

# Fire assessment report

## Services cast in concrete slabs to AS 1530.4:2014 and AS 4072.1:2005

Sponsor: Trafalgar Group

Report number: FAS200393 Revision: R1.0

Issued date: 26 March 2021 Expiry date: 31 March 2026

# Quality management

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| | | **Signature** | | | |

# Executive summary

This report documents the findings of the assessment undertaken to determine the likely fire resistance level of various services embedded within conduits cast into a concrete slab – if tested in general accordance with AS 1530.4:2014 and assessed considering the general principles specified in AS 4072.1:2005.

The analysis in section 5 of this report found that the proposed systems together with the described variations are likely to achieve the outcomes shown in Table 1 – if tested in general accordance with AS 1530.4:2014.

**Table 1 Variations and assessment outcome**

| Item | Item name | Reference test | Tested installation detail | Variations | System FRL |
|---|---|---|---|---|---|
| 1. | Concrete slab thickness | FRT200337 R1.1 | The tested system consisted of a 190 mm thick concrete slab. The residual concrete thickness above the void in the tested void type conduit penetrations (illustrated in Figure 1) was 78 mm. | Concrete slab thickness must be not less than 190 mm.<br>For void type conduit configurations, the residual concrete thickness above the void must be as follows.<br>• minimum 93 mm for -/90/90 applications<br>• minimum 105 mm for -/120/120 applications. | Up to -/120/120* |
| 2. | Conduit types and size | | The tested cables were embedded within PVC conduits ranging in size from Ø25 mm, Ø32 mm and Ø40 mm. | For cables, Ø16 mm, Ø20 mm, Ø25 mm, Ø32 mm and Ø40 mm PVC conduits may be used | |
| 3. | Type and size of PEX pipes | | The tested system consisted of Ø20 mm PE-Xb pipes and Ø20 PE-Xa/AL/PE pipes. | Ø20 mm PE-Xb pipes and Ø20 PE-Xa/AL/PE pipes may be used. | |
| 4. | Fire protection | | • The tested uPVC conduits with telecommunication or power cables were protected using Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service.<br>• The tested uPVC conduits were also protected using Trafalgar FyrePEXTM HP intumescent sealant installed at the exposed side of the service.<br>• The tested PE-Xb and PE-Xa/AL/PE pipes with uPVC conduits were protected using Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service. | • uPVC conduits, PE-Xb and PE-Xa/AL/PE pipes, electrical cables, telecommunication cables and cable bundles may be protected with the appropriate size of Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service.<br>• Alternatively, the services may also be protected with FyrePEX™ HP intumescent sealant placed within the conduit for a depth of 30 mm at either exposed or unexposed side of the service. | |

| Item | Item name | Reference test | Tested installation detail | Variations | System FRL |
|---|---|---|---|---|---|
| 5. | Service configuration | | The tested services included straight through conduit, U-profile conduit and void type conduit configurations. | Proposed systems may use void type conduit (Figure 1), U-profile conduit (Figure 2), side entry conduit (Figure 3), straight through conduit (Figure 4) and top-side deck box configurations (Figure 5). | |
| 6. | Void protection | | The tested void type conduit configuration included a 78 mm thick concrete slab above the void. | A 30 mm thick Maxilite can be used to protect the underside of the void.<br>In this instance, boards must be direct fixed to the concrete slab using 6 mm anchors (dyna bolt or screw-type) at 400 mm centres – 25 to 50 mm away from the sides. | |
| 7. | Travel distances | | • The tested uPVC conduits with telecommunication or power cables were tested with travel distances of 250 mm or 500 mm within the concrete slab.<br>• The tested PE-Xb and PE-Xa/AL/PE pipes within uPVC conduits in void type configuration were tested with a travel distance of 500 mm. | • The travel distance of conduit and cable services – incorporating straight through conduit, U-profile conduit, side entry conduit and top-side deck box configurations – within the concrete slab must be not less than 250 mm.<br>• The travel distance of PE-Xb and PE-Xa/AL/PE pipes – incorporating void type conduit and top-side deck box configurations – within the concrete slab must be as follows.<br>– not less than 250 mm for -/90/90 applications<br>– not less than 500 mm for -/120/120 applications. | |
| 8. | Types of cables | | The tested system consisted of various electrical and telecommunication cables. The largest copper conductor area of a single tested service was 16 mm$^2$. | • Electrical and telecommunication cables including but not limited to submain, TPS, LAN, RG6, CAT, fibre optics, SDI and fire rated cables may be used.<br>• Cables must only consist of copper conductors. Cable insulation may be either PVC or XLPE. Cable sheathing (if any) must be PVC.<br>• The collective copper conductor area of a cable or cable bundle within a single conduit must not exceed 16 mm$^2$. | |

| Item | Item name | Reference test | Tested installation detail | Variations | System FRL |
|---|---|---|---|---|---|
| 9. | Blank conduits | | The tested system consisted of a Ø25 mm uPVC conduit without any services installed within it – straight through conduit configuration. | Ø16 mm, Ø20 mm and Ø25 mm conduits may be left blank with no service installed. Local protection as described above in item 4 must be used. | |
| 10. | Bottom concrete cover to conduits | | The void type conduit configurations were placed with a bottom concrete cover of 50 mm to conduits. | Bottom concrete cover to conduits must be not less than 50 mm. | |
| 11. | Variations to the separating wall | | The tested system consisted of a 75 mm thick Hebel wall separating element with an established FRL of -/90/90. | • It is proposed that any separating wall element with an established FRL of at least -/90/90 or 90/90/90 can be used. The FRL of the wall element must have been either tested or assessed by an Accredited Testing Laboratory in accordance with AS 1530.4:2014.<br>• The head (or base) detail of the wall and the concrete floor separating element must also have an established FRL not less than -/90/90 – established in a similar manner.<br>• Alternatively, the separating wall element may have a lower stated FRL (eg -/60/60 or 60/60/60). In such cases, the FRLs of the proposed service penetrations are limited by this lower FRL of the wall separating element. | |
| Note - Services incorporating void type conduit configuration with a concrete slab thickness of minimum 93 mm above the void will achieve an FRL of -/90/90. The concrete slab thickness above the void must be increased to minimum 105 mm for -/120/120 applications.<br>The travel distance of PE-Xb and PE-Xa/AL/PE pipes – incorporating void type conduit configuration – within the concrete slab must be greater than 250 mm for -/90/90 applications. | | | | | |

The variations and outcome of this assessment are subject to the limitations and requirements described in sections 2, 3 and 6 of this report. The results of this report are valid until 31 March 2026.

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# 1. Introduction

This report documents the findings of the assessment undertaken to determine the likely fire resistance level (FRL) of various services embedded within conduits cast into a concrete slab – if tested in general accordance with AS 1530.4:2014[1] and assessed considering the general principles specified in AS 4072.1:2005 (R2016)[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<br>South Granville<br>NSW 2142<br>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 general 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.



[1] Standards Australia, 2014, Methods for fire tests on building materials, components and structures, Part 4: Fire-resistance tests for elements of construction, AS 1530.4:2014, Standards Australia, NSW.

[2] Standards Australia, 2005, Components for the protection of openings in fire-resistant separating elements, Part 1: Service penetrations and control joints, AS 4072.1:2005 (R2016), 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.

## 2.2 Compliance with the National Construction Code

This assessment report has been prepared to meet the evidence of suitability requirements of the National Construction Code Volumes One and Two – Building Code of Australia (NCC) 2019 including Amendments[4] under A5.2 (1) (d).

This assessment has been written in accordance with the general principles outlined in EN 15725:2010[5] for extended application reports on the fire performance of construction products and building elements. It also references test evidence for meeting a performance requirement or deemed to satisfy (DTS) provisions of the NCC under A5.4 for fire resistance levels as applicable to the assessed systems.

This assessment report may also be used to demonstrate compliance with the requirements for evidence of suitability under NCC 2016 including Amendments[6].

## 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 28 September 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.
- This assessment does not address the effects on the structural behaviour and performance of the concrete slabs due to the presence of voids or services – under normal service and in fire. Such matters must be referred to structural engineers.
- It is a requirement of this assessment that the service penetrations incorporating void type conduit and U-profile conduit configurations must always be placed at a distance not less than 87.5 mm from the separating wall element.
- This report is only valid for the assessed systems and must not be used for any other purpose. Any changes with respect to size, construction details, loads, stresses, edge or end conditions – other than those identified in this report – may invalidate the findings of this assessment. If there are changes to the system, a reassessment will need to be done by an Accredited Testing Laboratory (ATL).



4 National Construction Code Volume One and Two – Building Code of Australia 2019 including Amendments, Australian Building Codes Board, Australia.
5 European Committee for Standardization, 2010, Extended application reports on the fire performance of construction products and building elements, EN 15725:2010, European Committee for Standardization, Brussels, Belgium.
6 National Construction Code Volume One and Two – Building Code of Australia 2016 including Amendments, Australian Building Codes Board, Australia.

- 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 system consists of electrical and telecommunication cables, cables bundles, and permitted types of PEX pipes embedded within PVC conduits cast into concrete slabs. The services may span horizontally entering and existing from different compartments – which are separated by a vertical wall separating element – using any of the following configurations.

- Void-type conduits configuration as shown in Figure 1.
- U-profile conduit configuration as shown in Figure 2.
- Side entry configuration as shown in Figure 3.

Additionally, the services may also span vertically using any of the following configurations.

- Straight-through conduit configuration as shown in Figure 4.
- Top-side deck box configuration as shown in Figure 5.

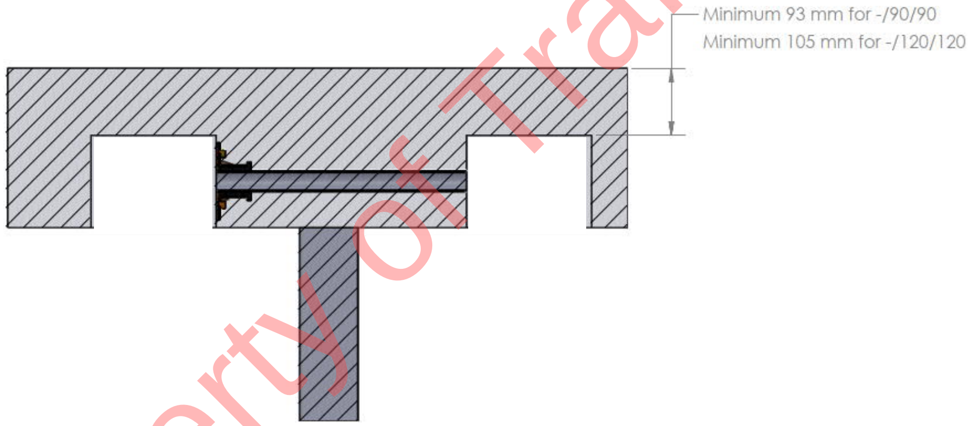



**Figure 1 Void-type conduits configuration**

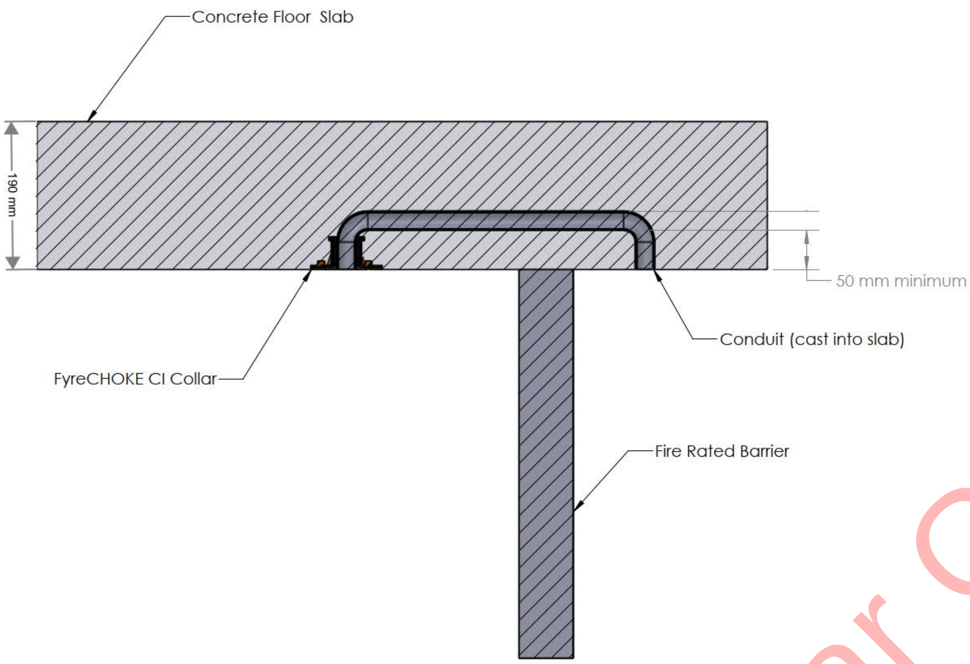



**Figure 2 U-profile conduit configuration**

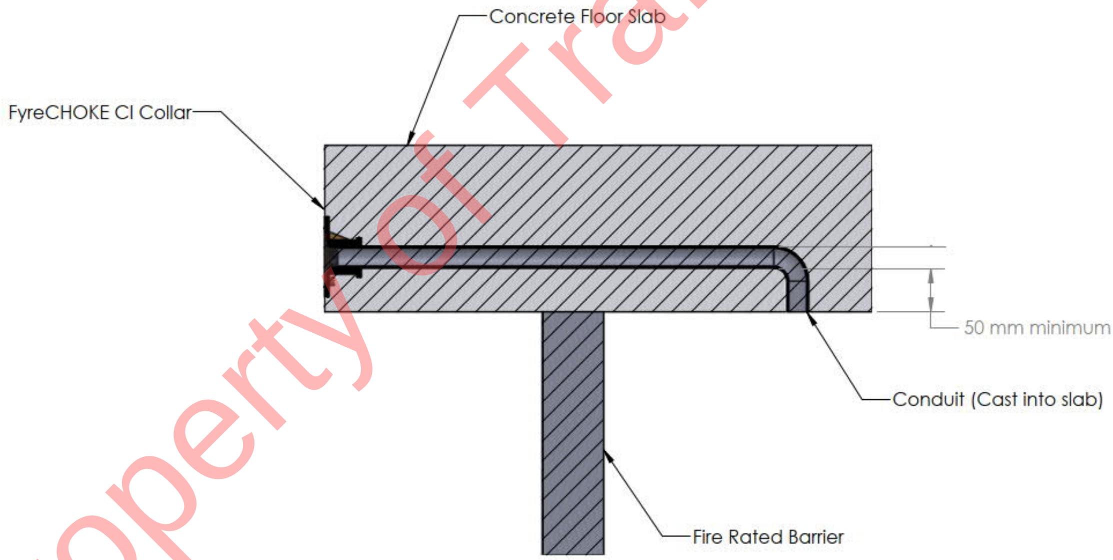



**Figure 3 Side entry configuration**

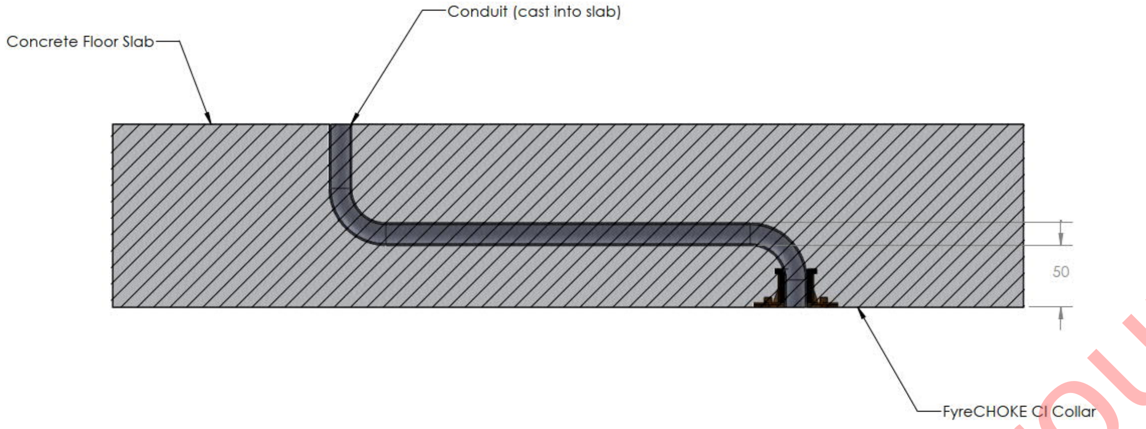



Figure 4 Straight-through conduit configuration

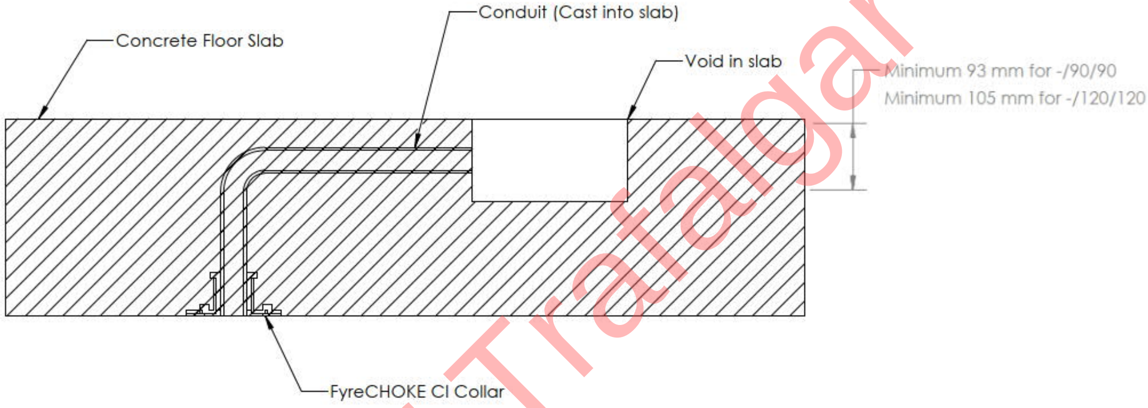



Figure 5 Top-side deck box configuration

## 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 A.

Table 3 Referenced test data

| Report number | Test sponsor | Test date | Testing authority |
|---|---|---|---|
| FRT200337 R1.1 | Trafalgar Group | 15 January 2021 | Warringtonfire Australia |
| FSH 2076 | Trafalgar Group | 16 October 2019 | CSIRO |

## 4.3 Variations to the tested systems

The variations to the tested systems – together with the referenced standard fire test – are described in Table 4.

**Table 4 Variations to tested systems**

| Item | Item name | Reference test | Tested installation detail | Variations |
|---|---|---|---|---|
| 1. | Concrete slab thickness | FRT200337 R1.1 | The tested system consisted of a 190 mm thick concrete slab. The residual concrete thickness above the void in the tested void type conduit penetrations (illustrated in Figure 1) was 78 mm. | Concrete slab thickness must be not less than 190 mm.<br>For void type conduit configurations, the residual concrete thickness above the void must be as follows.<br>• minimum 93 mm for -/90/90 applications.<br>• minimum 105 mm for -/120/120 applications. |
| 2. | Conduit types and size | | The tested cables were embedded within PVC conduits ranging in size from Ø25 mm, Ø32 mm and Ø40 mm. | For cables, Ø16 mm, Ø20 mm, Ø25 mm, Ø32 mm and Ø40 mm PVC conduits may be used |
| 3. | Type and size of PEX pipes | | The tested system consisted of Ø20 mm PE-Xb pipes and Ø20 PE-Xa/AL/PE pipes. | Ø20 mm PE-Xb pipes and Ø20 PE-Xa/AL/PE pipes may be used. |
| 4. | Fire protection | | • The tested uPVC conduits with telecommunication or power cables were protected using Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service.<br>• The tested uPVC conduits were also protected using Trafalgar FyrePEXTM HP intumescent sealant installed at the exposed side of the service.<br>The tested PE-Xb and PE-Xa/AL/PE pipes with uPVC conduits were protected using Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service. | • uPVC conduits, PE-Xb and PE-Xa/AL/PE pipes, electrical cables, telecommunication cables and cable bundles may be protected with the appropriate size of Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service.<br>• Alternatively, the services may also be protected with FyrePEX™ HP intumescent sealant placed within the conduit for a depth of 30 mm at either exposed or unexposed side of the service. |
| 5. | Service configuration | | The tested services included straight through conduit, U-profile conduit and void type conduit configurations. | Proposed systems may use void type conduit (Figure 1), U-profile conduit (Figure 2), side entry conduit (Figure 3), straight through conduit (Figure 4) and top-side deck box configurations (Figure 5). |
| 6. | Void protection | | The tested void type conduit configuration included a 78 mm thick concrete slab above the void. | A 30 mm thick Maxilite can be used to protect the underside of the void. |

| Item | Item name | Reference test | Tested installation detail | Variations |
|---|---|---|---|---|
| 7. | Travel distances | | • The tested uPVC conduits with telecommunication or power cables were tested with travel distances of 250 mm or 500 mm within the concrete slab.<br>• The tested PE-Xb and PE-Xa/AL/PE pipes within uPVC conduits in void type configuration were tested with a travel distance of 500 mm. | • The travel distance of conduit and cable services – incorporating straight through conduit, U-profile conduit, side entry conduit and top-side deck box configurations – within the concrete slab must be not less than 250 mm.<br>• The travel distance of PE-Xb and PE-Xa/AL/PE pipes – incorporating void type conduit and top-side deck box configurations – within the concrete slab must be as follows.<br>– not less than 250 mm for -/90/90 applications<br>– not less than 500 mm for -/120/120 applications. |
| 8. | Types of cables | | The tested system consisted of various electrical and telecommunication cables. The largest copper conductor area of a single tested service was 16 mm$^2$. | • Electrical and telecommunication cables including but not limited to submain, TPS, LAN, RG6, CAT, fibre optics, SDI and fire rated cables may be used.<br>• Cables must only consist of copper conductors. Cable insulation may be either PVC or XLPE. Cable sheathing (if any) must be PVC.<br>• The collective copper conductor area of a cable or cable bundle within a single conduit must not exceed 16 mm$^2$. |
| 9. | Blank conduits | | The tested system consisted of a Ø25 mm uPVC conduit without any services installed within it – straight through conduit configuration. | Ø16 mm, Ø20 mm and Ø25 mm conduits may be left blank with no service installed. Local protection as described above in item 4 must be used. |
| 10. | Bottom concrete cover to conduits | | The void type conduit configurations were placed with a bottom concrete cover of 50 mm to conduits. | Bottom concrete cover to conduits must be not less than 50 mm. |
| 11. | Variations to the separating wall | | The tested system consisted of a 75 mm thick Hebel wall separating element with an established FRL of -/90/90. | • It is proposed that any separating wall element with an established FRL of at least -/90/90 or 90/90/90 can be used. The FRL of the wall element must have been either tested or assessed by an Accredited Testing Laboratory in accordance with AS 1530.4:2014.<br>• The head (or base) detail of the wall and the concrete floor separating element must also have an established FRL not less than -/90/90 – established in a similar manner.<br>• Alternatively, the separating wall element may have a lower stated FRL (eg -/60/60 or 60/60/60). In such cases, the FRLs of the proposed service penetrations are limited by this lower FRL of the wall separating element. |

## 4.4 Purpose of the test

AS 1530.4:2014 sets out the methods for conducting fire tests on building materials, components and structures. Specifically, section 2 of this standard contains the general requirements for these tests. Section 10 sets out the procedure for determining the fire resistance of elements of construction penetrated by services such as electrical services, pipes and conduits.

However, AS 1530.4:2014 does not include specific requirements for the testing of services which are embedded and travelling horizontally through a concrete floor. For this reason, the referenced test is not in direct compliance with AS 1530.4:2014. However, the general principles specified in AS 1530.4:2014 for the testing of services have been adopted in the referenced test. Therefore, it will be referenced as being in general accordance with AS 1530.4:2014.

AS 4072.1:2005 sets out the minimum requirements for the construction, installation and application of fire resistance tests to sealing systems around penetrations through separating building elements that are required to have an FRL.

# 5. Assessment of variations

## 5.1 Description of variation

The system consists of electrical and telecommunication cables, cables bundles, and permitted types of PEX pipes embedded within PVC conduits cast into concrete slabs.

The proposed system incorporates variations to the geometry of the system, cable and conduit sizing, cable type and arrangement, local fire protection methodology, conduit configuration, sizing of the floor and wall separating elements, and other extensions of applicability specified in Table 4.

## 5.2 Methodology

The method of assessment used is summarised in Table 5.

**Table 5 Method of assessment**

| Assessment method | |
|---|---|
| Level of complexity | Complex assessment |
| Type of assessment | Qualitative |

## 5.3 Assessment

### 5.3.1 Slab thickness

The tested system in FRT200337 R1.1 consisted of a 190 mm thick concrete slab. The density of concrete was nominally 2600 kg/m$^3$. All the tested services achieved an insulation performance of 120 minutes except the services which incorporated void type conduit configuration as shown in Figure 1. These services are referred to as Specimen E in FRT200337 R1.0.

The depth for the void used for service E was 112 mm. Consequently, the residual concrete thickness was 78 mm – above the void. Temperatures on the top surface of the concrete slab – directly above these voids – were measured during the test. The maximum temperature recorded at this location exceeded the insulation failure threshold at 69$^{th}$ minute.

The primary reason for premature insulation failure was the lower residual concrete thickness above the void. Therefore, it is proposed to increase the slab thickness above the void such that an insulation performance of up to 120 minutes can be achieved.

For this, 3D thermal analyses using SAFIR software were conducted to determine the effect of the increased slab thickness above the void – as detailed in Appendix B. Based on the finite element analyses conducted, it was determined that a minimum concrete depth of 93 mm and 105 mm – above the void – are required to maintain an insulation performance of 90 minutes and 120 minutes, respectively. Figure 1 shows the assessed construction.

### 5.3.2 Conduit types and size

The tested cables were embedded within PVC conduits ranging in size from Ø25 mm, Ø32 mm and Ø40 mm. It is proposed that the conduit size can be varied to Ø16, Ø20 mm, Ø25 mm, Ø32 and Ø40 mm.

The tested system consisted of all conduit sizes except Ø16 mm and Ø20 mm. Given that these two conduit sizes have the same construction and composition as the tested conduits, and are smaller in size (lower combustible content), it is unlikely to lead to any significant variation in the insulation and integrity performance for a period not less than 120 minutes under similar exposure conditions.

### 5.3.3 Local fire protection

The Specimen C2 of FRT200337 R1.1 report consisted of a Ø25 mm straight-through uPVC conduit with two TPS and two CAT6 cables. The specimen was locally protected by FyreCHOKE CI25 cast-in collar placed on the exposed side. Similarly, the Specimen C3 of FRT200337 R1.1 report consisted of a Ø25 mm straight-through uPVC conduit with two TPS and two CAT6 cables. The specimen was locally protected by FyrePEX™ HP intumescent sealant placed within the conduit for a depth of 30 mm on the exposed side. Upon testing, both specimens C2 and C3 maintained integrity and insulation performance up to 120 minutes with a considerable margin of safety. The maximum unexposed side temperatures recorded on C2 and C3 services at 120 minutes were 83ºC and 84ºC, respectively. Therefore, this result proves that both FyreCHOKE cast-in collar and FyrePEX™ HP intumescent sealant provides similar fire protection for services. Therefore, the proposed services can be protected with either of these fire protection methods.

The Specimen D1 of FRT200337 R1.1 report consisted of a Ø25 mm U-profile uPVC conduit with two TPS and two CAT6 cables. The specimen was locally protected by FyreCHOKE CI25 cast-in collar placed on the unexposed side. The Specimen D2 consisted of a Ø25 mm U-profile uPVC conduit with two TPS and two CAT6 cables. The specimen was locally protected by FyreCHOKE CI25 cast-in collar placed on the exposed side. Upon testing, both specimens D1 and D2 maintained integrity and insulation performance up to 120 minutes with a considerable margin of safety. The maximum unexposed side temperatures recorded on Specimens D1 and D2 at 120 minutes were 80ºC and 92ºC, respectively. Therefore, this result proves that the local fire protection can be used on either side of the service without affecting the fire performance.

Based on the discussion provided above, FyreCHOKE cast-in collar or FyrePEX™ HP intumescent sealant can be used either on the exposed or on the unexposed side to protect the services – referenced in this assessment report for up to 120 minutes.

### 5.3.4 Conduit configuration

The tested services of FRT200337 R1.1 included straight through conduits (Specimen C), U-profile conduits (Specimen D and F) and void type conduits (specimen E). It is proposed to include straight through conduit, U-profile conduit, void type conduit, side entry conduit and top-side deck box configurations in this assessment report.

#### Straight through conduit and U-profile conduit configurations

Straight through conduits and U-profile conduits were tested in referenced test and all services achieved integrity and insulation performance up to 120 minutes except Specimen D3 – which demonstrated an insulation related failure at 79 minutes because of the thermocouple (TC81) placed on the Autoclaved Aerated Concrete (AAC) wall exceeded the insulation failure threshold. TC81 was located on the surface of the AAC wall system. Based on the post-test observations, a crack in the wall was observed at the location where the TC81 was located. As a result, the wall system failed early in insulation due to hot gases leaking from the exposed side of the wall through this crack.

The penetration services were not directly connected to the AAC wall and thus would not have significantly contributed to the rise in heat transfer. This is due to the fact that the other thermocouples mounted on the Hebel wall (TC69 and TC76) remained within the prescribed insulation failure threshold for 120 minutes. It is therefore concluded that if cracks did not occur in AAC wall, TC81 would likely have recorded temperatures similar to those recorded by TC69 and TC76 (along on the AAC wall surface).

Therefore, it is concluded that the services referenced in this report can use straight through conduit or U-profile conduit configurations for an FRL up to -/120/120.

#### Void type conduit configuration

Void type conduit configuration was tested in the referenced test. Thermocouples placed on the unexposed side of the penetrations maintained insulation performance up to 120 minutes. However, the temperature on the top surface of the concrete slab – directly above the void – exceeded the insulation failure threshold at the 69th minute. As described in section 5.3.1, the primary reason for the premature insulation failure of this service was the reduced concrete depth above the void. Therefore, it is proposed that a minimum concrete depth of 93 mm and 105 mm – above the void – are required to maintain an insulation performance of 90 minutes and 120 minutes, respectively. Provided that the above modification in accommodated, the services referenced in this report can use the void type conduit configuration for an FRL of up to -/120/120.

### Top-side deck box configuration

The proposed top-side deck box configuration is similar to that of assessed straight through conduit configuration assessed above, with only difference being the service exits horizontally at a location of the slab where a void is present. Provided that the travel distance and residual concrete depth at the void is maintained as follows, the proposed construction is expected perform similarly to the assessed straight through conduit configuration.

- Travel distance
  - Travel distance of conduit and cable services within the concrete slab must be not less than 250 mm.
  - Travel distance of PE-Xb and PE-Xa/AL/PE within the concrete slab must be not less than 250 mm for -/90/90 applications and not less than 500 mm for -/120/120 applications.
- Residual depth
  - A residual depth of not less than 93 mm for -/90/90 applications.
  - A residual depth of not less than 105 mm for -/120/120 applications.

Provided that above criteria are met, it is concluded that the services referenced in this report can use Top-side deck box configuration for an FRL up to -/120/120.

### Side entry conduit configuration

It is considered that the U-profile conduit configuration is more onerous than the side entry conduit configuration because of the level heat exposure and subsequent heat transfer behaviour through the conduits. Therefore, side entry conduit configuration is positively assessed in this assessment.

## 5.3.5 Void protection

The depth for the void used for service E was 112 mm. Consequently, the minimum residual concrete thickness was 78 mm above the void of the referenced specimen of FRT200337 R1.1. Temperatures on the top surface of the concrete slab, directly above these voids, were measured during the test and the maximum temperature recorded at this location exceeded the insulation failure threshold at the $69^{th}$ minute. Subsequently, section 5.3.1 of this report recommended to allow minimum residual concrete depths of 93 mm and 105 mm – above the void – to maintain an insulation performance of 90 minutes and 120 minutes, respectively.

In this section, it is proposed to use Trafalgar Maxilite boards as a protection for the void type conduit configurations as an alternative to stipulating an increased concrete depth.

The tested specimen of FSH 2076 consisted of a bulkhead ceiling system consisting of various Maxilite board types and joint details protecting a steel framed floor system. The two-level ceiling system was constructed within a plasterboard lined enclosure and suspended from a steel framed floor system. Detail 3 and Detail 4 of the referenced report are relevant for this report and they demonstrate the performance of ceiling segments protected by 30 mm thick Maxilite blue and Maxilite white board, respectively.

Thermocouples placed on the unexposed side of these boards within the cavity showed that the incipient spread of fire criterion of the ceiling (threshold of 250ºC) was exceeded around 30 minutes after the start of the test. However, the unexposed side temperatures (temperatures on the unexposed side of the exposed board within the cavity) showed a plateau beyond 30 minutes and demonstrated a maximum temperature of around 320ºC at 120 minutes.

Therefore, if the concrete is protected with a 30 mm thick Maxilite board – which will be fixed directly to the underside of the concrete slab, the likely temperatures of the concrete slab interface would be around 320ºC at 120 minutes.

Figure C.5 and Table C.1 of EN 13381.3:2015[7] provides temperatures within a concrete slab along the depth if exposed to standard fire conditions. This information can also be used to determine the equivalent concrete thickness of a protection material. As the temperature of the concrete-to-Maxilite board interface is expected to be 320ºC at 120 minutes, the Table C.1 of EN 13381-3:2015 states that the equivalent concrete thickness of a 30 mm thick Maxilite board is around 60 mm. This means that a 30 mm thick Maxilite board is capable of providing a protection similar to that of 60 mm thick concrete.

Section 5.3.1 of this report stated the need for an additional 27 mm of concrete depth (105 mm overall thickness) to achieve an FRL of -/120/120/ for service penetrations incorporated in void type conduit configurations. Based on the discussion provided above, it is concluded that a 30 mm thick Maxilite board is capable of providing this protection with a significant margin of safety.

In this instance, boards must be direct fixed to the concrete slab using 6 mm anchors (dyna bolt or screw-type) at 400 mm centres – 25-50 mm away from the sides.

### 5.3.6 The distance between the services from the exposed side to the unexposed side

#### Cables within conduits

The distance between the services from the exposed side to the unexposed side in U-profile conduit configuration was ranging from 250 mm to 500. The test specimens maintained integrity and insulation performance up to 120 minutes with a significant margin of safety. Therefore, it is considered that the distance between the services from the exposed side to the unexposed side can be greater than 250 mm for cables and conduits that has been assessed in this report when adopting U-profile conduit, straight-through conduit and side entry conduit configurations, for FRL applications up to -/120/120.

#### PE-Xb and PE-Xa/AL/PE within conduits

The distance between the exposed and unexposed side services tested with void type conduit configurations were spaced 500 mm apart. Based on the performance during the test, it is proposed that this spacing to be reduced to 250 mm for applications that require an FRL of -/90/90.

The test specimens with void type conduit configurations included FyreCHOKE CI32 cast-in collar placed on the exposed side (0 mm from the exposed side) or on the unexposed side (500 mm from the exposed side). As expected with penetrations tested with collars, unexposed side temperature initially showed a sudden rise in temperature followed by a significant drop. This is attributed to the fire collar successfully activating upon exposure to the fire, closing off any path of heat transfer to unexposed side.

The initial peak temperatures for the service with FyreCHOKE CI32 cast-in collar placed on the exposed side (0 mm) and on the unexposed side (500 mm) were around 115ºC and 150ºC, respectively. The initial rise in temperature was higher for the service which incorporated the FyreCHOKE CI32 cast-in collar on the unexposed side. This observation is reasonable as it is expected that the collar activation may take longer if the collar is placed on the unexposed side resulting in higher initial temperature peak. In the proposed service penetration, the cast-in collar is expected to be placed at 250 mm from the exposed side. Therefore, based on the test evidence, the initial temperature rise of the proposed service is expected to be between 115ºC to 150ºC – which is less than the insulation failure threshold.

The tested service with a total travel distance of 500 mm within the concrete showed a maximum unexposed side temperature of 107ºC at 120 minutes. Given that the travel distance is reduced to 250 mm in the proposed service, the gradual temperature increase (after the initial peak) of the unexposed side thermocouples placed on the service is expected to be display a higher temperature – than observed during the test.

[7] European Committee for Standardization 2015, Test methods for determining the contribution to the fire resistance of structural members – Part 3: Applied protection to concrete members, EN 13381-3:2015, European Committee for Standardization, Brussels, Belgium.

Nevertheless, given the safety of margin with respect to the insulation performance observed during the test, it is reasonable to consider that the services with void type conduit configuration will achieve at least 90 minutes of insulation and integrity performance.

### 5.3.7 The distance from the service to separating wall on the exposed side

In the tested system, the minimum distance from the void to the separating wall on the exposed side was 87.5 mm. Similarly, the distance from the service to the separating wall in U-profile conduit configuration was also maintained at minimum 87.5 mm.

Therefore, it is a requirement of this assessment that the service penetrations incorporating void type conduit and U-profile conduit configurations must always be placed at a distance not less than 87.5 mm.

### 5.3.8 Variation in type of cables

The tested services included a single 16 $mm^2$ power cable and a bundle of two TPS and two CAT6. All the cables consisted of copper cores. The tested 16 $mm^2$ 2C + E electrical cable consisted of XLPE insulation. The sheathing of the tested cables was made of PVC.

It is proposed that electrical and telecommunication cables including but not limited to submain, TPS, LAN, RG6, CAT, fibre optics, SDI and fire rated cables may be used. They must be of similar construction to the tested services general. Specifically, the proposed services must only consist of copper cores. Cable insulation may be either PVC or XLPE. Cable sheathing must be PVC.

In general, the tested system consisted of electrical cables consisting of PVC and XLPE sheathing. The conductors were made of copper. Furthermore, PEX pipes were also tested as part of the referenced test. All the tested specimens maintained integrity and insulation for a period not less than 120 minutes. While the tested arrangement does not conform to the standard configurations specified in AS 1530.4:2014, it can be reasonably interpreted that the test results can be applied to other cables of similar construction – in line with the approach suggested in the standard for services penetrating vertical or horizontal separating elements.

The cable or cable bundle size per conduit is limited by the collective area of the copper conductors of individual cables (in a bundle). The tested system consisted of an overall conductor area of 16 $mm^2$. Based on the above discussion, it is likely that if the collective copper conductor area of proposed cables and cable bundles does not exceed 16 $mm^2$, insulation failure may not occur for the range of variables assessed within this report. Thus, the size of conduit bundles can be increased (bound by the limits of other assessed variables such as conduit size), provided that the total copper conductor area does not exceed 16 $mm^2$. The increase in the PVC or XLPE sheathing content with the increase in the number of cables in a cable bundle is unlikely to cause an integrity failure as no such indication was observed during the referenced tests. In fact, the filling of the conduit with cables has an effect of blocking the passage of hot gasses and smoke over to the unexposed side.

### 5.3.9 Use of blank conduits

Specimen C1 of the referenced test report FRT200337 R1.1 consisted of a Ø25 uPVC conduit without any services inside them protected by FyreCHOKE CI25 cast-in collar placed on the exposed side.

During the test, temperatures were measured on the unexposed side of the service and the maximum recorded temperature after 120 minutes was 85ºC, which demonstrated a significant margin of safety in terms of the insulation performance. Therefore, it is considered that smaller conduits – Ø16 mm and Ø20 – with no services installed will also maintain integrity and insulation for a period of up to 120 minutes, if tested under similar conditions.

### 5.3.10 Bottom concrete cover to conduits

In the tested system, the conduits for the PEX pipes were supported on 50 mm chairs. Thus, the nominal concrete bottom cover to these conduits was minimum 50 mm in the tested system. Therefore, it is requirement of this assessment that the service penetrations must always maintain a bottom cover of not less than 50 mm.

### 5.3.11 Separating wall

The tested system consisted of a 75 mm thick AAC wall separating element with an established FRL of -/90/90. It is proposed that any separating wall element with an established FRL not less than -/90/90 or 90/90/90 can be used. The FRL of the wall element must have been either tested or assessed by an accredited testing laboratory in accordance with AS 1530.4:2014 sections 2 and 3. The wall-to-floor head joint must also have an established FRL either via testing or an assessment to AS 1530.4 sections 2 and 10.

If the separating wall element and the head joint detail have been tested to achieve a minimum FRL of -/90/90, then there is reasonable confidence that the temperatures measured on the separating wall – 25 mm from the concrete soffit on the unexposed side – would not exceed the insulation failure threshold before 90 minutes. The same applies to the temperature measured on the concrete soffit, 25 mm away from the unexposed face of the separating wall element. As the performance of the proposed services embedded within the concrete slab are also evaluated considering the temperatures recorded at these locations, the established performance of the joint is indeed important.

The separating wall element may alternatively have a lower stated FRL (eg -/60/60 or 60/60/60). In such cases, the FRLs of the proposed service penetrations are limited by this lower FRL of the wall separating element.

## 5.4 Conclusion

This assessment demonstrates that the proposed services are expected to achieve FRLs given in Table 6 – if it were tested in general accordance with AS 1530.4:2014.

**Table 6 Assessment outcome**

| Item | Item name | Reference test | Variations | System FRL |
|---|---|---|---|---|
| 1. | Concrete slab thickness | FRT200337 R1.1 | Concrete slab thickness must be not less than 190 mm.<br>For void type conduit configurations, the residual concrete thickness above the void must be as follows.<br>• minimum 93 mm for -/90/90 applications<br>• minimum 105 mm for -/120/120 applications. | Up to -/120/120* |
| 2. | Conduit types and size | | For cables, Ø16 mm, Ø20 mm, Ø25 mm, Ø32 mm and Ø40 mm PVC conduits may be used | |
| 3. | Type and size of PEX pipes | | Ø20 mm PE-Xb pipes and Ø20 PE-Xa/AL/PE pipes may be used. | |
| 4. | Fire protection | | • uPVC conduits, PE-Xb and PE-Xa/AL/PE pipes, electrical cables, telecommunication cables and cable bundles may be protected with the appropriate size of Trafalgar FyreCHOKE cast-in collar – with or without gasket installed at the exposed or unexposed side of the service.<br>• Alternatively, the services may also be protected with FyrePEX$^{TM}$ HP intumescent sealant placed within the conduit for a depth of 30 mm at either exposed or unexposed side of the service. | |
| 5. | Service configuration | | Proposed systems may use void type conduit (Figure 1), U-profile conduit (Figure 2), side entry conduit (Figure 3), straight through conduit (Figure 4) and top-side deck box configurations (Figure 5). | |
| 6. | Void protection | | A 30 mm thick Maxilite can be used to protect the underside of the void. In this instance, boards must be direct fixed to the concrete slab using 6 mm anchors (dyna bolt or screw-type) at 400 mm centres – 25 to 50 mm away from the sides. | |
| 7. | Travel distances | | • The travel distance of conduit and cable services – incorporating straight through conduit, U-profile conduit, side entry conduit and top-side deck box configurations – within the concrete slab must be not less than 250 mm.<br>• The travel distance of PE-Xb and PE-Xa/AL/PE pipes – incorporating void type conduit and top-side deck box configurations – within the concrete slab must be as follows.<br>– not less than 250 mm for -/90/90 applications<br>– not less than 500 mm for -/120/120 applications. | |

| Item | Item name | Reference test | Variations | System FRL |
|---|---|---|---|---|
| 8. | Types of cables | | • Electrical and telecommunication cables including but not limited to submain, TPS, LAN, RG6, CAT, fibre optics, SDI and fire rated cables may be used.<br>• Cables must only consist of copper conductors. Cable insulation may be either PVC or XLPE. Cable sheathing (if any) must be PVC.<br>The collective copper conductor area of a cable or cable bundle within a single conduit must not exceed 16 $mm^2$. | |
| 9. | Blank conduits | | Ø16 mm, Ø20 mm and Ø25 mm conduits may be left blank with no service installed. Local protection as described above in item 4 must be used. | |
| 10. | Bottom concrete cover to conduits | | Bottom concrete cover to conduits must be not less than 50 mm. | |
| 11. | Variations to the separating wall | | • It is proposed that any separating wall element with an established FRL of at least -/90/90 or 90/90/90 can be used. The FRL of the wall element must have been either tested or assessed by an Accredited Testing Laboratory in accordance with AS 1530.4:2014.<br>• The head (or base) detail of the wall and the concrete floor separating element must also have an established FRL not less than -/90/90 – established in a similar manner.<br>• Alternatively, the separating wall element may have a lower stated FRL (eg -/60/60 or 60/60/60). In such cases, the FRLs of the proposed service penetrations are limited by this lower FRL of the wall separating element. | |
| Note - Services incorporating void type conduit configuration with a concrete slab thickness of minimum 93 mm above the void will achieve an FRL of -/90/90. The concrete slab thickness above the void must be increased to minimum 105 mm for -/120/120 applications.<br>The travel distance of PE-Xb and PE-Xa/AL/PE pipes – incorporating void type conduit configuration – within the concrete slab must be greater than 250 mm for -/90/90 applications. | | | | |

# 6. Validity

Warringtonfire Australia 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 general 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 Summary of supporting test data

## A.1 Test report – FRT200337 R1.1

**Table 7 Information about test report**

| Item | Information about test report |
|---|---|
| Report sponsor | Trafalgar Group |
| Test laboratory | Warringtonfire Australia, Unit 2, 409-411 Hammond Road, Dandenong, Victoria 3175, Australia. |
| Test date | The fire resistance test was completed on 15 January 2021. |
| Test standards | The test was done in general accordance with AS 1530.4:2014. |
| Variation to test standards | • AS 1530.4:2014 requires the services to project a minimum of 500 mm on each side of the supporting construction. The conduits in penetration system C do not protrude 500 mm on the exposed side of the horizontal separating element. Therefore, the penetration system was tested in general accordance with the standard – and no fire resistance level (FRL) was assigned.<br>• AS 1530.4:2014 does not include specific requirements for testing services that are embedded and travel through the separating element and exit on the same side they enter from. Penetration systems D, E and F have services embedded and travelling within the horizontal separating element. Therefore, the penetration systems were tested in general accordance with the standard – and no FRLs were assigned. |
| General description of tested specimen | There were 6 services penetrations involving pipes, conduit, cables and cables tray penetrating a 190 mm thick concrete ceiling slab with some embedded in the slab and traversing over an AAC separating wall system before emerging in the other compartment and the remaining services passing through to above the slab. Services C, D, E and F are relevant for this assessment. |
| Instrumentation | The test report states that the instrumentation was in accordance with AS 1530.4:2014. |

The test specimen achieved the following results – see Table 8.

**Table 8 Results summary for this test report**

| Penetration system | | | Criteria | Results |
|---|---|---|---|---|
| C | 1 | • 1 × Ø25 mm uPVC conduit<br>• 2 × Ø25 mm uPVC conduit elbows | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |
| | 2 | • 2 × TPS cables<br>• 2 × CAT 6 cables<br>• 1 × Ø25 mm uPVC conduit<br>• 2 × Ø25 mm uPVC conduit elbows | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |
| | 3 | • 2 × TPS cables<br>• 2 × CAT 6 cables<br>• 1 × Ø25 mm uPVC conduit<br>• 2 × Ø25 mm uPVC conduit elbows | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |
| D | 1 | • 2 × TPS cables<br>• 2 × CAT 6 cables<br>• 1 × Ø25 mm uPVC conduit | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |

| Penetration system | | | Criteria | Results |
|---|---|---|---|---|
| | | • 2 × Ø25 mm uPVC conduit elbows | | |
| | 2 | • 2 × TPS cables<br>• 2 × CAT 6 cables<br>• 1 × Ø25 mm uPVC conduit<br>• 2 × Ø25 mm uPVC conduit elbows | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |
| | 3 | • 1 × 16 mm$^2$ power cable<br>• 1 × Ø40 mm uPVC conduit<br>• 1 × Ø40 mm uPVC conduit elbow | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | Failure at 79 minutes |
| E | 1 | • 1 × Ø20 mm PE-XA/AL/PE pipes<br>• 1 × Ø32 mm uPVC conduit | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | Failure at 68 minutes |
| | 2 | • 1 × Ø20 mm PE-Xb pipes<br>• 1 × Ø32 mm uPVC conduit | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | Failure at 68 minutes |
| | 3 | • 1 × Ø20 mm PE-Xb pipes<br>• 1 × Ø32 mm uPVC conduit | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | Failure at 68 minutes |
| F | 1 | • 2 × TPS cables<br>• 2 × CAT 6 cables<br>• 1 × Ø25 mm uPVC conduit<br>• 2 × Ø25 mm uPVC conduit elbows | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |
| | 2 | • 1 × 16 mm$^2$ power cable<br>• 1 × Ø40 mm uPVC conduit<br>• 1 × Ø40 mm uPVC conduit elbow | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |
| | 3 | • 1 × 16 mm$^2$ power cable<br>• 1 × Ø40 mm uPVC conduit<br>• 1 × Ø40 mm uPVC conduit elbow | Structural adequacy | Not applicable |
| | | | Integrity | No failure at 125 minutes |
| | | | Insulation | No failure at 125 minutes |

## A.2 Test report – FSH 2076

**Table 9 Information about test report**

| Item | Information about test report |
|---|---|
| Report sponsor | Trafalgar Group |
| Test laboratory | CSIRO – Infrastructure technologies. 14 Julius Avenue, North Ryde, NSW 2113, Australia. |
| Test date | The fire resistance test was completed on 16 October 2019. |
| Test standards | The test was done in accordance with AS 1530.4:2014. |
| Variation to test standards | The test was conducted with no load applied to the surface of the floor. It is requirement of the test standard that a floor/ceiling system to be tested as composite load bearing element.<br>The furnace pressure was in excess of the requirements of the standard during 0-7 minutes into the test. |
| General description of tested specimen | The tested specimen of FSH 2076 consisted of a bulkhead ceiling system comprising of various Maxilite board types and joint details protecting a steel framed floor system. The two-level ceiling system was constructed within a plasterboard lined enclosure and suspended from a steel framed floor system. Detail 3 and Detail 4 of the referenced report are relevant for this report and they demonstrate the performance of ceiling segments protected by 30 mm thick Maxilite blue and Maxilite white board, respectively. |
| Instrumentation | The test report states that the instrumentation was in accordance with AS 1530.4:2014. |
| Results | The maximum unexposed side temperature of the Maxilite board was around 320ºC at 120 minutes. |

# Appendix B SAFIR modelling assessment

## B.1 Introduction

This section provides a brief overview of the thermal analyses conducted to determine the effect of the increased slab thickness above the void using SAFIR finite element (FE) software.

The modelling was performed based on the following:

- Service penetration through the concrete is assumed not to affect the temperatures on the top surface of the concrete slab, directly above the void. Therefore, penetrations were not analysed.
- A 3-D thermal model was considered appropriate to analyse the heat transfer behaviour around the block-out.
- The following two cases were considered for the SAFIR thermal model:
  - Model A: 190 mm deep slab with a slab thickness of 93 mm above the void.
  - Model B: 190 mm deep slab with a slab thickness of 105 mm above the void.

## B.2 SAFIR software

SAFIR is a computer program that analyses various structures in the presence of fire or extreme stress. SAFIR can compute the transfer of heat through the structure or the effects of tension on the structure, respectively, by using the Finite Element Method (FEM).

SAFIR requires a grid comprised of "nodes" which designates the shape of the structure being analysed. Each node has a set of two or three coordinates based either on the Cartesian or cylindrical coordinate systems. The node coordinates are user specified and therefore exact measurements can be used when designing the grid.

The areas created inside the node grid are called "elements". The elements describe to SAFIR what type of material is located in that area. Each element is specified in SAFIR by the nodes that surround it in an anti-clockwise direction (see Figure 6), a number that represents the material of the element, and the amount of residual tension in the element.

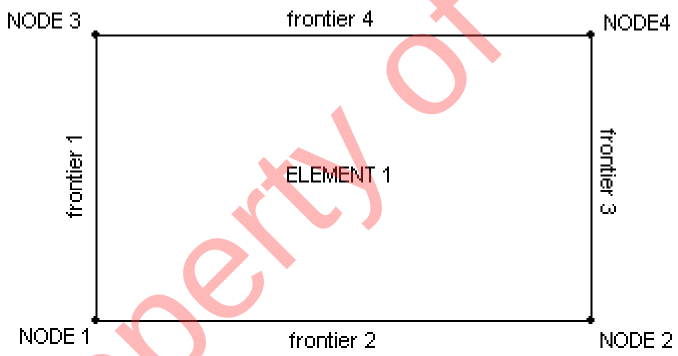



**Figure 6 Node and element layout**

Any type of material can be used in SAFIR if certain parameters are known e.g. conductivity and specific heat capacity. There are already a range of materials for which SAFIR has data including steel, concrete and Gypsum plasterboards.

When SAFIR is analysing heat transfer in a structure, the temperature curve of the fire has to be designated as well as which element "frontiers" are being heated. The temperature curve of the fire is set out in a ".txt" file that SAFIR can access. The file contains a set of paired numbers representing time and the temperature of the fire at that time. The data about nodes, elements and frontiers are compiled into a ".in" file. SAFIR reads this file and calculates the heat transfer or tension effects for a set length of time.

## B.3 Input parameters

### B.3.1 General

The following general parameters were applied in the thermal model:

- The temperature for the ambient environment has been specified as 20°C.
- The coefficient of heat transfer by convection is taken as 25 $W/m^2K$ for hot-face and 9 $W/m^2K$ for unexposed face, as per EN 1991-1-2:2002[8].
- The surface emissivity of the concrete is taken as 0.7.

### B.3.2 Thermal properties

The thermal properties of concrete were obtained from SAFIR database.

### B.3.3 Model Geometry

Model A consisted of a 1000 m wide × 1000 mm long × 190 mm deep concrete slab with 315 mm × 315 mm void at the centre. The slab thickness above the void was 93 mm (see Figure 7).

Model B consisted of a 1000 m wide × 1000 mm long × 190 mm deep concrete slab with 315 mm × 315 mm void at the centre. The slab thickness above the void was 105 mm.

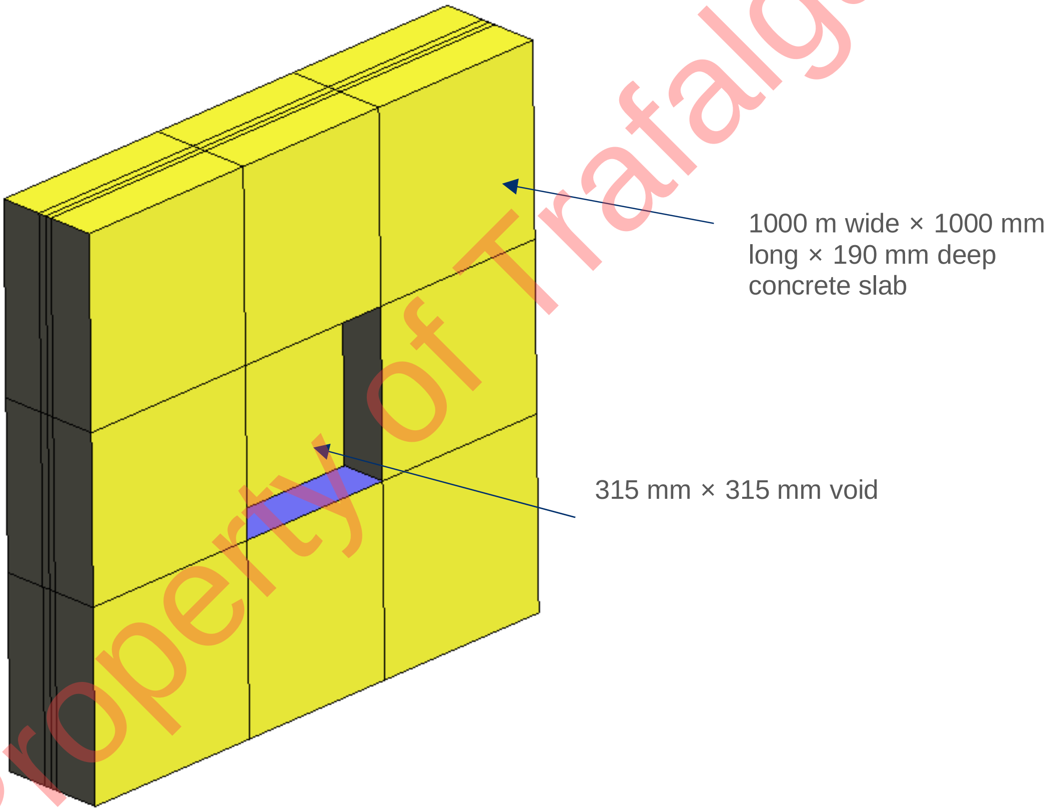



**Figure 7 The developed finite element model**

8 Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire

## Boundary Conditions

In all developed thermal models, the exposed side of the slab was exposed to standard fire conditions (FISO) as prescribed in AS 1530.4:2014. The unexposed side of the system was assigned with F20 boundary condition for ambient temperature. Figure 8 shows the assigned boundary conditions for the models.

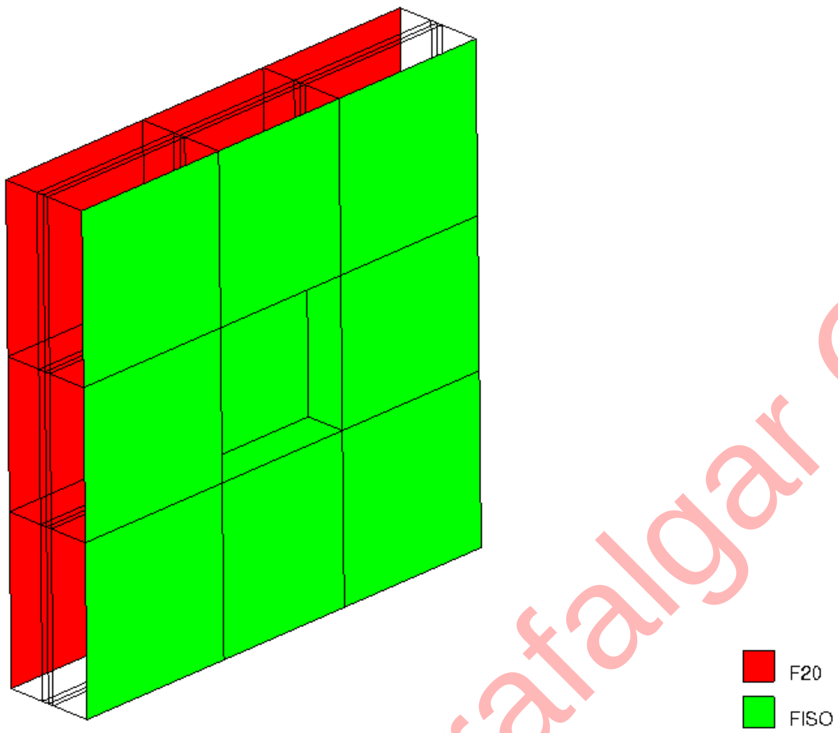



**Figure 8** **Boundary conditions**

## Mesh characteristics

Figure 9 shows the mesh configurations of the models developed to simulate the wall and column junction.

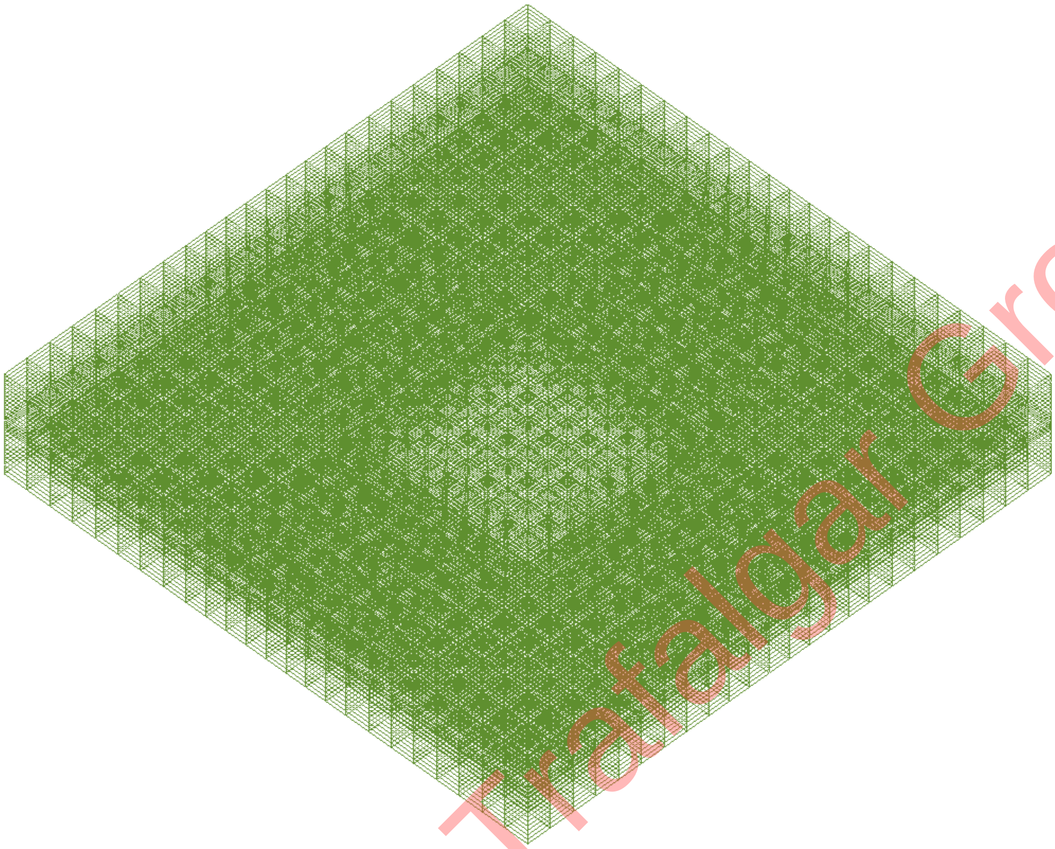
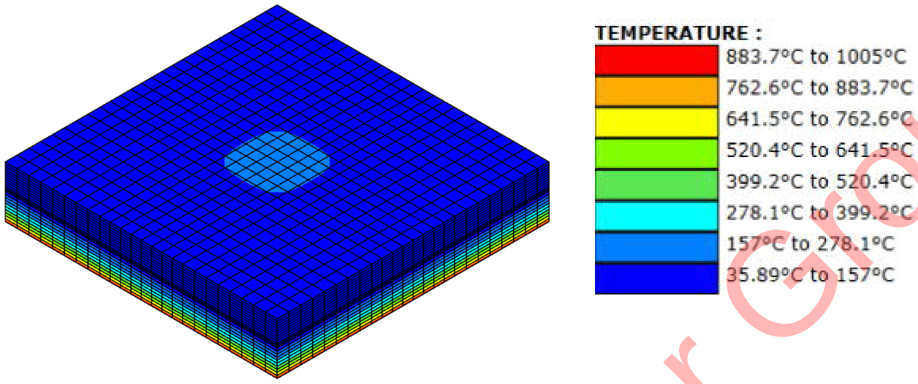


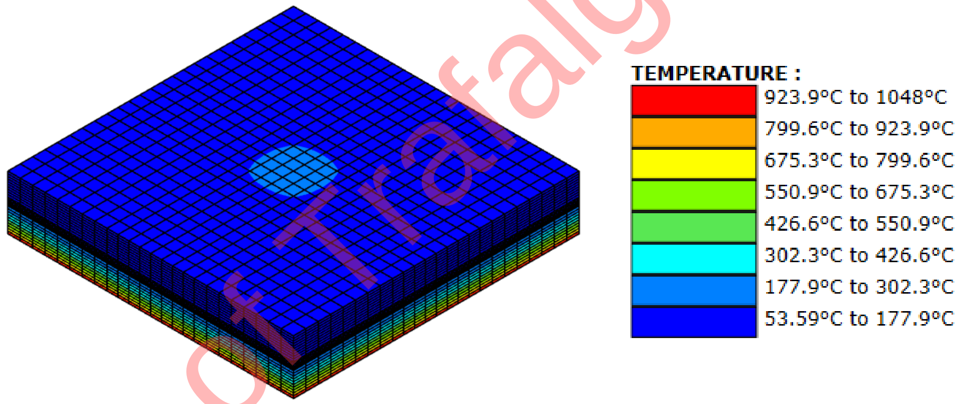
**Figure 9 The mesh configuration of the Model B**

## Results

The thermal simulation was conducted up to 120 minutes and Table 10 shows the thermal contours of the models and the maximum unexposed side temperatures obtained.

**Table 10 Thermal contours and maximum unexposed side temperature**

<table>
<tr><th>Model</th><th>Maximum unexposed side temperature (ºC)</th></tr>
<tr><td>Model A</td><td>


Thermal contours at 90th minute is shown above. The maximum temperature on the unexposed side at 90 minutes was 185ºC – which is a temperature rise of 165ºC.</td></tr>
<tr><td>Model B</td><td>


Thermal contours at 120th minute is shown above. The maximum temperature on the unexposed side at 90 minutes was 195ºC – which is a temperature rise of 175ºC.</td></tr>
</table>

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