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Aspects of the Design of Fire-Resistant Plasterboard Walls in Fire

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ABSTRACT: This paper gives the detailed results of a series of fire tests on plasterboard fire-resistant wall construction where that construction was penetrated by steel elements simulating the presence of penetrating purlins or rafters. The tests were conducted to investigate the temperatures experienced by such penetrating elements on the unexposed side of the wall and within the wall itself. The aim of the experiments was to investigate fire spread due to the temperature rise of penetrating elements and whether protection of such elements on each side of the wall is necessary. The experimental work shows that for practical fire wall construction, typical of which is likely to be found in warehouse construction, the temperatures achieved by the steel members on the unexposed side of the wall are not sufficiently high to cause fire spread. It is concluded that protection of the penetrating roof members is not required. Since fire walls are often used in single storey buildings, where the roof structure is mostly unprotected, it is important to ensure that a fire wall is not damaged by the deforming roof structure and that there is adequate fire-stopping around penetrations to prevent spread of flame through gaps. Measures to achieve these outcomes are considered in this paper.

Keywords: fire wall, steel penetrations, fire resistance, warehouse buildings, fire tests

1 INTRODUCTION

The refurbishment or extension of warehouse and other buildings often requires the construction of fire walls throughout parts of an existing building or between an existing and new part. The purpose of such construction is to “compartmentalise” the building so as to conform to building regulations and/or insurance requirements. A convenient way to do this is to use drywall construction utilising plasterboard and steel studs as this does not require the use of cranes and can be relatively easily constructed from within the building after construction of the main building structure. In such situations, the Building Code of Australia (BCA) regards these walls as non-loadbearing elements since they are only designed to carry their own weight. The positioning of fire walls throughout the building means that roof members such as steel purlins (if a wall is parallel to the rafters) and rafters (if a wall is parallel to the purlins) may need to pass through the tops of the walls. Potentially, heat may be transferred through these penetrating steel members resulting in an increased chance of spread of fire should combustibles be directly adjacent or in contact with the steel members on the unexposed side of the wall. If the temperature rise of the penetrating elements on the unexposed side is sufficiently high, then it may not be possible for the top of the wall to be sufficiently laterally restrained in the fire situation. The standard fire tests described in this paper were conducted so as to determine the temperatures likely to be achieved by the steel penetrating elements on the unexposed side of the wall. The tests were conducted in the fire test laboratory at the Centre for Environmental Safety and Risk Engineering of Victoria University.

In addition to the transmission of heat from one side of a fire wall to the other, it is possible that loads may be applied to the wall by virtue of deformation of the adjacent unprotected roof structure. The application of such loads to a wall could result in its failure and in the subsequent spread of fire, particularly since these walls are only designed to support their own weight. It is therefore necessary to anticipate such deformations and prevent significant loads being applied to the plasterboard construction. These matters are considered in this paper and relevant design recommendations are given to minimise the likelihood of damage.

A previous paper considered the penetration of concrete walls by steel roof members (Bennetts and Goh, 2001).

2 TEST SET-UP AND SPECIMENS

2.1 *Test Set-Up*

The tests were conducted in a standard fire test furnace that internally measures 2.1 m width × 1.8 m depth × 2.1 m height. Figure 1 shows an overall view of the furnace with a specimen mounted on one side.

Figure 1 Overall View of Test Set-up

2.2 *Test Specimens*

To cover the range of likely practical situations eight specimens were tested. The tests are summarised in Table 1. Each test specimen (except tests VUT155 and VUT157) contained two 200 mm wide x 1200 mm long steel plates. The thickness of the plates varied (2, 8, 12 and 20 mm) in different tests. The plates were chosen to simulate members ranging from a purlin (in the case of the 2 mm plate), a typical cleat plate (8 mm), a hot-rolled beam web (12mm), a combination of cleat plate and hot-rolled web (20mm), or a flange of a hot-rolled section (20mm). A typical test specimen with thermocouple (T/C) locations is shown in Figure 2.

Table 1 Summary of Fire Test Specimens

Test No	Stud Size (mm)	Exposed Wall Layers	Penetrating Plate Thicknesses (mm)	Steel Beam in Wall?
VUT148	92	1 x 16 mm	2 and 8	no
VUT149	92	2 x 16 mm	8 and 12	no
VUT150	92	2 x 16 mm	2 and 12	no
VUT151	150	1 x 16 mm	2 and 8	no
VUT153	150	2 x 16 mm	2 and 12	no
VUT154	150	1 x 16 mm	8 and 12	no
VUT155	200	2 x 16 mm	12	yes
VUT157	92	1 x 16 mm	20 and C20020 purlin	no

This figure shows an elevation view of the wall specimen with the two penetrating plates (top) and a cross-section through the wall (bottom). T/C's 1–8 were located on the thinner plate with T/C's 9–16 on the thicker plate. T/C's 1 and 9 were on the exposed side of the wall, 25mm out from the plasterboard, whilst 5-8 and 13-16 were on the unexposed side, 25mm and 50mm away from the plasterboard, respectively. The other thermocouples are within the wall.

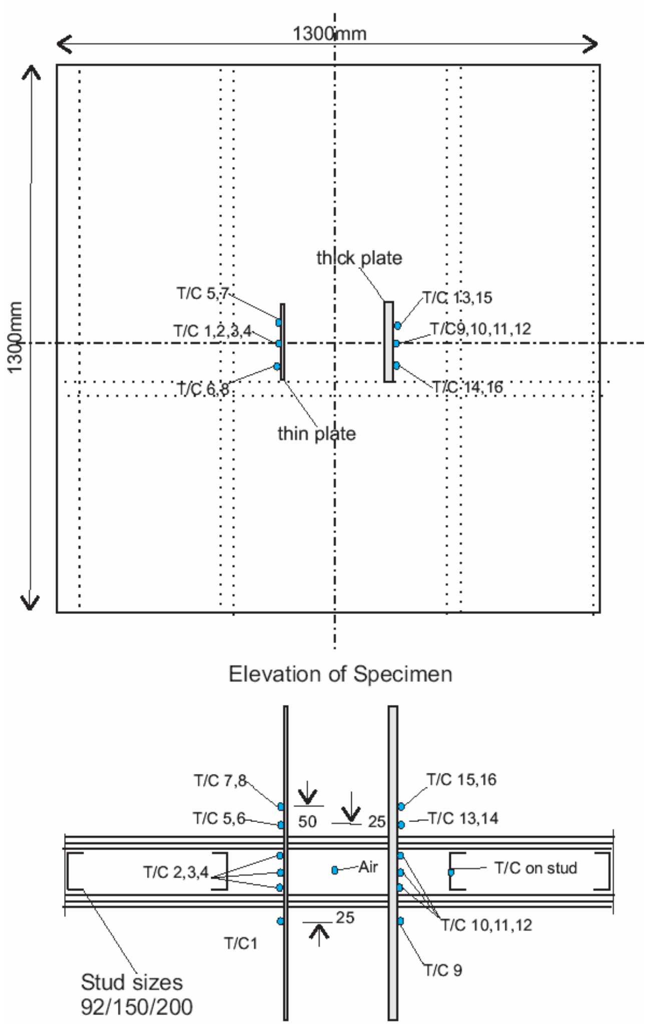

Figure 2 Details of Specimen

Figure 3 Specimen before Cladding with Plasterboard

Figure 3 shows a specimen during construction, from the unexposed side, prior to fixing the plasterboard sheets. The thermocouples spot-welded to the steel plates can be observed. Test VUT155 incorporated one penetrating steel plate with dimensions 12 mm thick x 200 mm wide x 1200 mm long and a 200UC46 steel member placed within the plasterboard wall. Test VUT157 contained a C20020 Purlin and a 20mm steel plate identical to the one used in test VUT155. In all cases the gaps between the steel plates and the plasterboards were sealed with fire-resistant mastic (PYROPANEL fire-resistant sealant). The plasterboard sheets were cut around the penetrating plates before fixing to the frames.

3 TESTS AND RESULTS

3.1 *Steel Temperatures*

Wall specimens with a single layer of Boral Firestop plasterboard on each side were subjected to a standard fire test exposure of 120 minutes (VUT148, VUT151, VUT154 and VUT157), whereas specimens with a double layer of plasterboard on each side of the wall (VUT149, VUT150, VUT153 and VUT155) were subjected to fire test exposure of 180 minutes. It should be noted that wall construction required to have an FRL of 60/60/60 will incorporate a single layer of 16mm Boral Firestop on each side of the wall, whereas walls required to have an FRL of -/120/120 will typically have a double layer on each side of the wall.

For all tests, the furnace temperature versus time relationship closely followed the standard time temperature curve given in AS1530.4 (Standards Australia, 2005). Unexposed plasterboard temperatures were below 100°C at 180 minutes for the wall specimens with double layers of plasterboard on each side of the wall. During the tests with the specimens incorporating single layers of Boral Firestop, the unexposed face temperatures were below 115°C and 300°C at 60 minutes and 90 minutes, respectively, for walls with 92 mm studs; and below 105°C and 225°C at 60 minutes and 90 minutes, respectively, for walls with 150 mm studs.

The temperature of the steel penetrating elements is now considered with a summary of the maximum temperatures reached by the penetrating elements on the *unexposed* side of the walls given in Table 2 (one layer of 16mm Boral Firestop on each side) and Table 3 (two layers of Boral Firestop on each side). For all penetrating members the maximum temperature on the unexposed side was 270°C or less after 60 minutes for walls (92mm studs) with one layer of 16 mm plasterboard but reached up to 351°C after 90 minutes. In the case of 150 mm studs and single layers of plasterboard, the temperatures of the 2, 8 and 12 mm steel plates were less than 255°C at 90 minutes.

In the case of the double layer walls (Table 3), the maximum temperature of the penetrating element (2, 8 and 12mm plates) on the unexposed side of the wall remained below 240°C after 120 minutes irrespective of the stud size. However, the 12 mm steel plate reached a maximum temperature of more than 300°C after 180 minutes for the wall incorporating 92 mm studs. In the case of the wall incorporating 150mm studs the temperature did not exceed 201°C after 120 minutes and 285°C after 180 minutes.

Table 2 Summary of Maximum Temperature Attained by Plates for Walls with Single layers of Boral Firestop

Plate Thickness (mm)	Stud Size (mm)	Temperature on Unexposed Side (°C)		
		60 min	90 min	120 min
2	92	187	246	284
	150	179	237	267
8	92	235	299	333
	150	158	251	317
12	150	161	242	307
20	92	270	351	404

Table 3 Summary of Maximum Temperature Attained by Plates for Walls with Double layers of Boral Firestop

Plate Thickness (mm)	Stud Size (mm)	Temperature on Unexposed Side (°C)		
		90 min	120 min	180 min
2	92	116	150	217

	150	98	141	211
8	92	175	208	262
12	92	201	237	305
	150	158	201	283

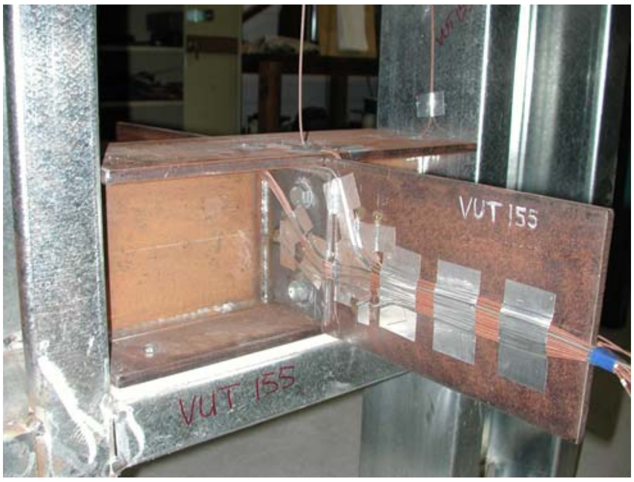

Figure 4 Steel Beam incorporated in Wall Cavity

A 12 mm plate was tested (VUT155) in conjunction with a double layer wall that incorporated a 200UC46 beam placed within the wall cavity The 12 mm plate was discontinuous at the beam web with the plates being bolted on each side to 8mm cleat plates were welded to the beam web (Figure 4). In this configuration, the beam acts as a significant heat sink and results in the penetrating elements having lower temperatures. Maximum temperatures on the unexposed side of 115°C and 177°C were obtained after 120 and 180 minutes, respectively. This can be compared with 158°C and 201°C for the 12mm plate penetrating a double layer wall but without the presence of a beam section within the wall.

Appendix A give temperatures along the 2mm and 12mm penetrating plates, respectively for 150mm stud walls with one and two layers of plasterboard and show the rapid reduction of temperature from the exposed to unexposed face and also the temperature likely to be achieved within the cavity by a penetrating member.

3.2 *Air and Stud Temperatures*

In addition to the measurement of temperature of the penetrating elements, the temperatures of the studs and the adjacent air were measured throughout the tests. A summary of typical results is given in Table 4 and illustrates the air and steel temperatures achieved for walls with double and single layers of plasterboard.

Table 4 Air and Steel Temperatures

Test No	Time (mins)					
	60		90		120	
	Air	Stud	Air	Stud	Air	Stud
148	470		580		620	
149	150	125	300	255	400	350
151	450		550			
153	170	160	330	300	450	410

4 INTERPRETATION OF THERMAL DATA

4.1 *Mechanisms of Heat Transfer*

The flow of heat through a steel member into a wall cavity and then through to the other side of the wall involves a number of heat transfer mechanisms. In the main, heat is conducted along the steel member and into the wall cavity where some of this heat is lost by radiation and convection to the internal surroundings of the wall. However, most of the heat from the penetrating member is lost by conduction along the steel members and subsequent heat loss from the unexposed side of the member via radiation and convection. These mechanisms of heat loss are illustrated in Figure 5 and account for the very significant reduction in steel temperature from one side of the wall to the other.

It should be noted that the thinner the penetrating element, the less the heat transmitted through the wall. This is because the conduction of heat is directly proportional to the cross-sectional area of the conducting element. Thus it follows that sheeting (thickness typically 0.5mm) will conduct less than purlins (1mm – 3mm), which in turn, will conduct less than structural sections (typically greater than 12mm). The test results show that if an attached steel member, such as a hot rolled section, is located within the wall, this member will provide a heat sink that will further reduce the temperature of the penetrating element.

4.2 *Practical Implications*

In the case of fire walls in warehouse situations, the walls do not extended above the roof but finish flush with the sheeting and the top of the purlins. Some heat therefore will be transmitted via the sheeting to the non-fire side of the wall, but the resulting temperature of the sheeting on the unexposed side of the wall will be low compared with that experienced by thicker penetrating members such as purlins and hot rolled members.

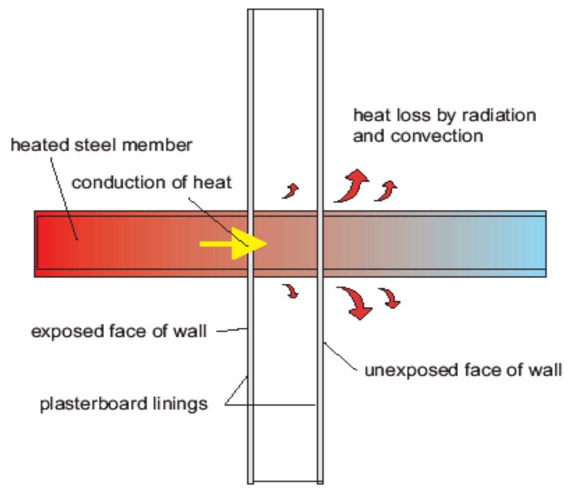

Figure 5 Mechanisms of Heat Transfer

The findings from the above tests illustrate that higher temperatures will be experienced by thicker elements penetrating the wall.

As noted earlier, the key mechanisms for loss of heat conducted through a penetrating element are radiation and convection to the surroundings on the non-fire side of the wall. Since this is the case, these results only apply to situations where such mechanisms are possible. To be specific, the testing described in this paper only relates to situations where penetrating elements on the non-fire side of the wall are not significantly in contact with solids at locations close to the wall. The presence of such solids in contact with the surface area of the steel member would inhibit the loss of heat from the member through radiation and convection close to the wall and this would increase the temperature experienced by the steel on the unexposed side.

Testing undertaken by Schwartz and Lie (1985) and others has shown that contact surface temperatures of more than 300°C are required for ignition of common materials in contact with a hot surface. Much higher temperatures are required to cause ignition of combustibles, not in direct contact, through radiation. Similarly, with respect to the ability of penetrating steel members to provide effective lateral restraint to the top of a wall, temperatures in excess of 600°C would be required to compromise such restraint. Even at 400°C, steel retains more than 60% of its strength and stiffness (Poh, 1996; SCI, 1993). According to the temperature data obtained in the current experiment (see Appendix A), purlins within the wall would not be expected to exceed 500°C within the wall at the connection with a wall frame.

For warehouse situations, due to the height of the wall, it will be generally necessary to utilise plasterboard wall construction that incorporates 150mm studs. A wall required to achieve 120 minutes will have two layers of 16mm on each side and the maximum temperature of penetrating steel purlins (represented by 2 mm thick plates) on the unexposed side of the wall will not exceed 150°C according to the above test results; and in the case of a 12mm element (representing a hot rolled section), 201°C. In the case of hot rolled members, any attached members within the wall or on the unexposed face of the wall, will further reduce the measured temperature. These temperatures are not sufficiently high to lead to fire spread or any significant reduction in strength or stiffness.

5 INTERACTION WITH STRUCTURE

The interaction of the structure with the wall is considered only in relation to the situations associated with factory and warehouse buildings

5.1 *Walls Parallel to Rafters*

In the event of a fire on one side of a fire-resistant wall, the steel roof structure may deform significantly. If the plane of the wall is perpendicular to the purlins, deformation of the purlins and rafters on the fire side of the wall may be significant with the heated rafters dragging the purlins downwards into the wall as illustrated in Figure 6. Such deformation could result in the application of load to the top of the wall and its subsequent failure. The deformation of rafter and attached purlins is now considered in detail.

For warehouse and factory buildings, the load likely to be present on the rafters in the event of a fire is the self-weight of the roof. As a result, the gravity loads in the fire situation will typically be about 0.25 of the ultimate capacity of a frame under gravity loads. This means that temperatures in excess of 650°C will be required over substantial lengths of a rafter to get significant rafter vertical deflection. Purlins adjacent to the heated rafter will be also be heated and are likely to be considerably hotter due to their much greater exposed surface area-to-mass ratio. The growth in length of the purlins will be “absorbed” by buckling of the purlins between the rafters and by the demand for increased length as the adjacent rafter deflects downwards. As the heated rafter deflects downwards it will seek to bend the purlins attached to it. This will result in the formation of a point of rotation or “hinge” at some location along the length of the purlin.

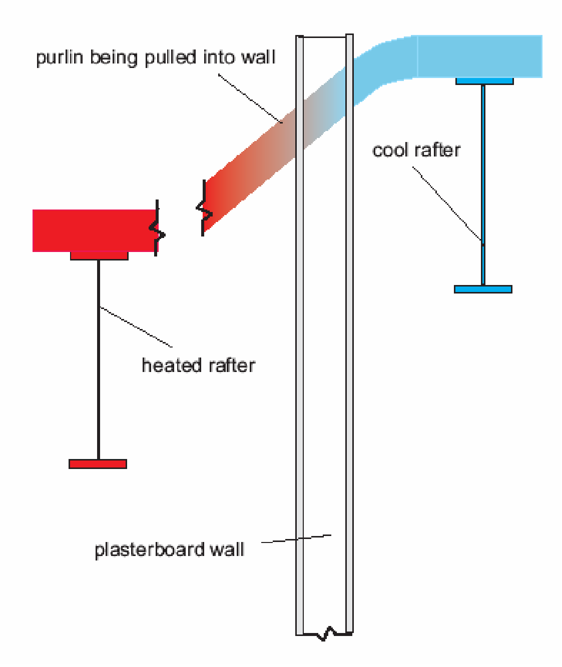

Figure 6 Impact of Deforming Purlins

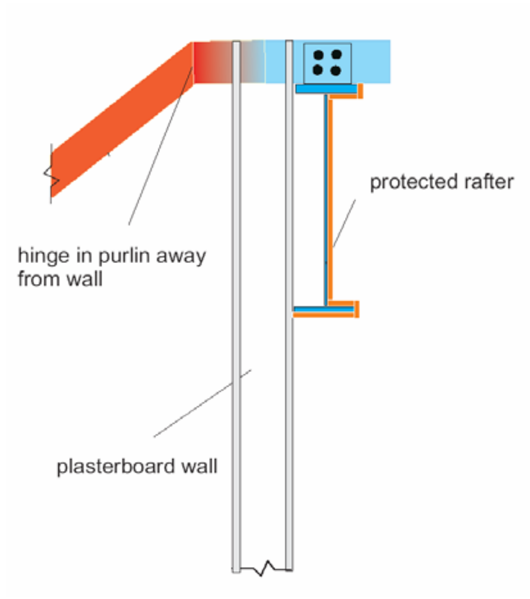

Figure 7 Protection of Beam

If the wall can be located directly adjacent to a rafter that is fire protected (Figure 7), then damage to the wall can be avoided if:

(a) a sufficient gap is provided below the purlin such that the wall will not be damaged by the downwards displacement of the purlin, or

(b) at the wall location, the flexural strength of the purlins is sufficient to prevent purlin failure at the wall location

These two options are now considered in more detail**.** What is the likely deformation of a purlin? The deformation of the purlin will be controlled by the deflection of the rafter. This will continue until the rafter is stationary or the bolts connecting the purlin to the rafter fail. Assuming a purlin temperature of 750^{o}C and a length *l* gives a rafter expansion of $11.7 \times 10^{-6} \times 750 \times l = 0.0088 \times l$. It is only when this slack has been taken up by the demand for increased length due to vertical displacement of the rafter that the purlin will experience tension. The angle α between the horizontal and the deforming purlin (considered as a line) can be calculated from:

$$\alpha = \cos^{-1}\left(\frac{1}{1+11.7\times10^{-6}\times750}\right) = 7.5^{0}$$

If the thickness of the wall is 214mm (C150 studs with 4 layers of 16mm plasterboard) then the purlins could be pulled down into the wall by $214\tan\alpha = 28mm$. The provision of a gap below the purlins of more than this depth would prevent the application of direct force to the wall. This is because further small changes in vertical movement of the rafter will generate tensile forces within the purlins with eventual failure of purlin bolts at the heated rafter.

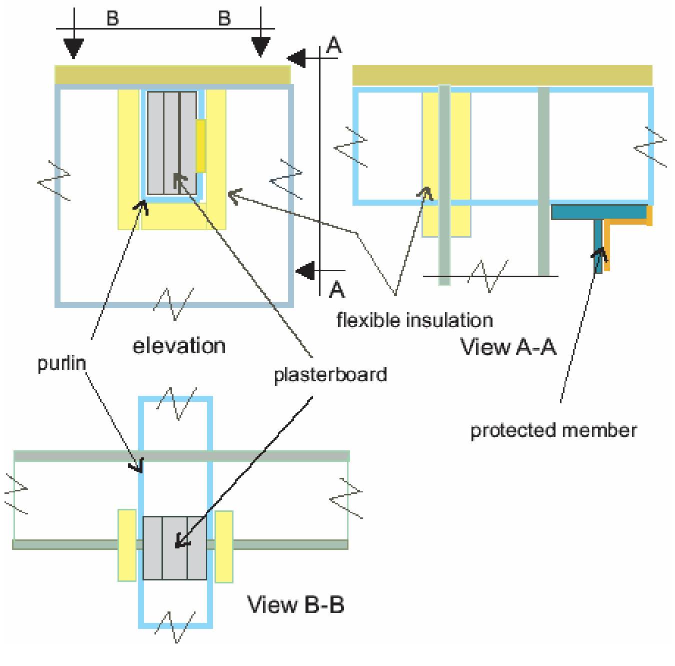

Figure 8 Example of Gap Filling

There will be some plastic deformation at the bolts (estimated as being about 20% of the thermal expansion of the purlin). Thus the provision of a gap of more 35mm would be expected to prevent damage to the top of the wall by the downward deflecting purlins. This gap should be packed with a fire-resistant material in such a way so as to tolerate such movement whilst minimising forces applied to the outer layers of sheeting. One example of gap filling is shown in Figure 8. Such gap filling can be achieved in other ways to prevent the direct passage of flame to the other side of the wall.

Option (b) is now considered and relates to situations where it can be demonstrated that the hinge point within the purlin will remain on the fire-side of the wall (see Figure 7). This can only be the case if the restoring moment applied to the end of the purlin at the protected rafter location is sufficiently high – such as would be achieved by purlin continuity at the cleat. Under these circumstances it would be reasonably expected that a softening "hinge" would form on the fire-side of the wall, but close to the wall, due to the combination of:

(i) lower steel temperatures at the exposed wall lining and within the wall compared with the temperatures experienced on the exposed side
(ii) enhanced torsional restraint to the purlins at the wall location due to the combination of the cleat plate to the rafter and the plasterboard lining, it being noted that the plasterboard will be relatively unaffected at the early stage of the fire
(iii) the lack of rotational and lateral restraint to the purlin away from the wall
(iv) the inclination of the section to buckle laterally when the bottom flange is in compression
(v) the greater reduction in strength of the section away from the wall due to heating
(v) the weakening effect of the buckling associated with the thermal expansion of the purlin

Once such a softened hinge has formed adjacent to the wall, the maximum downward force applied at the hinge and which must be resisted by the purlin section between the exposed wall face and purlin cleat at the protected rafter, is:

$$2 \times 0.20 \times V_{bs} \times \sin\alpha$$

where two purlin cleat bolts each with a shear capacity of V_{bs} have been assumed. Assuming a temperature of around 700°C – fasteners are usually at a slightly lower temperature than the attached steel members due to their lower exposed surface area-to-mass ratio - the strength of the fasteners will be reduced to 20% of the original capacity. The above force will be easily resisted by a continuous purlin.

If the fire wall cannot be located directly adjacent to a rafter, or if the rafter can't be protected, then the purlins must be vertically supported by steel framing within the wall. Not only must there be direct connection between the purlins and the framing but vertical loads applied to the purlins must be resisted by the framing. The load that the framing must resist at each purlin may be taken as the sum of the 50% of the gravity load supported by the purlin between the two rafters plus the load that could be applied by the purlin being pulled downwards by a deforming rafter. The load per purlin that may be applied to each side of the wall and associated with the latter effect can be taken as:

$$2 \times 0.20 \times V_{bs} \times \sin\alpha$$

5.2 *Walls Perpendicular to Rafters*

The second situation is where an unprotected steel rafter penetrates a fire wall. In this case, the structural adequacy of the wall may be achieved by:

(a) incorporating an unprotected steel column within the wall providing direct support to the steel rafter, or
(b) providing a protected column on one side of the wall directly adjacent to the wall and providing direct vertical support to the steel rafter, or
(c) providing unprotected steel columns on each side of the wall

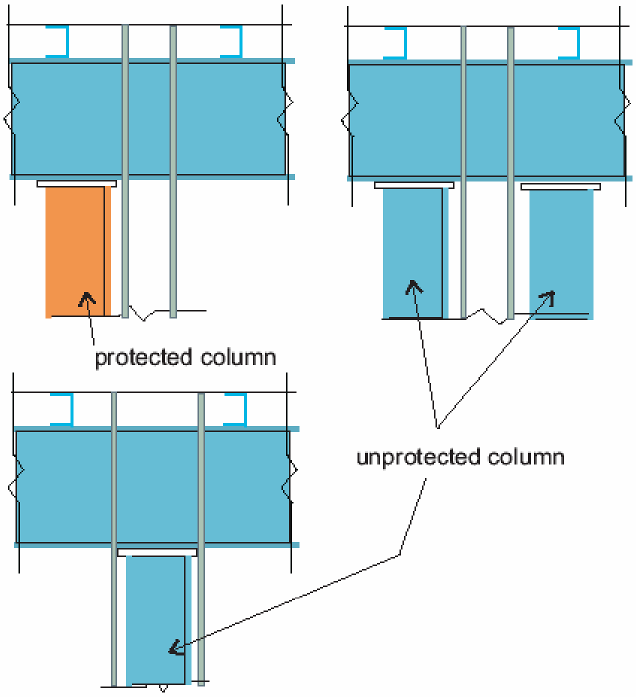

Figure 9 Options for Columns to Support Rafters

In the latter case, the presence of the two columns means that given a fire on one side of the wall, failure of the column on that side will not result in loss of vertical support to the rafter since the column on the other side will provide the necessary support. The options are illustrated in Figure 9. The vertical load that columns must be capable of resisting corresponds to the roof gravity loading that could be applied to the columns due to settling of the roof on to the supporting columns.

The vertical displacement of a rafter on the fire-side of a wall can be very large and could result in significant rotation of the rafter at the wall location. However, if the rafter is flexurally continuous through the wall and over the supporting column – and this is normally the case – then a plastic hinge would be expected to form away from the wall on the heated side due to the temperature gradient and higher temperatures experienced by the rafter away from the wall. Under these circumstances, it is considered that no special measures would be required to accommodate significant deformation. Only normal fire-stopping measures would be required.

It is only when the rafter is not flexurally continuous at the fire wall that substantial rotation may occur at the wall location. Such situations must be carefully considered on a case-by-case basis to ensure that the wall will not be damaged by rafter rotation. No specific guidance is given in this paper for this situation.

6 CONCLUSIONS

The fire test results presented in this paper demonstrate that should steel members penetrate fire-resistant plasterboard walls, the maximum temperature reached by the penetrating member on the unexposed side of the wall will be much lower than that experienced on the exposed side. This unexposed temperature appears to be affected by:

- the thickness of the penetrating element
- the size of the air cavity
- the number of layers of fire-resistant plasterboard
- the presence of steelwork within the wall cavity and connected to the penetrating element

For practical warehouse wall construction, the temperatures experienced by the penetrating elements are unlikely to result in spread of fire.

Adequate fire stopping of penetrations is important to prevent passage of flame through gaps around penetrating members. As discussed in this paper, it may be necessary for such fire-stopping measures to be capable of accommodating significant vertical member deformation at the wall so as to prevent damage to the wall or significant gaps opening around the members - especially if adequate measures cannot be incorporated to minimise such deformations in the vicinity of the wall.

Various measures for minimising such deformations are presented in this paper.

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8 ACKNOWLEDGEMENTS

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Appendix A

Temperature data for VUT151 is given in Table A1. These are for a 2mm plate penetrating a 150mm stud wall having one layer of 16mm Boral Firestop on each side. Temperatures have been rounded to the nearest 5^{o}C.

Table A1 Temperature (^{o}C) versus time (mins)

Time	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
0	25	25	25	25	25	25	25	25
10	580	200	105	60	40	40	35	35
20	710	280	170	110	66	65	52	50
30	800	350	230	175	82	80	62	60
40	850	415	310	250	125	120	92	85
50	885	465	380	315	150	145	110	105
60	910	505	440	375	180	170	130	125
70	940	530	480	425	200	190	150	145
80	965	570	520	460	220	205	155	150
90	980	600	550	500	242	225	175	165
100	1000	625	580	530	260	245	190	180
110	1020	640	605	550	265	255	195	185
120	1030	650	620	570	275	265	195	190

Temperature data for VUT153 is given in Table A2. These results are for a 2mm plate penetrating a 150mm stud wall with two layers of 16mm Boral Firestop on each side.

Temperature data for VUT154 is given in Table A3.This shows the results for a 12mm plate penetrating a 150mm stud wall clad with one layer of 16mm Boral Firestop on each side.

Table A2 Temperature (^{o}C) versus time (mins)

Time	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
0	25	25	25	25	25	25	25	25
10	580	140	80	50	25	25	25	25
20	700	210	130	100	45	45	35	35
30	775	250	160	125	60	60	45	45
40	840	270	180	135	65	65	50	50
50	880	300	190	140	65	65	55	55
60	910	310	200	150	70	70	55	55
70	940	340	250	180	75	75	60	60
80	955	370	280	220	80	80	65	65
90	975	402	330	270	100	100	75	75
100	990	435	355	290	115	110	90	85
110	1010	470	400	330	130	125	100	95
120	1030	500	440	370	140	133	110	105
130	1040	530	480	420	160	150	125	115
140	1050	560	510	445	170	160	130	120
150	1060	585	530	480	180	170	135	125
160	1070	630	580	520	190	180	140	130
170	1080	690	635	570	200	190	145	135
180	1090	710	605	615	210	200	150	140

Table A3 Temperature (^{o}C) versus time (mins)

Time mins	TC9	TC10	TC11	TC12	TC13	TC14	TC15	TC16
0	25	25	25	25	25	25	25	25
10	95	60	45	35	25	25	25	25
20	200	125	100	85	50	50	40	40
30	340	205	155	110	75	75	60	60
40	445	290	225	165	100	100	80	80
50	520	365	280	220	140	140	110	110
60	575	420	345	265	165	163	140	135
70	630	475	400	320	195	193	165	160
80	670	520	450	355	220	217	180	175
90	710	570	485	400	245	240	200	195
100	750	600	535	445	270	265	230	225
110	800	635	570	475	295	290	250	245
120	830	655	585	500	310	305	255	250

Temperature data for VUT153 is given in Table A4 This shows the results for a 12mm plate penetrating a 150mm stud wall clad with two layers of 16mm Boral Firestop on each side.

Table A4 Temperature (^{o}C) versus time (mins)

Time mins	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
0	30	30	30	30	30	30	30	30
10	380	115	75	40	30	30	30	30
20	480	245	155	100	50	48	40	40
30	685	325	210	135	70	68	60	58
40	740	350	245	167	90	88	70	67
50	800	375	270	180	105	103	95	92
60	840	400	290	200	120	117	100	97
70	870	430	310	230	135	132	112	109
80	900	460	345	250	150	147	125	120
90	925	485	365	275	165	163	135	130
100	940	500	395	300	175	172	147	142
110	955	530	425	325	187	184	160	154
120	975	550	450	355	200	197	170	164
130	995	570	480	380	220	216	180	173
140	1005	595	500	405	235	231	190	180
150	1025	620	527	440	250	245	200	190
160	1040	640	550	455	260	255	210	200
170	1050	675	570	480	270	265	220	210
180	1055	695	600	500	275	265	230	220