Nullifire Australia
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SC902 Technical Advisory Note

Core-filling of Intumescent Protected Structural Steel Hollow Sections

Introduction

The structural fire performance of any steel section is determined by its Hp/A (heated perimeter to cross sectional area ratio) which is regarded as a constant, and the performance, amount and type of any passive fire rating material applied.

Due to the limitations of fire rating products, in many circumstances, the FRL is only achieved once a minimum Hp/A level is met.

Extensive testing and experiences has shown that the fire performance of structural hollow sections is relatively poor compared to other sections. As a result, high Hp/A hollow sections depend on core-filling to achieve the required FRL's.

Core-filling is an essential construction practice in the steel PFP process and used as a 'fall back' solution for structural steel members with Hp/A's too high to achieve the desired FRL. By pouring a concrete or grout mixture with a normal aggregate mix inside the void of structural hollow section columns, the goal is to reduce the effective Hp/A of the structural steel element, thus justifiying a significant reduction in the required dry film thickness, so that certain hollow sections can be used to achieve higher FRL's.

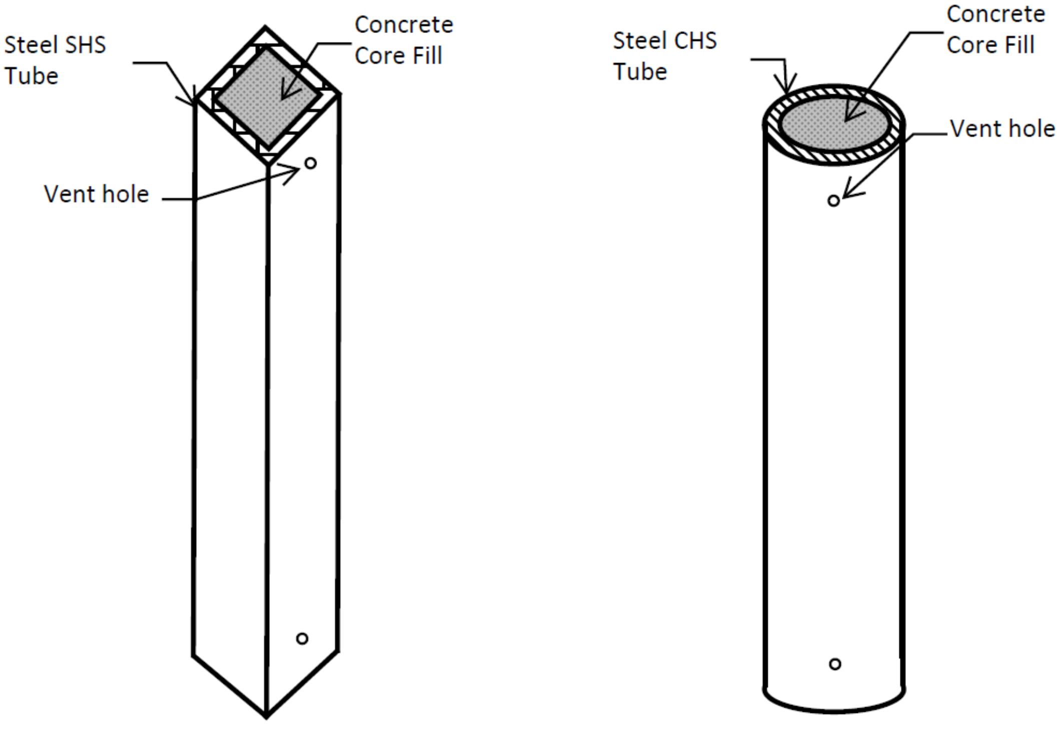

Figure 1. – A typical concrete core-filling detail.

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Procedure

A typical standard concrete mix of less than 40MPa is recommended as this allows for the easy egress of steam that is formed in the concrete during a fire event.

Additionally, steam vents are drilled at the top of the columns so that steam may escape during a fire event. If these holes are not present, or blocked, this could lead to cracking or worse. Similarly, if very high MPa concrete mix is used, the increased density could trap the expanding steam during a fire event and lead to an explosive result.

A typical core-fill follows a three step procedure:

1. The structural steel hollow column is erected, or fixed in an upright position.
2. A mix of concrete (40MPa or less) is poured into the open top of the column (if possible) or pumped through a drilled hole at the base.
3. A vent hole is drilled at the top of the column and masked over after filling is completed.

Common Misconceptions, Q&As

Q: Is core-filling possible for small hollow sections, 100x100 SHS or smaller?

A: Yes, there have been circumstances where core-filled hollow sections as small as 75X75X3 SHS have been used.

Q: Is 28-32MPa concrete sufficient?

A: Yes, it is strongly advice that a normal aggregate or grout mixture is used, any mixture higher than 40MPa should not be used.

Q: Is core-filling normally specified on beams and bracing elements?

A: Core-filling should only be used on hollow steel columns, high Hp/A beams and bracing elements will require either upsizing or a review of critical steel temperatures in order to meet high FRLs.

Q: Is cost-reduction a benefit of core-filling?

A: Even though core-filling results in a reduced dry film thickness (DFT), the process of core-filling in itself may be more expensive than the intumescent application and may offset any cost reduction received by the reduction in the quantity of intumescent required. This may be dependent on the individual situation.

Testing Evidence Used and Sample Calculation

In the absence of a specific Australian Standard to reference in regards to fire performance of core filled hollow section steel, Nullifire Australia use a reduced effective Hp/A value that is justified by calculations from testing evidence carried out by third parties and published tests in industry, such as:

1. **Design Guide for Concrete Filled Columns (CORUS Methodology) by the Steel Construction Institute, UK.**
2. **Rush, D, Bisby, L., Gillie, M., Jowsey, A., and Lane, B. (2014). Intumescent fire protection design for concrete filled structural hollow sections. Fire Safety Journal, 67, pp13-23. DOI: 10.1016/j.firesaf.2014.05.004 (Rush et.al)**

By filling hollow sections with concrete, a composite section is produced which will increase the section's room temperature load carrying capacity. In a fire scenario, the concrete core serves as a heat sink. Concrete or grout filled hollow sections that are externally protected against fire i.e. with intumescent coatings, will maintain the composite action in the fire limit state whilst the external protection serves to limit the rise in steel temperature such that the column capacity is always in excess of the fire limit state design load over the required fire resistance period.

Reductions in the thickness of the external protection are possible because of the heat sink effect, which effectively reduces the section Hp/A value of the column. The performance of structural steel members in a fire event is determined based on the Hp/A itself.

The Hp/A reduction is due to thermal and structural loads being shared by the concrete, thus enhancing the structural and thermal performance of the composite element. The **CORUS methodology** and **Rush et.al** design guide used provides evidence that the methodology Nullifire Australia adopts is a very conservative approach and that actual testing data show that the observed steel temperatures in the protected sections are well below the target design limiting temperatures.

Assume an 89X89X3.5 SHS, with 345 Hp/A, with 550°C critical steel temperature is to be core-filled in order to achieve a 120/-/- FRL:

Excerpt Equation (1) and Equation (2) from page.6 of **Rush et.al**

$$\frac{H_p}{A_{eff}} = \frac{1000}{t_{se}} = \frac{1000}{t_s + t_{ce}}$$

$$t_{ce} = \begin{cases} 0.15 b_i, & b_i < 12\sqrt{t_{FR}} \\ 1.8\sqrt{t_{FR}}, & b_i \geq 12\sqrt{t_{FR}} \end{cases}$$

<u>Calculating for an 89X89X3 SHS:</u>

bi = 89 – (2x3) = 83 t_{ce} = (0.15 x 83) = 12.45

Hp/A_{eff} = 1000/(3+12.45) = **<u>64.72</u>**

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Rush et.al made the following statements in relation to the method given in Equation (1) and (2):

"It is clear from this (Method described by Equation 1 and Equation 2) that use of current guidance and DFT design data from unfilled steel sections to prescribe DFTs for CFS sections results in highly conservative steel tube temperatures during standard furnace testing. The limiting temperature was never reached; only tests 23 and 24 experienced temperatures greater than the prescribed 520°C, and in both cases this occurred more than 30 minutes after the required F.R. time had been met."

Nullifire SC900 Series Intumescent Basecoat Testing

Further direct evidence for the benefits of core-filling using Nullifire's SC900 series (SC901/902) is shown in TRN1427, with indicative testing carried out in the UK using Tremco Illbruck/Nullifire UK's testing facilities.

Fig. 2 - Test set up.

Fig. 3 – Post-test.

Nullifire UK prepared a series of tests on sets of 5 SHS 90mmX6mm dimension columns, with 550°C limiting temperature using DFT's ranging from 1.27mm to 5.38mm, and filled with various materials such as concrete, recycled glass and CSP (ceramic, stone and porcelain).

The best performing material was concrete, when used in conjunction with 5.38mm DFT of SC901 intumescent basecoat, the composite column reached a critical steel temperature of 550°C at 120.8 minutes.

The result from Tremco Illbruck/Nullifire UK's indicative tests showed that SC900 Series do provide 60, 90 and 120 min protection to light hollow section RHS steel. However, the extent of the benefits by concrete-filled protection remains unclear without further official third party certified tests.

Conclusions

The third party calculations and testing evidence by **Rush et. al** and **CORUS** with **The Steel Construction Institute, UK** and indicative testing carried out by **Tremco Illbruck/Nullifire UK** provides reliable evidence that concrete core-filling improves the structural-fire performance of hollow steel sections. By core-filling, a reduced effective section factor (Hp/A) can be used to justify a reduction in intumescent coatings.