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Structural Fire Engineering to Promote Steelwork: A UK Perspective

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Structural engineering at elevated temperatures is becoming more prevalent throughout the UK and Europe as designers look to optimize fireproofing costs to increase steelwork usage.

Introduction

The importance of fireproofing materials in the event of a fire in a building is critical. However, for many designers little thought is generally given to specific details relating to fireproofing structural steelwork. This article provides a high-level overview of approaches being adopted in the UK and Europe that combine structural engineering approaches, testing of fireproofing materials and collaborative efforts between designers and manufacturers to arrive at optimized, efficient, robust and safe designs. Such approaches take advantage of steel design and over the last two decades have played an important role in making steel the preferred choice for the construction industry.

Figure 1 shows the cost breakdown for elements forming the structural frame of a typical multi-storey building. It is shown that the cost of fire protection to the steelwork can be in the order of 20% of the frame costs. This is not an insignificant value and as such, designers are now looking for innovative ways to reduce cost on projects. Structural fire engineering can provide a solution in this respect.

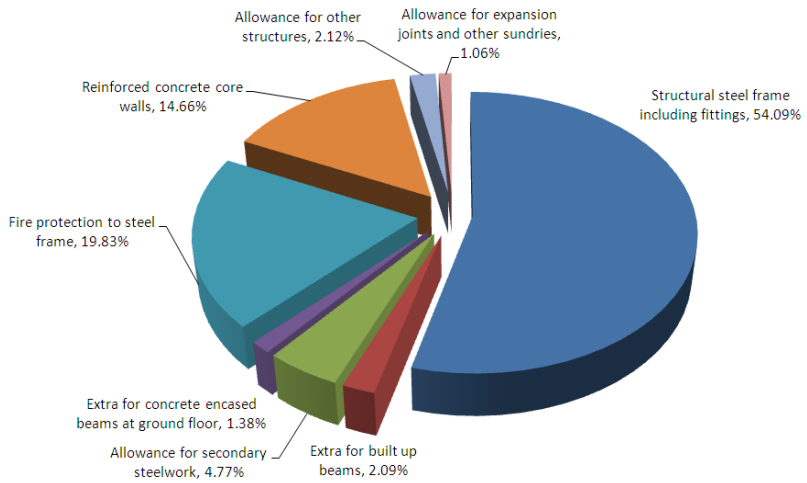

Figure 1: Example relative cost breakdown of components of the structural frame cost for a 14-storey office building in central London (Building Magazine, 2011) showing the proportion of cost associated with fire protection.

Structural Fire Engineering

There are three common methods of structural fire engineering: -

1. **Reducing fire resistance periods**

Prescriptive codes such as the IBC or NFPA 101 define periods of fire resistance for elements of structure. These are typically periods of up to 180 minutes in 30 minute intervals. A fire engineer however, can look at the anticipated fuel within a building, the compartment geometry, the potential ventilation and the use of suppression systems to arrive at a realistic transient fire and therefore define a performance-based fire resistance period. It is not uncommon in the UK for high-rise buildings to reduce from 120 minutes (the maximum fire rating in the UK) to 90 minutes fire resistance. This allows for greater choice for fireproofing materials and can reduce cost significantly.

2. **Limiting steel temperature**

Fire resistance periods should ideally be complemented by a limiting steel temperature (the temperature that the steel will reach whilst still maintaining enough strength to carry an amount of load and thus prevent collapse) for every single structural member. This should be determined by a competent structural engineer and can be used by the fireproofing manufacturer to assess the appropriate thickness of insulation. In the UK and Europe, fireproofing materials are tested to a range of temperatures 662°F to 1382°F (350°C to 750°C). The limiting steel temperature is a function of the member capacity and the degree to which it is loaded at the time of a fire. Structural codes such as the Eurocodes provide a methodology to calculate the limiting steel temperature. This approach frequently results in higher failure temperatures than the defaults assumed by fireproofing manufacturers in the absence of it being calculated. Therefore, a reduced thickness of material is required and often substantial cost savings are achieved. At present however, the limiting steel temperature for the North American market is implicit within the UL 263 fire test and is set at 1000°F (538°C) for columns and 1100°F (593°C) for beams. These temperatures may appear to be conservative, but there are a number of scenarios in which they may not be safe.

3. **Optimization by weight**

The greater mass or weight of a steel section, the more slowly it will heat in comparison to a lighter steel section. Large sections will therefore require a comparatively thin thickness of fireproofing material to achieve a specific fire resistance period when compared to smaller sections. Structural engineers often design for the lightest, most efficient steel section; however this can result in high fireproofing costs. Designers in the UK are now looking at optimization approaches which account for the combined cost of steel, fireproofing material and application rates. In almost all cases, this approach demonstrates that the lightest steel design is not the most economic. This process is illustrated in Figure 2.

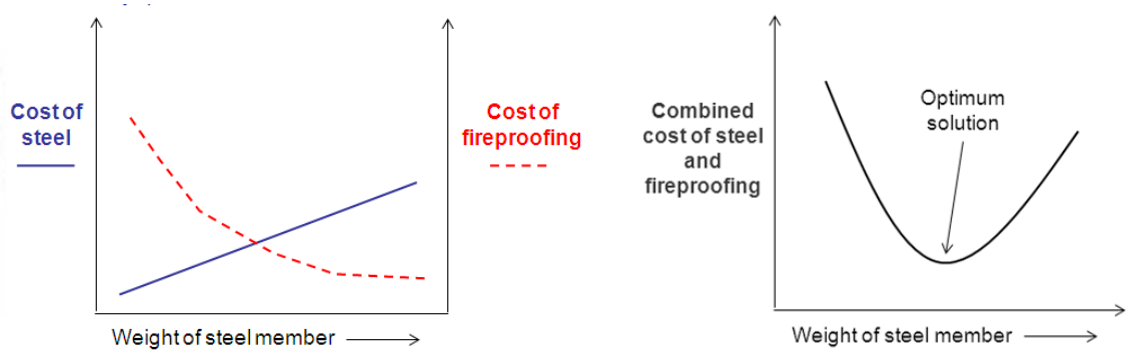

Figure 2: (Left) Illustration of the typical steel and fireproofing costs associated with an increase in the weight of a steel member, (right), combined cost of steel and fire proofing, showing optimum solution with respect to steel weight.

Choice of Fire Protection Material

Thin-film intumescent coatings now dominate the UK structural fireproofing market in new buildings as shown in Figure 3. This can be attributed to the commitment on the part of the manufacturers to research and design. This has been helped and encouraged by the growth of in-shop application and structural fire engineering by consulting engineers.

In-shop application is more expensive than most other forms of fire protection in terms of initial cost, however, for projects where speed is of the essence, health and safety creates difficulties, access is difficult, the weather may cause problems, disruption of other trades on site, etc., this premium can pay big dividends later. It is mainly used where medium to large buildings are constructed quickly. Estimates in the UK suggest that in-shop application accounts for about 15% market share of all fireproofing materials, with around 25% of all thin-film intumescent coating applied this way.

Fifteen years ago, intumescents in the UK were a niche product with an approximate overall 20-25% market share. Today that figure is in excess of 70% and manufacturers are now starting to look at structural fire engineering approaches which assist clients to reduce cost, increase efficiency and promote the use of structural steelwork.

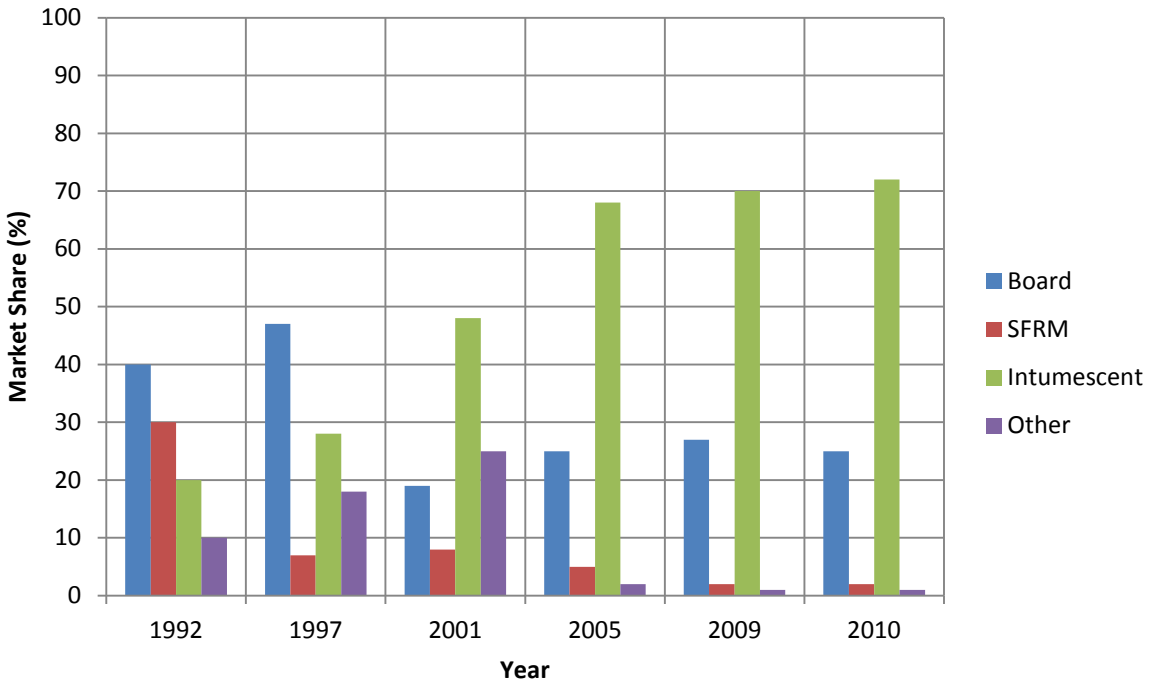

Figure 3: Fireproofing material usage by date in the UK for new building construction. *Courtesy of the British Constructional Steelwork Association (BCSA) and Tata Steel.*

Influencing the Steel Market

The feature of the fire protection market which has enabled the UK steel construction industry to solve the problem of fire is illustrated in Figure 4 and is often referred to as a virtuous circle. In the UK, the key event was the appearance of lightweight fire protection systems in the 1980s. These reduced prices considerably which improved the economies of steel construction which in turn increased the amount of steel in use. This then encouraged more fireproofing companies into the market which then encouraged research and innovation (in the form of structural fire engineering and product development) and decreased prices. Ultimately this approach improved the economics of steel construction and the circle began again.

Figure 5 shows the change in usage of the main framing options in multi-storey, non-domestic construction, over the last thirty years. It is shown that steel has increased its market share hugely since the early 1980's. One of the key reasons for this is attributed the reduction in cost of fire protection for fabricated steelwork.

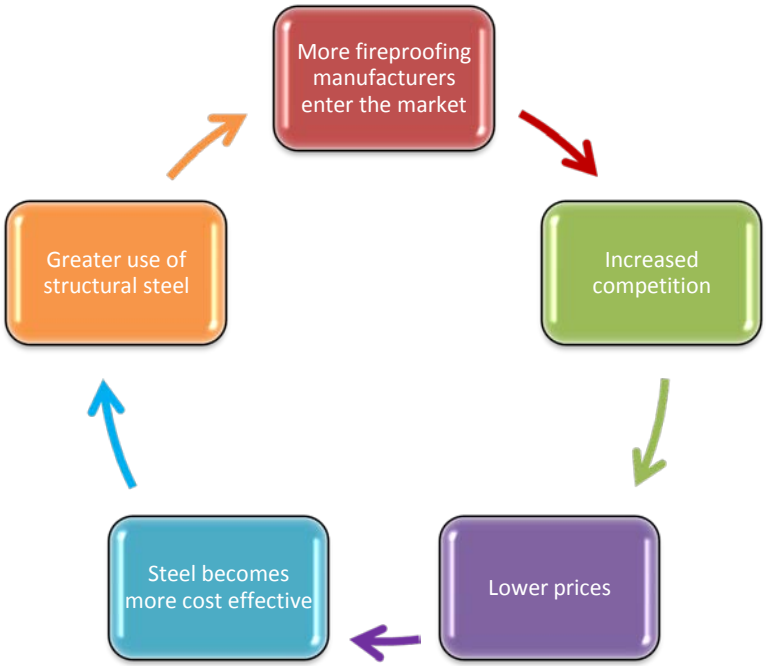

Figure 4: Virtuous circle showing interaction between fireproofing manufacturers and increased use of structural steelwork. *Courtesy of the British Constructional Steelwork Association (BCSA) and Tata Steel.*

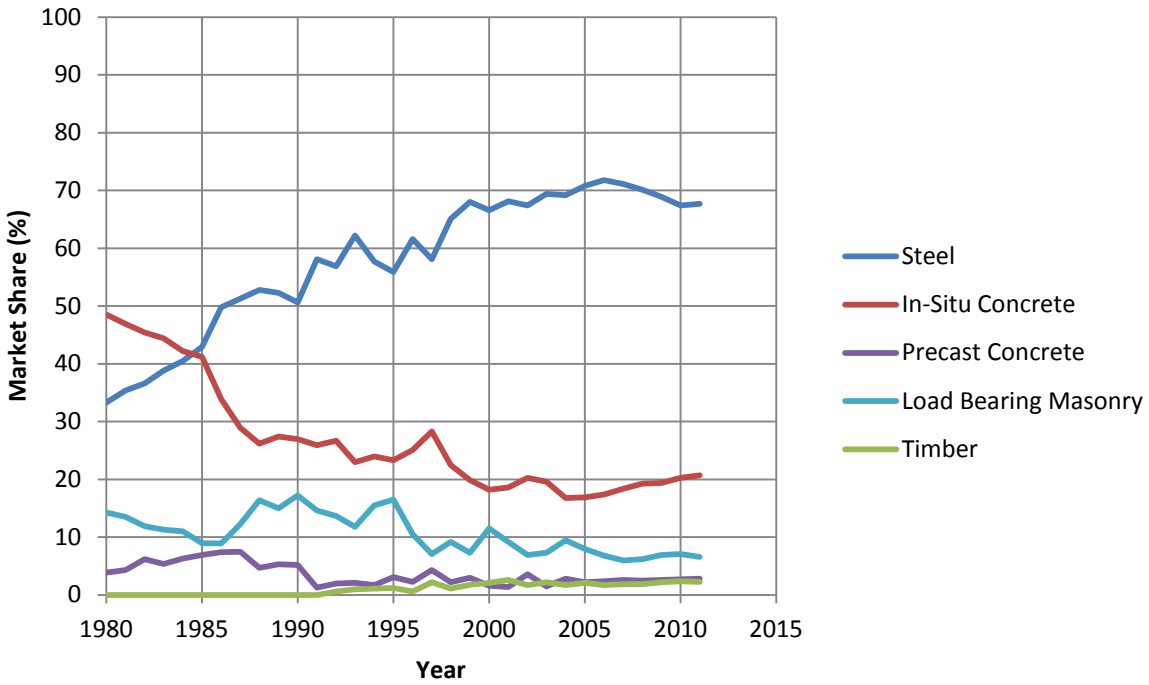

Figure 5: Structural material usage for multi-storey buildings by date in the UK. *Courtesy of Construction Markets Annual Survey, the British Constructional Steelwork Association (BCSA) and Tata Steel.*

Summary

There are a number of methods of undertaking structural fire engineering, each with the potential to bring substantial cost savings to a project. Importantly though, they can be used to quantify structural performance in the event of a fire rather than assuming performance, implicit from a fire test alone.

Fireproofing manufacturers in the UK and Europe now employ qualified structural and fire engineers and are beginning to align with consulting engineers, steelwork fabricators and steel construction institutes to demonstrate added value by incorporating fireproofing characteristics into steelwork designs. This approach is welcomed by the steel industry as it helps to promote steel as a construction material and ultimately leads to robust and safe designs in the event of a fire.