The fire resistance rating of FBL-100 protected wall and floor systems when tested in accordance with AS 1530.4-2014

Assessment Report

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Copyright and disclaimer

Important disclaimer

Contents

1 Introduction

This report is an assessment of the fire resistance rating of FBL-100 protected wall and floor systems when tested in accordance with AS 1530.4-2014.

This report is prepared for the purpose of meeting requirements of NZBC where a Fire Resistance Rating (FRR) or Resistance to Incipient Spread of Fire (RISF) is required.

This report reviews and confirms the extent to which the reference fire resistance tests listed in section 2 meet the requirements of the standard fire test standards listed in section 4 of the report. The proposed variations to the tested construction presented in section 3 are subject to an analysis in Appendix B, and the conclusions are presented in Section 5 of this report.

The field of applicability of the results of this assessment report is presented in Section 6.

2 Supporting Data

This assessment report refers to various test reports to support the analysis and conclusions of this report. They are listed below;

Report Reference	Test Standard	Description
FSP 1888	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of timber framed floor/ceiling system with a 13 mm thick GIB plasterboard as the ceiling lining. The plasterboard was half pre-painted with three coats of ceiling paint and half unpainted. Both sides were coated with 750 microns of FBL-100 intumescent coating.
FSP 1889	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of the timber framed floor/ceiling system with a 6-mm thick fibre cement sheet as the ceiling lining, and was coated with 1000 microns of FBL-100 intumescent coating.
FSP 1890	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of a timber framed floor/ceiling system with a 12-mm thick Ecoply Plywood as the ceiling lining, and was coated with 710 microns of FBL-100 intumescent coating.
FSP 1893	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of floor/ceiling system with a 19 mm thick structural timber ply flooring board with the joists coated with 1000 microns of FBL-100 intumescent coating.
FSP 1894	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of a timber framed floor/ceiling system with a 13-mm thick GIB standard plasterboard as ceiling lining. The plasterboard ceiling was coated with 1000 microns of FBL-100 Intumescent coating.
FSP 1918	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of timber framed floor/ceiling system with a 13-mm thick GIB standard plasterboard as ceiling lining. The plasterboard was coated with 1078 microns of FBL-100 intumescent coating and then coated by a roller with two coats of ceiling paint.
FSH 1920	AS 1530.4 - 2014	A full scale fire resistance test on a timber framed floor/ceiling system with a 13-mm thick GIB standard plasterboard as ceiling lining. The plasterboard was coated with 1040 microns of FBL-100 Intumescent coating. Additional 50mm long screws were used to fix plasterboard to the joist
FSP 1929	AS 1530.4 - 2014	A pilot scale fire resistance test on a section of timber framed floor/ceiling system with a 13-mm thick GIB standard plasterboard as ceiling lining containing a butt joint. The plasterboard was coated with 1115 microns FBL-100 intumescent coating.

The tests described above were carried out at CSIRO North Ryde and were sponsored by Tech Coatings NZ Limited.

3 Proposed Variations

3.1 Lined floor systems

The proposed floor construction as tested in FSH 1920 subjected to the following variations:

- The inclusion of walls lined on each side with tested lining and applied coating as that tested in FSH 1920.
- The structural framing shall be *radiata* pine or denser solid timber.
- Flooring shall be 19mm or thicker structural plywood, fibre cement or particleboard.
- The floor structure shall be designed in accordance with NZS 3603.
- The floor joist framing shall be at least 190mm deep and 45mm wide.
- The ceiling linings shall be to 13mm GIB standard plasterboard or 12mm Ecoply plywood or 6mm fibre cement or thicker.
- The inclusion of ceiling painted plasterboard prior to application of FBL-100 coating.
- The inclusion of ceiling paint top coat after the application of FBL-100 coating on plasterboard.
- The proposed construction is summarised in Table 1 and Figures 9 to 12.

3.2 Unlined floor systems

The proposed floor construction as tested in FSH 1920 subjected to the following variations:

- The structural framing shall be radiata pine or denser solid timber.
- The underside of the flooring and joists shall be coated with the same amount of coating as the floor specimen tested in FSP 1893.
- Flooring shall be 19mm or thicker structural plywood, fibre cement or particleboard.
- The floor structure shall be designed in accordance with NZS 3603 and where applicable using a reduced design capacity.
- The support for the floor structure shall be provided by
    - the direct bearing of at least 50mm under the joist on a protected timber wall or bearer, a masonry structure or the like.
    - joist hangers that are fully protected with at least 1 layer of 13mm GIB Fyreline plasterboard prior to the application of the paint system.
- The proposed construction is summarised in Table 1 and Figure 13.

3.1 Lined wall systems

The proposed wall construction as tested in FSH 1920 subjected to the following variations:

- Orientated as a wall rather than floor as tested.
- Wall framing shall be at least 90mm deep.
- The structural framing shall be *radiata* pine or denser solid timber.
- The wall structure shall be designed in accordance with NZS 3603 and where applicable using a reduced design cross section as listed in Table 1.
- The inclusion of walls lined on one or both sides and the applied FBL-100 as tested in FSH 1920.
- The wall/ceiling linings shall be to 13mm GIB standard plasterboard or 12mm Ecoply plywood or 6mm fibre cement or thicker.
- The inclusion of painted plasterboard prior to application of FBL-100 coating.
- The inclusion of a paint top coat after the application of FBL-100 coating on plasterboard.
- The proposed construction is summarised in Table 1 and Figures 1 to 8.

Table 1: Schedule of components for lined floor and wall installation

Item		Detail
1	Name	**FBL-100**
	Material	Water-based, thin-film, intumescent coating.
	Installation	Prepare substrate surface as per AS/NZS 2311:2017, section 3 with a minimum dry film thickness to be 1040 µm
2	Name	**19mm flooring**
	Material	Structural plywood, fibre cement or particleboard
	Installation	Perimeter fixing - 50mm x 8g 304 s/s countersunk screws @ 150mm centres. Mid sheet fixing - 50mm x 8g 304 s/s countersunk screws @ 400mm centres.
3	Name	**12mm or thicker H2 Ecoply**
	Material	Structural plywood
	Installation	Perimeter fixing - 40mm x 8g square drive screws @ 200mm centres. Mid Sheet Fixing - 40mm x 8g square drive screws @ 600mm centres.
4	Name	**6mm or thicker Villaboard**
	Material	Fibre cement (Painted or unpainted prior to coating application)
	Installation	Perimeter fixing - 30mm x 7g Villadrive screws @ 200mm centres. Mid Sheet Fixing - 30mm x 7g Villadrive screws @ 300mm centres.
5	Name	**13mm or thicker GIB standard plasterboard**
	Material	Standard plasterboard (Painted or unpainted prior to coating application)
	Installation	*45 minute applications – Figures 3, 4 and 10* Perimeter fixing - 32mm x 6g GIB Grabber screws@ 200mm centres. Mid Sheet Fixing - Daubes of Gibfix All bond @ 200mm centres, 32mm x 6g GIB grabber screws @ 600mm centres. *60/60/60 installation – Figures 3, 4 and 10* Perimeter fixing - 32mm x 6g GIB Grabber screws@ 200mm centres. Mid Sheet Fixing - Daubes of Gibfix All bond @ 200mm centres 32mm x 6g GIB grabber screws @ 600mm centres. Additional Mid Sheet - Fixings with 50mm x 7g plasterboard screws @ 200 centres
6	Name	**Wall Frame**
	Material	*Radiata pine* or a denser solid timber of Grade; MSG6, MSG8, MSG10, MSG12
	Specification	• The wall shall be designed in accordance with NZS 3603-1993 amdt 4 • Walls framing shall be at least 90mm deep • Design capacity shall be reduced (load increased) as specified in Section 5 based on design
7	Name	**Floor Frame**
	Material	*Radiata pine* or a denser solid timber of Grade; MSG6, MSG8, MSG10, MSG12

	Specification	• The floor shall be designed in accordance with NZS 3603 as appropriate for the loading, span, spacing and materials the joist is made from.
		• The design capacity shall be reduced (or load increased) as specified in Section 5 based on design
		• Floor joists shall be at least 190mm deep
		• Structural framing shall be Radiata pine or denser solid timber.
		• Joists shall;
		  o directly bear on for at least 50mm on a protected timber wall or bearer, a masonry structure or the like, or
		  o be supported by joist hangers that are fully protected with at least 1 layer of 13mm GIB Fyreline plasterboard prior to the application of the FBL-100 coating

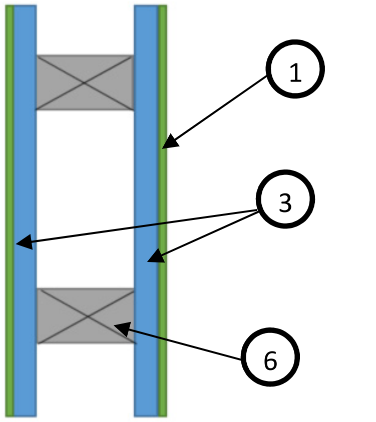

Figure 1: 30 minute applications with fire from both sides

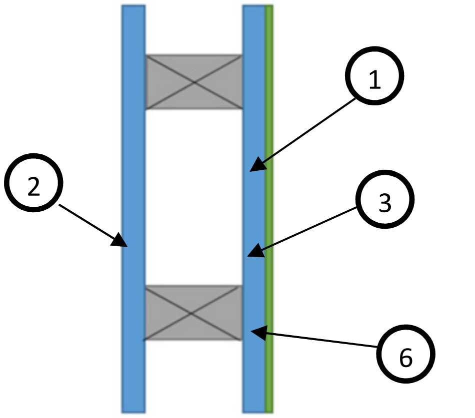

Figure 2: 30 minute applications with fire from the painted side only

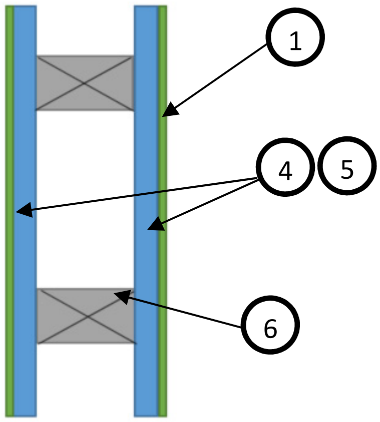

Figure 3: 45 minute applications with fire from both sides

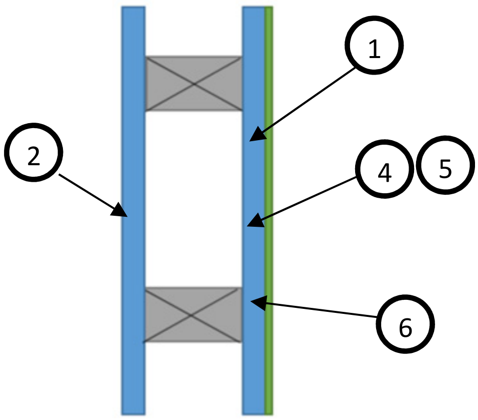

Figure 4: 45 minute applications with fire from the painted side only

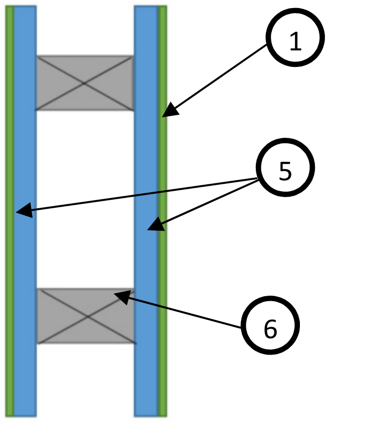

Figure 5: 60 minute applications with fire from both sides

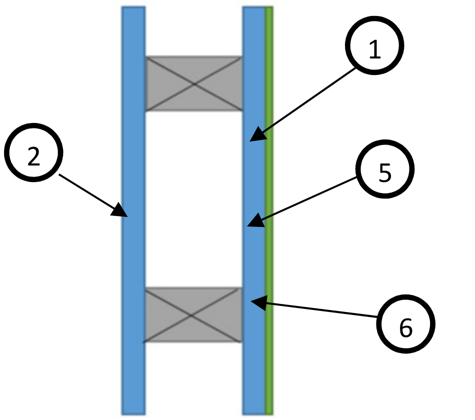

Figure 6: 60 minute applications with fire from the painted side only

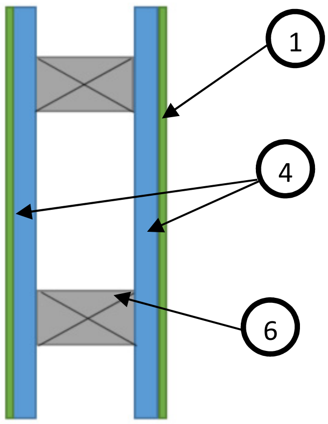

Figure 7: 60 minute applications with fire from both sides

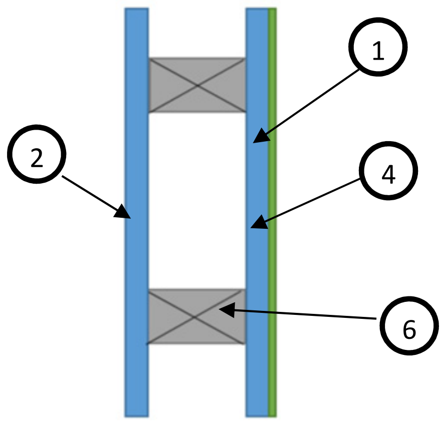

Figure 8: 60 minute applications with fire from the painted side only

Figure 9: 30 minute floor applications

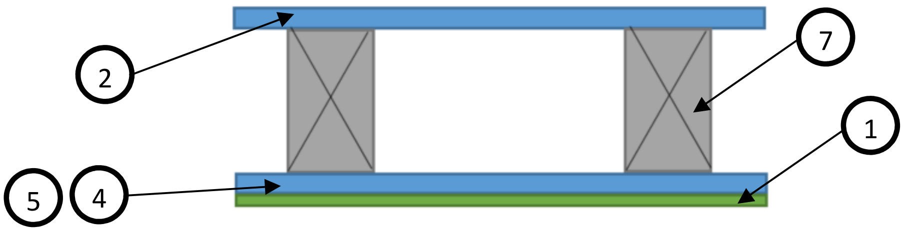

Figure 10: 45 minute floor applications

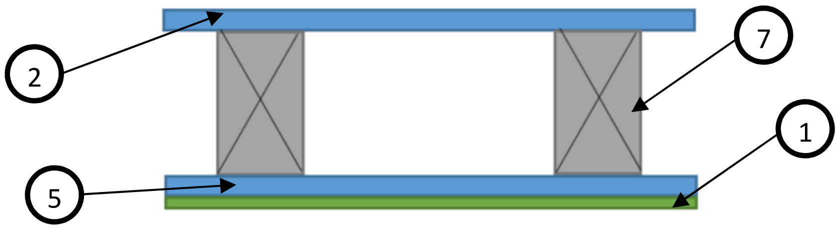

Figure 11: 60 minute floor applications

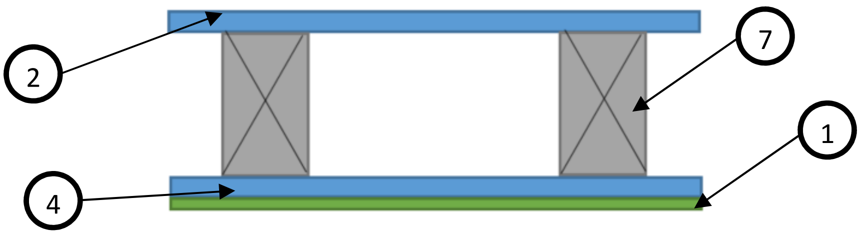

Figure 12: 60 minute floor applications

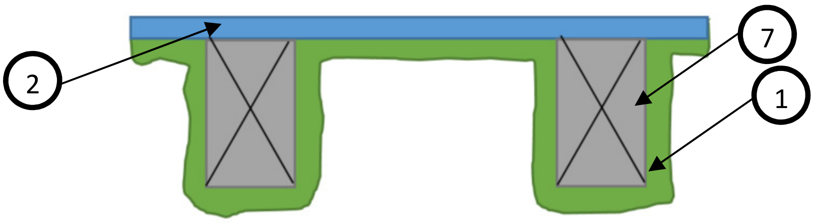

Figure 13: 30 minute floor applications

4 Referenced Standards

Standards:

AS 1530.4-2014	Methods for fire tests on building materials, components and structures Part 4: Fire resistance tests of elements of building construction.
NZS 3603- 1993 (amdt 4)	Timber structures standard.

5 Conclusion

On the basis of the analysis presented in this report, it is the opinion of this Accredited Testing Laboratory that the tested prototypes described in Section 2 when varied as described in Section 3 will achieve the Fire Resistance Rating (FRR) and Resistance to incipient spread of fire (RISF) stated below when submitted to a standard fire test in accordance with the test methods referenced in Section 4 and subject to the requirements of section 7, validity of section 8 and limitation of section 9.

Table 2: Floor System FRR and RISF

Coated lining and Structural element	Construction Specification	FRR	RISF (mins)
Plywood lined timber framed floor	Figure 9 and Table 1	30/30/30	30
Plasterboard lined timber framed floor	Figure 10 and Table 1	45/45/45	30
Fibre cement lined timber framed floor	Figure 10 and Table 1	45/45/45	30
Plasterboard lined timber framed floor	Figure 11 and Table 1	60/60/60	30
Fibre cement lined the timber framed floor	Figure 12 and Table 1	60/60/60	30
No ceiling lining exposed timber frame floor	Figure 13 and Table 1 No Reduction in joist capacity	30/30/30	-
	Figure 13 and Table 1 Joist capacity reduction listed in Table 3	45/45/45	-

Table 3: Joist capacity for profile coated joists Figure 13.

Joist Section	Reduction factor for ultimate strength capacity at 45 minutes		
	MSG 6 & MSG 8	**MSG 10**	**MSG 12**
190 x 45	0.56	0.78	1.0
240 x 45	0.40	0.56	1.0
290 x 45	0.34	0.48	0.95

Table 4: Wall System FRR

Coated lining and Structural element	**Construction Specification**	**Load Capacity**	**FRR**
Plywood lined timber framed wall	Figure 1 and Table 1	No Reduction in wall capacity for fire load case	30/30/30
	Figure 2 and Table 1		30/30/30 from the coated side only
Plasterboard and Fibre cement lined timber framed wall	Figure 3 and Table 1		45/45/45
	Figure 4 and Table 1		45/45/45 from the coated side only
Plasterboard lined timber framed wall	Figure 5 and Table 1		60/60/60
	Figure 6 and Table 1		60/60/60 from the coated side only
Fibre cement lined timber framed wall	Figure 7 and Table 1		60/60/60
	Figure 8 and Table 1		60/60/60 from the coated side only

6 Direct Field of Application of Results

The results of this report are applicable to horizontal, floor\ceilings exposed to fire from below or for walls exposed from one or either side depending on design.

7 Requirements

It is required that the supporting construction is tested or assessed to achieve the required FRR up to the required FRR based on the assessed design in accordance with AS 1530.4-2014.

Any variations with respect to size, constructional details, loads, stresses, edge or end conditions that are other than those identified in this report, may invalidate the conclusions drawn in this report.

8 Term of Validity

This assessment report will lapse on 30th December 2023. Should you wish us to re-examine this report with a view to the possible extension of its term of validity, would you please apply to us three to four months before the date of expiry. This Division reserves the right at any time to amend or withdraw this assessment in the light of new knowledge.

9 Limitations

The conclusions of this assessment report may be used to directly assess the fire resistance rating performance under such conditions, but it should be recognised that a single test method will not provide a full assessment of the fire hazard under all fire conditions.

Because of the nature of fire resistance 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 report does not provide an endorsement by CSIRO of the actual products supplied to industry. The referenced assessment can therefore relate only to the actual prototype test specimens, testing conditions and methodology described in the supporting data, and does not imply any performance abilities of constructions of subsequent manufacture.

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 the subject of constant review and improvement and it is recommended that this report is reviewed on or, before, the stated expiry date.

The information contained in this assessment report shall not be used for the assessment of variations other than those stated in the conclusions above. The assessment is valid provided no modifications are made to the systems detailed in this report. All details of construction should be consistent with the requirements stated in the relevant test reports and all referenced documents.

Appendix A Supporting Test Data

A.1. CSIRO report FSH 1919

On 17 May 2018, this Division conducted a full-scale fire-resistance test in accordance with AS 1530.4-2014 on a specimen comprised a 4520-mm long x 3000-mm wide x 273-mm thick and comprised 240-mm deep x 45-mm thick MSG H3 treated radiata pine joists and blocking. The floor was lined with 19-mm thick CCA structural plywood and the underside of the floor/ceiling clad with a single layer of standard 13-mm thick GIB plasterboard protected with a 1094µ of FBL-100 Intumescent coating.

Floor Structure

The floor structure comprised 240-mm x 45-mm x 4320-mm long MSG H3 treated timber joists, spaced at nominally 400-mm centres. Timber blockings consisting of 240-mm x 45-mm MSG H3 treated were fixed at nominally 1200-mm centres. Trimmer joists 3000-mm long 240-mm x 45-mm MSG H3 treated timber were fixed at both ends of the specimen with 75-mm X 3.06-mm D Head framing nails, three 100-mm x 14g Bugle Screws were used per joist.

The timber floor joists were clad on the unexposed face using 19-mm thick CCA structural plywood sheets nominally 1200-mm wide x 2400-mm wide. The plywood sheets were fixed to the timber floor joists using 50-mm x 8g 304 S/S countersunk screws, perimeter fixing at 150-mm centres and the intermediate sheet fixing at 400-mm centres.

Ceiling Lining

The specimen was lined on the exposed face of the floor joists with one layer of 13-mm thick GIB standard Plasterboard, nominally measuring 2400-mm long x 1200-mm wide x 13-mm thick. The plasterboard sheets were directly fixed to the underside of the timber joists with 32-mm x 6g GIB grabber screws & GibFix All-Bond adhesive.

Perimeter fixing of the plasterboard sheets was done using 32-mm 6g GIB Grabber screws at 200-mm centres, with mid sheet fixing using daubes of Gibfix All-Bond at 200-mm centres and 32-mm x 6g GIB grabber screws at 600-mm centres. All plasterboard joints were set with GIB paper tape and two coats of GIB MaxSet setting compound.

Intumescent Coating

The exposed face of the plasterboard ceiling was painted with 4 coats of approximately 400µ WFT coats of FBL-100 Intumescent coating using an airless spray gun. This equates to approximately 1000µ microns dry film thickness. The final paint thickness of 1094µ DFT was measured after the final paint application, using a Defelsko PosiTector 200b Ultrasonic probe.

The floor/ceiling specimen was exposed to the furnace chamber from the underside.

A total load of 2510 kg comprising of a steel frame carrying a total of 4 concrete slabs was applied to the specimen for the duration of the test.

The specimen, when tested, failed incipient spread of fire at 42 minutes. The specimen maintained structural adequacy, integrity and insulation up to 55 minutes. The test was terminated at 55 minutes due to the imminent structural failure of the specimen.

A.2. CSIRO report FSH 1920

On 31 July 2018, this Division conducted a full-scale fire-resistance test in accordance with AS 1530.4-2014 on a specimen comprised a 4690-mm long x 3000-mm wide x 273-mm thick timber framed floor/ceiling system with 19-mm thick structural timber plywood flooring, lined with a single layer of 13-mm thick GIB standard plasterboard. The exposed face of the plasterboard ceiling was protected with 1040µ of FBL-100 Intumescent coating.

Floor Structure

The floor structure comprised 240-mm x 45-mm x 4600-mm long MSG H3 treated timber joists, spaced at nominally 400-mm centres. Timber blockings 240-mm x 45-mm MSG H3 treated were fixed at nominally 1200 mm centres. Trimmer joists 3000-mm long 240-mm x 45 mm MSG H3 treated timber were fixed at both ends of the specimen with 75-mm X 3.06 mm D Head framing nails, three 100-mm x 14g Bugle Screws were used per joist.

The timber floor joists were clad on the unexposed face using 19-mm CCA thick structural plywood sheets nominally 1200-mm wide x 2400-mm wide. The plywood sheets were fixed to the timber floor joists using 50-mm x 8g 304 S/S countersunk screws, perimeter fixings were located at 150-mm centres and the intermediate sheet fixing located at 400-mm centres.

Ceiling Lining

The specimen was lined on the exposed face of the floor joists with one layer of 13-mm thick GIB standard Plasterboard, nominally measuring 2400-mm long x 1200-mm wide and 13-mm thick.

The plasterboard sheets were directly fixed to the underside of the timber joists using 32-mm x 6g GIB grabber screws according to standard screwing pattern and GibFix All-Bond adhesive.

Mid sheet fixing comprised daubes of Gibfix All-Bond located at 200-mm centres and 32-mm x 6g GIB grabber screws located at 600-mm centres. Additional Mid Sheet fixings at 50-mm x 7g plasterboard screws were located at 200-mm centres.

Perimeter fixings comprised 32-mm 6g GIB Grabber screws located at 200-mm centres.

All plasterboard joints were set with GIB paper tape and two coats of GIB MaxSet.

Intumescent Coating

The exposed face of the plaster ceiling was painted with 2 coats x 800µ WFT of FBL-100 Intumescent coating using an airless spray gun. The final paint thickness of 1040µ DFT was measured after the final application of paint was applied, using a Defelsko PosiTector 200c Ultrasonic probe.

The specimen was unrestrained along the long axis sides. The resulting gaps along the free edges were sealed with compressed ceramic fibre and mastic.

The floor/ceiling specimen was exposed to the furnace chamber from the underside.

A total load of 2510 kg comprising of a steel frame carrying a total of 4 concrete slabs was applied to the specimen for the duration of the test.

The specimen, when tested, failed incipient spread of fire at 30 minutes and failed integrity at 61 minutes due to flaming on the unexposed face. Structural adequacy was maintained for the 62 minutes duration of the test.

A.3. CSIRO report FSP 1889

On 12 March 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on a specimen comprised a 1200-mm x 1200-mm x 215-mm timber framed floor/ceiling system. The floor system comprised 190 mm x 45 mm MSG (Machine Stress Graded), H2 Treated Timber Joist at 600-mm centres with one joist located in the middle of the frame. The floor consisted of 19mm thick H2 Ecoply Structural Plywood. The underside of the frame was lined with a single layer of 6-mm thick Villaboard fibre cement sheet. A total dry film thickness of 1038 microns of FBL-100 intumescent coating was then applied by spraying onto the exposed face of the Villaboard fibre cement.

A.4. CSIRO report FSP 1890

On 13 March 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on a specimen comprised a 1200-mm x 1200-mm x 221-mm timber framed floor/ceiling system. The floor system comprised 190 mm x 45 mm MSG (Machine Stress Graded), H2 Treated Timber Joists at 600-mm centres with one joist located in the middle of the frame. The floor consisted of 19mm thick H2 Ecoply Structural Plywood. The underside of the frame was lined with a single layer of 12-mm thick Ecoply Plywood. A total dry film thickness of 710 microns of FBL-100 intumescent coating was then applied by spraying onto the exposed face of the Ecoply Plywood.

A.5. CSIRO report FSP 1893

On 22 March 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on a specimen comprised a 1200-mm x 1200-mm x 222-mm timber framed floor/ceiling system. The floor system comprised 190-mm x 45-mm MSG (Machine Stress Graded), H2 Treated Timber Joists at 600-mm centres with one joist located in the middle of the frame. The floor consisted of 19mm thick H2 Ecoply Structural Plywood. The underside of the Plywood and joists were coated with 1000 microns dry film thickness of FBL-100 intumescent coating.

A.6. CSIRO report FSP 1894

On 20 March 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on a 1200-mm x 1200-mm x 222-mm timber framed floor/ceiling system. The floor system comprised 190 mm x 45 mm MSG (Machine Stress Graded), H2 Treated Timber Joist at 600-mm centres with one joist located in the middle of the frame. The floor consisted of 19mm thick H2 Ecoply Structural Plywood. The underside of the frame was lined with a single layer of 13-mm thick plasterboard and coated with 1000 microns dry film thickness of FBL-100 intumescent coating.

A.7. CSIRO report FSP 1888

On 9 March 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on 1200-mm x 1200-mm x 233-mm timber framed floor/ceiling system. The floor system comprised 190-mm x 45-mm MSG (Machine Stress Graded), H2 Treated Timber Joist at 600-mm centres with one joist located in the middle of the frame. The floor consisted of 19mm thick H2 Ecoply Structural Plywood. The underside of the frame was lined with a single layer of 13-mm thick plasterboard. One half the plasterboard on the exposed side had a single coat of Resene Broadwall Waterborne Wallboard Sealer followed by two coats of Resene Spacecote Flat applied by roller. A total dry film thickness of 750 microns of FBL-100 intumescent coating was applied by spraying two coats of 550 wet film thickness over the full plasterboard face on the unexposed side.

A.8. CSIRO report FSP 1929

On 18 April 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on a 1200-mm long x 1200-mm wide x 223-mm thick timber framed floor/ceiling system. The floor system comprised 190 mm high x 45 mm wide MSG (Machine Stress Graded), H3 treated radiata pine joists spaced at 600-mm centres with one joist located in the centre of the frame. The floor consisted of a layer of 19-mm thick CAA Structural Plywood. The underside of the floor framing was lined with a single layer of 13-mm thick GIB standard grade plasterboard with a butt joint and coated with an 1115-µm dry film thickness of ICG 100 intumescent coating.

A.9. CSIRO report FSP 1918

On 24 July 2018, this Division conducted a pilot-scale fire-resistance test in accordance with AS 1530.4-2014 on a 1200-mm long x 1200-mm wide x 223-mm thick timber framed floor/ceiling system. The floor system comprised 190 mm high x 45 mm wide MSG (Machine Stress Graded), H3 treated radiata pine joists spaced at 600-mm centres with one joist located in the centre of the frame. The floor consisted of a layer of 19-mm thick CAA Structural Plywood. The underside of the floor framing was lined with a single layer of 13-mm thick GIB standard grade plasterboard and coated with 1078µ microns dry film thickness of ICG 100 intumescent coating then coated by a roller with two coats of Resene SpaceCote Flat ceiling paint.

A.10. Summary of test report data

Table A1: Results for lined flooring

Test report	**Maximum TC temperature (°C)**							
	Paint/plasterboard interface		Joist/plasterboard interface		10mm cover over joist		20mm cover over joist	
Time in the test	45 min.	60 min.	45 min.	60 min.	45 min.	60 min.	45 min.	60 min.
FSH 1919 - 13mm std. GIB plasterboard 1094µm – FBL-100	818	-	178	-	100	-	98	-
FSH 1920 - 13mm std. GIB plasterboard with extra screws 1040µm – FBL-100	853	862	273	667	104	240	94	109
FSP 1889 - 6mm fibre cement 1038µm – FBL-100	363	418	323	402	218	291	112	162
FSP 1894 - 13mm std. GIB plasterboard 1000µm – FBL-100	616	923	280	372	127	219	103	114
FSP 1929 - 13mm std. GIB plasterboard – butt joint 1115µm – FBL-100	-	-	304	452	227	291	123	172
FSP 1888 13mm std. GIB plasterboard, painted side 750µm – FBL-100	600 Lost a TC at 41min.	-	607	-	106	-	105	-
FSP 1888 13mm std. GIB plasterboard, unpainted side 750µm – FBL-100	843		215		111		104	
FSP 1918 13mm std. GIB plasterboard 1078µ – FBL-100	806	847	248	393	117	281	101	142

Table A2: results for lined flooring – Ecoply plywood

Test report	Maximum TC temperature (°C)							
	Paint/plasterboard interface		Joist/plasterboard interface		10mm cover over the joist		20mm cover over the joist	
	30min.	44min.	30min.	44min.	30min.	44min.	30min.	44min.
FSP 1890 12mm Ecoply plywood ceiling lining 710µm – FBL-100	520	709	182	591	103	240	86	105

Table A3: Results for unlined flooring

Test report	Maximum TC temperature (°C)					
	Joist/paint		10mm cover over the joist		20mm cover over the joist	
	30min.	45min.	30min.	45min.	30min.	45min.
FSP 1893 – no lining 1000µm – FBL-100	435	616	166	372	106	320

Table A4: Results for RISF and ICG paint behaviour

Test report	Maximum TC temperature (°C) at 30min. on Joist/plasterboard interface	Time to reach >300°C on Joist/plasterboard interface	Time to reach >300°C on joist 10mm cover	A time where coating starts to fall off	Temp at 30 minutes on the back of the linings
FSH 1919 13mm std. GIB plasterboard 1094µm – FBL-100		51			
FSH 1920 - 13mm std. GIB plasterboard with extra screws 1040µm – FBL-100		47	Max. at 62 min. is 284°C		250°C
FSP 1889 6mm fibre cement 1038µm – FBL-100	249	41	62	66	250°C
FSP 1890 12mm Ecoply plywood ceiling lining 710µm – FBL-100	182	38	Max. at 44min. is 240°C	32	<200°C
FSP 1894 13mm std. GIB plasterboard 1000µm – FBL-100	156	56	68	48	
FSP 1929 13mm std. GIB plasterboard with butt joint 1115µm – FBL-100	250	45	62	N/A	
FSP 1888 13mm std. GIB plasterboard, painted side 750µm – FBL-100	115	45	Max at 48min is 206°C	38	
FSP 1888 13mm std. GIB plasterboard, unpainted side 750µm – FBL-100	111	48	Maxi at 48min is 126°C	38	
FSP 1918 13mm std. GIB plasterboard 1078µ – FBL-100 Ceiling paint finish	117	52	63	32	
FSP 1893 – no lining 1000µm – FBL-100		18 (at joist paint interface)	41		

Table A5: Results for char depth of joists

Test report	Char Depth at 30 minutes (mm)	Char Depth at 45 minutes (mm)	Char Depth at 60 minutes (mm)
FSH 1920 - 13mm std. GIB plasterboard with extra screws 1040µm – FBL-100	0	0	8.7
FSP 1889 6mm fibre cement 1038µm – FBL-100	0	6.2	10
FSP 1890 12mm Ecoply plywood ceiling lining 710µm – FBL-100	0		
FSP 1893 – no lining 1000µm – FBL-100	0	12.5	

Appendix B Analysis of Variations

B.1 Load case analysis

The assessment makes use of an analysis of the load cases as to the difference in the vertical load capacity required for walls and floors before and during a fire event. Lateral and uplift loading has not been considered as these loads actions are not included in the fire load case.

For walls and floors, AS\NZS 1170.0-2002 (amdt 5) specifies the load cases appropriate for strength. These include short-term loads, long-term loads and the relevant load cases considered for wall and floor framing exposed to fire are a), b) and c).

4.2.2 Strength

The basic combinations for the ultimate limit states used in checking strength (see Clause 7.2.2) shall be as follows, where the long-term and combination factors are given in Table 4.1:

(a)	$E_d = [1.35G]$	permanent action only (does not apply to prestressing forces)
(b)	$E_d = [1.2G, 1.5Q]$	permanent and imposed action
(c)	$E_d = [1.2G, 1.5\psi_\ell Q]$	permanent and long-term imposed action
(d)	$E_d = [1.2G, W_u, \psi_c Q]$	permanent, wind and imposed action
(e)	$E_d = [0.9G, W_u]$	permanent and wind action reversal
(f)	$E_d = [G, E_u, \psi_E Q]$	permanent, earthquake and imposed action
(g)	$E_d = [1.2G, S_u, \psi_c Q]$	permanent action, actions given in Clause 4.2.3 and imposed action

For walls and floors the required load cases be AS\NZS 1170.0-2002 (amdt 5) are described below.

4.2.4 Combinations of actions for fire

The combination of factored actions used when confirming the ultimate limit state for fire shall be as follows:

$$[G, \text{thermal actions arising from the fire}, \psi_\ell Q]$$

NOTE: Where it is appropriate to consider the stability of remaining walls that may collapse outwards after a fire event, other ultimate limit states criteria are given in Section 6.

To make practical use of the above information, the ratio of the fire load case (4.2.4) divided by the ambient load cases (4.2.2 a), b) and c)) is plotted against the ratio of dead load\ Live load or G\Q.

The resulting plot of the ratio is shown below

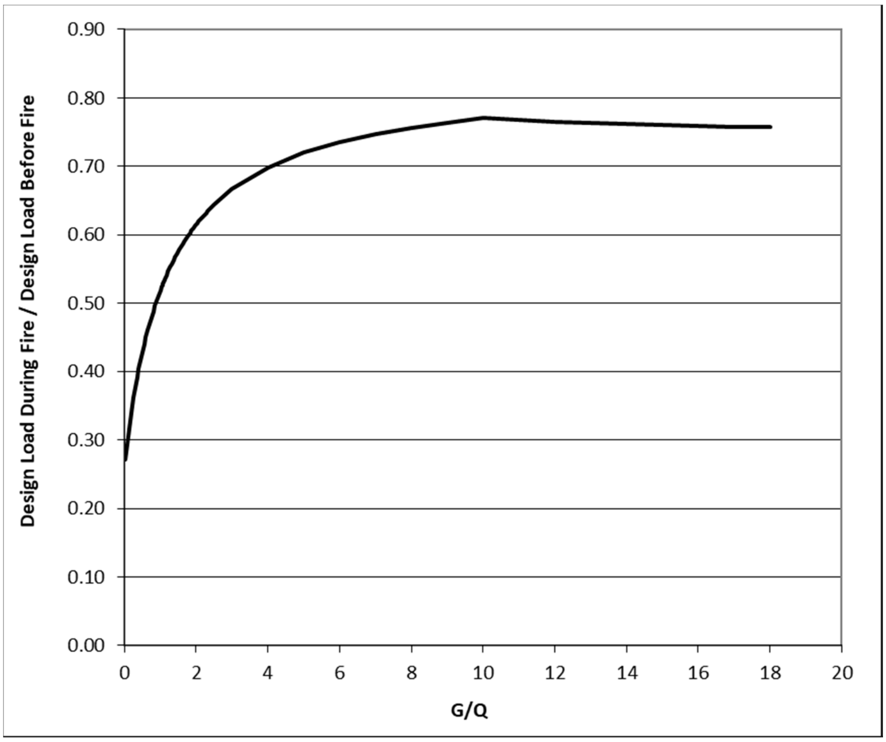

Figure B1 – Load Demand during fire load case

The significance of this plot is that it verifies the fire load case does not exceed 77% of the ambient strength load cases for any ratio of G/Q.

The conclusion is used in the structural capacity check for the fire load case and the justification that it is permissible to allow a reduction in joist or stud capacity to 77% of the original design capacity without the fire load case governing the design.

For floor applications where when the dead load is limited to a maximum of 1.2kPa and live load is 1.5kPa the load demand for the fire load case is only 39% of the original design capacity without the fire load case governing the design.

B.2 Proposed floor systems

The proposed floor construction as tested in FSH 1920 subjected to the following variations:

- The inclusion of walls lined on each side with tested lining and applied coated as that tested in FSH 1920.
- The structural framing shall be *radiata* pine or denser solid timber.
- Flooring shall be 19mm or thicker structural plywood, fibre cement or particleboard.
- The floor structure shall be designed in accordance with NZS 3603.
- The floor joist framing shall be at least 190mm deep and 45mm wide.
- The ceiling linings shall be to 13mm GIB standard plasterboard or 12mm or thicker Ecoply plywood or 6mm or thicker fibre cement.
- The inclusion of ceiling painted plasterboard prior to application of FBL-100 coating.
- The inclusion of ceiling paint top coat after the application of FBL-100 coating on plasterboard.
- The proposed construction is summarised in Table 1 and Figures 9 to 12.

Structural adequacy and char

The critical aspect of the structural performance of floor systems are the amount of char of the joist compared to that for the full scale loaded floor system tested in FSH 1920, which was lined with 13mm Gib plasterboard protected with 1040µm of FBL-100.

With reference to the data presented in Appendix A the char levels at 30, 45 and 60 minutes are presented for each of the tested substrate and protection systems in Table B1.

Table B1: Results for char depth of joists

Test report	Char Depth at 30 minutes (mm)	Char Depth at 45 minutes (mm)	Char Depth at 60 minutes (mm)
FSH 1920 - 13mm std. GIB plasterboard with extra screws 1040µm – FBL-100	0	0	8.7
FSP 1889 6mm fibre cement 1038µm – FBL-100	0	6.2	9.9
FSP 1890 12mm Ecoply plywood ceiling lining 710µm – FBL-100	0		

Structural adequacy and residual timber properties for the fire load case

The temperature profile within the framing during the fire event is difficult to know with a high level of certainty due to a complex interaction the heating and moisture movement within the timber even in parts of the timber remote from the charred front. Fortunately, timber is a highly effective thermal insulator which mitigates these effects for short-term exposure. However, for long and gradual heating, it is considered reasonable and conservative to apply a reduction to the timber properties of the uncharred section.

Taking into account the thermal insulating properties of the timber and the transient nature of the heating it is considered reasonable and conservative to consider the whole uncharred timber section to be at 200°C. This is more accurate and least conservative for the highly stressed parts of the element and most thermally conservative for the least stressed parts of the element, thereby minimising the overall conservatism.

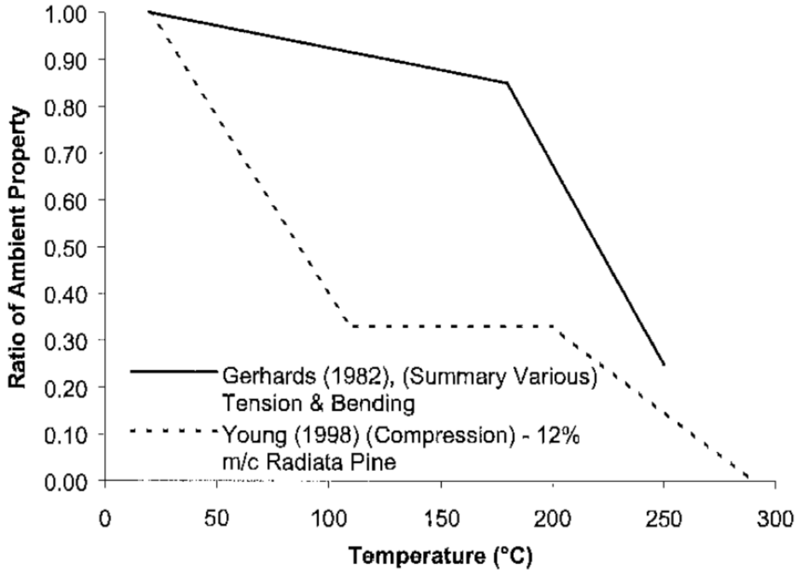

Figure B2 – Residual timber properties at medium temperatures

The reduction in the mechanical properties is shown above in Figure B1. The reduction in tensile and bending properties of specimens are significantly different to those obtained from tests conducted in pure compression (Young et al., 1998). Note the results of Gerhards (1982) is a summary of properties from a literature review.

It is considered very difficult to know the exact temperature profile within the timber for the duration of the fire event. Due to the high thermal resistance and moisture of timber it is likely most of the uncharred part of the element will remain at or below 100C for the duration of the fire event. On balance, the most structural critical part of the section is that closest to the char boundary and therefore higher in temperature. In this assessment, a conservative approach is taken and the analysis is undertaken on the basis that the whole timber section is at 200°C. Based on the literature review relating to residual timber properties the residual capacities for bending and compression strength are 60 and stiffness is shown in Table B2.

Table B2: Results for char depth of joists

Timber Property	**Residual capacity during the fire load event**
Bending Strength	69%
Compression Strength	69%
Bending and Compression stiffness	30%

The joist applications considered in this report are based on the spans in NZS 3604 and shown in Table B3 to B5 for framing at least 45mm thick and 190mm deep.

Table B3 – SG6 spans for 1.5kPa floor loads in NZS 3604

(a) 1.5 kPa floor load (dry in service)			
Floor joist size	Maximum span* of joists at a maximum spacing (mm) of:		
	400	450	600
(mm x mm)	(m)	(m)	(m)
90 x 45	1.30	1.25	1.10
140 x 35	1.90	1.80	1.60
140 x 45	2.45	2.35	1.80
190 x 45	3.20	3.10	2.85
240 x 45	3.95	3.90	3.50
290 x 45	4.70	4.55	4.15

Table B4 - SG8 spans for 1.5kPa floor loads in NZS 3604

(a) 1.5 kPa floor load SG 8 (dry in service)			
Floor joist size	Maximum span* of joists at a maximum spacing (mm) of:		
	400	450	600
(mm x mm)	(m)	(m)	(m)
90 x 45	1.45	1.40	1.25
140 x 35	2.10	2.00	1.80
140 x 45	2.70	2.60	2.00
190 x 45	3.55	3.45	3.15
240 x 45	4.40	4.30	3.90
290 x 45	5.20	5.05	4.60

Table B5 - SG10 spans for 1.5kPa floor loads in NZS 3604

(a) 1.5 kPa floor load (dry in service)			
Floor joist size	Maximum span* of joists at a maximum spacing (mm) of:		
	400	450	600
(mm x mm)	(m)	(m)	(m)
90 x 45	1.55	1.50	1.30
140 x 35	2.25	2.15	1.90
140 x 45	2.90	2.80	2.15
190 x 45	3.80	3.70	3.35
240 x 45	4.70	4.60	4.20
290 x 45	5.60	5.40	4.95

This assessment is based on a calculation of the ratio of bending stress in the fire load case compared with that in the non-fire load case. The calculations are presented in Table B6 below.

Table B6– Calculation in accordance with NZS 3603 for lined floors – Fire and non-fire load case.

Example of Calculations

	Bending Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
	Compression Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
	Modulus of Elasticity Reduction		**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**
	D	mm	190	240	290	190	240	290	190	240	290	190	240	290
	B	mm	45	45	45	45	45	45	45	45	45	45	45	45
	Span	m	2.55	3.25	3.9	2.55	3.25	3.9	2.55	3.25	3.9	2.55	3.25	3.9
	Spacing	mm	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Live Load	kpa	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Dead load		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Grade		6	6	6	8	8	8	10	10	10	12	12	12
	t	mm	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
	Pinned Supports		yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Input	**D**	mm	190	240	290	190	240	290	190	240	290	190	240	290
	B	mm	45	45	45	45	45	45	45	45	45	45	45	45
	E	MPa	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
	G	0.5	400	400	400	400	400	400	400	400	400	400	400	400
	J	mm^4	2.28E+06	3.00E+06	3.72E+06	2.28E+06	3.00E+06	3.72E+06	2.28E+06	3.00E+06	3.72E+06	2.28E+06	3.00E+06	3.72E+06
	k10		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	H		2.55	3.25	3.9	2.55	3.25	3.9	2.55	3.25	3.9	2.55	3.25	3.9
	Lx	mm	1912.5	2.4	2.9	1.9	2.4	2.9	1.9	2.4	2.9	1.9	2.4	2.9
	Ly	mm	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
	Char Factor t	mm	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Offset of Centroid	**d**	mm	9.40	10.64	11.87	9.40	10.64	11.87	9.40	10.64	11.87	9.40	10.64	11.87
BENDING														
	Phi		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Before Fire	**K1**		0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Major Axis Bendir	**Dc**	mm	190	240	290	190	240	290	190	240	290	190	240	290
	Bc	mm	45	45	45	45	45	45	45	45	45	45	45	45
	Iyc	mm^4	2.57E+07	5.18E+07	9.15E+07	2.57E+07	5.18E+07	9.15E+07	2.57E+07	5.18E+07	9.15E+07	2.57E+07	5.18E+07	9.15E+07
	Ixc	mm^4	1.44E+06	1.82E+06	2.20E+06	1.44E+06	1.82E+06	2.20E+06	1.44E+06	1.82E+06	2.20E+06	1.44E+06	1.82E+06	2.20E+06
	Zxc	mm^2	2.71E+05	4.32E+05	6.31E+05	2.71E+05	4.32E+05	6.31E+05	2.71E+05	4.32E+05	6.31E+05	2.71E+05	4.32E+05	6.31E+05
	S		12.67	16.00	19.33	12.67	16.00	19.33	12.67	16.00	19.33	12.67	16.00	19.33
	k8		0.97	0.86	0.70	0.97	0.86	0.70	0.97	0.86	0.70	0.97	0.86	0.70
	k4		1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	k5		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F'b	MPa	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
	Phi Mx	N.mm	1.37E+06	1.94E+06	2.31E+06	1.37E+06	1.94E+06	2.31E+06	1.37E+06	1.94E+06	2.31E+06	1.37E+06	1.94E+06	2.31E+06
BENDING														
After Fire	**K1**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Major Axis Bendir	**Dc**	mm	180.1	230.1	280.1	180.1	230.1	280.1	180.1	230.1	280.1	180.1	230.1	280.1
	Bc	mm	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1
	Iyc	mm^4	3.77E+05	4.88E+05	5.99E+05	3.77E+05	4.88E+05	5.99E+05	3.77E+05	4.88E+05	5.99E+05	3.77E+05	4.88E+05	5.99E+05
	Zxc	mm^2	1.90E+05	3.10E+05	4.59E+05	1.90E+05	3.10E+05	4.59E+05	1.90E+05	3.10E+05	4.59E+05	1.90E+05	3.10E+05	4.59E+05
	S		15.39	19.67	23.94	15.39	19.67	23.94	15.39	19.67	23.94	15.39	19.67	23.94
	k8		0.88	0.69	0.50	0.88	0.69	0.50	0.88	0.69	0.50	0.88	0.69	0.50
	k4		1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	k5		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F'b	MPa	6.9	6.9	6.9	9.66	9.66	9.66	9.66	9.66	9.66	19.32	19.32	19.32
	Phi Mx	N.mm	1.17E+06	1.48E+06	1.58E+06	1.63E+06	2.07E+06	2.21E+06	1.63E+06	2.07E+06	2.21E+06	3.27E+06	4.14E+06	4.43E+06
Load Demand in fire for Dead load < 1.2kpa			0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Design Ratio (after fire\before fire) x load demand			0.46	0.51	0.57	0.33	0.36	0.41	0.33	0.36	0.41	0.16	0.18	0.20

With reference to the calculations presented in Table B6, it is confirmed the proposed floor joist constructions, the protection levels, duration of exposure and char for various spans, grade, and section are more stressed than for the non-fire load case provided the dead loads are less than 1.2kPa.

Based on the above discussion it is confirmed for the proposed protection systems with less than 9.9mm char at the required test duration, the fire load case is less critical than the non-fire load case and it is considered the structural adequacy of the proposed wall and floor framing will be maintained for the times listed in Table B7 when tested in accordance with AS 1530.4-2014.

Table B7 – Load capacity and given time

Lining and Structural element	Construction Specification	Time (mins)	Is fire Load capacity greater than ambient load capacity at this time?
Coated plywood lined timber framed floor	Figure 9 and Table 1	30	Yes
Coated plasterboard and Fibre cement lined timber framed floor	Figure 10 and Table 1	45	Yes
Coated plasterboard lined timber framed floor	Figure 11 and Table 1	60	Yes
Coated fibre cement lined the timber framed floor	Figure 12 and Table 1	60	Yes

Integrity

With reference to the proposed floor systems, the critical aspects of the integrity performance of proposed floor systems are based on the ability of the ceiling lining to remain in place as a viable substrate for the protection systems.

The proposed ceiling linings all provided various levels of adhesion for the coating, and the linings also had an inherent fire resistance even as the coating had fallen away. The mode of degradation of the floor systems tested generally follow these steps;

a) Degradation of the coating ceiling interface
b) Charing of joist behind the lining
c) The fire spread into the cavity
d) Spread through flooring above, and flaming integrity failure and insulation failure.

For the tests of lined floor systems referenced in Appendix A, the critical time of interest for structural adequacy (time of relatively low char) was in the case of the full scale FSH 1920 and the pilot scale tests FSP 1888, FSP 1889, FSP 1890, FSP 1894, FSP 1918 and FSP 1929, always less than the time at which fire spread to the cavity and spread through the flooring above.

In theory the performance of ceiling linings in pilot scale can overestimate the integrity performance of the floor-ceiling system, however, in this case, critical times for structural adequacy are so low, and before there is significant fire attack to the floor cavity, it is considered the pilot scale test results are still representative at this time.

Based on the low levels of fire attack to the cavity for the proposed protected lining options it is considered the proposed construction for lined floors will achieve an integrity performance of at least the time for structural adequacy when tested in accordance with AS 1530.4-2014.

Insulation

With reference to the proposed floor systems, the critical aspects of the insulation performance of proposed floor systems are based on the ability of the ceiling lining to remain in place and as a variable substrate for the protection systems and prevent the direct attack to the flooring above.

The proposed ceiling linings all provided various levels of adhesion for the coating, and the linings also had an inherent fire resistance even when the coating had fallen away. The mode of degradation of the floor systems tested generally follow these steps;

a) Degradation of the coating ceiling interface
b) Charing of joist behind the lining
c) The fire spread into the cavity
d) Spread through flooring above, and flaming integrity failure and insulation failure.

For the test referenced in Appendix A, the critical time of interest for structural adequacy (time of relatively low char) was in the case of the full scale FSH 1920 and the pilot scale tests FSP 1888, FSP 1889, FSP 1890, FSP 1894, FSP 1918 and FSP 1929 was always less than the time at which fire spread to the cavity and caused insulation failure.

As for integrity performance, in theory the performance of ceiling linings in pilot scale can overestimate the integrity performance of the linings, however, in this case, critical times for structural adequacy are so low, and before there is significant fire attack to the floor cavity, it is considered the pilot scale test results are still representative at this time.

Based on the low levels of fire attack to the cavity for the proposed protected lining options it is considered the proposed construction for lined floors will achieve an insulation performance of at least the time for structural adequacy when tested in accordance with AS 1530.4-2014.

Resistance to incipient spread of fire

With reference to the proposed floor systems, the critical aspects of the resistance to incipient spread of fire performance of proposed floor systems are based on the ability of the ceiling lining to remain in place and as a substrate for the protection systems and prevent the lining temperature from reaching 250°C.

With reference to data presented in Appendix A Table A4, it is confirmed the RISF for plasterboard and fibre cement linings when coated with 1040 µm of FBL-100 coating was at least 30 minutes when tested in accordance with AS 1530.4-2014.

As the proposed construction does not apply a variation to the coating or lining thickness, this will also apply to the proposed construction.

B.3 Unlined floor systems

The proposed floor construction as tested in FSH 1920 subjected to the following variations:

- The structural framing shall be radiata pine or denser solid timber.
- The underside of the flooring and joist shall be coated with the same amount of coating as the floor specimen tested in FSP 1893.
- Flooring shall be 19mm structural plywood or 19mm or thicker fibre cement or particleboard.
- The floor structure shall be designed in accordance with NZS 3603 and where applicable using a reduced design capacity.
- The support for the floor structure shall be supported by
  - the direct bearing of at least 50mm under the joist on a protected timber wall or bearer, a masonry structure or the like.
  - joist hangers that are fully protected with at least 1 layer of 13mm GIB Fyreline plasterboard prior to the application of the paint system.
- The proposed construction is summarised in Table 1 and Figure 13.

The proposed construction comprises floor systems as tested in FSV 1920 without ceiling lining and with floor joists and the underside of flooring coated with 1000µ of FBL-100 Intumescent coating.

Structural adequacy and char

With respect to the proposed floor construction, the critical aspects of the floor system performance with respect to structural adequacy is the amount of char of the joist compared that for the full scale loaded floor system tested in FSH 1920 lined with 13mm Gib plasterboard protected with 1040µm of FBL-100.

With reference to the data presented in Appendix A the char levels at 30 and 45 minutes are presented in Table B4 for this system.

Table B8: Results for char depth of joists for profile coating

Test report	Char Depth at 30 minutes (mm)	Char Depth at 45 minutes (mm)
FSP 1893 – no lining 1000µm – FBL-100	0	12.5

Structural adequacy and residual timber properties for the fire load case

Based on reference to the discussion in Section B2 the properties of timber shown in Table B2 and the methodology for the calculation of the residual section is also applicable.

There are some differences in the way the section properties were calculated. For a lined system, the char attack is primarily from the lower edge with side char reducing the further it is from the lined edge. For a profile coated specimen the char measured in the side and the lower edge is applied to the whole section and the reduced section properties based on the notional rectangular section left.

As for the lined systems, the temperature profile within the framing during the fire event is difficult to know with a high level of certainty due to a complex interaction the heating and moisture movement within the timber even in parts of the timber remote from the charred front. Fortunately, timber is a highly effective thermal insulator which mitigates these effects for short-term exposure. However, for long and gradual heating, it is considered reasonable and conservative to apply a reduction to the timber properties of the uncharred section.

Taking into account the thermal insulating properties of the timber and the transient nature of the heating it is considered reasonable and conservative to consider the whole uncharred timber section to be at 200°C. This is more accurate and least conservative for the highly stressed parts of the element, and most thermally conservative for the least stressed parts of the element thereby minimising the overall conservatism.

The reduction in the mechanical properties is shown above in Figure B1. The reduction in tensile and bending properties of specimens are significantly different to those obtained from tests conducted in pure compression (Young et al., 1998). Note the results of Gerhards (1982) is a summary of properties from a literature review.

It is considered very difficult to know the exact timber profile within the timber section for the duration of the fire event as discussed previously due to the high thermal resistance and moisture of timber. It is likely most of the uncharred part of the element will remain at or below 100C for the duration of the fire event. On balance, the most structural critical part of the section is that closest to the char boundary and therefore higher in temperature. In this assessment, a conservative approach is taken, and the analysis undertaken considered the whole timber section is at 200°C. Based on the literature review relating to residual timber properties, the residual capacities for bending and compression strength are 60 and stiffness are shown in Table B2.

As for lined systems, the joist applications considered in this report are based on the spans in NZS 3604 and shown in Table B3 to B5 for framing at least 45mm thick and 190mm deep.

This assessment is based on a calculation of the ratio of stress in the fire load case compared with that in the non-fire load case. The calculations are presented below in Table B9 below.

Table B9– Calculation in accordance with NZS 3603 for unlined floors – fire and non-fire load case.

Example of Calculations			2.94								
	Bending Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
	Compression Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
	Modulus of Elasticity Reduction		**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**
	D	mm	190	240	290	190	240	290	190	240	290
	B	mm	45	45	45	45	45	45	45	45	45
	Span	m	3.1	3.9	4.55	2.55	3.25	3.9	3.7	4.6	5.4
	Spacing	mm	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Live Load	kpa	2	2	2	2	2	2	2	2	2
	Dead load										
Grade			6	6	6	8	8	8	10	10	10
	t	mm	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
	Pinned Supports		yes	yes	yes	yes	yes	yes	yes	yes	yes
Input	**D**	mm	190	240	290	190	240	290	190	240	290
	B	mm	45	45	45	45	45	45	45	45	45
	E	MPa	6000	6000	6000	8000	8000	8000	6000	6000	6000
	G	0.5	400	400	400	533.3333	533.3333	533.3333	400	400	400
	J	mm^4	4.40E+05	5.73E+05	7.06E+05	4.40E+05	5.73E+05	7.06E+05	4.40E+05	5.73E+05	7.06E+05
	k10		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	H		3.1	3.9	4.55	2.55	3.25	3.9	3.7	4.6	5.4
	Lx	mm	2325.0	2.9	3.4	1.9	2.4	2.9	2.8	3.5	4.1
	Ly	mm	1200	1200	1200	1200	1200	1200	1200	1200	1200
	Char Factor t	mm	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Offset of Centroid	**d**	mm	11.98	13.59	15.20	11.98	13.59	15.20	11.98	13.59	15.20
BENDING											
	Phi		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Before Fire	**K1**		0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Major Axis Bendir	**Dc**	mm	190	240	290	190	240	290	190	240	290
	Bc	mm	45	45	45	45	45	45	45	45	45
	Iyc	mm^4	2.57E+07	5.18E+07	9.15E+07	2.57E+07	5.18E+07	9.15E+07	2.57E+07	5.18E+07	9.15E+07
	Ixc	mm^4	1.44E+06	1.82E+06	2.20E+06	1.44E+06	1.82E+06	2.20E+06	1.44E+06	1.82E+06	2.20E+06
	Zxc	mm^2	2.71E+05	4.32E+05	6.31E+05	2.71E+05	4.32E+05	6.31E+05	2.71E+05	4.32E+05	6.31E+05
	S		12.67	16.00	19.33	12.67	16.00	19.33	12.67	16.00	19.33
	k8		0.97	0.86	0.70	0.97	0.86	0.70	0.97	0.86	0.70
	k4		1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	k5		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F'b	MPa	6.9	6.9	6.9	9.66	9.66	9.66	6.9	6.9	6.9
	Phi Mx	N.mm	1.37E+06	1.94E+06	2.31E+06	1.92E+06	2.71E+06	3.24E+06	1.37E+06	1.94E+06	2.31E+06
BENDING											
After Fire	**K1**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Major Axis Bendir	**Dc**	mm	177.5	227.5	277.5	177.5	227.5	277.5	177.5	227.5	277.5
	Bc	mm	20	20	20	20	20	20	20	20	20
	Iyc	mm^4	3.52E+04	4.58E+04	5.65E+04	3.52E+04	4.58E+04	5.65E+04	3.52E+04	4.58E+04	5.65E+04
	Zxc	mm^2	1.05E+05	1.73E+05	2.57E+05	1.05E+05	1.73E+05	2.57E+05	1.05E+05	1.73E+05	2.57E+05
	S		26.63	34.13	41.63	26.63	34.13	41.63	26.63	34.13	41.63
	k8		0.41	0.25	0.17	0.41	0.25	0.17	0.41	0.25	0.17
	k4		1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	k5		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F'b	MPa	6.9	6.9	6.9	9.66	9.66	9.66	9.66	9.66	9.66
	Phi Mx	N.mm	2.98E+05	3.03E+05	3.07E+05	4.18E+05	4.24E+05	4.30E+05	4.18E+05	4.24E+05	4.30E+05
RESULTS											
	Load Demand in fire for Dead load < 1.2kpa		0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
	Design Ratio (after		1.79	2.49	2.94	1.79	2.49	2.94	1.28	1.78	2.10
	Capacity Reduction Factor		0.56	0.40	0.34	0.56	0.40	0.34	0.78	0.56	0.48

With reference to the calculations presented in Table B9, it is confirmed the proposed floor joist constructions, the protection provided, duration of exposure of 30 and 45 minutes and char for various spans, grade, and section are more stressed than for the non-fire load case provided the dead loads are less than 1.2kPa.

Based on the above discussion it is confirmed for the proposed protection systems with less than 0mm char at 30 minutes test duration, the fire load case is less critical than the non-fire load case and it is considered the structural adequacy of the proposed wall and floor framing will be maintained for 30 minutes when tested in accordance with AS 1530.4-2014.

Based on the above discussion and reference to Table B8 it is confirmed for the proposed protection systems with less than 12.5mm char at 45 minutes test duration the fire load case is more critical than the non-fire load case and it is considered the load capacity of the proposed floor framing shall be reduced by the factor shown in Table B10 so as to maintain the structural adequacy of 45 minutes when tested in accordance with AS 1530.4-2014.

Table B10 – Framing capacity reduction profile coated joists Figure 13.

Joist Section	Reduction factor for ultimate strength capacity at 45 minutes		
	MSG 6 & MSG 8	MSG 10	MSG 12
190 x 45	0.56	0.78	1.0
240 x 45	0.40	0.56	1.0
290 x 45	0.34	0.48	0.95

Integrity

With reference to the proposed floor systems, the critical aspects of the integrity performance of proposed floor systems are based on the ability of the coating to remain in place and protect the joist from structural degradation (charring) and the flooring from direct integrity and insulation failure.

With reference to the tests of unlined lined floor systems referenced in Appendix A (FSP 1893), the critical time of interest for structural adequacy in FSP 1893 was 30 and 45 minutes, prior to an integrity or insulation failure of the flooring. During the test, a dark spot appeared on the flooring at 46 minutes.

In theory the performance of linings in pilot scale can overestimate the integrity performance of the floor-ceiling system, however, in this case, critical times for structural adequacy are so low and before there is significant fire attack to the plywood and as such it is considered the pilot scale test results are representative of the full scale performance at this time.

Based on the low levels of fire attack (char) to the joists and flooring and absence of integrity failure up to 45 minutes, it is considered the proposed construction will achieve an integrity performance of at least the time for structural adequacy when tested in accordance with AS 1530.4-2014.

Insulation

With reference to the proposed floor systems, the critical aspects of the insulation performance of proposed floor systems are based on the ability of the coating to remain in place and slow the attack to the joists and flooring above.

With reference to to the test report FSP 1893 which comprised a timber joist and the underside of the flooring coated with 1000µm – FBL-100 coating. When tested it achieved an insulation performance of 45 minutes without failure.

Similarly for integrity, in theory, the performance of pilot scale can overestimate the insulation performance, however, in this case, the critical times for structural adequacy are so low, and before there is significant fire attack to the flooring, it is considered the pilot scale test results are still representative at this time if applied to larger specimens.

Based on the low levels of fire attack to the flooring proposed protected lining options it is considered the proposed construction for unlined floors will achieve an insulation performance of at least the time for structural adequacy (30 and 45 minutes) when tested in accordance with AS 1530.4-2014.

B.4 Proposed wall systems

The proposed wall construction as tested in FSH 1920 subjected to the following variations:

- Orientated as a wall rather than floor as tested.
- Wall framing shall be at least 90mm deep.
- The structural framing shall be *radiata* pine or denser solid timber.
- The wall structure shall be designed in accordance with NZS 3603 and where applicable using a reduced design cross section as listed in Table 1.
- The inclusion of walls lined on one or both sides and the applied FBL-100 as tested in FSH 1920.
- The wall/ceiling linings shall be to 13mm GIB standard plasterboard or 12mm Ecoply plywood or 6mm fibre cement or thicker.
- The inclusion of painted plasterboard prior to application of FBL-100 coating.
- The inclusion of a paint top coat after the application of FBL-100 coating on plasterboard.
- The proposed construction is summarised in Table 1 and Figures 1 to 8.

Orientation of the tested and proposed element

This assessment is based on a series of lined and protected full scale and pilot scale floor ceiling tests whose modes of degradation where described generally as follows

a) Degradation of the coating lining interface, progressive falloff of coating
b) Charing of joist behind the lining
c) The fire spread into the cavity (with or without breach of the lining)
d) Spread through flooring above, and flaming integrity failure and insulation failure.

The primary and initial mode of degradation of the coating is expected to be similar when the coating is on a wall, however, due to gravity acting in a different direction, it is considered safe and conservative that the coating will not fall off as quickly when exposed as a floor.

This will have a number of compounding beneficial effects in the early stages of the test, though these positive effects may diminish past the 45-60 minute as the total fall off of the coating may occur at that time rather than progressively fall away as was observed in the floor/ceiling tests.

Based on the above it is considered that for all of the proposed lining systems the performance obtained with a floor-ceiling test can be conservatively applied to wall orientation of the same coating specification and lining material and fixity.

Structural adequacy and char

The critical aspects of the performance of wall systems, such as the amount of char of the stud with the proposed linings compared that for the full scale loaded floor system tested in FSH 1920 lined with 13mm Gib plasterboard protected with 1040µm of FBL-100.

With reference to the data presented in Appendix A the char levels at 30, 45 and 60 minutes are presented for each of the tested substrate and protection systems in Table B1.

Structural adequacy and residual timber properties for the fire load case

The temperature profile within the framing during the fire event is difficult to know with a high level of certainty due to a complex interaction the heating and moisture movement within the timber even in parts of the timber remote from the charred front. Fortunately, timber is a highly effective thermal insulator which mitigates these effects for short-term exposure. However, for long and gradual heating, it is considered reasonable and conservative to apply a reduction to the timber properties of the uncharred section.

Taking into account the thermal insulating properties of the timber and the transient nature of the heating it is considered reasonable an conservative to consider the whole uncharred timber section to be at 200°C. This is more accurate and least conservative for the highly stressed parts of the element, and most thermally conservative for the least stressed parts of the element thereby minimising the overall conservatism.

The reduction in the mechanical properties is shown in Figure B1. The reduction in tensile and bending properties of specimens are significantly different to those obtained from tests conducted in pure compression (Young et al., 1998). Note the results of Gerhards (1982) is a summary of properties from a literature review.

It is considered very difficult to know the exact timber profile within the timber section for the duration of the fire event as discussed previously, due to the high thermal resistance and moisture of timber it is likely most of the uncharred part of the element will remain at or below 100°C for the duration of the fire event. On balance, the most structural critical part of the section is that closest to the char boundary and therefore higher in temperature. In this assessment, a conservative approach is taken, and the analysis is undertaken on the basis the whole timber section is at 200°C. Based on the literature review relating to residual timber properties the residual capacities for bending and compression strength and stiffness are shown in Table B2.

The wall applications considered in this report are based on the various stud heights ranging from 2.4m to 4.2m for framing at least 45mm thick and 90mm deep.

This assessment is based on a calculation of the ratio of stress in the fire load case compared with that in the non-fire load case. The calculations are presented below in Table B11 and Table 12 below.

Table B11– Calculation in accordance with NZS 3603 for lined wall – G6 and G8 grade

Example of Calculations

	Bending Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
	Compression Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
	Modulus of Elasticity Reduction		**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**
	D	mm	90	90	90	90	90	90	90	90	90	90	90	90	90	90
	B	mm	45	45	45	45	45	45	45	45	45	45	45	45	45	45
	Height	mm	2400	2700	3000	3300	3600	3900	4200	2400	2700	3000	3300	3600	3900	4200
	Grade		6	6	6	6	6	6	6	8	8	8	8	8	8	8
	t	mm	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
	Design Ratio Fire Load Case		**0.62**	**0.62**	**0.66**	**0.76**	**0.88**	**0.99**	**0.97**	**0.61**	**0.61**	**0.64**	**0.75**	**0.86**	**0.97**	**0.96**
	Pinned Supports		no	no	no	no	no	no	no	no	no	no	no	no	no	no
Input	**D**	mm	90	90	90	90	90	90	90	90	90	90	90	90	90	90
	B	mm	45	45	45	45	45	45	45	45	45	45	45	45	45	45
	E	MPa	6000	6000	6000	6000	6000	6000	6000	8000	8000	8000	8000	8000	8000	8000
	G	0.5	400	400	400	400	400	400	400	533.3333	533.3333	533.3333	533.3333	533.3333	533.3333	533.3333
	J	mm^4	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05
	k10		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	H		2400	2700	3000	3300	3600	3900	4200	2400	2700	3000	3300	3600	3900	4200
	Lx	mm	1800	2025	2250	2475	2700	2925	3150	1800	2025	2250	2475	2700	2925	3150
	Ly	mm	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
	Char Factor t	mm	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Offset of Centroid	**d**	mm	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93
COMPRESSION																
Before Fire	**K1**		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Major Axis																
	Iy	mm^4	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05
	Ix	mm^4	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06
	A	mm^2	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00
	Pcr	N	5.00E+04	3.95E+04	3.20E+04	2.64E+04	2.22E+04	1.89E+04	1.63E+04	6.66E+04	5.26E+04	4.26E+04	3.52E+04	2.96E+04	2.52E+04	2.18E+04
	S3		20.01	22.51	25.01	27.51	30.01	32.51	35.01	20.01	22.51	25.01	27.51	30.01	32.51	35.01
	K8		0.67	0.55	0.46	0.38	0.32	0.28	0.24	0.67	0.55	0.46	0.38	0.32	0.28	0.24
Minor Axis																
	Pcr		2.81E+04	2.81E+04	2.81E+04	2.81E+04	2.81E+04	2.81E+04	2.81E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04
	S2		26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68
	K8		0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Phi		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	F'c	MPa	15	15	15	15	15	15	15	18	18	18	18	18	18	18
	Phi Ncx	N	1.95E+04	1.61E+04	1.34E+04	1.12E+04	9.45E+03	8.09E+03	7.01E+03	2.34E+04	1.93E+04	1.61E+04	1.34E+04	1.13E+04	9.71E+03	8.41E+03
	Phi Ncy	N	8.20E+03	8.20E+03	8.20E+03	8.20E+03	8.20E+03	8.20E+03	8.20E+03	9.84E+03	9.84E+03	9.84E+03	9.84E+03	9.84E+03	9.84E+03	9.84E+03
After Fire	**K1**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Dc	mm	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1
	Bc	mm	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1
	Iyc	mm^4	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05
	Ixc	mm^4	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06
	Zxc	mm^2	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04
	Ac	mm^3	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03
	a	mm	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10
	b	mm	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01
	h	mm	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10
Major Axis Buckling																
	Pcr	N	9.25E+03	7.31E+03	5.92E+03	4.89E+03	4.11E+03	3.50E+03	3.02E+03	1.23E+04	9.74E+03	7.89E+03	6.52E+03	5.48E+03	4.67E+03	4.03E+03
	S		22.53	25.34	28.16	30.97	33.79	36.61	39.42	22.53	25.34	28.16	30.97	33.79	36.61	39.42
	k8		0.55	0.45	0.37	0.30	0.26	0.22	0.19	0.55	0.45	0.37	0.30	0.26	0.22	0.19
Minor Axis Buckling																
	Pcr	N	5.16E+03	5.16E+03	5.16E+03	5.16E+03	5.16E+03	5.16E+03	5.16E+03	6.87E+03	6.87E+03	6.87E+03	6.87E+03	6.87E+03	6.87E+03	6.87E+03
	S		30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17
	k8		0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	F'c	MPa	10.35	10.35	10.35	10.35	10.35	10.35	10.35	12.42	12.42	12.42	12.42	12.42	12.42	12.42
	Phi		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Phi Ncx	N	1.81E+04	1.47E+04	1.20E+04	9.99E+03	8.44E+03	7.23E+03	6.26E+03	2.17E+04	1.77E+04	1.44E+04	1.20E+04	1.01E+04	8.68E+03	7.52E+03
	Phi Ncy	N	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.26E+04	1.26E+04	1.26E+04	1.26E+04	1.26E+04	1.26E+04	1.26E+04
BENDING																
Major Axis Bending																
	Mcr		1.30E+06	1.30E+06	1.30E+06	1.30E+06	1.30E+06	1.30E+06	1.30E+06	1.73E+06	1.73E+06	1.73E+06	1.73E+06	1.73E+06	1.73E+06	1.73E+06
	S		7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41
	k8		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	k4		1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
	k5		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	F'b	MPa	6.9	6.9	6.9	6.9	6.9	6.9	6.9	9.66	9.66	9.66	9.66	9.66	9.66	9.66
	Phi Mx	N.mm	3.30E+05	3.30E+05	3.30E+05	3.30E+05	3.30E+05	3.30E+05	3.30E+05	4.62E+05	4.62E+05	4.62E+05	4.62E+05	4.62E+05	4.62E+05	4.62E+05
Applied Load																
	M*	N.mm	5.68E+04	5.68E+04	5.68E+04	5.68E+04	5.68E+04	5.61E+04	4.86E+04	6.82E+04	6.82E+04	6.82E+04	6.82E+04	6.82E+04	6.73E+04	5.83E+04
	N*	N	8195.938952	8195.939	8195.939	8195.939	8195.939	8090.733	7008.84	9835.127	9835.127	9835.127	9835.127	9835.127	9708.88	8410.608
Before Fire																
Minor axis	**Design ratio y**		1.00	1.00	1.00	1.00	1.00	0.99	0.86	1.00	1.00	1.00	1.00	1.00	0.99	0.86
Major axis	**Design ratio x**		0.42	0.51	0.61	0.73	0.87	1.00	1.00	0.42	0.51	0.61	0.73	0.87	1.00	1.00
	Max		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
After Fire																
Fireload\ambinet Load			0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Fire load Case N*		N	6310.872993	6310.873	6310.873	6310.873	6310.873	6229.865	5396.807	7573.048	7573.048	7573.048	7573.048	7573.048	7475.838	6476.168
Fire Load Case M*		N.mm	43734.34984	43734.35	43734.35	43734.35	43734.35	43172.96	37399.87	52481.22	52481.22	52481.22	52481.22	52481.22	51807.55	44879.85
Minor axis	**Design ratio y**		0.62	0.62	0.62	0.62	0.62	0.61	0.53	0.61	0.61	0.61	0.61	0.61	0.61	0.52
Major axis	**Design ratio x**		0.48	0.56	0.66	0.76	0.88	0.99	0.97	0.46	0.54	0.64	0.75	0.86	0.97	0.96
	Max		0.62	0.62	0.66	0.76	0.88	0.99	0.97	0.61	0.61	0.64	0.75	0.86	0.97	0.96

Table B12– Calculation in accordance with NZS 3603 for lined wall – G10 and G12 grade

Example of Calculations

		Bending Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
		Compression Strength Reduction		**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**	**69%**
		Modulus of Elasticity Reduction		**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**	**30%**
		D	mm	90	90	90	90	90	90	90	90	90	90	90	90	90	90
		B	mm	45	45	45	45	45	45	45	45	45	45	45	45	45	45
		Height	mm	2400	2700	3000	3300	3600	3900	4200	2400	2700	3000	3300	3600	3900	4200
	Grade			10	10	10	10	10	10	10	12	12	12	12	12	12	12
		t	mm	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
		Design Ratio Fire Load Case		**0.61**	**0.61**	**0.61**	**0.72**	**0.84**	**0.95**	**0.94**	**0.61**	**0.61**	**0.61**	**0.71**	**0.83**	**0.94**	**0.93**
		Pinned Supports		no	no	no	no	no	no	no	no	no	no	no	no	no	no
Input		**D**	mm	90	90	90	90	90	90	90	90	90	90	90	90	90	90
		B	mm	45	45	45	45	45	45	45	45	45	45	45	45	45	45
		E	MPa	10000	10000	10000	10000	10000	10000	10000	14000	14000	14000	14000	14000	14000	14000
		G	0.5	666.6667	666.6667	666.6667	666.6667	666.6667	666.6667	666.6667	933.3333	933.3333	933.3333	933.3333	933.3333	933.3333	933.3333
		J	mm^4	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05	8.36E+05
		k10		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		H		2400	2700	3000	3300	3600	3900	4200	2400	2700	3000	3300	3600	3900	4200
		Lx	mm	1800	2025	2250	2475	2700	2925	3150	1800	2025	2250	2475	2700	2925	3150
		Ly	mm	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
		Char Factor t	mm	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Offset of Centroid		**d**	mm	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93	6.93
COMPRESSION																	
Before Fire		**K1**		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Major Axis																
		Iy	mm^4	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05	6.83E+05
		Ix	mm^4	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06	2.73E+06
		A	mm^2	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00	4050.00
		Pcr	N	8.33E+04	6.58E+04	5.33E+04	4.40E+04	3.70E+04	3.15E+04	2.72E+04	1.17E+05	9.21E+04	7.46E+04	6.17E+04	5.18E+04	4.42E+04	3.81E+04
		S3		20.01	22.51	25.01	27.51	30.01	32.51	35.01	20.01	22.51	25.01	27.51	30.01	32.51	35.01
		K8		0.67	0.55	0.46	0.38	0.32	0.28	0.24	0.67	0.55	0.46	0.38	0.32	0.28	0.24
	Minor Axis																
		Pcr		4.68E+04	4.68E+04	4.68E+04	4.68E+04	4.68E+04	4.68E+04	4.68E+04	6.56E+04	6.56E+04	6.56E+04	6.56E+04	6.56E+04	6.56E+04	6.56E+04
		S2		26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68
		K8		0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		Phi		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
		F'c	MPa	20	20	20	20	20	20	20	25	25	25	25	25	25	25
		Phi Ncx	N	2.60E+04	2.15E+04	1.79E+04	1.49E+04	1.26E+04	1.08E+04	9.35E+03	3.25E+04	2.69E+04	2.24E+04	1.86E+04	1.57E+04	1.35E+04	1.17E+04
		Phi Ncy	N	1.09E+04	1.09E+04	1.09E+04	1.09E+04	1.09E+04	1.09E+04	1.09E+04	1.37E+04	1.37E+04	1.37E+04	1.37E+04	1.37E+04	1.37E+04	1.37E+04
After Fire		**K1**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Dc	mm	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1
		Bc	mm	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1	35.1
		Iyc	mm^4	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05	4.18E+05
		Ixc	mm^4	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06	1.69E+06
		Zxc	mm^2	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04	4.75E+04
		Ac	mm^3	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03	3.17E+03
		a	mm	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10	35.10
		b	mm	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01	44.01
		h	mm	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10
	Major Axis Buckling																
		Pcr	N	1.54E+04	1.22E+04	9.87E+03	8.15E+03	6.85E+03	5.84E+03	5.03E+03	2.16E+04	1.71E+04	1.38E+04	1.14E+04	9.59E+03	8.17E+03	7.05E+03
		S		22.53	25.34	28.16	30.97	33.79	36.61	39.42	22.53	25.34	28.16	30.97	33.79	36.61	39.42
		k8		0.55	0.45	0.37	0.30	0.26	0.22	0.19	0.55	0.45	0.37	0.30	0.26	0.22	0.19
	Minor Axis Buckling																
		Pcr	N	8.59E+03	8.59E+03	8.59E+03	8.59E+03	8.59E+03	8.59E+03	8.59E+03	1.20E+04	1.20E+04	1.20E+04	1.20E+04	1.20E+04	1.20E+04	1.20E+04
		S		30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17	30.17
		k8		0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
		F'c	MPa	13.8	13.8	13.8	13.8	13.8	13.8	13.8	17.25	17.25	17.25	17.25	17.25	17.25	17.25
		Phi		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Phi Ncx	N	2.41E+04	1.97E+04	1.60E+04	1.33E+04	1.13E+04	9.64E+03	8.35E+03	3.02E+04	2.46E+04	2.00E+04	1.67E+04	1.41E+04	1.21E+04	1.04E+04
		Phi Ncy	N	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.75E+04	1.75E+04	1.75E+04	1.75E+04	1.75E+04	1.75E+04	1.75E+04
BENDING																	
	Major Axis Bending																
		Mcr		2.16E+06	2.16E+06	2.16E+06	2.16E+06	2.16E+06	2.16E+06	2.16E+06	3.02E+06	3.02E+06	3.02E+06	3.02E+06	3.02E+06	3.02E+06	3.02E+06
		S		7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41	7.41
		k8		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		k4		1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
		k5		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		F'b	MPa	13.8	13.8	13.8	13.8	13.8	13.8	13.8	19.32	19.32	19.32	19.32	19.32	19.32	19.32
		Phi Mx	N.mm	6.60E+05	6.60E+05	6.60E+05	6.60E+05	6.60E+05	6.60E+05	6.60E+05	9.24E+05	9.24E+05	9.24E+05	9.24E+05	9.24E+05	9.24E+05	9.24E+05
Applied Load																	
	M*		N.mm	7.57E+04	7.57E+04	7.57E+04	7.57E+04	7.57E+04	7.48E+04	6.47E+04	9.47E+04	9.47E+04	9.47E+04	9.47E+04	9.47E+04	9.34E+04	8.10E+04
	N*		N	10927.92	10927.92	10927.92	10927.92	10927.92	10787.64	9335.775	13659.9	13659.9	13659.9	13659.9	13659.9	13484.56	11681.4
Before Fire																	
Minor axis		**Design ratio y**		1.00	1.00	1.00	1.00	1.00	0.99	0.85	1.00	1.00	1.00	1.00	1.00	0.99	0.86
Major axis		**Design ratio x**		0.42	0.51	0.61	0.73	0.87	1.00	1.00	0.42	0.51	0.61	0.73	0.87	1.00	1.00
		Max		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
After Fire																	
Fireload\ambinet Load				0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Fire load Case N*			N	8414.497	8414.497	8414.497	8414.497	8414.497	8306.486	7188.547	10518.12	10518.12	10518.12	10518.12	10518.12	10383.11	8994.678
Fire Load Case M*			N.mm	58312.47	58312.47	58312.47	58312.47	58312.47	57563.95	49816.63	72890.58	72890.58	72890.58	72890.58	72890.58	71954.94	62333.12
Minor axis		**Design ratio y**		0.61	0.61	0.61	0.61	0.61	0.60	0.52	0.61	0.61	0.61	0.61	0.61	0.60	0.52
Major axis		**Design ratio x**		0.44	0.52	0.61	0.72	0.84	0.95	0.94	0.43	0.51	0.60	0.71	0.83	0.94	0.93
		Max		0.61	0.61	0.61	0.72	0.84	0.95	0.94	0.61	0.61	0.61	0.71	0.83	0.94	0.93

With reference to the calculations presented in Table B11 and B12, it is confirmed the proposed wall stud constructions, the protection levels, duration of exposure and char for various spans, grade, and section are less stressed than for the non-fire load case regardless of the dead and live load ratios.

Based on the above discussion it is confirmed for the proposed protection systems with less than 9.9mm char at the required test duration the fire load case is less critical than the non-fire load case and it is considered the structural adequacy of the proposed wall and floor framing will be maintained for the times listed in Table B13 when tested in accordance with AS 1530.4-2014.

Table B13 – Load capacity and given time

Coated lining and Structural element	Construction Specification	Load Capacity	Time (minutes)
Plywood lined timber framed wall	Figure 1 and Table 1	No reduction in wall capacity for fire load case	30
	Figure 2 and Table 1		30 from the coated side only
Plasterboard and Fibre cement lined timber framed wall	Figure 3 and Table 1		45
	Figure 4 and Table 1		45 from the coated side only
Plasterboard lined timber framed wall	Figure 5 and Table 1		60
	Figure 6 and Table 1		60 from the coated side only
Fibre cement lined timber framed wall	Figure 7 and Table 1		60
	Figure 8 and Table 1		60 from the coated side only

Integrity

With reference to the proposed wall systems, the critical aspects of the integrity performance of proposed wall systems are based on the ability of the coating and lining to remain in place and as a variable substrate for the protection systems.

As discussed above for structural adequacy the tested floor systems can be used to assess the wall performance conservatively.

The proposed wall linings all provided various levels of adhesion for the coating, and the linings also had an inherent fire resistance even as the coating had fallen away. The mode of degradation of the tested linings generally follow these steps;

a) Degradation of the coating lining interface, progressive fall off of coating
b) Charing of joist behind the lining
c) The fire spread into the cavity (with or without breach of the lining)
d) Spread through flooring above, and flaming integrity failure and insulation failure.

For the tests of lined floor systems referenced in Appendix A, the critical time of interest for structural adequacy (time of relatively low char) was in the case of the full scale FSH 1920 and the pilot scale tests FSP 1888, FSP 1889, FSP 1890, FSP 1894, FSP 1918 and FSP 1929 always less than the time at which fire spread to the cavity and spread through the flooring above.

The significance of this finding is that as for floors, walls will be limited structurally at or before the lining falls away or integrity failure is imminent.

In theory the performance of ceiling linings in pilot scale can overestimate the integrity performance of the floor-ceiling system, however, in this case, critical times for structural adequacy are so low, and before there is significant fire attack to the floor cavity, it is considered the pilot scale test results are still representative at this time.

Based on the low levels of fire attack to the cavity and the discussion of the orientation of the element above, it I considered for the proposed protected walls without penetrations will achieve an integrity performance of at least the time for structural adequacy when tested in accordance with AS 1530.4-2014.

Insulation

With reference to the proposed wall systems, the critical aspects of the insulation performance of proposed wall systems are based on the ability of the wall lining to remain in place as a substrate for the protection systems and prevent the direct attack to the non-fire side lining above.

The proposed wall linings all provided various levels of adhesion for the coating, and the linings also had an inherent fire resistance even when the coating had fallen away.

For the test referenced in Appendix A, the critical time of interest for structural adequacy (time of relatively low char) was in the case of the full scale FSH 1920 and the pilot scale tests FSP 1888, FSP 1889, FSP 1890, FSP 1894, FSP 1918 and FSP 1929, always less than the time it which fire spread to the cavity and caused insulation failure.

As for integrity performance, in theory the performance of wall linings in pilot scale can overestimate the integrity performance of the linings, however, in this case, critical times for structural adequacy are so low, and before there is significant fire attack to the cavity, it is considered the pilot scale test results are still representative at this time.

Based on the low levels of fire attack to the cavity for the proposed protected lining options, it is considered the proposed construction for lined walls will achieve an insulation performance of at least the time for structural adequacy when tested in accordance with AS 1530.4-2014.

In conclusion, it is considered the proposed construction will achieve the FRR presented in Table B14 when tested in accordance with AS 1530.4-2014.

Table B14 – Summary of assessed performance

<table>
<tr><th>Coated lining and Structural element</th><th>Construction Specification</th><th>Load Capacity</th><th>FRR</th></tr>
<tr><td rowspan="2">Plywood lined timber framed wall</td><td>Figure 1 and Table 1</td><td rowspan="8">No Reduction in wall capacity for fire load case</td><td>30/30/30</td></tr>
<tr><td>Figure 2 and Table 1</td><td>30/30/30 from the coated side only</td></tr>
<tr><td rowspan="2">Plasterboard and fibre cement lined timber framed wall</td><td>Figure 3 and Table 1</td><td>45/45/45</td></tr>
<tr><td>Figure 4 and Table 1</td><td>45/45/45 from the coated side only</td></tr>
<tr><td rowspan="2">Plasterboard lined timber framed wall</td><td>Figure 5 and Table 1</td><td>60/60/60</td></tr>
<tr><td>Figure 6 and Table 1</td><td>60/60/60 from the coated side only</td></tr>
<tr><td rowspan="2">Fibre cement lined timber framed wall</td><td>Figure 7 and Table 1</td><td>60/60/60</td></tr>
<tr><td>Figure 8 and Table 1</td><td>60/60/60 from the coated side only</td></tr>
</table>

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