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PERFORMANCE OF STEEL SECTIONS IN FIRE CONDITIONS – V1

Fire and Security Consulting Services (FSCS) is often required to assess the adequacy of steel building elements under fire conditions. These sections may be steel columns or beams providing structural strength for a building or light gauge steel sheeting and purlins used for cladding or separation within the building.

The National Construction Code – Building Code of Australia (NCC – BCA) provides, in Part B, for the structural design of steel building elements by reference to *Australian Standard AS4100 – Steel Structures*[1] for the required structural strength and in Part C, the required Fire Resistance Level (FRL).

However when an alternative design is contemplated (Alternative Solution) or an assessment needs to be made on the adequacy of the building elements where there the fire loads are unusual in size and / or composition, it is useful to be able to determine the performance of the structure.

With respect to the meaning of fire resistance or guidance on the determination of fire sizes, readers are directed to the FSCS papers *Fire Resistance – a Fire Engineer's Perspective* [2] and *Developing Design Fires for Alternative Solutions* [3] respectively, both of which can be downloaded from the FSCS web site http://fscs-techtalk.com.

AS4100, in *Section 12 – "Fire*" provides advice on the protection of structural steel sections however there is little detail on light steel sections' performance under fire conditions, and importantly elsewhere the design considerations with the structure under both static and dynamic loads. These static and dynamic loads era discussed in detail in the FSCS paper at reference [2]

The fire resistance (or fire endurance) of steel elements varies greatly. The temperature limits for structural steel members are based on the criteria contained in ASTM E119 [4].This is the same criterion as referenced in AS4100 [1]. The maximum single point temperature in a steel beam, column, or girder is 649°C and the allowable average temperature in these members is 530 °C. During the testing, failure is assumed to occur if either the maximum single point temperature or average temperature is exceeded.

Figure 1 below is a reproduction of Figure 12.4 from AS4100 which depicts the variation of mechanical properties of steel with temperature.

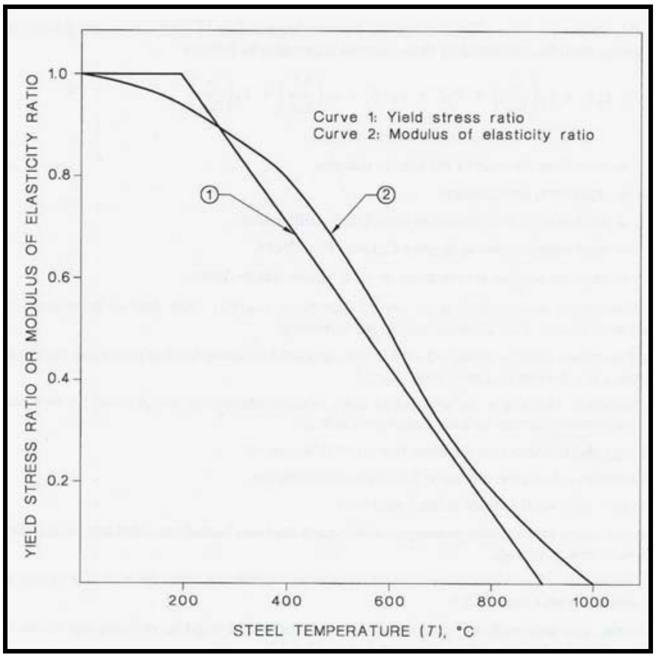

Figure 1 – Figure 12.4 from AS4100

AS4100 provides information as to what time the limiting temperature is reached for both protected and unprotected steel sections.

Alternatively, and as a guide, the graph at Figure 1 (Figure 12.4 in AS4100) can be used to determine yield strength of an unprotected steel section at a determined temperature. Both AS4001 and ASTM E119 limit the maximum permissible design stress to approximately 60 percent of the yield strength.

As a general rule, flame temperatures in compartments containing general combustibles based on carbonaceous substances will be ~1,000^{o}C and those with flammable or combustible liquids (including plastics) ~1,200^{o}C. This does not mean that the steel sections will have reached these temperatures immediately after fire start and depending on the mass of the structure and the disposition of the fuel, the core temperature of the steel sections will take some time to reach that of the flame temperature. In fact, in some fire scenarios where the fuel load is limited or the fire is oxygen limited, the steel sections may not reach the flame temperatures.

The temperature of the fire compartment and importantly the temperature in relation to the steel sections can be determined by calculation using modelling as described in the FSCS paper at reference [3], with results showing the rise in temperature over time.

This lag of temperature rise is important to a Fire Engineer who is interested in the structural adequacy of the building in the initial stages where occupant evacuation takes place.

For fire fighter intervention, the same issue determines the length of time that is available for access to and within the building prior to the structure reaching the point at which building collapse occurs.

Not withstanding the BCA requirements for the structural elements to have specified FRLs, an Alternative Solution may provide an acceptable design without fire insulation for the structural steel members.

Figures 2 and 3 below show the effects of fire on steel sections, Figure 2 is a photo of Wibrock Industries (to the right) in Sydney. This photo was taken to demonstrate the effectiveness of wall wetting sprinklers on the Wibrock building. Note the ~200mm unprotected steel columns and the ~50mm angle braces of the fire affected building which remained in intact during the fire.

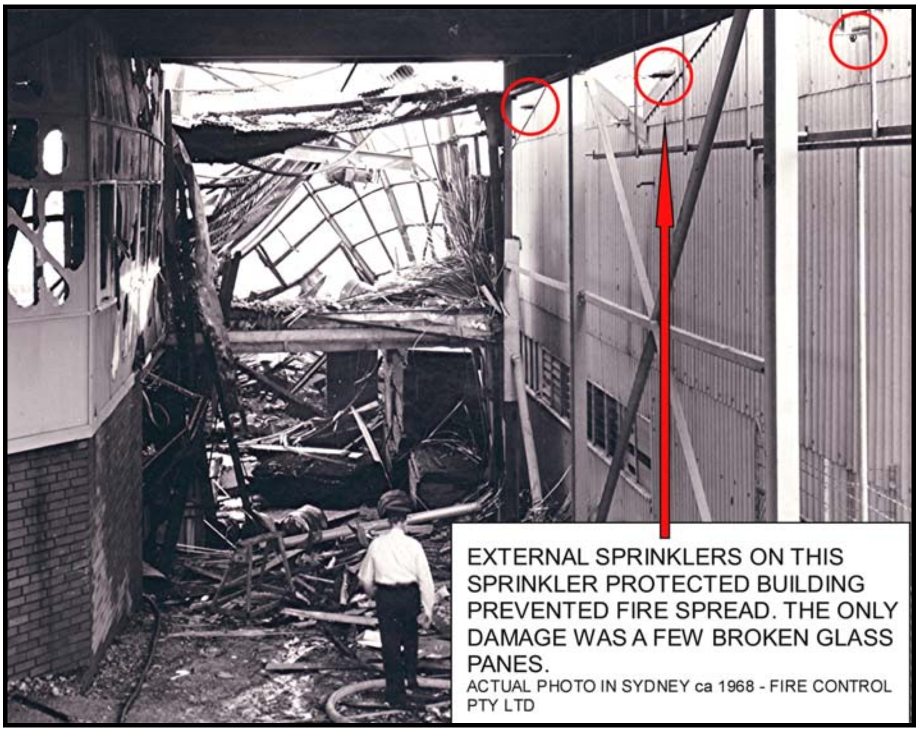

Figure 2 – Wibrock Industries Fire

Figure 3 is a photo of Ap Lei Chau Power Station on Hong Kong Island which, during construction in 1967 was destroyed by fire. The photo shows the unprotected main loadbearing ~24' (610mm) universal columns and ~18' (457mm) beams still intact but the smaller ~6" (150mm) beams collapsing where supported from one end only.

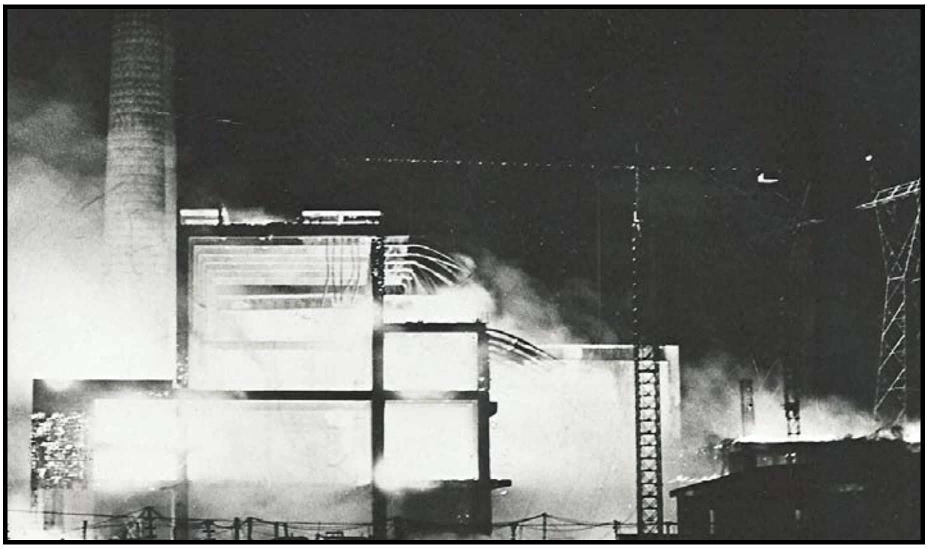

Figure 3 – Ap Lie Chau Power Station Fire

Where light gauge steel sheeting is use for building cladding or separation of areas within buildings, it is sometimes necessary to estimate the adequacy of the element to prevent fire spread. This is often used where steel sheet clad buildings are in proximity to another building either on the same lot or on an adjoining lot.

Note that fire spread by conduction of flame impingement or proximity of the fuel load on the fire side will always be the determining factor for fire spread potential. Thus heat flux calculations based on the temperature of the cladding or partition can be used to determine fire spread. The FSCS paper *Heat Flux Calculations and Assessment* [5] which can be downloaded from the FSCS web site http://fscs-techtalk.com,can be used. The propensity for ignition of adjoining materials needs to be known to effect this calculation.

However where steel cladding and the supporting studs / purlins / girts are adequately designed and fixed, deformation of the sheeting is likely to be minimal and the only issue to be addressed is the adequacy of the material itself.

The structural adequacy of light gauge roof sheeting and intermediate light section sections such as girts and purlins can be assessed by reference to studies by Gerlich [6], Makelainen and Miller [7] and BSI [8]. The results of these studies are shown in Figure 5 and, similarly to columns and beams, a prediction of structural adequacy can be made with 60% (0.6) being used as the limiting factor.

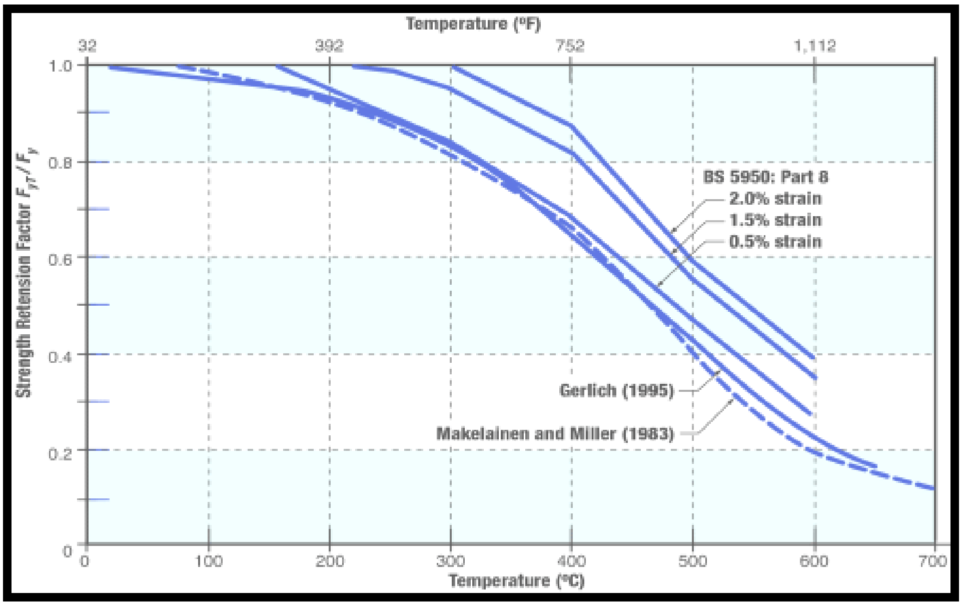

Figure 5 – Light Gauge Steel Strength

References

[1] AS4100 Australian Standard – Steel Structures

[2] Fire and Security Consulting Services - *Fire Resistance – a Fire Engineer's Perspective*

[3] Fire and Security Consulting Services - *Developing Design Fires for Alternative Solutions*

[4] ASTM E119, "Standard Test Methods for Fire Tests of Building Construction and Materials," ASTM Fire Test Standard, 5th Edition, American Society of Testing and Materials, West Conshohocken, Pennsylvania, pp. 793–813, 1999

[5] Fire and Security Consulting Services - *Heat Flux Calculations and Assessment*

[6[Gerlich, J.T. August 1995. Design of Loadbearing Light Steel Frame Walls for Fire Resistance, Fire Engineering Research Report 95/3. University of Canterbury, Christchurch, NZ.

[7] Makelainen, P., and Miller, K. 1983. Mechanical Properties of Cold-Formed Galvanized Sheet Steel Z32 at Elevated Temperatures. Helsinki University of Technology, Finland.

[8] BS BSI. 2000. Structural use of steelwork in building. Code of practice for design. Rolled and welded sections, 5950-1:2000. British Standards

I trust that this paper provides information that can be used in the assessment of the adequacy of steel structures and cladding in fire conditions

Regards

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