular beams is NOT within the current scope of BSI or EN standards. Currently, there is no agreed European approach that deals with the fire protection of these types of beams.

### Changes in approach

Historically, the ASFP has considered that castellated and cellular beams can be protected with non-reactive fire protection systems, provided that a 'plus 20%' correction to fire protection thickness is applied, whereas there was no such ASFP guidance for reactive intumescent coatings. The Section Factor was calculated using traditional methods. This advice was originally based on the notion that web openings were spaced at substantial intervals, but has now been amended in the ASFP publication 'Fire protection for structural steel in buildings – 4th Edition' (theYellow Book) as published in 2007. Some other agencies have historically believed that the 'plus 20%' rule was equally applicable to reactive coatings, but have since removed that opinion as test data has become available.

The 4th Edition 'ASFP Yellow Book' also includes new guidance on the fire protection of cellular beams and castellated sections and gives particular advice *and conditions of use of proprietary test data* for fire protection of cellular beams using non-reactive systems. It also provides new product specific guidance allowing the use of reactive intumescent coatings *provided that* the ASFP fire test protocol has been followed such that product specific protection thicknesses are generated using a recognised model such as SCI RT 1088 v04, which may include its own limitations for scope of use.

Manufacturers of cellular beams may well have developed their own predictive models for calculation of protection thickness using specified reactive intumescent protection products. The key factor is the limiting temperature of the particular cellular beam. The value of the limiting temperature may well be different for different cellular beams since it is dependent on the residual mass, the shape, location and spacing of the openings.

### Outcomes

In recognition of the limited fire test data and predictive modelling available for cellular beams with rectangular and other non-circular shaped openings, ASFP and SCI mutually agreed to issue guidance to alert clients, designers and risk assessors to the current level of knowledge. The SCI issued AD 319 as an advisory desk note to steel designers. The ASFP issued two documents. Firstly, a new Technical Guidance Note 009:2008 as 'Guidance note for the fire protection of steel beams with web openings' which largely mirrors the SCI AD 319. Secondly, a news release was issued to fire and construction related industry journals to alert them and their readers to the state of play.

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### NOTE TO EDITOR:

A copy of the ASFP news release is reproduced below.

## PRESS RELEASE

26 March 2008



### IMPORTANT ADVICE TO ASFP MEMBERS, STRUCTURAL DESIGNERS, STEEL FABRICATORS, SPECIFIERS, REGULATORY ENFORCEMENT AUTHORITIES

#### **Intumescent coatings for fire protection of steel beams containing web openings**

Beams that contain openings, whether created within a rolled section or during fabrication, need to be considered totally differently than solid beams when considering their fire protection requirements. *Structural failure of such beams may be very different than normal beams and it is for the designer to provide the limiting temperature for any section design taking account of the nature of the critical stresses.*

Guidance on the appropriate product performance testing and the procedure for determining the appropriate thickness of any product designed to provide the required fire protection to these types of beam is detailed in the ASFP publication 'Fire Protection For Structural Steel In Buildings' (the so called 'Yellow Book'). However, in the case of intumescent coatings the current guidance is limited to beams with circular openings.

Some steel beam manufacturers already have proprietary software that can reliably provide the necessary information for beams with other shaped openings. Without such data, the manufacturers of intumescent coatings cannot specify the required product thickness for beams with non-circular openings.

#### **The current position is as follows:-**

- **Beams with circular openings:** May be protected by any intumescent product that has undertaken the ASFP Protocol for beams containing circular openings
- **Beams with elongated circular openings:** May be protected as with circular openings, provided a Limiting Temperature is available from the beam fabricator or the Structural Engineer for the project
- **Beams with opening other than the above:** The ASFP and the SCI have recently agreed to develop a protocol for evaluating the performance of intumescent coatings used to fire protect beams with rectangular and other shaped web openings. But it could take at least a year to complete this development and to allow manufacturers to conduct the necessary test and assessment work.

In the meantime, it is recommended that, unless the appropriate critical design data is available for a specific beam design, the following guidance is used:

***Product performance data obtained from the 'ASFP Yellow Book' testing and assessment protocol for beams containing circular openings may be used as a basis of providing fire protection to beams with non-circular openings assuming that the critical design temperature of the steel beam does not exceed 450°C.***

It will be up to the designer to decide whether this limiting temperature is adequate for all modes of structural failure at the fire limit state.

***NOTE: More detailed information is available in ASFP Technical Guidance Note 009 which can be downloaded free of charge at [www.asfp.org.uk](http://www.asfp.org.uk)***

#### **Conclusions**

Many may be asking themselves what might happen in a court of law if they are held responsible for a fire. The court will want to know about the decision making process that took place, the level of knowledge at the time, and the steps taken to comply with the law. Perhaps, more than anything else, the court will be interested in the extent to which long term public safety may have been compromised by short term commercial gain.