Fire assessment report

Fire resistance performance of steel beams and columns protected with A1 COREX boards

Sponsor: Trafalgar Group

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Quality management

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		Signature			

Executive summary

This report documents the findings of the assessment undertaken to determine the fire resistance performance of structural steel beams and columns protected with A1 COREX boards, in accordance with AS 1530.4:2014 and AS 4100:2020.

The data which forms the assessment was generated by test reports in accordance with EN 13381-4:2013, which detail the fire performance of loaded I section beams and unloaded I/H section column specimens with varying A1 COREX board thicknesses.

Based on the analysis conducted in sections 5 and 6, regression equations given in Table 1 were determined to predict the behaviour of both single and two-layer A1 COREX board protected structural steel – I/H section steel beams and columns, and hollow section beams and columns.

Table 1 Assessment summary

System	Regression equation
A1 COREX single layer protection	$t = -29.3473 + 1.944724 - 3.1305\left(\frac{h_i}{k_{sm}}\right) + 5.9186 \times 10^{-2}\,T + 1.222 \times 10^{-3} h_i T + 2.7519 \times 10^{-2}\left(\frac{h_i T}{k_{sm}}\right) + 0.711107\left(\frac{T}{k_{sm}}\right)$
A1 COREX two-layer protection	$t = -84.611 + 3.116547 + 12.60062\left(\frac{h_i}{k_{sm}}\right) + 8.7416 \times 10^{-2} T + 1.442 \times 10^{-3} h_i T + 2.894 \times 10^{-3}\left(\frac{h_i T}{k_{sm}}\right) + 0.502558\left(\frac{T}{k_{sm}}\right)$
t, T, h_i and k_{sm} are the time (in minutes), steel temperature (in ºC), thickness of the protection material (in mm) and exposed surface area to mass ratio (in m^2/tonne), respectively	

The regression equation was then used to determine the required A1 COREX board thickness to achieve a given Period of Structural Adequacy (PSA), provided that the section factor and the critical temperature of the steel beam is known. The PSA is defined as the time (in minutes) for the member to reach the limit state of structural adequacy in the standard fire test as per AS 1530.4:2014, and it must be greater than or equal to the required Fire Resistance Level (FRL) stipulated in the National Construction Code (NCC) for a given structural steel member. These results are given in Table 19 to Table 24 of this assessment report.

The variations and outcome of this assessment are subject to the limitations and requirements described in sections 2, 3 and 7 of this report. The results of this report are valid until 31 December 2025.

Contents

1. Introduction

This report documents the findings of the assessment undertaken to determine the fire resistance performance of structural steel beams and columns protected with A1 COREX boards, in accordance with AS 1530.4:2014[1] and AS 4100:2020[2].

This assessment was carried out at the request of Trafalgar Group. The sponsor details are included in Table 2.

Table 2 Sponsor details

Sponsor	Address
Trafalgar Group	26a Ferndell Street South Granville NSW 2142 Australia

2. Framework for the assessment

2.1 Assessment approach

An assessment is an opinion about the likely performance of a component or element of structure if it was subject to a standard fire test.

No specific framework, methodology, standard or guidance documents exists in Australia for doing these assessments. We have therefore followed the 'Guide to undertaking technical assessments of the fire performance of construction products based on fire test evidence' prepared by the Passive Fire Protection Forum (PFPF) in the UK in 2019[3].

This guide provides a framework for undertaking assessments in the absence of specific fire test results. Some areas where assessments may be offered are:

- Where a modification is made to a construction which has already been tested
- The interpolation or extrapolation of results of a series of fire resistance tests, or utilisation of a series of fire test results to evaluate a range of variables in a construction design or a product
- Where, for various reasons – eg size or configuration – it is not possible to subject a construction or a product to a fire test.

Assessments will vary from relatively simple judgements on small changes to a product or construction through to detailed and often complex engineering assessments of large or sophisticated constructions.

This assessment uses established empirical methods and our experience of fire testing similar products to extend the scope of application by determining the limits for the design based on the tested constructions and performances obtained. The assessment is an evaluation of the potential fire resistance performance if the elements were to be tested in accordance with AS 1530.4:2014.

This assessment has been written using appropriate test evidence generated at accredited laboratories to the relevant test standard. The supporting test evidence has been deemed appropriate to support the manufacturer's stated design.

2.2 Compliance with the National Construction Code

This assessment report has been prepared to meet the evidence of suitability requirements of the NCC 2022[4] under A5G3 (1) (d). It references test evidence for meeting deemed to satisfy (DTS)

[1] Standards Australia, 2014, Methods for fire tests on building materials, components and structures: Fire-resistance tests for elements of construction, AS 1530.4:2014, Standards Australia, NSW.
[2] Standards Australia, 2020, Steel structures, AS 4100:2020, Standards Australia, NSW.
[3] Passive Fire Protection Forum (PFPF), 2019, Guide to undertaking technical assessments of the fire performance of construction products based on fire test evidence, Passive Fire Protection Forum (PFPF), UK.
[4] National Construction Code Volumes One and Two - Building Code of Australia 2022, Australian Building Codes Board, Australia

provisions of the NCC under A5G5 for fire resistance level that apply to the assessed systems based on Specifications 1 and 2 for fire resistance for building elements.

Specifically, the assessment of the fire-resistance of protected steel structures conforms to the specifications of AS 4100:2020 – as required by the same NCC guidelines. Such an assessment is conducted in accordance with AS 4100:2020 Clause 12.6, using an accepted method of analysis such as the regression method described under Clause 12.6.2.1.

This assessment report may also be used to demonstrate compliance with the requirements for evidence of suitability under the relevant sections of previous versions of the NCC.

2.3 Declaration

The 'Guide to undertaking technical assessments of the fire performance of construction products based on fire test evidence' prepared by the PFPF in the UK requires a declaration from the client. By accepting our fee proposal on 17 November 2020, Trafalgar Group confirmed that:

- To their knowledge the component or element of structure, which is the subject of this assessment, has not been subjected to a fire test to the standard against which this assessment is being made.
- They agree to withdraw this assessment from circulation if the component or element of structure is the subject of a fire test by a test authority in accordance with the standard against which this assessment is being made and the results are not in agreement with this assessment.
- They are not aware of any information that could adversely affect the conclusions of this assessment and – if they subsequently become aware of any such information – they agree to ask the assessing authority to withdraw the assessment.

3. Limitations of this assessment

- The scope of this report is limited to an assessment of the variations to the tested systems described in section 4.3.
- This report details the methods of construction, test conditions and assessed results that are expected if the systems were tested in accordance with AS 1530.4:2014.
- The assessment is only applicable for boxed type protection done on structural steel I/H section beams and columns. Results obtained for I/H section beams and columns are directly applicable to welded I/H sections, angles, channels, PFCs (parallel flange channel) and T-sections with the same section factor. Boxed type protection with same fixing details and arrangements must be maintained.
- Results are also applicable to all sides exposed square, rectangular, and circular hollow section columns, and 3-sided square and rectangular hollow section beams. The required A1 COREX board thickness for a hollow beam and column of a given section factor is equal to that for the I/H section with the same section factor. Boxed type protection with same fixing details and arrangements must be maintained.
- This assessment addresses boxed type protection using single and two-layer boards within the prescribed range of section factors (50 m^{-1} and 385 m^{-1}) only.
- Maximum depth of the sections must be limited to 600 mm.
- A single layer A1 COREX board must be used if thickness requirement is less than or equal to 25 mm. Two A1 COREX boards must only be used if the thickness requirement is higher than 25 mm.
- If it can be shown that two layers of board meet the required period of structural adequacy for a lower critical temperature, then these results can be applied to higher critical temperatures with no reduction in the total thickness of boards.
- The fixing details and arrangements for the proposed systems must be similar to the tested construction. Refer section 4.5 for details.

- This report is only valid for the assessed systems. Any changes with respect to size, construction details other than those identified in this report, may invalidate the findings of this assessment. If there are changes to the system, a reassessment will be needed to verify consistency with the assessment in this report.
- This report has been prepared based on information provided by others. Warringtonfire has not verified the accuracy and/or completeness of that information and will not be responsible for any errors or omissions that may be incorporated into this report as a result.
- This assessment is based on the proposed systems being constructed under comprehensive quality control practices and following appropriate industry regulations and Australian Standards on quality of materials, design of structures, guidance on workmanship and the expert handling, placing and finishing of the products on site. These variables are beyond the control and consideration of this report.

4. Description of the specimen and variations

4.1 System description

The aim of this assessment report is to evaluate the fire resistance performance of structural steel members protected using A1 COREX boards – in accordance with the regression analysis methodology given in AS 4100:2020.

The proposed systems comprise of I/H section steel beams and columns, and hollow section beams and columns, protected using A1 COREX boards, subject to three and four sided fire exposure. Both single and two-layer board protection systems are considered.

4.2 Referenced test data

The assessment of the variation to the tested system and the determination of the likely performance is based on the results of the fire tests documented in the reports summarised in Table 3. Further details of the tested system are included in Appendix B.

Table 3 Referenced test data

Report number	Test sponsor	Test date	Testing authority
RFTR18001	DALSAN ALÇI SANAYİ ve TİCARET A.Ş	27 November 2017	Efectis, Turkey
RFTR18002	DALSAN ALÇI SANAYİ ve TİCARET A.Ş	29 November 2017	Efectis, Turkey
RFTR18003	DALSAN ALÇI SANAYİ ve TİCARET A.Ş	01 December 2017	Efectis, Turkey
RFTR18004	DALSAN ALÇI SANAYİ ve TİCARET A.Ş	03 December 2017	Efectis, Turkey

4.3 Variations to the tested systems

Not all the proposed variations have been subject to standard fire tests in accordance with the relevant standards. We have therefore assessed the proposed systems using baseline test information of similar systems using the assessment methods specified in the relevant standards. The variations to the tested systems together with the referenced baseline standard fire tests are described in Table 4. Details of the tested specimens are presented in Table 5 and Table 6.

.

Table 4 Variations to tested systems

Item	Reference test	Description	Variations
1	RFTR18001 RFTR18002 RFTR18003 RFTR18004	The referenced tests were conducted in accordance with EN 13381-4:2013[5].	The proposed variation is to assess the likely fire performance of steel beams and columns if tested in accordance with AS 1530.4:2014.
2	RFTR18001 RFTR18002 RFTR18003 RFTR18004	The referenced test reports present test data as per the test schedule proposed in EN 13381-4:2013 to assess beams and columns protected using passive protection to steel members.	The proposed variation is to determine the suitability of test data to AS 4100:2020 requirements to conduct regression analyses. If deemed suitable, it is proposed to determine the relationship between temperature and time for a given A1 COREX board – single or two-layered – protected steel beams and columns. Then using this relationship, it is proposed to determine the fire performance of various A1 COREX board protected steel beams and columns.

Table 5 Summary of tested specimens with single board protection

Ref. Test	Specimen	Length (mm)	Loaded	Hp/A (m^{-1})	E (m^2/t)	Board thickness (mm)
RFTR18001	Loaded beam LB	5200	Yes	145	18.47	12.5
	Reference beam RB	1000	No	140	17.83	12.5
	SC1	1000	No	214	27.26	15.0
	SC2	1000	No	221	28.15	12.5
	SC3	1000	No	162	20.64	12.5
	SC4	1000	No	51	6.50	15.0
	SC5	1000	No	50	6.37	20.0
	SC6	1000	No	50	6.37	12.5
RFTR18004	Loaded beam LB	5200	Yes	140	17.83	25.0
	Reference beam RB	1000	No	139	17.71	25.0
	SC1	1000	No	379	48.28	25.0
	SC2	1000	No	387	49.30	20.0
	SC3	1000	No	351	44.71	15.0
	SC4	1000	No	152	19.36	20.0
	SC5	1000	No	228	29.04	25.0
	SC6	1000	No	218	27.77	20.0

[5] European Standard, 2013, Test methods for determining the contribution to the fire resistance of structural members – Part 4: Applied passive protection to steel members, EN 13381-4:2013, European committee for standardization, Brussels.

Table 6 Summary of tested specimens with two-layer board protection

Ref. Test	Specimen	Length (mm)	Loaded	Hp/A (m^{-1})	E (m^2/t)	Board thickness (mm)
RFTR18002	Loaded beam LB	5200	Yes	144	18.34	45
	Reference beam RB	1000	No	134	17.07	45
	SC1	1000	No	367	46.75	45
	SC2	1000	No	157	20.00	40
	SC3	1000	No	226	28.79	40
	SC4	1000	No	367	46.75	40
	SC5	1000	No	50	6.37	40
	SC6	1000	No	228	29.04	45
RFTR18003	Loaded beam LB	5200	Yes	141	17.96	25
	Reference beam RB	1000	No	145	18.47	25
	SC1	1000	No	222	28.28	25
	SC2	1000	No	49	6.24	25
	SC3	1000	No	50	6.37	30
	SC4	1000	No	367	46.75	30
	SC5	1000	No	151	19.24	30
	SC6	1000	No	225	28.66	30

4.4 Purpose of the test

EN 13381-4:2013 specifies a test method for determining the contribution made by applied passive fire protection systems to the fire resistance of structural steel members, which can be used as beams or columns. It only covers fire protection systems that involve passive materials.

Sections 2 of AS 1530.4:2014 specifies the general requirements for conducting fire resistance tests. Sections 5 and 6 sets out the procedure for determining the fire resistance of elements of columns and beams, respectively.

AS 4100:2020 sets out minimum requirements for the design, fabrication, erection and modification of steelwork in structures in accordance with the limit states design method. Accordingly, AS 4100:2020 provides guidelines to determine the time dependant steel temperature of protected steel structural members using the results of a series of fire tests by means of a regression analysis equation. Using this relationship, the Period of Structural Adequacy (PSA) – the time (in minutes) for the member to reach the limit state of structural adequacy – of a structural steel member can be determined.

4.5 Schedule of components

Table 7 outlines the schedule of components for the assessed systems.

Table 7 Schedule of components of assessed systems

Item	Description	
Beam and columns	Section	I/H section steel beams and columns with Hp/A values in the range of 50 m^{-1} to 385 m^{-1} (refer to Table 19 to Table 24). Results are also applicable to hollow section beams (RHS and SHS) and columns (RHS, SHS and CHS).
	Exposure	3-sided or 4-sided fire exposure
Protection board	Type	A1 COREX board
	Density	Nominal 900 kg/m^3
	Application	Refer Table 19 to Table 24 for board thickness requirements. A single layer A1 COREX board must be used if the thickness requirement is less than or equal to 25 mm. Two A1 COREX boards must only be used if the thickness requirement is higher than 25 mm. The light blue shaded in area in the tables refer to the two board protection systems.
	Fixing method	For open section steel (such as I and H sections) beams, the boards must be fixed to the noggins using staples. Noggins must be made from A1 COREX boards. Figure 1 to Figure 3 show the fixing method for boards as tested and the fixing method of construction must be similar to the tested specimens of referenced tests. The dimensions given in these figures are in cm. For 4-sided hollow section steel beams (RHS and SHS) and columns (RHS, SHS and CHS), the boards must be installed as shown in Figure 4 and Figure 5. For 3-sided hollow section steel beams (RHS and SHS), the boards must be installed as shown in Figure 6. See Table 8 for staple requirements for each board thicknesses.

Table 8 Staple fixing requirement

Board thickness	Staple length (mm)	Spacing (mm)
12.5	30	100
15.0	40	
20	40	
25	50	

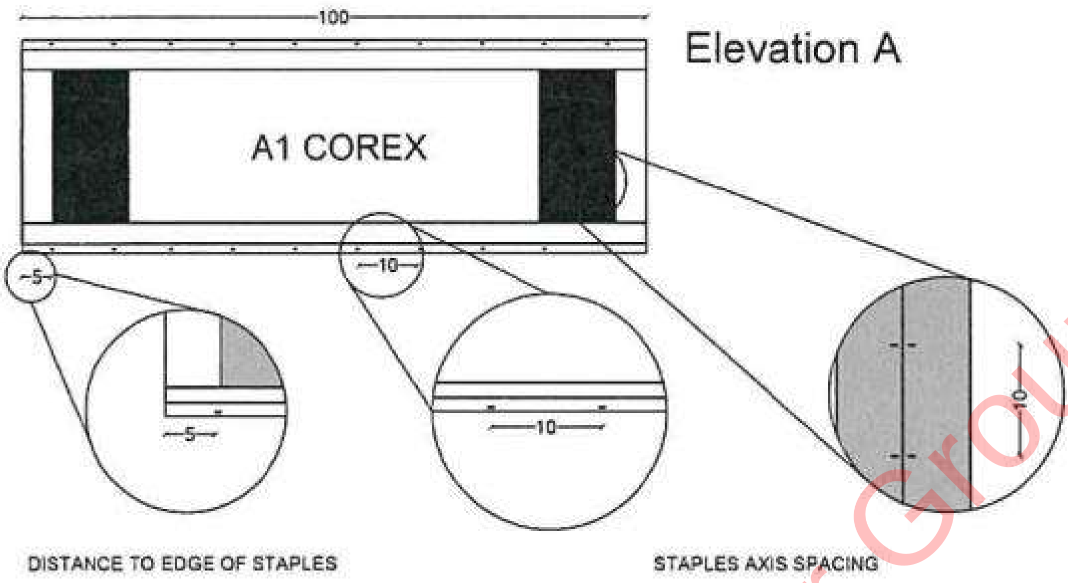

Figure 1 Fixing method of the first board layer (Extracted from RFTR18001 test report)

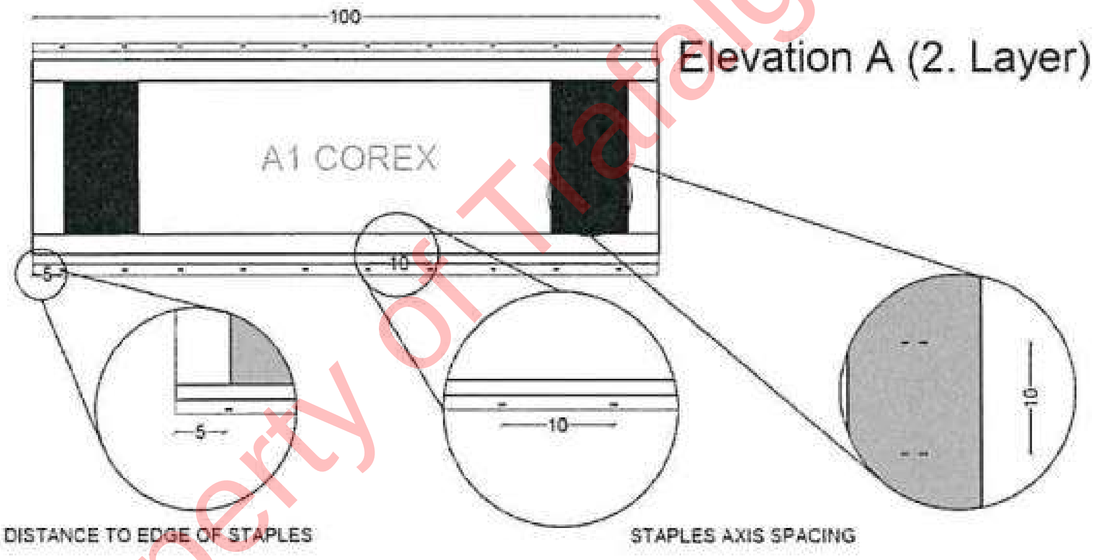

Figure 2 Fixing method of the second board layer (Extracted from RFTR18002 test report)

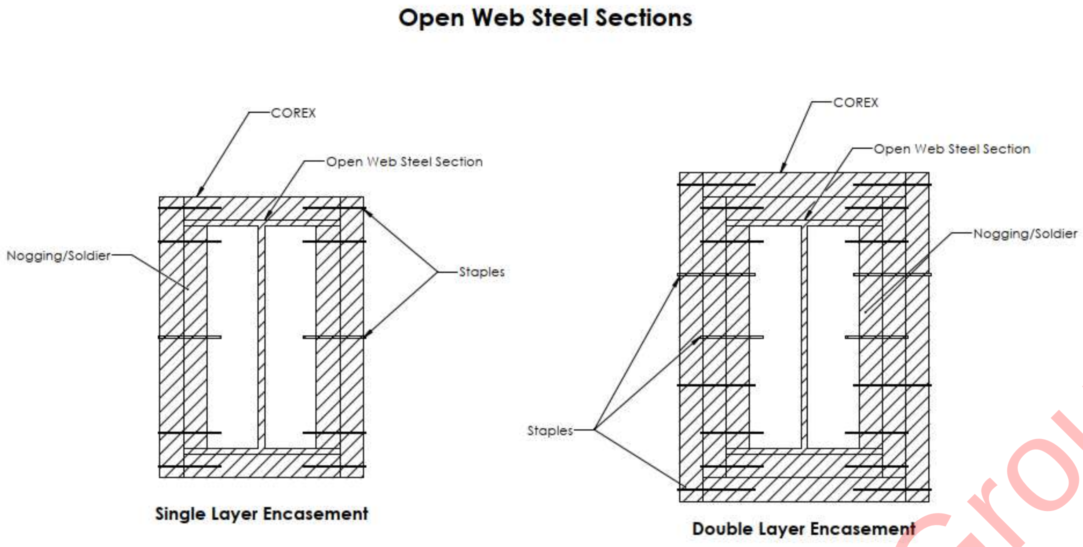

Figure 3 Single and double layer encasement on open steel section beams and columns – 4 sided

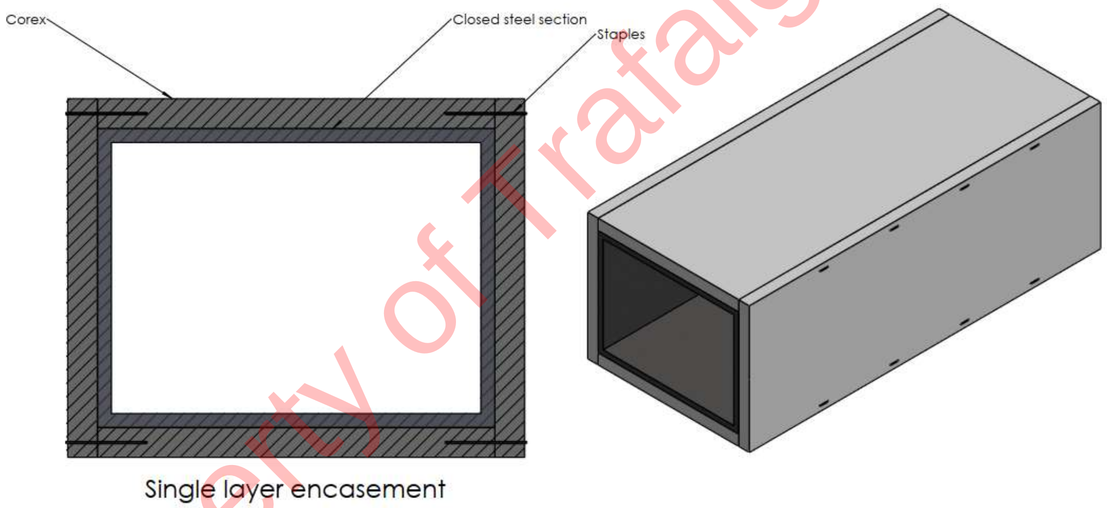

Figure 4 Single layer encasement on hollow section beams and columns – 4 sided

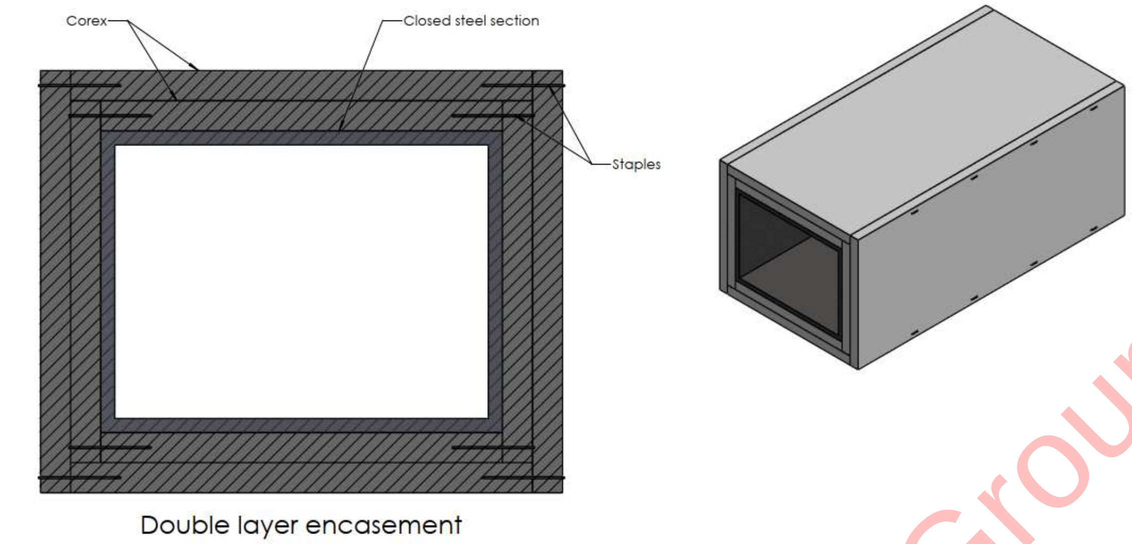

Figure 5 Double layer encasement on hollow section beams and columns – 4 sided

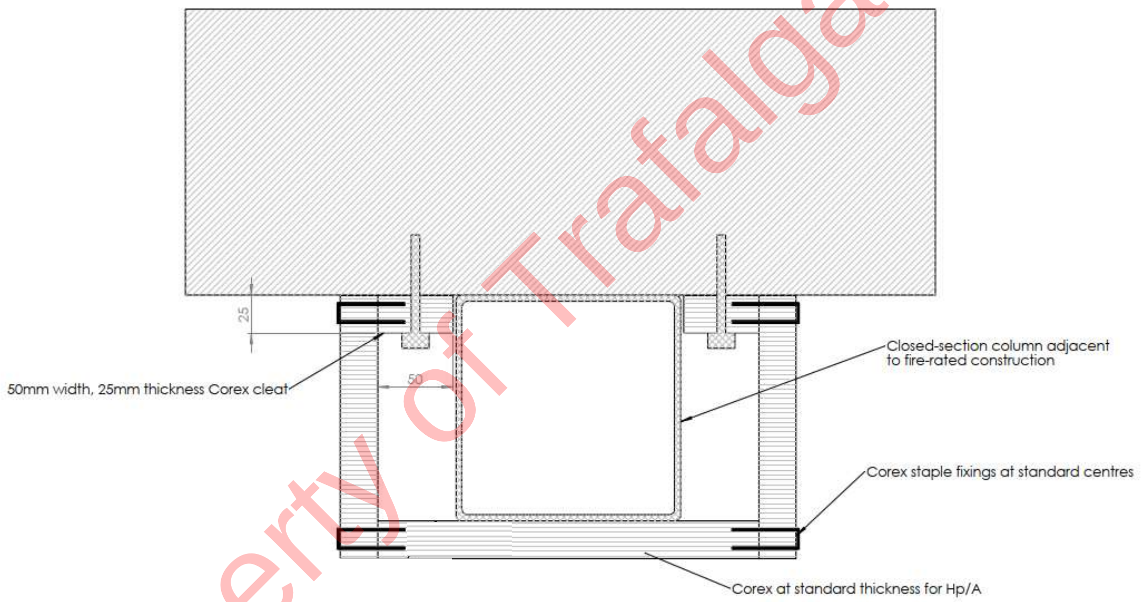

Figure 6 Encasement on hollow section beams and columns – 3 sided

5. Assessment 1 – Relevance of EN 13381-4:2013 test data to AS 1530.4:2014

5.1 Description of variation

This assessment report references fire test reports RFTR18001, RFTR18002, RFTR18003 and RFTR18004, which demonstrated the fire performance of various I/H section steel beams and columns protected with A1 COREX boards. These tests were conducted as per EN 13381-4:2013. It has been proposed to assess the likely fire performance of these tested beams in accordance with AS 1530.4:2014.

5.2 Methodology

The approach and method of assessment used for this assessment is summarised in Table 9.

Table 9 Method of assessment

Assessment method	
Level of complexity	Intermediate assessment
Type of assessment	Comparative

5.3 Assessment

5.3.1 General

The reference fire tests in RFTR18001, RFTR18002, RFTR18003 and RFTR18004 were conducted in accordance with EN 13381-4:2013. It is noted that this standard adopts the general testing procedure of EN 1363-1:2012[6]. These standards differ from AS 1530.4 2014, and the effects these differences have on the fire resistance performance of test specimens are discussed below.

5.3.2 Furnace temperature regime

The furnace temperature regime for fire resistance tests conducted in accordance with AS 1530.4:2014 follows the same trend as EN 1363-1:2012. In addition, the parameters outlining the accuracy of control of the furnace temperature in AS 1530.4:2014 and EN 1363-1:2012 are not appreciably different.

5.3.3 Furnace thermocouples

The furnace control thermocouples required by EN 1363-1:2012 are less responsive than those specified by AS 1530.4:2014.

This variation in sensitivity can produce a potentially more onerous heating condition for specimen tested to EN 1363-1:2012, particularly when the furnace temperature is changing quickly in the early stages of the test. Therefore, it is considered that the conditions stipulated in EN 1363-1:2012 produce more onerous results.

5.3.4 Furnace pressure

For beams, AS 1530.4:2014 specifies that a pressure of 20 Pa ± 3 Pa must be maintained 100 mm below the underside of the test specimen. The pressure requirement in EN 1363-1:2012 is the same as that specified in AS 1530.4:2014.

For columns, AS 1530.4:2014 states that a pressure of 0 ± 3 Pa must be maintained 500 mm above the notional floor level. The pressure requirement in EN 1363-1:2012 is the same as that specified in AS 1530.4:2014.

[6] European Standard, 2012, Fire resistance tests – Part 1: General Requirements, EN 1363-1:2012, European committee for standardization, Brussels.

5.3.5 Specimen temperature measurement

5.3.5.1 Beams

AS 1530.4:2014 states that for specimens longer than 3000 mm, a minimum of four measuring stations (transverse sections) should be used to determine the structurally critical temperature. At each of these stations, a minimum of two thermocouples should be positioned. For a specimen shorter than 3000 mm, a minimum of two transverse sections must be selected. At each, a minimum of four thermocouples must be positioned. As an extension, the standard suggests that for I-sections, at any of the selected measuring stations, thermocouples should be positioned such that there is one on the tip of the lower flange, one on the lower surface of the lower flange in line with the web, one midway along the web, and one on the tip of the upper flange (refer to Figure 7).

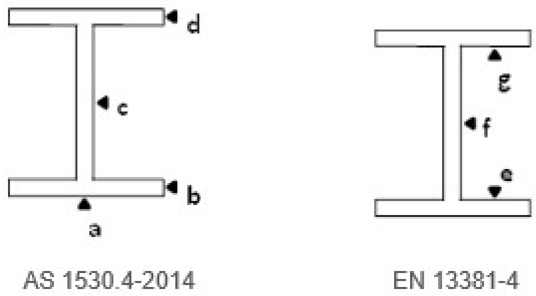

Figure 7 Specified thermocouple locations

The prescribed thermocouple locations of the EN 13381-4:2013 standard differ from the prescribed locations in AS 1530.4:2014. EN 13381-4:2013 requires beams to have three measuring stations at 1/4, 1/2 and 3/4 of the length of the beam. Two additional thermocouples are to be attached to the lower flange on alternate sides of the web at a distance of 250 mm from the central measuring station.

For short beams, the thermocouple stations are to be located at 1/3, 1/2 and 2/3 of the length of the heated section. At each station, at least 3 thermocouples will be located. At stations 1 and 3, the top surface of the lower left flange and lower surface of the upper right flange will be measured, along with the left side of the web. At station 2, the upper surface of the lower right flange, lower surface of the upper left flange and right side of the web will be measured. Typically, the midpoint on either side of the flange is taken to be the point of measurement.

The above differences in measurement locations are considered to cause deviations in the critical temperatures obtained for a given section. In particular, it is considered that the AS 1530.4:2014 positions could produce hotter recorded critical temperatures than those produced by the positions defined in EN 13381-4:2013. This is mainly due to the AS 1530.4:2014 standard calling for three flange thermocouples and one web thermocouple, whereas the EN 13381-4:2013 standard calling for only two flange thermocouples and one web thermocouple.

Testing experience shows that for beams, the lower flange is the hottest, followed by the web and then the upper flange. The flange tip is slightly hotter than mid flange.

However, in this assessment, the results of the beam tests have only been considered to evaluate the stickability criteria and subsequent stickability correction factors. Temperature data derived from beam test specimens were not used in the regression analysis. Therefore, the difference in thermocouple locations of beam specimens between two standards is not considered to affect the output of this assessment.

5.3.5.2 Columns

AS 1530.4:2014 states that for specimens longer than 3000 mm, a minimum of four measuring stations (transverse sections) should be used to determine the structurally critical temperature. At each of these stations, a minimum of two thermocouples should be positioned at each measuring station. For a specimen shorter than 3000 mm, a minimum of two transverse sections shall be selected. At each section, a minimum of four thermocouples must be positioned.

The prescribed thermocouple locations of the EN 13381-4:2013 standard differ from the prescribed locations in AS 1530.4:2014. Tested short column specimens as per EN 13381-4:2013 had two measuring stations.

In this assessment report, the structurally critical temperature was taken as the average of the measured temperatures. If the column specimens were to be tested in accordance with AS 1530.4:2014, the nominated critical temperature would be the mean of all temperature measurements of the specimen, instrumented correctly according to the AS 1530.4:2014 standard.

In all of the referenced test reports, there were thermocouples well distributed along the length of the columns on both surfaces. Therefore, it is considered that the adopted calculation procedure for structurally critical temperatures for columns will result in similar temperatures if calculated in accordance with the suggested approach in AS 1530.4:2014.

5.3.6 Performance criteria

AS 1530.4:2014 specifies structural adequacy criteria for columns and beams as follows.

The specimen must be deemed to have failed the structural adequacy criterion in accordance with AS 1530.4:2014 upon collapse, or when the following occurs:

(a) When the following criteria for axially loaded elements has been exceeded:

- Limiting axial contraction C = h/100
- Limiting rate of axial contraction, ΔC/Δt = 3h/1000 mm/min, where h = the initial height

(b) When the following criteria for laterally loaded elements has been exceeded:

- Deflection of L^2/400d mm
- Rate of deflection = L^2/9000d mm/min, where L and d are clear span of the specimen and distance from the top of the structural section to the bottom of the design tension zone, respectively.
- Since relatively rapidly deflections can occur before stable conditions are reached, the rate of deflection limit must not apply before a deflection of L/30 is exceeded.

The structural adequacy criteria specified by EN 1363-1:2012 is the same as that specified in AS 1530.4:2014.

5.3.7 Support Conditions

EN 13381-4:2013 specifies that loaded beams must be simply supported, and allowance shall be made for free expansion at each end. Loading must be uniformly distributed at two or more locations and applied directly via loading spacers (which must be thermally insulated from the beam) introduced through the cover slabs.

The AS 1530.4:2014 support conditions are less specific, simply stating that support conditions will be as to best represent the conditions seen by the specimen in real world situations. The above description of EN 13381-4:2013 supports are considered to be in agreement with this idea.

5.3.8 Application of referenced test data to AS 1530.4:2014

The variations in furnace heating regimes, furnace thermocouples and the responses of the different thermocouple types to the furnace conditions are not expected to have a significant effect on the outcome of the referenced fire resistance tests.

Based on the above discussion, the temperature data in RFTR18001, RFTR18002, RFTR18003 and RFTR18004 for the beams and columns tested in accordance with EN 13381-4:2013 can be used to determine the structurally critical temperatures in accordance with AS 1530.4:2014.

5.4 Conclusion

Based on the above discussion, it is considered that the results related to the structural adequacy and critical temperature of the referenced tests can be used as a basis to assess the fire performance of beams if tested in accordance with AS 1530.4:2014.

6. Assessment 2 – Fire performance of A1 COREX board protected steel beams and columns

6.1 Description of variation

The tested systems consisted of loaded and reference beams, and a set of short columns protected with A1 COREX boards. Protection was provided using a single or two-layer board configurations using 12.5 mm, 15 mm, 20 mm and 25 mm thick A1 COREX boards. This assessment addresses the following variations:

- Variations in exposure conditions (four and three-sided exposure)
- Variations in section geometry
- Variations in board thickness.

6.2 Methodology

The approach and method of assessment used for this assessment is summarised in Table 10.

Table 10 Method of assessment

Assessment method	
Level of complexity	Complex assessment
Type of assessment	Quantitative

6.3 Assessment

6.3.1 Suitability of the test data to AS 4100:2020 requirements

AS 4100:2020 states the following conditions to conduct a regression analysis:

(a) Steel members must be protected with board, sprayed blanket or similar insulation material having a dry density less than 1000 kg/m^3.

(b) All tests must incorporate the same protection system.

(c) All members must have the same exposure conditions.

(d) The test series must include at least nine tests.

(e) The test series may include unloaded prototypes, provided that stickability has been demonstrated.

(f) The results of the regression analysis equation must only be used for interpolation within the window of application defined by the test data.

6.3.1.1 Exposed surface area to mass ratio (E)

The European preference is to use the term Section Factor of Heated Perimeter to Area Ratio $\left(\frac{H_P}{A}\right)$ instead of the Exposed Surface Area to Mass Ratio (E) adopted by AS 4100:2020. E is usually expressed in m^2/tonne while H_p/A is usually expressed in m^{-1}. The two terms are notionally equivalent and can be converted using the following relationship, assuming the density of steel to be 7850 kg/m^3.

$$E = K_{sm} = \frac{1}{7.85}\frac{H_P}{A}$$

For the purposes of this assessment, the analysis has been undertaken using $\frac{H_P}{A}$ and the results have been expressed in terms of both E and $\frac{H_P}{A}$.

6.3.1.2 Calculation of temperature

With reference to the discussion presented in sections 5, it was confirmed that the reference test data could be considered to conduct the regression analysis as per AS 4100:2020.

6.3.1.3 Protection system and number of specimens

Referenced test reports consisted of test specimens which used single and two-layer board protection systems. Therefore, two regression equations were developed to predict the behaviour of structural steel beams and columns protected using A1 COREX boards.

Table 11 and Table 12 show a summary of the test specimens selected to conduct the regression analysis for single and two-layer board protected configurations, respectively. Loaded and referenced beams were not included in the analysis and regression equations were developed only using the results of column tests which were subjected to 4-sided fire exposure.

There were 12 unloaded 1000 mm column specimens for each of the cases: single and two-layer protection configurations. Therefore, the test specimens satisfy the minimum number of specimen requirement given in AS 4100:2020.

Table 11 Summary of specimens used for single board protection configuration

Ref. Test	Specimen	Hp/A (m^{-1})	E (m^2/t)	Board thickness (mm)
RFTR18001	SC1	214	27.26	15.0
	SC2	221	28.15	12.5
	SC3	162	20.64	12.5
	SC4	51	6.50	15.0
	SC5	50	6.37	20.0
	SC6	50	6.37	12.5
RFTR18004	SC1	379	48.28	25.0
	SC2	387	49.30	20.0
	SC3	351	44.71	15.0
	SC4	152	19.36	20.0
	SC5	228	29.04	25.0
	SC6	218	27.77	20.0

Table 12 Summary of specimens used for two-layer board protection configuration

Ref. Test	Specimen	Hp/A (m^{-1})	E (m^2/t)	Board thickness (mm)
RFTR18002	SC1	367	46.75	45
	SC2	157	20.00	40
	SC3	226	28.79	40
	SC4	367	46.75	40
	SC5	50	6.37	40
	SC6	228	29.04	45

Ref. Test	Specimen	Hp/A (m^{-1})	E (m^2/t)	Board thickness (mm)
RFTR18003	SC1	222	28.28	25
	SC2	49	6.24	25
	SC3	50	6.37	30
	SC4	367	46.75	30
	SC5	151	19.24	30
	SC6	225	28.66	30

6.3.1.4 Exposure condition

With reference to test specimens summarised in section 6.3.1.3, it is confirmed that all the test specimens used in this assessment were exposed to fire from four sides. Generally, 4-sided fire exposure is considered to be more onerous, and thus, the outcome of this assessment is appliable to both 3-sided and 4-sided fire exposure.

6.3.1.5 Specimen length

AS 1530.4:2014 requires a minimum beam length of 3 m for transversely loaded beams. However, where a series of steel members are to be tested to determine the effectiveness of different insulation thicknesses, it is permissible to use unloaded specimens with a minimum length of 1 m if stickability performance has been demonstrated to be satisfactory on a loaded specimen of at least 3 m long.

With reference to test specimens summarised in section 6.3.1.3, it is confirmed that these specimen length requirements have been met.

6.3.1.6 Window of application

The window of application is the range of exposed surface area to mass ratios and board thicknesses for which the regression coefficients will be validated. The window is formed by plotting the data points and drawing straight lines joining the points around the perimeter (see Figure 8 and Figure 9).

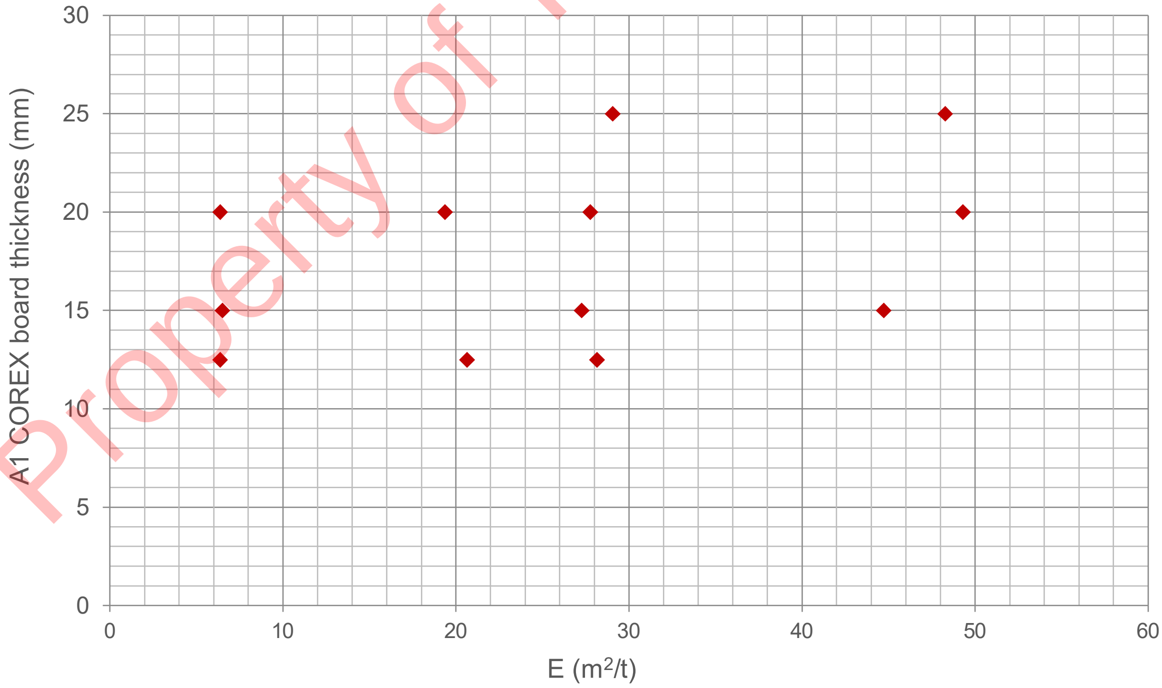

Figure 8 Application window defining the limits of interpolation for single board protection configurations

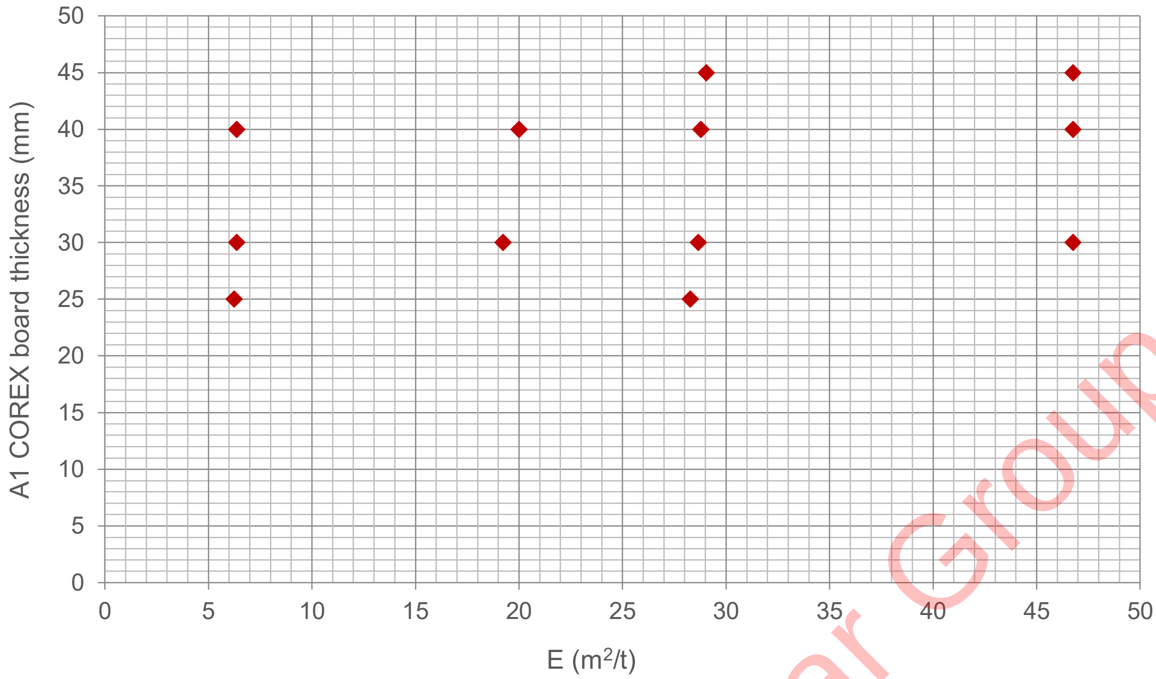

Figure 9 **Application window defining the limits of interpolation for two-layer board protection configurations**

6.3.2 Regression analysis

6.3.2.1 Specimen section

Table 11 and Table 12 show a summary of the test specimens selected to conduct the regression analyses – in accordance with Clause 12.6.2.1 of AS 4100:2020 – for single and two-layer board protected configurations, respectively. The four loaded beams and the corresponding reference beams were used to obtain the stickability correction factors.

6.3.2.2 Stickability correction factors for reference beams

AS 4100: 2020 requires the protection material to demonstrate stickability, the ability of a fire protection material to remain in place as the member deflects under load during fire test, for the required period of structural adequacy.

As shown in Table 13, the loaded beams maintained structural adequacy up to 179 minutes and consequently stickability during this period. It is to be noted that AS 4100:2020 does not provide guidance on the use of stickability correction factors. However, EN 13381-4:2013 requires using stickability correction factors to consider the performance of boards under load and subsequent deflection.

A conservative approach was taken in this assessment, and as required by the EN 13381-4:2013 standard, stickability correction factors were determined by comparing the time for the loaded beam to reach the design temperature with that of the equivalent reference beam. These factors are then used to correct the data from short beams – against loaded beams.

Table 14 contains a summary of the stickability correction factors determined for single and two-layer board protected beams and columns. Stickability correction factors for intermediate board thicknesses were determined by interpolation.

Table 13 Loaded and referenced beams

Ref. Test	Specimen	Length (mm)	Hp/A (m^{-1})	E (m^2/t)	Board thickness (mm)	Failure time (minutes)
RFTR18001	Loaded beam LB	5200	145	18.47	12.5	84
	Reference beam RB	1000	140	17.83	12.5	-
RFTR18004	Loaded beam LB	5200	140	17.83	25.0	112
	Reference beam RB	1000	139	17.71	25.0	-
RFTR18002	Loaded beam LB	5200	144	18.34	45	179
	Reference beam RB	1000	134	17.07	45	-
RFTR18003	Loaded beam LB	5200	141	17.96	25	97
	Reference beam RB	1000	145	18.47	25	-

Table 14 Stickability correction for beams

Temperature (°C)	Single layer protection		Two-layer protection	
	K_{min} (for 12.5 mm)	K_{max} (for 25 mm)	K_{min} (for 25 mm)	K_{max} (for 45 mm)
350	1.000	0.97	1.000	1.00
400	0.990	0.97	0.990	1.00
450	1.000	0.98	0.970	1.00
500	1.000	0.99	0.930	1.00
520	1.000	0.99	0.940	1.00
550	1.000	0.99	0.950	1.00
600	1.000	0.97	0.930	1.00
620	1.000	0.97	0.930	1.00
650	1.000	0.97	0.930	1.00
700	1.000	0.97	0.930	1.00
750	1.000	0.97	0.930	1.00

6.3.2.3 Corrected times for the regression analysis

Table 15 and Table 16 show the corrected times obtained for single and two-layer protected beams and columns based on the determined stickability correction factors. These time-temperature data were subsequently used in the regression analysis.

Table 15 Corrected times obtained for regression analysis for single layer protected beams and columns

Referenced test report	Beam	Time in minutes taken to reach the critical temperature (°C)										
		350	400	450	500	520	550	600	620	650	700	750
RFTR18001	SC1	41.1	44.9	49.6	54.7	56.9	60.2	66.4	69.3	73.8	81.8	92.7
	SC2	34.7	37.4	41.5	45.7	47.3	50.0	55.7	58.0	61.8	68.7	78.0
	SC3	40.5	44.8	50.3	55.8	58.2	61.8	68.5	71.2	75.7	83.7	94.0
	SC4	85.3	96.3	108.9	121.3	126.4	134.4	147.6	153.4	162.5	178.6	197.0
	SC5	99.2	111.0	124.8	138.5	143.8	151.8	163.3	168.6	176.8	190.5	204.7
	SC6	73.8	82.962	94.2	104.8	109.2	115.8	127.5	132.3	139.5	151.5	164.2
RFTR18004	SC1	62.3	65.7	69.9	74.5	76.2	78.9	82.2	84.4	88.0	94.4	104.1
	SC2	49.9	52.6	56.5	60.4	61.9	64.4	68.2	70.4	73.9	80.3	89.9
	SC3	40.8	42.4	46.1	49.6	50.9	53.2	57.4	59.4	62.6	68.6	77.7
	SC4	61.7	67.8	75.3	83.0	86.2	91.1	98.9	102.6	108.5	118.8	131.9
	SC5	64.7	70.1	76.7	84.2	86.9	91.3	97.5	100.9	106.4	115.9	128.2
	SC6	58.6	63.3	69.2	75.3	77.8	81.8	88.4	91.5	96.5	105.6	117.2

Table 16 Corrected times obtained for regression analysis for two-layer protected beams and columns

Referenced test report	Beam	Time in minutes taken to reach the critical temperature (°C)										
		350	400	450	500	520	550	600	620	650	700	750
RFTR18001	SC1	125.8	134.1	142.4	150.7	154.0	159.0	167.3	170.6	175.6	183.9	192.1
	SC2	126.9	135.7	144.5	153.3	156.8	162.1	170.9	174.4	179.7	188.5	197.3
	SC3	115.9	124.2	132.5	140.8	144.2	149.2	157.5	160.8	165.8	174.2	182.5
	SC4	106.2	114.2	122.1	130.0	133.2	137.9	145.8	149.0	153.7	161.7	169.6
	SC5	203.9	216.1	228.2	240.3	245.1	252.4	264.5	269.3	276.6	288.7	300.8
	SC6	136.1	144.8	153.5	162.2	165.7	170.9	179.6	183.1	188.3	197.0	205.7
RFTR18004	SC1	54.8	62.0	69.2	76.3	79.2	83.5	90.7	93.6	97.9	105.1	112.3
	SC2	119.2	130.0	140.8	151.6	155.9	162.3	173.1	177.4	183.9	194.7	205.4
	SC3	146.4	157.5	168.7	179.8	184.3	191.0	202.2	206.6	213.3	224.5	235.6
	SC4	67.1	74.3	81.5	88.6	91.5	95.8	102.9	105.8	110.1	117.3	124.4
	SC5	85.0	93.1	101.1	109.2	112.4	117.3	125.3	128.6	133.4	141.5	149.5
	SC6	75.0	82.6	90.1	97.7	100.7	105.3	112.8	115.8	120.4	127.9	135.5

6.3.2.4 Regression equation

The relationship between the temperature (T) and time (t) is given as follows in AS 4100:2020. h_i and k_{sm} are the thickness of the protection material and exposed surface area to mass ratio, respectively. k_1 to k_6 are regression coefficients.

$$t = k_0 + k_1 h_i + k_2\left(\frac{h_i}{k_{sm}}\right) + k_3 T + k_4 h_i T + k_5\left(\frac{h_i T}{k_{sm}}\right) + k_6\left(\frac{T}{k_{sm}}\right)$$

Based on the time-temperature data presented in Table 15, the regression analysis was conducted and consequently regression coefficients suitable for the current protection system were determined (refer Table 17).

Table 17 Regression Coefficients

Regression Coefficient	Single layer protection	Two-layer protection
k_0	-29.3473	-84.611
k_1	1.944724	3.116547
k_2	-3.1305	12.60062
k_3	0.059186	0.087416
k_4	0.001222	0.001442
k_5	0.027519	0.002894
k_6	0.711107	0.502558

6.3.2.5 Regression model applicable window

Single layer protection

The minimum and maximum protected loaded beams with single A1 COREX board failed at 84 and 112 minutes, respectively. In addition, data utilised for regression included critical times (t) ranging from 35 minutes to 204 minutes and critical temperatures ranging from 350ºC to 750ºC, for which stickability was demonstrated. The minimum and maximum thicknesses of single board system tested on loaded steel beams were 12.5 mm and 25 mm, respectively.

Therefore, the regression model developed for single A1 COREX board protected steel beams and column is considered to be applicable to period of structural adequacies up to of 120 minutes – provided that the board thickness is within 12.5 mm and 25 mm.

Two-layer protection

The minimum and maximum protected loaded beams with two A1 COREX board layers failed at 97 and 179 minutes, respectively. In addition, data utilised for regression included critical times (t) ranging from 64 minutes to 269 minutes and critical temperatures ranging from 350ºC to 750ºC, for which stickability was demonstrated. The minimum and maximum thicknesses of the board system tested on loaded steel beams were 25 mm and 45 mm, respectively.

Therefore, the regression model developed for single two A1 COREX board layers protected steel beams and column is considered to be applicable to period of structural adequacies up to of 180 minutes.

6.3.3 Protection thickness for hollow section beams and columns

AS 4100:2020 does not specify guidelines on assessing hollow sections using the baseline test evidence of I/H sections. Therefore, using the general principles given in EN 13381-4:2013, the outcome of this assessment is assessed to hollow section (CHS, RHS and SHS) beams and columns with boxed protection. The required fire protection thickness for a hollow beam and column of a given section factor is equal to that for the I or H section.

6.3.4 Fixing method for hollow section steel beams and columns

For 4-sided hollow section beams and columns such as square and rectangular hollow sections, the A1 COREX boards must be installed as shown in Figure 4 for single layer encasement and Figure 5 for double layer encasement. For hollow section beams, it is recommended to install the top layer first to allow for the installation of the A1 COREX boards on the two sides and bottom surface. The staples used for the fixing must be identical to the staples used for the open section steel tests, and spaced at maximum centres shown in Table 8.

For 3-sided hollow section beams with floor slab protecting the top surface, the A1 COREX boards must be installed as shown in Figure 6. 50 mm wide × 25 mm thick COREX board cleats is to be anchored to the ceiling/floor system with appropriate anchor. The A1 COREX boards on the sides and the bottom surface will then be fixed together with the staples used in the open section tests, and spaced at maximum centres as shown in Table 8.

6.4 Conclusion

Two regression equations were developed in this assessment to predict the structural fire response of steel beams and columns protected with A1 COREX boards with single and two-layer protection configurations.

Table 19 to Table 24 show the outcome obtained from the regression equations, which provide the required A1 COREX board thicknesses to achieve a given period of structural adequacy provided that the section factor and the critical temperature of the steel section is known.

Based on the outcome of this assessment, a single board must be used for thickness requirements equal or less than 25 mm. Where, an insulation thickness greater than 25 mm is required, two boards must be used.

If it can be shown that two layers of board meet the required period of structural adequacy for a lower critical temperature, then these results can be applied to higher critical temperatures with no reduction in the total thickness of boards.

Table 18 Regression equations

System	Regression equation
A1 COREX single layer protection	$t = -29.3473 + 1.944724 - 3.1305\left(\frac{h_i}{k_{sm}}\right) + 5.9186 \times 10^{-2}\,T + 1.222 \times 10^{-3} h_i T + 2.7519 \times 10^{-2}\left(\frac{h_i T}{k_{sm}}\right) + 0.711107\left(\frac{T}{k_{sm}}\right)$
A1 COREX two-layer protection	$t = -84.611 + 3.116547 + 12.60062\left(\frac{h_i}{k_{sm}}\right) + 8.7416 \times 10^{-2} T + 1.442 \times 10^{-3} h_i T + 2.894 \times 10^{-3}\left(\frac{h_i T}{k_{sm}}\right) + 0.502558\left(\frac{T}{k_{sm}}\right)$
t, T, h_i and k_{sm} are the time (in minutes), steel temperature (in ºC), thickness of the protection material (in mm) and exposed surface area to mass ratio (in m^2/tonne), respectively.	

Table 19 Period of structural adequacy – 30 minutes

Steel section		Board thickness requirement (mm) for various critical temperatures (ºC)									
HP/A	E	350	400	450	500	550	600	620	650	700	750
50	6.37	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
60	7.64	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
70	8.92	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
80	10.19	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
90	11.46	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
100	12.74	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
110	14.01	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
120	15.29	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
130	16.56	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
140	17.83	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
150	19.11	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
160	20.38	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
170	21.66	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
180	22.93	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
190	24.20	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
200	25.48	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
210	26.75	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
220	28.03	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
230	29.30	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
240	30.57	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
250	31.85	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
260	33.12	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
270	34.39	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
280	35.67	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
290	36.94	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
300	38.22	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
310	39.49	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
320	40.76	12.8	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
330	42.04	12.9	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
340	43.31	13.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
350	44.59	13.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
360	45.86	13.2	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
370	47.13	13.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
380	48.41	13.4	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
385	49.04	13.4	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5

Table 20 Period of structural adequacy – 45 minutes

Steel section		Board thickness requirement (mm) for various critical temperatures (°C)									
HP/A	E	350	400	450	500	550	600	620	650	700	750
50	6.37	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
60	7.64	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
70	8.92	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
80	10.19	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
90	11.46	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
100	12.74	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
110	14.01	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
120	15.29	13.4	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
130	16.56	14.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
140	17.83	14.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
150	19.11	15.0	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
160	20.38	15.4	13.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
170	21.66	15.8	13.4	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
180	22.93	16.1	13.8	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
190	24.20	16.4	14.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
200	25.48	16.7	14.4	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
210	26.75	16.9	14.7	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5
220	28.03	17.2	14.9	12.8	12.5	12.5	12.5	12.5	12.5	12.5	12.5
230	29.30	17.4	15.2	13.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5
240	30.57	17.6	15.4	13.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5
250	31.85	17.8	15.6	13.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
260	33.12	18.0	15.8	13.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5
270	34.39	18.1	15.9	13.9	12.5	12.5	12.5	12.5	12.5	12.5	12.5
280	35.67	18.3	16.1	14.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5
290	36.94	18.4	16.2	14.2	12.5	12.5	12.5	12.5	12.5	12.5	12.5
300	38.22	18.5	16.4	14.4	12.5	12.5	12.5	12.5	12.5	12.5	12.5
310	39.49	18.7	16.5	14.5	12.7	12.5	12.5	12.5	12.5	12.5	12.5
320	40.76	18.8	16.6	14.6	12.8	12.5	12.5	12.5	12.5	12.5	12.5
330	42.04	18.9	16.8	14.8	12.9	12.5	12.5	12.5	12.5	12.5	12.5
340	43.31	19.0	16.9	14.9	13.0	12.5	12.5	12.5	12.5	12.5	12.5
350	44.59	19.1	17.0	15.0	13.2	12.5	12.5	12.5	12.5	12.5	12.5
360	45.86	19.2	17.1	15.1	13.3	12.5	12.5	12.5	12.5	12.5	12.5
370	47.13	19.3	17.2	15.2	13.4	12.5	12.5	12.5	12.5	12.5	12.5
380	48.41	19.3	17.3	15.3	13.5	12.5	12.5	12.5	12.5	12.5	12.5
385	49.04	19.4	17.3	15.3	13.5	12.5	12.5	12.5	12.5	12.5	12.5

Table 21 Period of structural adequacy – 60 minutes

Steel section		Board thickness requirement (mm) for various critical temperatures (°C)									
HP/A	E	350	400	450	500	550	600	620	650	700	750
50	6.37	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
60	7.64	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
70	8.92	13.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
80	10.19	14.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
90	11.46	16.0	13.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
100	12.74	17.0	14.2	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
110	14.01	17.9	15.1	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5
120	15.29	18.7	16.0	13.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
130	16.56	19.4	16.7	14.2	12.5	12.5	12.5	12.5	12.5	12.5	12.5
140	17.83	20.0	17.3	14.9	12.6	12.5	12.5	12.5	12.5	12.5	12.5
150	19.11	20.5	17.8	15.4	13.2	12.5	12.5	12.5	12.5	12.5	12.5
160	20.38	21.0	18.3	15.9	13.7	12.5	12.5	12.5	12.5	12.5	12.5
170	21.66	21.4	18.8	16.4	14.2	12.5	12.5	12.5	12.5	12.5	12.5
180	22.93	21.8	19.2	16.8	14.7	12.7	12.5	12.5	12.5	12.5	12.5
190	24.20	22.1	19.5	17.2	15.0	13.1	12.5	12.5	12.5	12.5	12.5
200	25.48	22.4	19.9	17.5	15.4	13.4	12.5	12.5	12.5	12.5	12.5
210	26.75	22.7	20.2	17.9	15.7	13.8	12.5	12.5	12.5	12.5	12.5
220	28.03	22.9	20.5	18.2	16.0	14.1	12.5	12.5	12.5	12.5	12.5
230	29.30	23.2	20.7	18.4	16.3	14.4	12.5	12.5	12.5	12.5	12.5
240	30.57	23.4	20.9	18.7	16.6	14.6	12.8	12.5	12.5	12.5	12.5
250	31.85	23.6	21.2	18.9	16.8	14.9	13.1	12.5	12.5	12.5	12.5
260	33.12	23.8	21.4	19.1	17.0	15.1	13.3	12.6	12.5	12.5	12.5
270	34.39	24.0	21.6	19.3	17.2	15.3	13.5	12.8	12.5	12.5	12.5
280	35.67	24.1	21.7	19.5	17.4	15.5	13.7	13.0	12.5	12.5	12.5
290	36.94	24.3	21.9	19.7	17.6	15.7	13.9	13.2	12.5	12.5	12.5
300	38.22	24.4	22.1	19.9	17.8	15.9	14.1	13.4	12.5	12.5	12.5
310	39.49	24.6	22.2	20.0	18.0	16.1	14.3	13.6	12.6	12.5	12.5
320	40.76	24.7	22.3	20.2	18.1	16.2	14.4	13.7	12.7	12.5	12.5
330	42.04	24.8	22.5	20.3	18.3	16.4	14.6	13.9	12.9	12.5	12.5
340	43.31	24.9	22.6	20.4	18.4	16.5	14.7	14.0	13.1	12.5	12.5
350	44.59	25.0	22.7	20.6	18.5	16.6	14.9	14.2	13.2	12.5	12.5
360	45.86	29.5	22.8	20.7	18.7	16.8	15.0	14.3	13.3	12.5	12.5
370	47.13	29.6	22.9	20.8	18.8	16.9	15.1	14.4	13.5	12.5	12.5
380	48.41	-	23.0	20.9	18.9	17.0	15.2	14.6	13.6	12.5	12.5
385	49.04	-	23.1	20.9	18.9	17.1	15.3	14.6	13.6	12.5	12.5
Note											
	The highlighted cells refer to the protection achieved using two boards.										

Table 22 Period of structural adequacy – 90 minutes

Steel section		Board thickness requirement (mm) for various critical temperatures (ºC)									
HP/A	E	350	400	450	500	550	600	620	650	700	750
50	6.37	17.6	13.9	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
60	7.64	20.5	16.9	13.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5
70	8.92	22.8	19.2	16.1	13.3	12.5	12.5	12.5	12.5	12.5	12.5
80	10.19	24.7	21.1	18.0	15.2	12.8	12.5	12.5	12.5	12.5	12.5
90	11.46	26.8	22.7	19.6	16.9	14.4	12.5	12.5	12.5	12.5	12.5
100	12.74	27.8	24.0	21.0	18.2	15.8	13.5	12.7	12.5	12.5	12.5
110	14.01	28.6	26.8	22.1	19.4	17.0	14.7	13.8	12.6	12.5	12.5
120	15.29	29.4	27.5	23.2	20.5	18.0	15.7	14.9	13.7	12.5	12.5
130	16.56	30.0	28.2	24.0	21.4	18.9	16.7	15.8	14.6	12.7	12.5
140	17.83	30.6	28.8	24.8	22.2	19.7	17.5	16.6	15.4	13.5	12.5
150	19.11	31.1	29.3	27.5	22.9	20.4	18.2	17.4	16.1	14.2	12.5
160	20.38	31.6	29.7	27.9	23.5	21.1	18.9	18.0	16.8	14.9	13.1
170	21.66	32.0	30.1	28.3	24.1	21.7	19.5	18.6	17.4	15.5	13.7
180	22.93	32.3	30.5	28.7	24.6	22.2	20.0	19.2	17.9	16.0	14.3
190	24.20	32.7	30.8	29.0	27.3	22.7	20.5	19.7	18.4	16.5	14.8
200	25.48	33.0	31.1	29.3	27.6	23.1	20.9	20.1	18.9	17.0	15.2
210	26.75	33.3	31.4	29.6	27.9	23.5	21.4	20.5	19.3	17.4	15.6
220	28.03	33.5	31.7	29.8	28.1	23.9	21.7	20.9	19.7	17.8	16.0
230	29.30	33.8	31.9	30.1	28.3	24.3	22.1	21.3	20.1	18.2	16.4
240	30.57	34.0	32.1	30.3	28.6	24.6	22.4	21.6	20.4	18.5	16.7
250	31.85	34.2	32.3	30.5	28.7	24.9	22.7	21.9	20.7	18.8	17.1
260	33.12	34.4	32.5	30.7	28.9	27.2	23.0	22.2	21.0	19.1	17.4
270	34.39	34.6	32.7	30.9	29.1	27.4	23.3	22.5	21.3	19.4	17.6
280	35.67	34.7	32.9	31.0	29.3	27.6	23.5	22.7	21.5	19.7	17.9
290	36.94	34.9	33.0	31.2	29.4	27.7	23.8	23.0	21.8	19.9	18.1
300	38.22	35.1	33.2	31.3	29.6	27.9	24.0	23.2	22.0	20.1	18.4
310	39.49	35.2	33.3	31.5	29.7	28.0	24.2	23.4	22.2	20.4	18.6
320	40.76	37.1	35.1	33.2	31.3	29.5	24.4	23.6	22.4	20.6	18.8
330	42.04	37.2	35.2	33.3	31.4	29.7	24.6	23.8	22.6	20.8	19.0
340	43.31	37.3	35.3	33.4	31.6	29.8	24.8	24.0	22.8	20.9	19.2
350	44.59	37.5	35.5	33.5	31.7	29.9	24.9	24.1	23.0	21.1	19.4
360	45.86	37.6	35.6	33.6	31.8	30.0	28.3	24.3	23.1	21.3	19.5
370	47.13	37.7	35.7	33.7	31.9	30.1	28.4	24.4	23.3	21.4	19.7
380	48.41							24.6	23.4	21.6	19.8
385	49.04							24.7	23.5	21.7	19.9
Note											
	The highlighted cells refer to the protection achieved using two boards.										

Table 23 Period of structural adequacy – 120 minutes

Steel section		Board thickness requirement (mm) for various critical temperatures (°C)									
HP/A	E	350	400	450	500	550	600	620	650	700	750
50	6.37	25.4	22.1	18.4	15.1	12.5	12.5	12.5	12.5	12.5	12.5
60	7.64	28.0	26.1	21.8	18.6	15.7	13.1	12.5	12.5	12.5	12.5
70	8.92	30.0	28.1	24.6	21.3	18.4	15.8	14.8	13.4	12.5	12.5
80	10.19	31.6	29.7	27.9	23.6	20.7	18.0	17.1	15.6	13.5	12.5
90	11.46	33.0	31.1	29.2	27.5	22.6	19.9	18.9	17.5	15.3	13.3
100	12.74	34.2	32.2	30.4	28.6	24.2	21.5	20.6	19.1	16.9	14.9
110	14.01	35.2	33.2	31.3	29.5	27.8	23.0	22.0	20.5	18.3	16.3
120	15.29	36.0	34.1	32.2	30.4	28.6	24.2	23.2	21.8	19.5	17.5
130	16.56	36.8	34.8	32.9	31.1	29.3	27.6	24.3	22.9	20.6	18.6
140	17.83	37.4	35.5	33.6	31.7	30.0	28.3	27.6	23.8	21.6	19.5
150	19.11	38.0	36.1	34.1	32.3	30.5	28.8	28.1	24.7	22.5	20.4
160	20.38	38.6	36.6	34.7	32.8	31.0	29.3	28.6	27.7	23.2	21.2
170	21.66	39.0	37.0	35.1	33.3	31.5	29.8	29.1	28.1	24.0	21.9
180	22.93	39.5	37.5	35.5	33.7	31.9	30.2	29.5	28.5	24.6	22.5
190	24.20	39.9	37.9	35.9	34.1	32.3	30.5	29.9	28.9	27.2	23.1
200	25.48	40.2	38.2	36.3	34.4	32.6	30.9	30.2	29.2	27.6	23.7
210	26.75	40.5	38.5	36.6	34.7	32.9	31.2	30.5	29.5	27.9	24.2
220	28.03	40.8	38.8	36.9	35.0	33.2	31.5	30.8	29.8	28.2	24.6
230	29.30	41.1	39.1	37.2	35.3	33.5	31.7	31.0	30.0	28.4	26.8
240	30.57	41.4	39.4	37.4	35.5	33.7	32.0	31.3	30.3	28.6	27.1
250	31.85	41.6	39.6	37.6	35.8	33.9	32.2	31.5	30.5	28.9	27.3
260	33.12	41.8	39.8	37.9	36.0	34.2	32.4	31.7	30.7	29.1	27.5
270	34.39	42.0	40.0	38.1	36.2	34.4	32.6	31.9	30.9	29.3	27.7
280	35.67	42.2	40.2	38.2	36.4	34.5	32.8	32.1	31.1	29.4	27.9
290	36.94	42.4	40.4	38.4	36.5	34.7	33.0	32.3	31.3	29.6	28.0
300	38.22	42.6	40.6	38.6	36.7	34.9	33.1	32.4	31.4	29.8	28.2
310	39.49	42.8	40.7	38.7	36.9	35.0	33.3	32.6	31.6	29.9	28.3
320	40.76	45.0	42.9	40.8	38.8	36.9	35.1	34.4	33.3	31.6	29.9
330	42.04		43.1	41.0	39.0	37.1	35.2	34.5	33.4	31.7	30.0
340	43.31		43.2	41.1	39.1	37.2	35.3	34.6	33.6	31.8	30.2
350	44.59		43.3	41.3	39.3	37.3	35.5	34.8	33.7	31.9	30.3
360	45.86		43.5	41.4	39.4	37.5	35.6	34.9	33.8	32.1	30.4
370	47.13		43.6	41.5	39.5	37.6	35.7	35.0	33.9	32.2	30.5
380	48.41										
385	49.04										
Note											
	The highlighted cells refer to the protection achieved using two boards.										

Table 24 Period of structural adequacy – 180 minutes

Steel section		Board thickness requirement (mm) for various critical temperatures (ºC)									
HP/A	E	350	400	450	500	550	600	620	650	700	750
50	6.37	35.8	33.8	31.9	30.0	28.2	26.4	25.8	25.0	25.0	25.0
60	7.64	39.1	37.0	35.0	33.1	31.3	29.5	28.8	27.7	26.1	25.0
70	8.92	41.6	39.6	37.5	35.6	33.7	31.9	31.2	30.1	28.4	26.8
80	10.19	43.7	41.6	39.6	37.6	35.7	33.9	33.2	32.1	30.4	28.7
90	11.46		43.3	41.3	39.3	37.4	35.5	34.8	33.7	32.0	30.3
100	12.74		44.8	42.7	40.7	38.8	36.9	36.2	35.1	33.3	31.6
110	14.01			44.0	41.9	40.0	38.1	37.4	36.3	34.5	32.8
120	15.29			45.0	43.0	41.0	39.1	38.4	37.3	35.5	33.8
130	16.56				43.9	41.9	40.0	39.3	38.2	36.4	34.6
140	17.83				44.7	42.7	40.8	40.0	38.9	37.1	35.4
150	19.11					43.4	41.5	40.7	39.6	37.8	36.1
160	20.38					44.1	42.1	41.4	40.2	38.4	36.7
170	21.66					44.6	42.7	41.9	40.8	39.0	37.2
180	22.93					45.2	43.2	42.4	41.3	39.5	37.7
190	24.20						43.7	42.9	41.8	39.9	38.2
200	25.48						44.1	43.3	42.2	40.3	38.6
210	26.75						44.5	43.7	42.6	40.7	38.9
220	28.03						44.8	44.0	42.9	41.1	39.3
230	29.30							44.4	43.2	41.4	39.6
240	30.57							44.7	43.5	41.7	39.9
250	31.85							45.0	43.8	42.0	40.2
260	33.12								44.1	42.2	40.4
270	34.39								44.3	42.4	40.6
280	35.67								44.5	42.7	40.9
290	36.94								44.7	42.9	41.1
300	38.22								44.9	43.1	41.3
310	39.49									43.3	41.4
320	40.76										43.7
330	42.04										43.9
340	43.31										44.0
350	44.59										44.2
360	45.86										44.3
370	47.13										44.5
380	48.41										
385	49.04										
Note											
	The highlighted cells refer to the protection achieved using two boards.										

7. Validity

Warringtonfire does not endorse the tested or assessed product in any way. The conclusions of this assessment may be used to directly assess fire hazard, but it should be recognised that a single test method will not provide a full assessment of fire hazard under all conditions.

Due to the nature of fire testing and the consequent difficulty in quantifying the uncertainty of measurement, it is not possible to provide a stated degree of accuracy. The inherent variability in test procedures, materials and methods of construction, and installation may lead to variations in performance between elements of similar construction.

This assessment is based on information and experience available at the time of preparation. The published procedures for the conduct of tests and the assessment of test results are subject to constant review and improvement. It is therefore recommended that this report be reviewed on, or before, the stated expiry date.

This assessment represents our opinion about the performance likely to be demonstrated on a test in accordance with AS 1530.4:2014, based on the evidence referred to in this report.

This assessment is provided to Trafalgar Group for their own specific purposes. Building certifiers and other third parties are responsible for deciding if they accept this assessment in a particular context.

Appendix A Drawings and additional information

Table 25 Details of drawings

Figure	Description
Figure 1	Extracted from 'RFTR18001'
Figure 2	Extracted from 'RFTR18002'
Figure 3	Provided by Trafalgar group
Figure 4	
Figure 5	
Figure 6	

Appendix B Summary of supporting test data

B.1 Test report – RFTR18001

Table 26 Information about test report

Item	Information about test report
Report sponsor	DALSAN ALÇI SANAYİ ve TİCARET A.Ş
Test laboratory	Efectis Dilovasi OSB, 5. Kisim, First Caddesi No 18, Dilovasi, Turkey.
Test date	The fire resistance test was completed on 27 November 2017.
Test standards	The test was done in accordance with EN 13381-4:2013.
Variation to test standards	None
General description of tested specimen	The test specimens consisted of one loaded and reference beam with single board protection. In addition, it also consisted of six unloaded I/H section columns with single board protection with varying thicknesses.
Instrumentation	The test report states that the instrumentation was in accordance with EN 13381-4:2013.

Upon testing, the loaded beam was able to maintain structural adequacy up to 84 minutes. Table 27 provides the relationship between the time and the steel surface temperature of referenced short columns.

Table 27 Results summary for this test report

Beam	Time in minutes taken to reach the critical temperature (°C)										
	350	400	450	500	520	550	600	620	650	700	750
SC1	41.3	45.5	49.8	54.8	57.0	60.3	66.8	69.7	74.2	82.3	93.3
SC2	34.7	37.8	41.5	45.7	47.3	50.0	55.7	58.0	61.8	68.7	78.0
SC3	40.5	45.3	50.3	55.8	58.2	61.8	68.5	71.2	75.7	83.7	94.0
SC4	85.8	97.7	109.3	121.5	126.7	134.7	148.5	154.3	163.5	179.7	198.2
SC5	101.0	113.5	126.3	139.3	144.7	152.7	166.3	171.7	180.0	194.0	208.5
SC6	73.8	83.8	94.2	104.8	109.2	115.8	127.5	132.3	139.5	151.5	164.2

B.2 Test report – RFTR18002

Table 28 Information about test report

Item	Information about test report
Report sponsor	DALSAN ALÇI SANAYİ ve TİCARET A.Ş
Test laboratory	Efectis Dilovasi OSB, 5. Kisim, First Caddesi No 18, Dilovasi, Turkey.
Test date	The fire resistance test was completed on 29 November 2017.
Test standards	The test was done in accordance with EN 13381-4:2013.
Variation to test standards	None
General description of tested specimen	The test specimens consisted of one loaded and reference beam with two-layer board protection. In addition, it also consisted of six unloaded I/H section columns with two-layer board protection with varying thicknesses.
Instrumentation	The test report states that the instrumentation was in accordance with EN 13381-4:2013.

Upon testing, the loaded beam was able to maintain structural adequacy up to 179 minutes. Table 29 provides the relationship between the time and the steel surface temperature of referenced short columns.

Table 29 Results summary for this test report

Beam	Time in minutes taken to reach the critical temperature (°C)										
	350	400	450	500	520	550	600	620	650	700	750
SC1	122.0	127.2	132.7	138.3	140.8	144.7	151.3	154.2	158.8	167.2	178.8
SC2	132.7	142.8	153.2	164.0	168.7	175.7	188.5	193.7	202.0	216.7	231.7
SC3	128.7	136.5	144.8	153.7	157.3	163.0	173.3	177.8	184.8	197.2	210.5
SC4	107.2	112.3	117.8	123.8	126.2	130.0	136.8	139.7	144.3	153.2	165.8
SC5	193.3	210.8	228.0	244.5	250.5	258.0	264.5	266.2	268.5	271.5	273.7
SC6	139.5	147.2	155.2	163.7	167.0	172.3	181.7	185.7	191.7	202.7	214.0

B.3 Test report – RFTR18001

Table 30 Information about test report

Item	Information about test report
Report sponsor	DALSAN ALÇI SANAYİ ve TİCARET A.Ş
Test laboratory	Efectis Dilovasi OSB, 5. Kisim, First Caddesi No 18, Dilovasi, Turkey.
Test date	The fire resistance test was completed on 01 December 2017.
Test standards	The test was done in accordance with EN 13381-4:2013.
Variation to test standards	None
General description of tested specimen	The test specimens consisted of one loaded and reference beam with two-layer board protection. In addition, it also consisted of six unloaded I/H section columns with two-layer board protection with varying thicknesses.
Instrumentation	The test report states that the instrumentation was in accordance with EN 13381-4:2013.

Upon testing, the loaded beam was able to maintain structural adequacy up to 97 minutes. Table 31 provides the relationship between the time and the steel surface temperature of referenced short columns.

Table 31 Results summary for this test report

Beam	Time in minutes taken to reach the critical temperature (°C)										
	350	400	450	500	520	550	600	620	650	700	750
SC1	64.2	69.7	75.5	81.8	84.5	89.0	97.2	100.8	106.5	117.0	129.2
SC2	117.2	129.3	140.7	152.0	156.5	163.5	174.5	178.8	185.0	195.0	206.8
SC3	143.5	159.7	176.2	193.3	200.3	211.2	230.0	236.2	244.5	259.0	274.2
SC4	67.2	70.8	74.8	79.2	81.0	84.0	89.3	91.7	95.5	103.2	115.7
SC5	90.0	97.8	106.0	115.0	119.0	125.2	136.3	141.0	148.2	160.2	173.3
SC6	80.2	86.3	92.8	99.8	102.7	107.7	116.8	120.8	127.0	137.7	149.7

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Table 32 Information about test report

Item	Information about test report
Report sponsor	DALSAN ALÇI SANAYİ ve TİCARET A.Ş
Test laboratory	Efectis Dilovasi OSB, 5. Kisim, First Caddesi No 18, Dilovasi, Turkey.
Test date	The fire resistance test was completed on 03 December 2017.
Test standards	The test was done in accordance with EN 13381-4:2013.
Variation to test standards	None
General description of tested specimen	The test specimens consisted of one loaded and reference beam with single board protection. In addition, it also consisted of six unloaded I/H section columns with single board protection with varying thicknesses.
Instrumentation	The test report states that the instrumentation was in accordance with EN 13381-4:2013.

Upon testing, the loaded beam was able to maintain structural adequacy up to 112 minutes. Table 33 provides the relationship between the time and the steel surface temperature of referenced short columns.

Table 33 Results summary for this test report

Beam	Time in minutes taken to reach the critical temperature (°C)										
	350	400	450	500	520	550	600	620	650	700	750
SC1	64.2	67.7	71.3	75.3	77	79.7	84.7	87	90.7	97.3	107.3
SC2	50.8	53.8	57.2	60.8	62.3	64.8	69.5	71.7	75.3	81.8	91.5
SC3	41	43	46.3	49.7	51	53.3	57.7	59.8	63	69	78.2
SC4	62.8	69.3	76.2	83.5	86.7	91.7	100.7	104.5	110.5	121	134.3
SC5	66.7	72.3	78.3	85	87.8	92.2	100.5	104	109.7	119.5	132.2
SC6	59.7	64.7	70	75.8	78.3	82.3	90	93.2	98.3	107.5	119.3

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