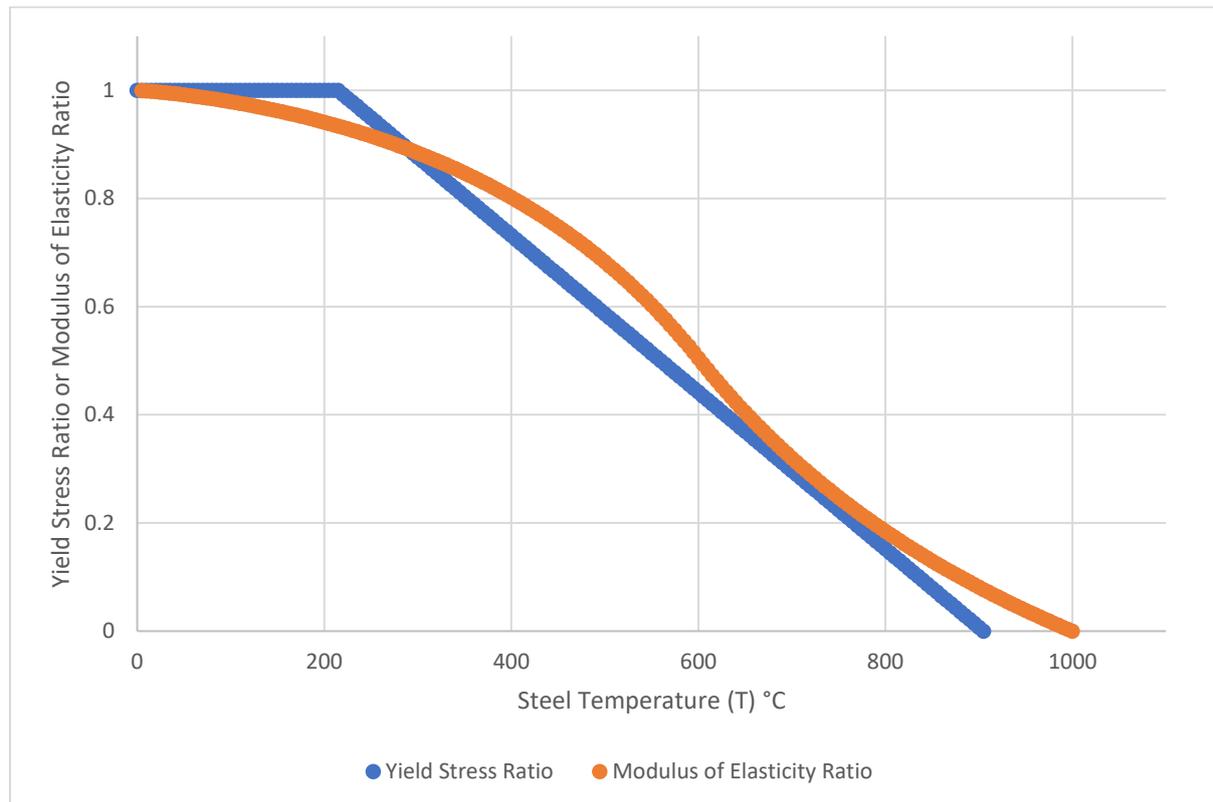


## SC902 Technical Advisory Note – PTA005

### Critical Steel Temperature & Load Ratio

#### Why Critical Steel Temperature Is Important for Structural Steel Fire Protection

AS4100 is the Australian Standard for Steel Structures. According to AS4100 section 12, load ratio of a steel member is associated with the limiting steel temperature (also known as critical steel temperature) of structural steel.



The above diagram was developed based on the information provided in AS4100 Cl 12.4 & 12.5 for determination of limiting steel temperature. It indicates that the higher the steel temperature is, the weaker (lower design member capacity) the steel member will be.

In order to ensure a steel structure has sufficient capacity to hold up the building during the fire, it is essential to determine the critical steel temperature and prevent the steel elements from reaching this temperature. This can be achieved by applying a passive fire protection material to the steel substrate.

## Load Ratio

Clause 12.5 of AS4100 describes the relationship between limiting steel temperature  $T_l$  and load ratio  $r_f$ . The following equation describes how the  $r_f$  on a structural member is used to determine the critical steel temperature.

$$T_l = 905 - 690r_f$$

Where the load ratio  $r_f$ , can be calculated as follows:

$$\text{Load Ratio } (r_f) = \frac{\text{Design Load for Fire (specified in AS1170.0 - Structural Design Actions)}}{\text{Design Member Capacity at room temperature}}$$

The design member capacity at room temperature varies with the effective length and steel section. For example:

- 400x400x16 SHS column @ 3m – Design Member Capacity in Axial Compression = 9380 kN
- 200x200x16 SHS column @ 4m – Design Member Capacity in Axial Compression = 3490 kN
- 219.1x8.2 CHS column @ 5m – Design Member Capacity in Axial Compression = 1290 kN

When critical steel temperatures or load ratios are not provided, the following assumptions are applied:

- 550°C (load ratio = 0.51) for columns supporting a concrete floor or equivalent
- 620°C (load ratio = 0.4) for beams supporting a concrete floor load or equivalent
- 700°C (load ratio = 0.3) for beams and columns supporting a light weight roof load or equivalent.

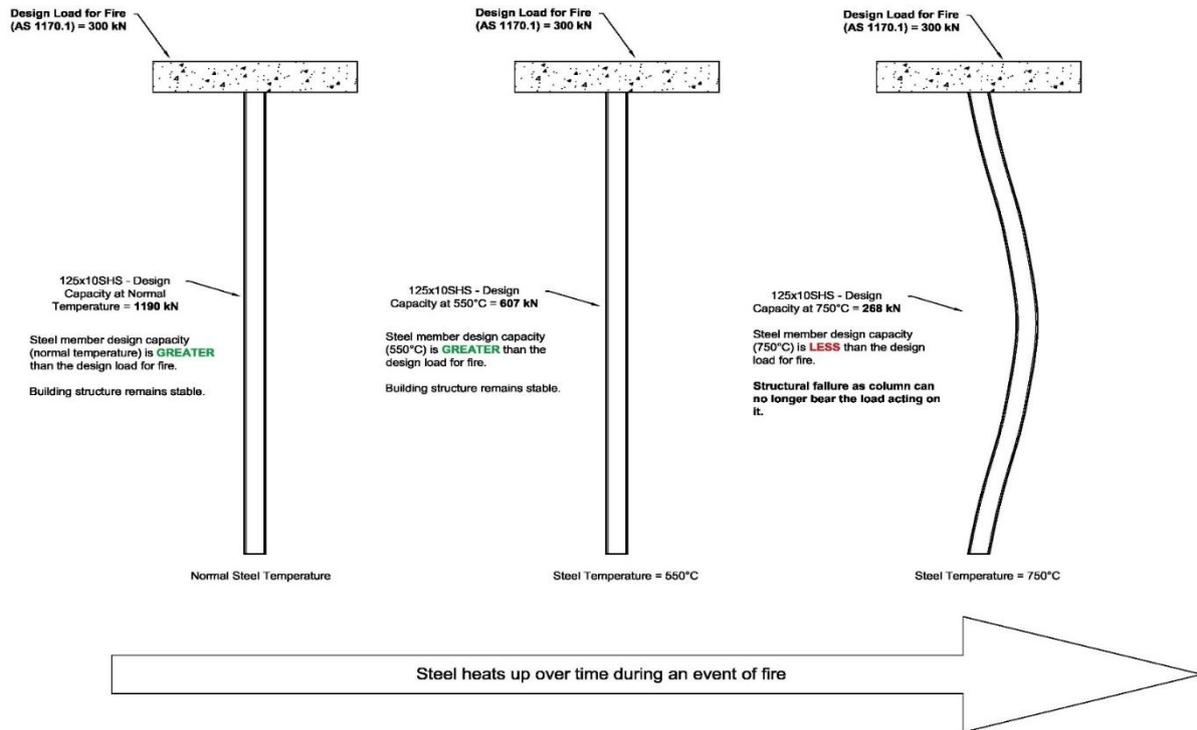
However, it is unknown whether these assumptions are conservative enough to satisfy the loading requirement for a specific project. In order to ensure the structure can achieve the proposed fire rating level, it is essential for the structural design engineer to check/supply the critical steel temperatures or load ratios.

## Case Study

A 3m long 125x125x10 square hollow section column has a design capacity of 1190 kN. The higher the steel temperature is, the lower the residual capacity would be. If the steel keeps heating up during a fire, at one point the residual design capacity of the steel would be less than the load it is carrying. Once it reaches this stage the building structure will start to collapse and fail as the columns can no longer bear the force acting on it.

Generally, a lower critical steel temperature will require more fire protection product than higher critical steel temperatures, simply because with the same configuration (type of fire, steel size, fire rating level...etc) the steel will reach the lower critical steel temperature first. This is explained visually in case one and two.

## Case One: 125x10 SHS Column Supporting 300 kN Under the Fire Load Case



### Calculation

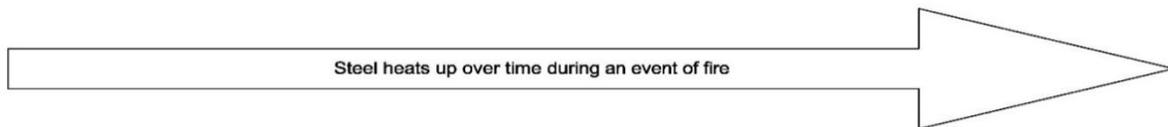
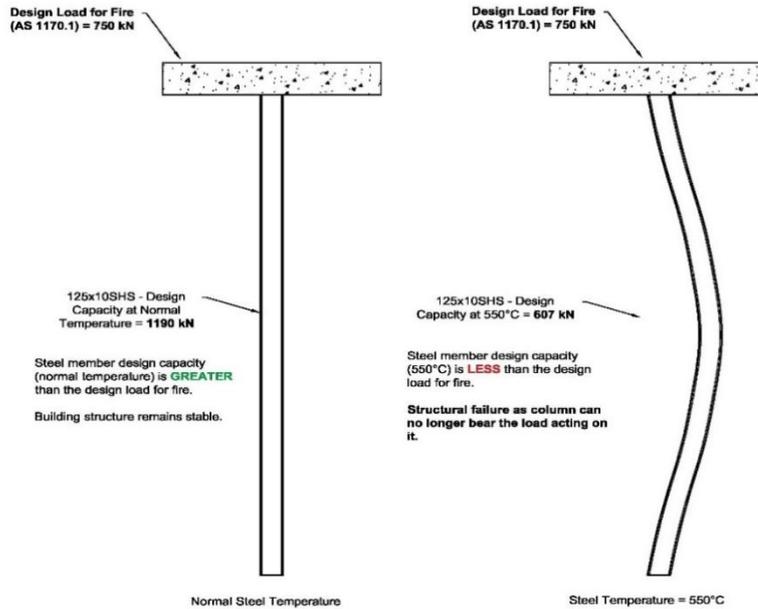
$$\text{Load Ratio } (r_f) = \frac{\text{Design Load for Fire (specified in AS1170.0 – Structural Design Actions)}}{\text{Design Member Capacity at room temperature}}$$

$$\text{Load Ratio } (r_f) = \frac{300 \text{ kN}}{1190 \text{ kN}} = 0.2521$$

$$\text{Limited Steel Temperature } (T_L) = 905 - 690 r_f = 905 - 690 \times 0.2521 = 731^\circ\text{C}$$

Therefore, under this specific loading condition, the temperature of the steel column should not exceed 731°C during the proposed fire rating period. Once the column reaches this temperature it will not have sufficient strength to support the design load.

## Case Two: 125x10 SHS Column Supporting 750 kN Under the Fire Load Case



### Calculation

$$\text{Load Ratio } (r_f) = \frac{\text{Design Load for Fire (specified in AS1170.0 – Structural Design Actions)}}{\text{Design Member Capacity at room temperature}}$$

$$\text{Load Ratio } (r_f) = \frac{750 \text{ kN}}{1190 \text{ kN}} = 0.631$$

$$\text{Limited Steel Temperature } (T_L) = 905 - 690 r_f = 905 - 690 \times 0.631 = 471^\circ\text{C}$$

Similar to the previous scenario, the temperature of the steel column under this specific loading condition should remain under 471°C in order to maintain the structural adequacy.

## Conclusion

The case studies demonstrate how the load ratio, steel size & supporting condition affect the limiting steel temperature of a structural steel member. It is vital that critical steel temperatures or load ratios are communicated when passive steel fire protection is required on a project to ensure that steel members are fire protected adequately.

Communication between the structural design engineer and the Permax engineering team can ensure that each steel element on a project is fire rated to the required critical steel temperature. The amount of passive fire protection material can also be optimised by using multi-temperature analysis of the structure so that the applied fire protection is in accordance with the exact limiting steel temperature.

The Permax team can also advise on whether or not the current steel member can achieve the proposed fire rating level under its loading conditions, hence avoiding last minute revisions to steel sizes.