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CLIENT REPORT

Firmdale Hotels – Assessment of fire resistance for existing building

Prepared for: Firmdale Hotels PLC
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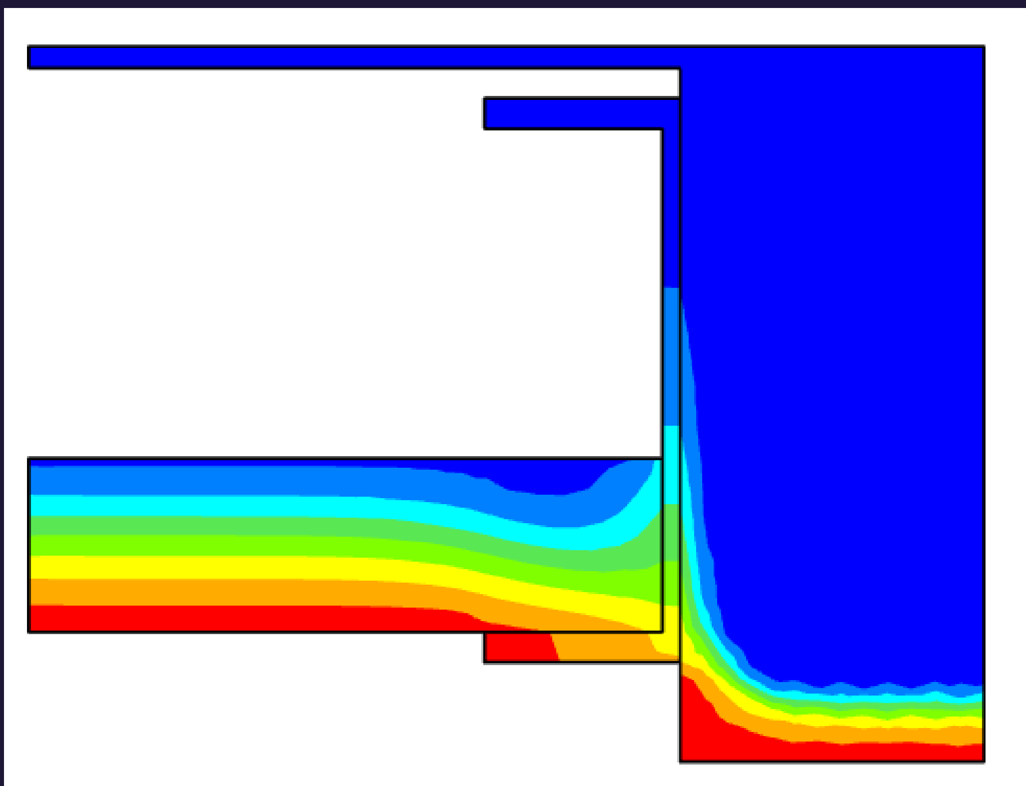

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Executive Summary

The client is undertaking the refurbishment of a Grade II listed building to create a 42-room hotel. Given the building's age (200 year old), substantial strengthening works are required for the floor system. Due to the extent of these modifications, the floor must be upgraded to achieve a 60 minute (REI) fire resistance rating. As the ceilings are listed features, the client is exploring the use of floor void fire batts, installed from above, to achieve the required level of fire performance. The client has reviewed a Corofil system designed for such an application and provided BRE with details and a fire resistance test report[1]. However, the specific construction parameters fall outside the direct field of application of the test report and cannot be covered within an extended field of application (EXAP) assessment.

The client requires an assessment of the anticipated fire resistance of the strengthened floor system when protected with the PFCTS CF passive fire protection system as detailed in the test report provided[1], as well as the existing primary and secondary beams.

Advanced numerical techniques have been employed to assess the fire resistance of the details. The analysis examines the influence of the protection and the construction set-up on the anticipated fire resistance. The thermal modelling undertaken using validated Finite Element software assesses the anticipated temperature distribution on the elements cross-section, when subject to a standard fire exposure.

The required fire resistance time is 60 minutes (REI60) for each detail and the corresponding residual area after 60 minutes under standard fire exposure are summarised in the table below. The residual areas can be used to calculate the capacity at 60 minutes fire exposure which in turn can be compared to the fire limit state loads for the building.

Detail	Residual Area [cm^2] at REI60
Detail 1 Typical section through the existing secondary beam	193.5
Detail 2 Typical section through the proposed intermediate secondary beam	98.28
Detail 3 Typical section through the proposed intermediate double secondary beam	203.83
Detail 4 Typical section through the proposed intermediate triple secondary beam	306.18
Detail 5 Typical section through strengthened primary beam with original secondary beam	812
Detail 6 Typical section through strengthened primary beam with intermediate secondary beam	782.6

1. Description of the project

The client is undertaking the refurbishment of a Grade II listed building to create a 42-room hotel. Given the building's age (200 year old), substantial strengthening works are required for the floor system. Due to the extent of these modifications, the floor must be upgraded to achieve a 60 minute (REI) fire resistance rating. As the ceilings are listed features, the client is exploring the use of floor void fire batts, installed from above, to achieve the required level of fire performance. The client has reviewed a Corofil system designed for such an application and provided BRE with details and a fire resistance test report[1]. However, the specific construction parameters fall outside the direct field of application of the test report and cannot be covered within an extended field of application (EXAP) assessment.

The client requires an assessment of the anticipated fire resistance of the strengthened floor system when protected with the PFCTS CF passive fire protection system as detailed in the test report provided[1], as well as the existing primary and secondary beams. It is understood the differences between the system as tested and the intended end use application are:

- Member sizes
- Spacing
- Load applied

The key deviations from the tested detail have been identified by the client and are highlighted below:

- Load requirements - The design exceeds the tested 2.0 kN/m².
- Shallower joists - Our joists are 190mm deep versus the tested 225mm
- Ceiling Construction - We have lath and plaster instead of the specified Gyproc ceiling

The BRE team is required to assess the following 6 details, illustrated in Figures 1 to 6 below, where the floor joists dimensions are 100 mm depth x 50/65 mm wide and the ceiling joists are 60 mm depth x 40 mm wide.

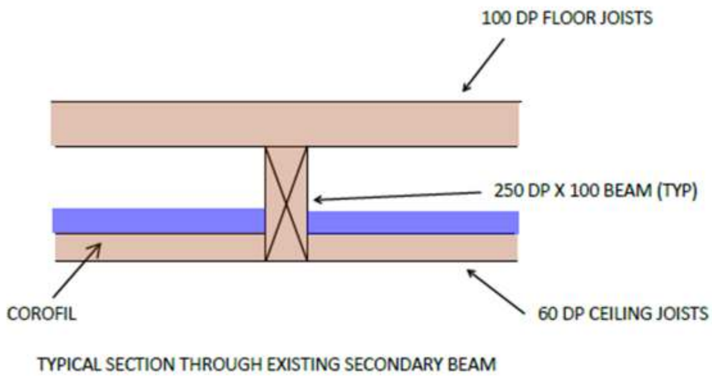


Figure 1 Detail 1 - Typical section through the existing secondary beam

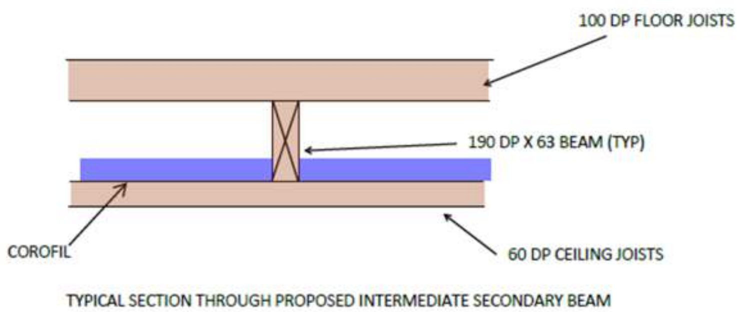


Figure 2 Detail 2 - Typical section through the proposed intermediate secondary beam

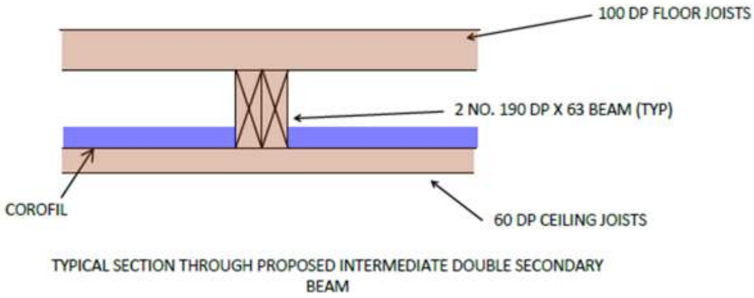


Figure 3 Detail 3 - Typical section through the proposed intermediate double secondary beam

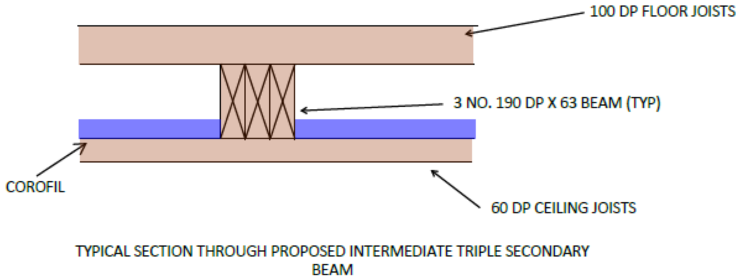


Figure 4 Detail 4 - Typical section through the proposed intermediate triple secondary beam

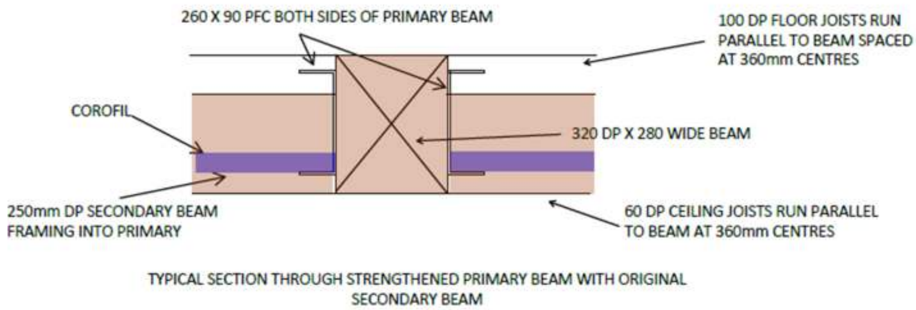


Figure 5 Detail 5 - Typical section through strengthened primary beam with original secondary beam

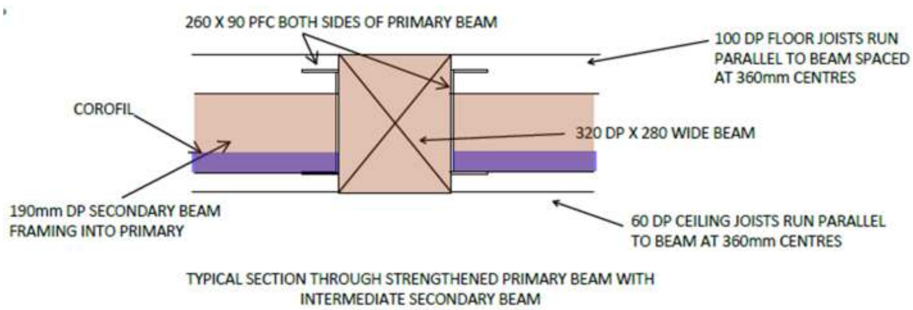


Figure 6 Detail 6 - Typical section through strengthened primary beam with intermediate secondary beam

Advanced numerical techniques are employed to assess the fire resistance of the 6 details and are presented further in this report. The analysis examines the influence of the protection and the construction set-up on the anticipated fire resistance.

The advanced heat transfer analysis aims to determine the temperature of the timber members and the depth of the charring layer, resulting in the dimensions of the residual cross-section at the required fire resistance time. Further, the structural engineer will verify the load-bearing capacity of the elements, based on the residual dimensions, for fire scenario load combinations.

2.Numerical approach

The numerical approach to calculate the heat transfer to the specified details when exposed to a standard fire exposure is based on the nonlinear finite element software SAFIR (2022)[2].

The main objective of structures-in-fire (SiF) analysis is to determine the mechanical behaviour of a structure during a fire until failure. The software SAFIR was developed to allow numerical modelling of the behaviour of structures subjected to fire. The software also allows thermal analysis, and the information obtained on the temperature distribution can be used to estimate load-bearing capacity. Several validation studies are available in the literature[3,4,5].

For the conduction problem, the heat exchange is based on the Fourier equation expressed as follows:

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+Q=c_p\rho\frac{\partial T}{\partial t} \quad (1)$$

In this case, the heat transfer mechanism is three-dimensional, without internal heat generation, and equation 1 can be rewritten as:

$$k_{(\theta)}\left(\frac{\partial T}{\partial x^2}+\frac{\partial T}{\partial y^2}+\frac{\partial T}{\partial z^2}\right)-c_{p(\theta)}\rho_{(\theta)}\frac{\partial T}{\partial t}=0 \quad (2)$$

Where $k_{(\theta)}$ is the thermal conductivity (W/mK), $c_{p(\theta)}$ is the specific heat (J/kgK), $\rho_{(\theta)}$ is the density (kg/m^3), and Q is the internal heat generation (W/m^2).

The following equation characterises the standard time-temperature curve (Figure 7):

$$\theta_g = 345\log_{10}(8\cdot t+1)+\theta_0 \text{ (°C)} \quad (3)$$

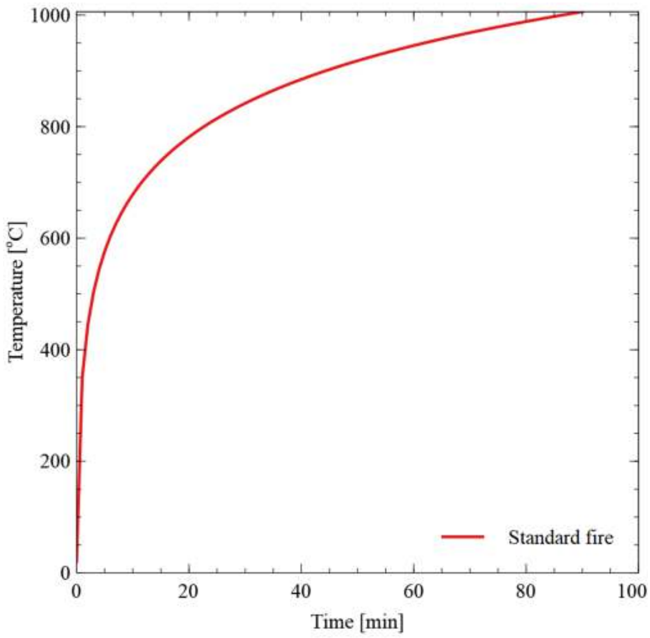


Figure 7 Standard time-temperature fire curve[6]

2.1 Material properties

For the advanced thermal analysis, the thermal properties considered for timber and structural steel can be found in EN 1993-1-2[7] and EN 1995-1-2[8].

The lath and plaster thermal properties were developed and validated against data found in the scientific literature.

The stone wool thermal conductivity was considered 0.036 W/mC and 110 kg/m^3 density[1].

2.2 Boundary conditions

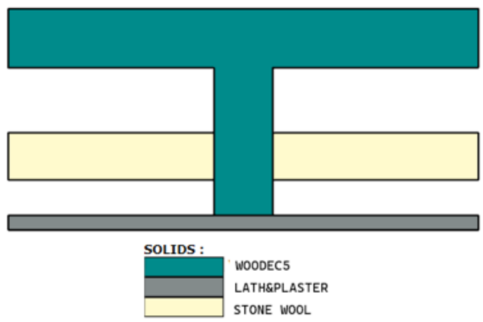
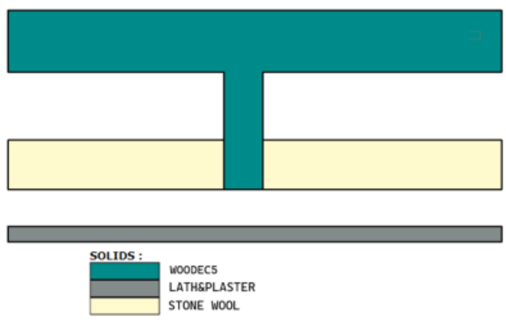
The heat flux at the boundary is calculated from the gas and surface temperature according to the following equation:

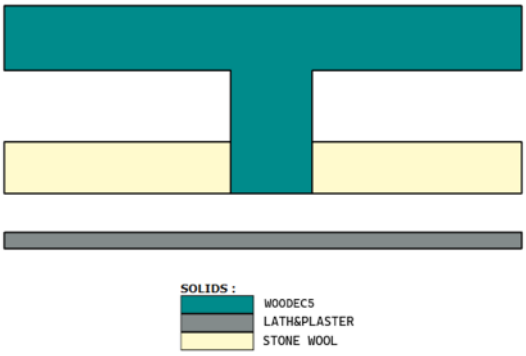
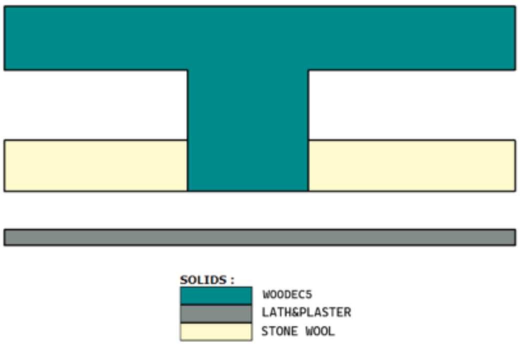
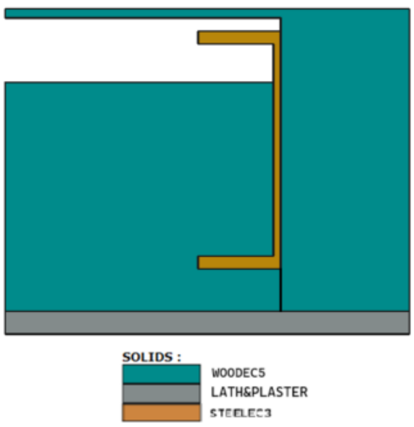
$$q = h(\theta_g - \theta_s) + \sigma\varepsilon({\theta_g}^4 - {\theta_s}^4) \text{ (W/m}^2\text{)} \tag{6}$$

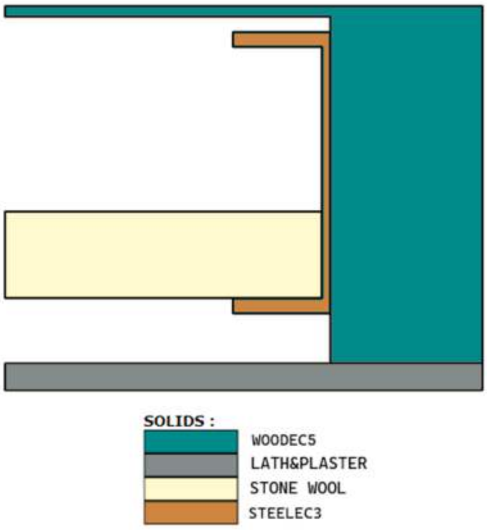
Where q is the total heat flux, ε is the relative emissivity, σ is the Stefan-Boltzmann constant, and θ_g and θ_s are the gas and surface temperatures, respectively. The convective heat transfer coefficient (h) for standard fire exposure considered in the analysis is approximately 25W/m^{2}K on the fire-exposed face.

The boundary conditions used for the thermal analysis are shown below:

Table 1 Boundary conditions used for the numerical analysis

Element	Boundary Conditions	Comments
Detail 1 - Typical section through the existing secondary beam		250x100 mm timber beam 25 mm Lath and plaster ceiling 80 mm stone wool 110 kg/m^3 Standard fire exposure
Detail 2 - Typical section through the proposed intermediate secondary beam		190x63 mm timber beam 25 mm Lath and plaster ceiling 80 mm stone wool 110 kg/m^3 Standard fire exposure

Element	Boundary Conditions	Comments
Detail 3 - Typical section through the proposed intermediate double secondary beam		2 x 190x63 mm timber beam 25 mm Lath and plaster ceiling 80 mm stone wool 110 kg/m^3 Standard fire exposure
Detail 4 - Typical section through the proposed intermediate triple secondary beam		3 x 190x63 mm timber beam 25 mm Lath and plaster ceiling 80 mm stone wool 110 kg/m^3 Standard fire exposure
Detail 5 - Typical section through strengthened primary beam with original secondary beam		320x280 mm timber beam 250 mm DP secondary beam 260x90 PFC (no fire protection on the steel work was considered in the numerical model) 260x90 PFC 25 mm Lath and plaster ceiling Standard fire exposure

Element	Boundary Conditions	Comments
Detail 6 - Typical section through strengthened primary beam with intermediate secondary beam		320x280 mm timber beam 260x90 PFC (no fire protection on the steel work was considered in the numerical model) 80 mm stone wool 110 kg/m^3 25 mm Lath and plaster ceiling Standard fire exposure

Details 5 and 6 were modelled considering the vertical axis of the geometrical detail as being the symmetry axis.

2.3 Numerical validation

The numerical validation of the heat transfer model is based on historical fire resistance test evidence on a timber floor system with metal lath and plaster ceiling (E29) presented in Investigations of Building Fires[9]. The boundary conditions selected for the validation model are representative of the build-up of the selected fire resistance test sample. A summary of the test evidence considered in the numerical validation is shown in the table below:

Table 2 General details for the test considered[9]

Test sample	Moisture (%)	Cover/ Ceiling thickness (mm)	Load	Duration (min)	Mode of failure
Timber floor	19.2 (Joists)	15.8	3.35kN/m^2	49	Unexposed surface flaming

Figure 8 below shows the cross-section temperature distribution through the timber floor system at 60 minutes.

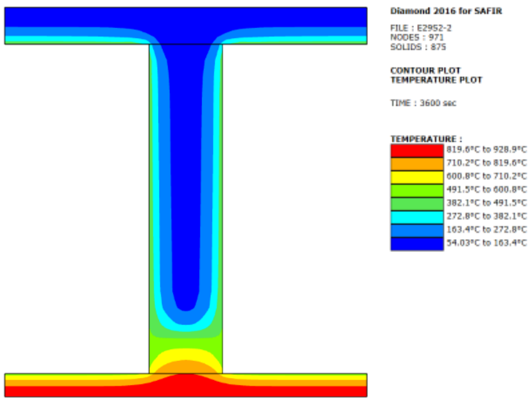


Figure 8 Cross-section heat distribution at 60 minutes for the timber floor system

Figure 9 shows a comparison between the measured data of the unexposed face of the metal lath and plaster layer (Lath-b) and the unexposed face on the floor system (Unexp) in relation to the calculated time-temperature history at the same locations. Based on the performance criteria proposed, the calculated failure time of the floor system is conservative compared to the test results. The calculated failure time is in good agreement with the existing tabulated data available in the literature.

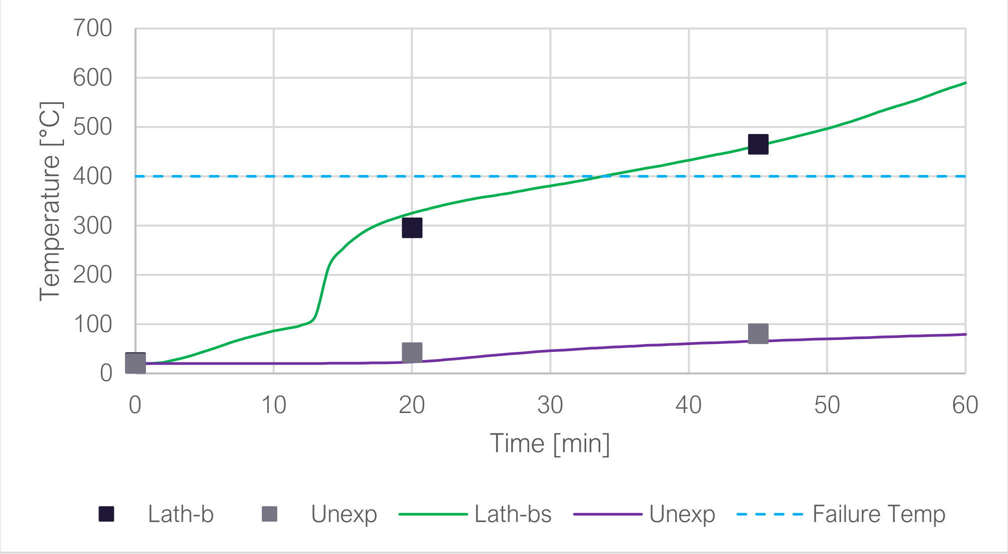


Figure 9 Comparison between measured data and calculated temperature (E29)

3.Heat Transfer Analysis

The numerical analysis considers the six construction details and explores the anticipated fire resistance in terms of cross-section load bearing capacity. The residual cross-section of timber elements after 60 minutes is presented below for each case. The critical temperature used in the analysis of the timber material is 300°C, as at this temperature timber starts to burn.

Detail 1 was considered to be a section through the existing secondary timber beam, of dimensions 250 mm x 100 mm. On each side of the beam, above the ceiling joists, it is placed 80 mm depth layer of stone wool. The floor system is protected by 25 mm layer of lath and plaster. The required fire resistance for this detail is 60-minute (R60).

Figure 10 shows the heat distribution through the construction details after 60 minutes standard fire exposure from below. The lath and plaster ceiling is expected to fall, together with the ceiling joists, after 39 minutes under standard fire exposure. The charred layer and the residual cross-section is shown in Figure 11, by the 300 °C isoline. The construction detail considered in the numerical analysis will present a residual area of 193.5 cm^2 after 60 minutes under standard fire exposure. The temperature of the unexposed face of the Corofil (stone wool) layer is 69 °C, therefore the unexposed face of the system is considered to achieve the insulation and integrity criteria for 60-minute under standard fire exposure(EI60).

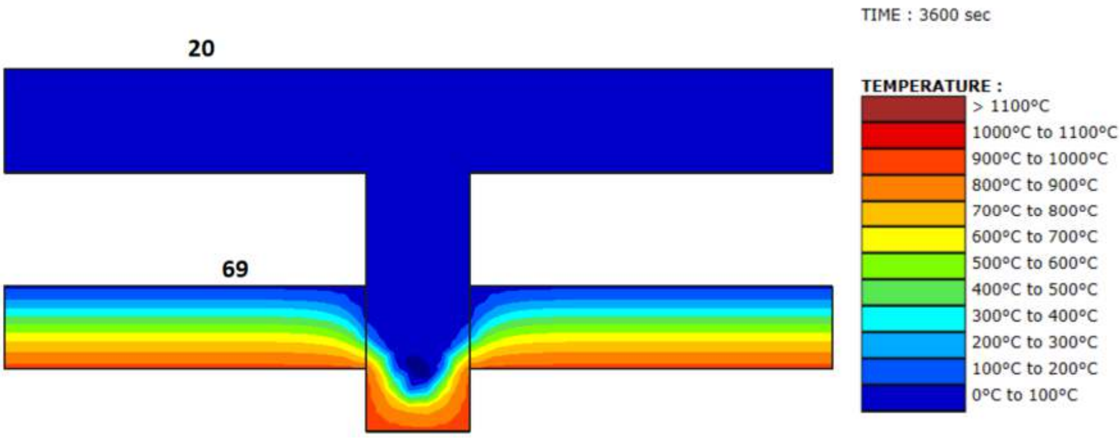


Figure 10 Heat distribution through the construction Detail 1: Typical section through the existing secondary beam

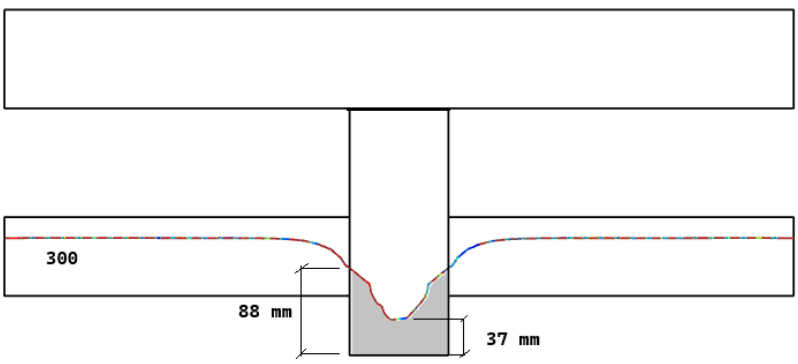


Figure 11 Charred layer (grey) after 60 minutes on the cross-section of the construction Detail 1: Typical section through the existing secondary beam

Detail 2 was considered to be a section through the proposed intermediate secondary timber beam, of dimensions 190 mm x 63 mm. On each side of the beam, above the ceiling joists, it is placed 80 mm depth layer of stone wool. The floor system is protected by 25 mm layer of lath and plaster. The required fire resistance for this detail is 60-minute (R60).

Figure 12 shows the heat distribution through the construction detail after 60 minutes standard fire exposure from below. The lath and plaster ceiling is expected to fall, together with the ceiling joists, after 39 minutes under standard fire exposure. The charred layer and the residual cross-section are shown in Figure 13, by the 300 ºC isoline. The construction detail considered in the numerical analysis will present a residual area of 98.28 cm^2 (156mm x 63 mm) after 60 minutes under standard fire exposure.The temperature of the unexposed face of the Corofil (stone wool) layer is 70 ºC, therefore the unexposed face of the system is considered to achieve the insulation and integrity criteria for 60-minute under standard fire exposure(EI60).

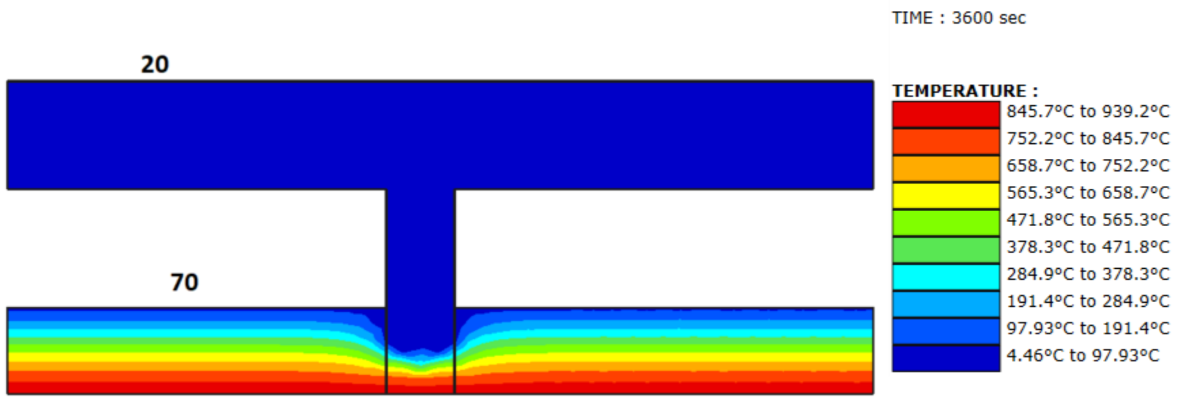


Figure 12 Heat distribution through the construction Detail 2: - Typical section through the proposed intermediate secondary beam

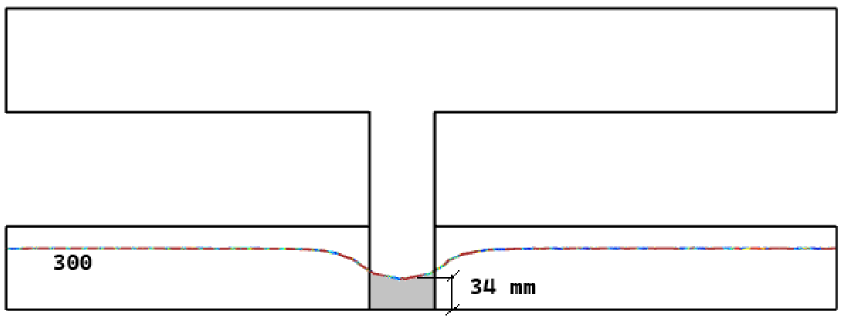


Figure 13 Charred layer (grey) after 60 minutes on the cross-section of the construction Detail 2: - Typical section through the proposed intermediate secondary beam

Detail 3 was considered to be a section through the proposed intermediate double secondary timber beam, of dimensions 2 x 190 mm x 63 mm. On each side of the beam, above the ceiling joists, it is placed 80 mm depth layer of stone wool. The floor system is protected by 25 mm layer of lath and plaster. The required fire resistance for this detail is 60-minute (R60).

Figure 14 shows the heat distribution through the construction detail after 60 minutes standard fire exposure from below. The lath and plaster ceiling is expected to fall, together with the ceiling joists, after 39 minutes under standard fire exposure. The charred layer and the residual cross-section is shown in Figure 15, by the 300 °C isoline. The construction detail considered in the numerical analysis will present a residual area of 203.83 cm^2 after 60 minutes under standard fire exposure. The temperature of the unexposed face of the Corofil (stone wool) layer is 70 °C, therefore the unexposed face of the system is considered to achieve the insulation and integrity criteria for 60-minute under standard fire exposure(EI60).

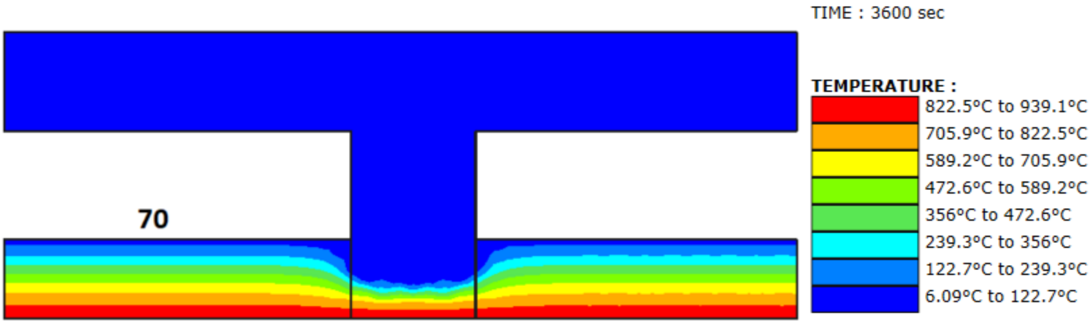


Figure 14 Heat distribution through the construction Detail 3: - Typical section through the proposed intermediate double secondary beam

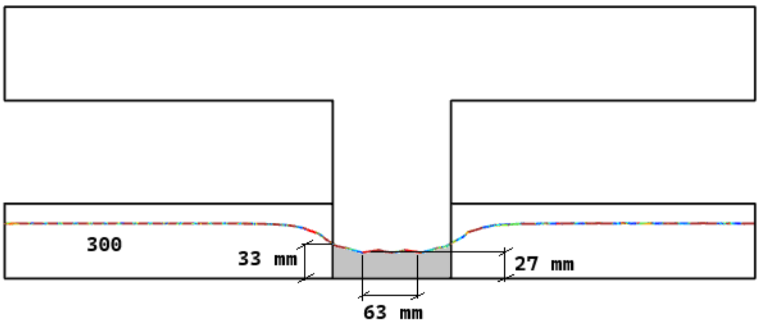


Figure 15 Charred layer (grey) after 60 minutes on the cross-section of the construction Detail 3: - Typical section through the proposed intermediate double secondary beam

Detail 4 was considered to be a section through the proposed intermediate triple secondary timber beam, of dimensions 3 x 190 mm x 63 mm. On each side of the beam, above the ceiling joists, it is placed 80 mm depth layer of stone wool. The floor system is protected by 25 mm layer of lath and plaster. The required fire resistance for this detail is 60-minute (R60).

Figure 16 shows the heat distribution through the construction detail after 60 minutes standard fire exposure from below. The lath and plaster ceiling is expected to fall, together with the ceiling joists, after 39 minutes under standard fire exposure. The charred layer and the residual cross-section is shown in Figure 17, by the 300 °C isoline. The construction detail considered in the numerical analysis will present a residual area of 306.18 cm^2 after 60 minutes under standard fire exposure.The temperature of the unexposed face of the Corofil (stone wool) layer is 69 °C, therefore the unexposed face of the system is considered to achieve the insulation and integrity criteria for 60-minute under standard fire exposure(EI60).

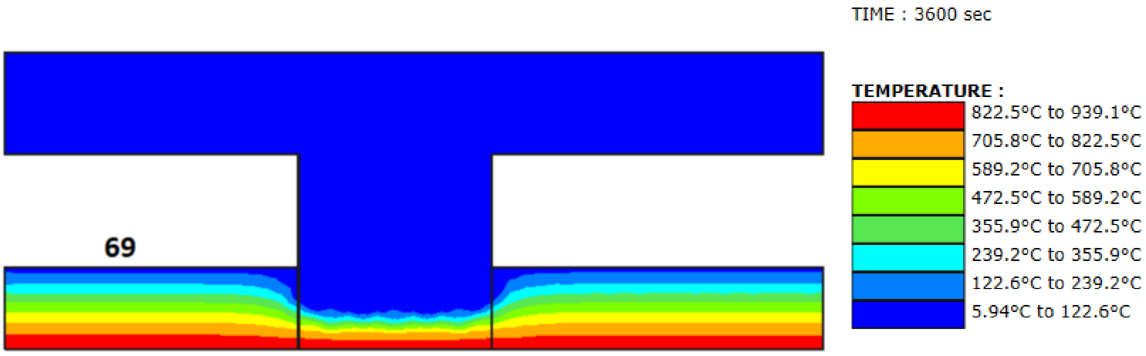


Figure 16 Heat distribution through the construction Detail 4: - Typical section through the proposed intermediate triple secondary beam

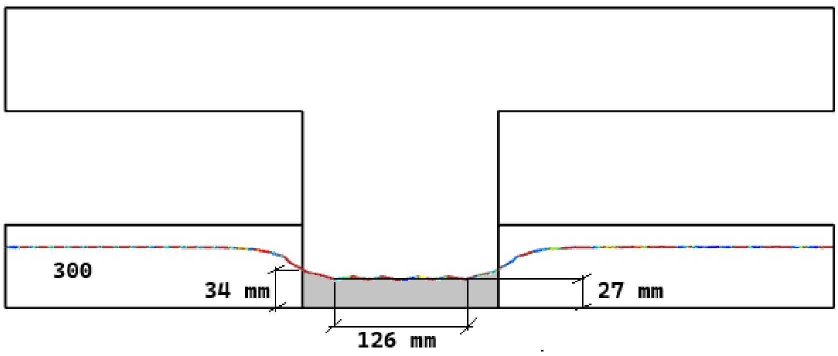


Figure 17 Charred layer (grey) after 60 minutes on the cross-section of the construction Detail 4: - Typical section through the proposed intermediate triple secondary beam

Detail 5 was considered to be a section through the strengthened primary timber beam with original secondary beams, of dimensions 320 mm x 280 mm. On each side of the beam, the original secondary beam is modelled. The floor system is protected by 25 mm layer of lath and plaster. The required fire resistance for this detail is 60-minute (R60).

Figure 18 shows the heat distribution through the construction detail after 60 minutes standard fire exposure from below. The lath and plaster ceiling is expected to fall, together with the ceiling joists, after 39 minutes under standard fire exposure. The charred layer and the residual cross-section is shown in Figure 19, by the 300 ºC isoline. The construction detail considered in the numerical analysis will present a residual area of 812 cm^2 (290mm x 280mm) after 60 minutes under standard fire exposure.

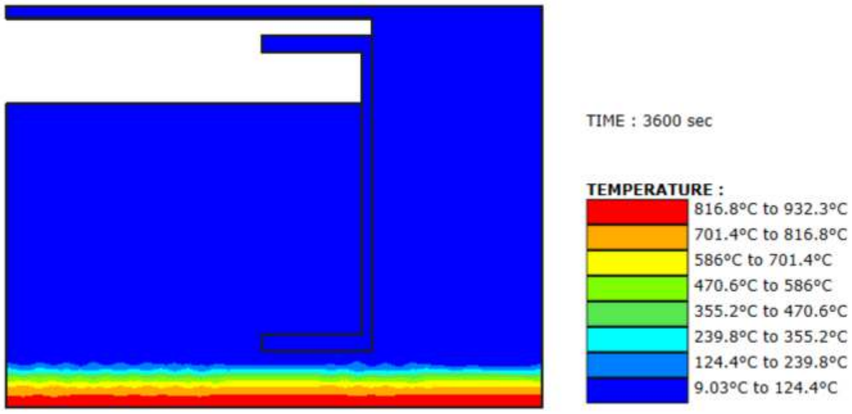


Figure 18 Heat distribution through the construction Detail 5: - Typical section through strengthened primary beam with original secondary beam

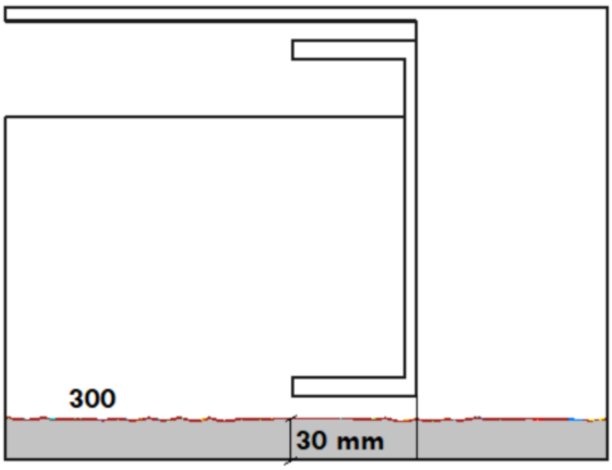


Figure 19 Charred layer (grey) after 60 minutes on the cross-section of the construction Detail 5: - Typical section through strengthened primary beam with original secondary beam

Detail 6 was considered to be a section through the strengthened primary timber beam, of dimensions 320 mm x 280 mm. On each side of the beam, above the ceiling joists, it is placed 80 mm depth layer of stone wool. The floor system is protected by 25 mm layer of lath and plaster. The required fire resistance for this detail is 60-minute (R60).

Figure 20 shows the heat distribution through the construction detail after 60 minutes of standard fire exposure from below. The lath and plaster ceiling is expected to fall, together with the ceiling joists, after 39 minutes under standard fire exposure. After 60 minutes under standard fire exposure, the steel profile presents an average temperature of 780 °C on the bottom flange. The steel critical temperature of 550 °C, is found on the profile web, 21 mm above the bottom flange.

The charred layer and the residual cross-section is shown in Figure 21, by the 300 °C isoline. The construction detail considered in the numerical analysis will present a residual area of 782.6 cm^2 after 60 minutes under standard fire exposure.The temperature of the unexposed face of the Corofil (stone wool) layer is 95 °C, therefore the unexposed face of the system is considered to achieve the insulation and integrity criteria for 60-minute under standard fire exposure(EI60).

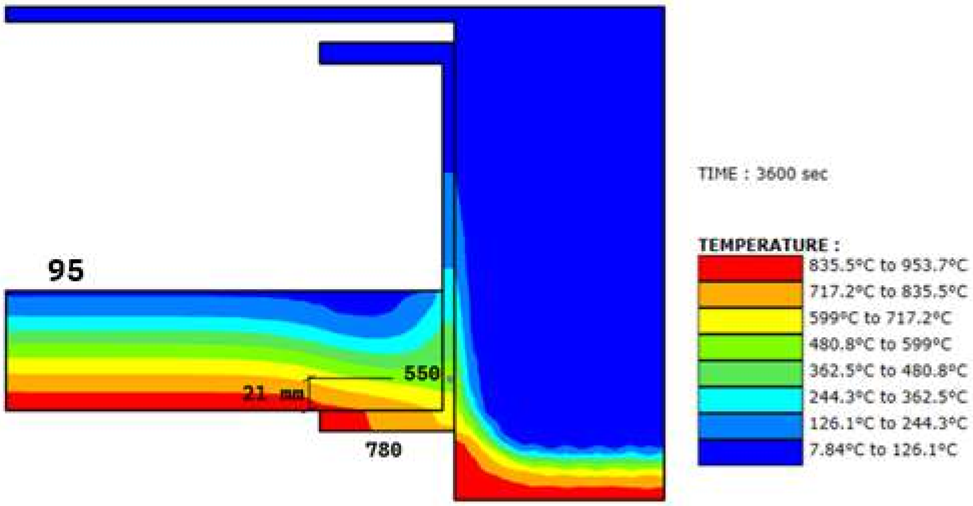


Figure 20 Heat distribution through the construction Detail 6: - Typical section through strengthened primary beam with intermediate secondary beam

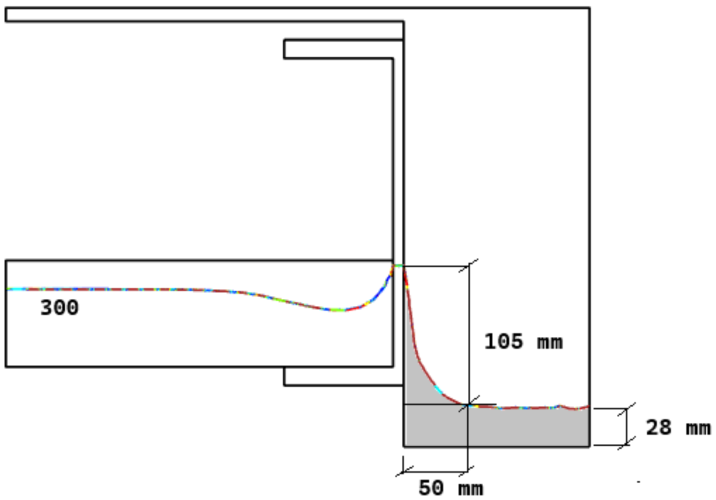


Figure 21 Charred layer (grey) after 60 minutes on the cross-section of the construction Detail 6: - Typical section through strengthened primary beam with intermediate secondary beam *(for dimensions, geometry has to consider the vertical symmetry axis)*

4.Conclusions

The client is undertaking the refurbishment of a Grade II listed building to create a 42-room hotel. Given the building's age (200 year old), substantial strengthening works are required for the floor system. Due to the extent of these modifications, the floor must be upgraded to achieve a 60 minute (REI) fire resistance rating. As the ceilings are listed features, the client is exploring the use of floor void fire batts, installed from above, to achieve the required level of fire performance. The client has reviewed a Corofil system designed for such an application and provided BRE with details and a fire resistance test report[1]. However, the specific construction parameters fall outside the direct field of application of the test report and cannot be covered within an extended field of application (EXAP) assessment.

The client requires an assessment of the anticipated fire resistance of the strengthened floor system when protected with the PFCTS CF passive fire protection system as detailed in the test report provided[1], as well as the existing primary and secondary beams.

Advanced numerical techniques have been employed to assess the fire resistance of the details. The analysis examines the influence of the protection and the construction set-up on the anticipated fire resistance. The thermal modelling undertaken using validated Finite Element software assesses the anticipated temperature distribution on the elements cross-section, when subject to a standard fire exposure.

The required fire resistance time is 60 minutes (REI60) for each detail and the corresponding residual area after 60 minutes under standard fire exposure are summarised in the table below. The residual areas can be used to calculate the capacity at 60 minutes fire exposure which in turn can be compared to the fire limit state loads for the building.

Detail	Residual Area [cm^2] at REI60
Detail 1 Typical section through the existing secondary beam	193.5
Detail 2 Typical section through the proposed intermediate secondary beam	98.28
Detail 3 Typical section through the proposed intermediate double secondary beam	203.83
Detail 4 Typical section through the proposed intermediate triple secondary beam	306.18
Detail 5 Typical section through strengthened primary beam with original secondary beam	812
Detail 6 Typical section through strengthened primary beam with intermediate secondary beam	782.6

5. References

1. BRE Global Test Report P117070-1003-Issue 1, Fire resistance test on a loadbearing timber-joist floor, incorporating the PFCTS CF system, tested in accordance with EN 1365-2:2014, while supporting a load of 2 kN/m^2, dated 21st April 2021.
2. Franssen J-M, et.al., Modelling structures in fire with SAFIR®: Theoretical background and capabilities, J. Str. Fire Eng., Vol. 8, No 3, pp 300-323.
3. Zaharia R., et.al., Validation of the Advanced Calculation Model SAFIR through DIN EN1991-1-2 Procedure, Proceedings of the 10th International Conference on Advances in Steel Concrete Composite and Hybrid Structures, 2012.
4. Ferreira J., et.al., Discussion on a systematic approach to validation of software for structures in fire, SiF 2018 The 10th International Conference on Structures in Fire, Fire SERT, Ulster University, Belfast, UK, June 6-8, 2018.
5. Ferreira J., Validation of SAFIR® through DIN EN 1992-1-2 NA. Comparison of the results for the examples presented in Annex CC, University of Liege - Faculty of Applied Sciences Structural Engineering Research Unit, 2017.
6. BS EN 1363-1, Fire resistance tests. General requirements, BSI, 2020.
7. BS EN 1993-1-2, Eurocode 3. Design of steel structures. Part 1-2: Structural fire design, BSI, 2005.
8. prEN 1995-1-2, Eurocode 5. Design of timber structures. General rules. Structural fire design, BSI, 2024.
9. National Building Studies Research Paper No. 12, Investigations on Building Fires Part V. Fire Tests on Structural Elements, Her Majesty's Stationary Office, 1953