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UPGRADING THE FIRE RESISTANCE OF FLOORS AND DOORS IN HERITAGE BUILDINGS

by

Gordon Cooke BSc PhD CEng MIMechE MICE FIFireE

International Fire Safety Consultant and Visiting Professor, School of Engineering, City University, London, UK (gordon@cookeonfire.com)

Synopsis

Simple methods are described for increasing the fire resistance of timber floors and doors in historic buildings to help limit the spread of smoke and heat. The methods are chosen to minimize damage to the appearance of the building and minimize the amount of work necessary to do the upgrading work. Upgrading forms an important but small part of the work and should only be done after a full fire risk assessment has been made.

Introduction

Historic buildings must be preserved as a reminder of the past and as inspiration for the future. Works of art and reminders of our predecessor's ways of life may be irreversibly lost due to accidental or malicious fire damage.

A rigorous property risk assessment associated with continuing good fire safety management may be the solution which enables the building to remain free of unsightly structural fire precautions and fixed fire suppression systems. Occasionally it will be essential and unavoidable to incorporate some fire compartmentation so as to prevent unrestricted spread of fire horizontally and/or vertically throughout a historic building. Elements of construction which can often have their fire resistance improved without obvious external damage to the construction or aesthetics, include timber doors and floors, and this paper indicates some ways in which this can be done.

Before improving (upgrading) the fire resistance of the construction, a fire risk assessment should be made. This is now common practice for life safety purposes, and the same principles can be applied to property damage and business continuity. Figure 1 shows the basis of the UK government plan for a life safety assessment.

In a museum for example, Step 2 in the plan would involve identifying and valuing (in the widest sense) each item (including furnishings) in each room and developing a strategy for removing them from a fire or protecting them in place. Smoke, heat and potential water damage has to be considered. It is clearly important to detect a fire at the earliest possible time and this may mean the installation of hidden fire detection such as an aspiration detection system which can be concealed from view and, through the use of laser technology, detects smoke particles much earlier than conventional point smoke detectors.

Fire development

Fire resistance only becomes important when the fire becomes fully developed. Figure 2 shows two real fire development histories, each involving a growth phase, a fully developed phase and a decay phase. The curves differ mainly because of different ventilation conditions. The curves, the results of large compartment fire tests conducted by BRE in the UK, show that in a compartment with office type fire load it is possible for flashover to be delayed by keeping all openings closed – in the test curve for the smaller compartment, panes of glass had to be removed to encourage the fire to develop. Hence closing doors and other ventilation openings not only prevents smoke damage beyond the room of fire origin but can also prevent the fire reaching flashover within the room of origin. This is important for heritage buildings.

Fire resistance

Fire compartmentation is achieved by having construction elements such as walls and floors which possess fire resistance, usually sufficient to withstand a burn-out of the contents. Fire resistance is the ability of the element to withstand, for a stated period of time, a standard furnace exposure following the ISO 834 temperature-time curve. The fire resistance is adequate if the element resists collapse (or instability), resists the passage of flames and hot gases from one side to the other, and prevents a temperature rise on the unexposed face of approximately 140 degC, Figure 3.

There is a considerable amount of information on fire resistance for many construction products and the contribution that materials make to fire resistance of the whole element assembly. Most wall/door test data refers to elements not larger than 3m. Larger, and especially taller, elements require fire resistance to be assessed by an expert, in what, in European terminology is called an extended application, and there is much effort currently being applied in CEN to develop simple rules for this work. Such work may be useful for historic buildings where elements such as doors are often much higher than the 3m height tested in a fire resistance furnace. In Europe the contributions of materials to fire resistance will change when the European standards for fire resistance come into force due to the greater fire severity associated with plate thermometer control of furnaces, but this will only become relevant if the amount of fire resistance is precisely specified, which is not normally appropriate for historic upgrading.

Figure 4 shows part of a historic ceiling. It would clearly be unacceptable to add a fire-protecting layer to the bottom of such a ceiling, but if access into the floor from above is possible the fire resistance can be improved in several ways, as demonstrated below.

Upgrading the fire resistance of timber floors

The upper drawing in Figure 5 shows a typical timber joisted floor. The ceiling is in poor condition and is assumed to be unable to resist the thermal impact of a flashover fire (a fire which has spread to involve all the contents of the room, normally associated with combustion gas temperatures above 650 degC). Also, gaps between floor boards will not prevent smoke and hot gas transfer after the ceiling has fallen down. Such a floor can have its fire resistance upgraded in several ways in which the existing ceiling is left in place so as to contribute sound insulation and, sometimes, fire resistance. If the existing ceiling is in poor condition it must be held up by wire mesh so that it does not load the new ceiling. The new ceiling may comprise fire-protecting boards or plaster on expanded metal, using timber battens to separate the old and new ceiling, as shown in the lower drawing in Figure 5. To improve the integrity of the whole floor assembly it is usual to add a thin sheet of plywood or hardboard on top of the existing floorboards, perhaps essential if the boards are square edged with large gaps between.

Where it is impossible or undesirable to add a ceiling from below, the floor can be upgraded by removing some of the floor boards, laying polythene sheet over the existing ceiling between floor joists, fixing expanded metal to the sides of joists but spaced away from the existing ceiling and then adding lightweight plaster so that a new rigid ceiling is formed, Figure 6.This accepts that the old ceiling can fall down early in a fire without affecting the fire resistance of the upgraded assembly. The polythene prevents staining of the existing ceiling by the water in the newly added plaster. A cut away view is shown in Figure 7. The polythene sheet should be tucked firmly into corners so that the added plaster gives protection against fire to the sides of the joists when the old ceiling falls. It is necessary to check that the floor can carry the additional weight of plaster and that the existing ceiling can temporarily carry the weight of wet plaster.

If the ceiling is in good condition and unlikely to fall down early in fire, the fire resistance may be improved by placing rock wool in the cavity, Figure 6.

A floor with large timber beams can have the fire resistance improved by installing strips of ceiling between beams, leaving most of the beam section exposed, Figure 8. The added ceiling can be fixed to timber battens which are fixed to the sides of the joists. A simple calculation is needed to ensure that after an agreed period of fire exposure the beams can carry the load. Assuming the ISO 834 standard fire exposure the amount of char is calculated by multiplying the charring rate (typically 0.6mm/min for most structural timbers) by the required fire resistance period in minutes. It is noted that the rate of charring depends strongly on the incident radiation intensity, Figure 9 but this is only relevant if a fire safety engineering approach is taken which considers real fire conditions as opposed to the standard (ISO 834) fire approach. The strength of the timber below the char line can be approximately taken as the room temperature strength. The radius of char may be taken as the char thickness. The position of the neutral axis is derived and thus the second moment of area of the section from which the moment of resistance can be calculated. If the moment of resistance exceeds the applied bending moment the structure will remain stable for the standard fire duration period chosen. Care needs to be taken to ensure that increased charring around exposed metal screws does not reduce their holding power.

Floor cavity fire barriers

Once fire has penetrated the ceiling it should not be allowed to travel horizontally between the floor and ceiling. Cavity barriers can stop this, Figure 10. They should be located immediately above walls and doors, and in a historic building this is usually done by raising some floor boards to gain access. Choice of cavity barrier depends on likely relative movement between floor and ceiling. A flexible layer of rock wool blanket can accommodate large movement, Figure 11. A lightweight spray applied to expanded metal, Figure 12, fills all gaps but is a wet trade and if it includes fibres may contaminate the building environment, but it cannot tolerate as much movement.

Upgrading the fire resistance of timber doors

Doorways are potential routes of fire spread. There is little advantage in having a fire-resisting door set (door and its frame) if the door is left open during a fire. This can be prevented by having electrically released door hold-open devices, Figure 13, actuated by fire detection. Panels above doors should be checked for fire resistance, and the presence of a glazed panel should be carefully considered, Figure 14. Radiation through the glazed area may be acceptable if transmitted radiation cannot ignite materials on the other side, and this can be calculated. If the level of incident radiation on combustible objects or finishes near the unexposed face is unacceptable then an intumescent/glass laminate may be used, if the greater thickness and weight can be tolerated.

Timber shrinks when it is heated and loses moisture. This can mean that tall doors may bow towards a fire and, especially at the top, allow the passage of hot gases and flames, Figure15. Extent of bow depends on design, thickness and direction of grain. Points of door restraint, i.e. hinges and latches, require careful consideration.

To prevent failure of integrity and insulation at door edges, intumescent seals may be used, Figure 16. The data in Figure 16 assumes that there is a good fit between the door face and the door frame and that the gap between the edge of the door and frame is not greater than approximately 3mm. The strips can be preformed and simply placed in a groove in the door and frame. The positions of strips in the door or frame is important and should allow for bowing of the door toward the fire, Figure 15. Such seals on their own will not prevent the spread of cold smoke, and where this is important intumescent seals should be used with smoke seals, the latter being flexible and robust for the design life.

A special design of fire and smoke seal for use with double swing doors is shown in Figure 17. An extruded aluminium section incorporating intumescent material and a neoprene smoke seal is fixed into a groove in each door edge along the top and the sides using metal nails. The aluminium soaks up the heat from the fire gases and conducts the heat to the intumescent causing it to swell as early as possible so preventing charring of the timber.

Upgrading the fire resistance of timber door panels

Historic doors often have panels which are thinner than the frame which holds them in place, Figure 18. The fire integrity of a door is usually weakest at the panel edges,

Figure 19. Panels near the top of the door are most likely to lose their integrity first in a real fire because, as we have seen from Figure 14, the fire is more severe near the top of the door. There are several ways of upgrading the integrity and insulation of panels, which are now described.

Intumescent paint, opaque or transparent, may be used to coat the whole of a door, Figure 20, or only the panel edges. The intumescent system must be compatible with the existing surface of the door, and layers of old paint will need to be removed to prevent the intumescent char from falling away due to weakness caused by the old paint layers - the manufacturer's instructions should be rigorously followed. If the intumescent is water-soluble it may be necessary to put a notice on the door stating that the surface should not be washed.

In some cases, admittedly rare, it may be possible to upgrade the integrity of beautiful door panels by applying a panel(s) of fire resisting glass such as Pyran or a wired glass, Figure 21. Attachment of the glass so that it remains in a stress-free condition in fire is difficult but is possible with careful detailing. This adds to the weight.

Where the panels can easily be removed from the frame by removing the timber retaining sections on one side, it is possible to remove the panel to make a narrow groove in the panel edges so that a thin steel strip can be inserted, Figure 22. This will improve the fire integrity but not the insulation, but is an option where the door is of outstanding beauty and upgrading cannot be avoided, Figure 23.

It should be noted that indicative fire resistance tests, using a one metre cube furnace, can be useful for examining the fire integrity and insulation of door panels or intumescent sealed joints. This avoids the cost of conducting full-scale fire resistance tests.

Finally, for doors that have to be upgraded but are mostly unseen, it is common practice to fix a layer of fire protecting board to the fire risk face of the door, Figure 24. Where high levels of fire resistance are needed it may also be necessary to fill the gap between panel edges and board with additional protecting material such as plaster. Hinges may need to be replaced to carry the added load. Such a door is heavy and unsightly.

The relevance of fire safety engineering to heritage protection work.

Following prescriptive methods for deciding levels of fire resistance is sometimes inappropriate for historic upgrading work. The application of fire safety engineering philosophies should result in the proper identification of the fire hazards and a range of remedial options based on a thorough scrutiny of all plausible fire scenarios. The work of ISO TC 92 SC4 is very relevant to this work. In the UK the recent revision of BS DD 240 Fire Safety Engineering into a series of eight BS Published Documents (PD 7974) is a welcome development.

Further reading

Home Office et al, Fire Safety. An employer's guide, HSE Books, London, UK, 1999

Increasing the fire resistance of existing timber floors, UK Building Research Establishment Digest 208, UK, 1980

Timber fire doors, UK Building Research Establishment Digest 220, U K, 1978

Read R E H, Morris W A and Cooke G M E, Guidelines for the construction of fire-resisting structural elements. BRE Report BR128, UK Building Research Establishment, U K, 1988

BSI, PD 7974, Application of fire safety engineering principles to the design of buildings, UK, 2003

ISO, Fire safety engineering, ISO/TR 13387, Parts 1 to 8, 1999

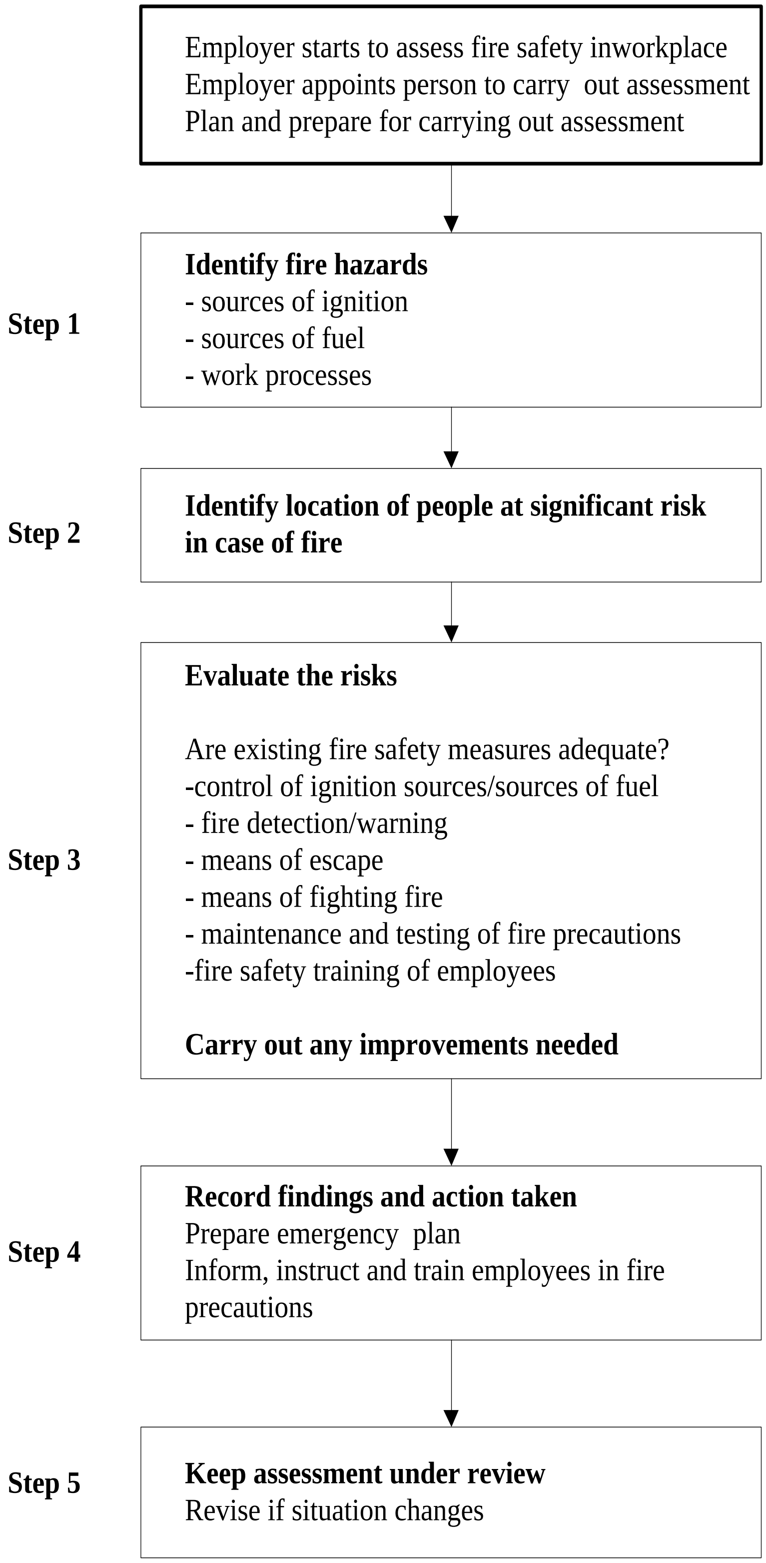


Figure 1 HSE Fire risk assessment plan for life safety

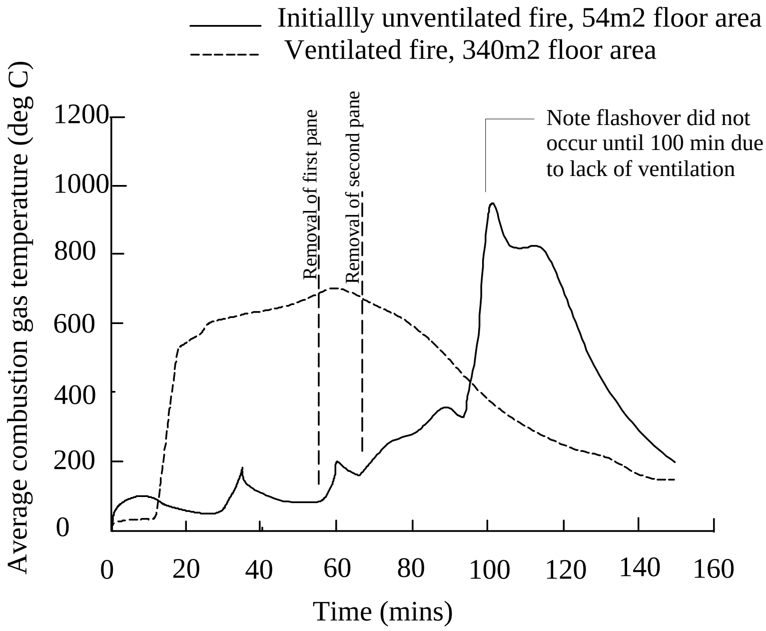


Figure 2 Typical fire development history showing effect of ventilation on combustion gas temperature

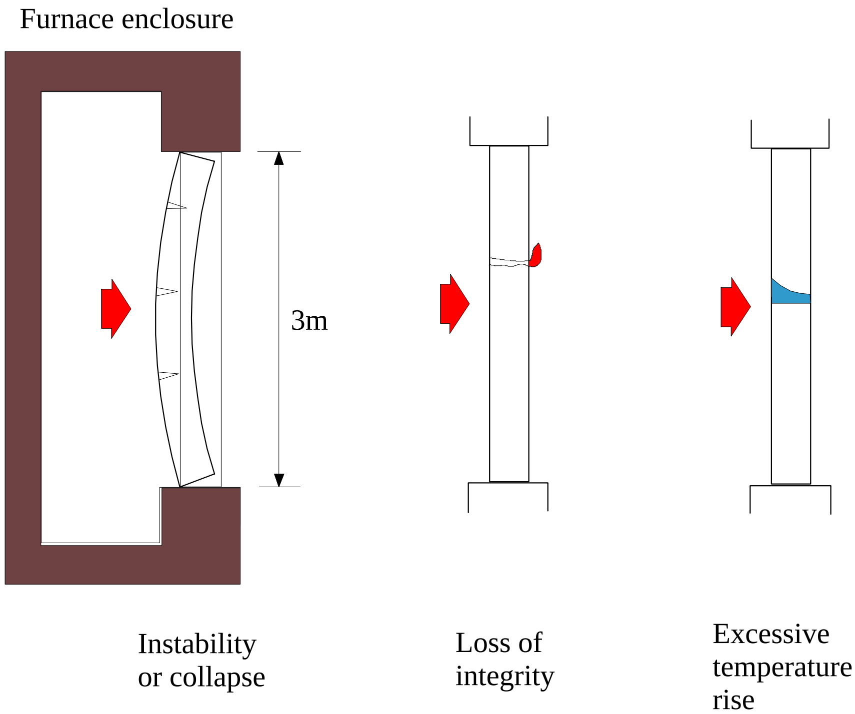
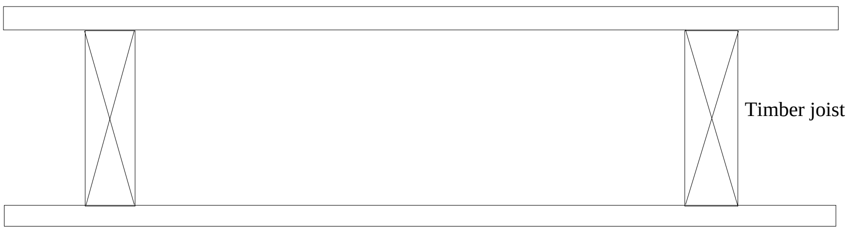


Figure 3 The three criteria of fire resistance

Figure 4 Example of ceiling which cannot be fire protected from below.



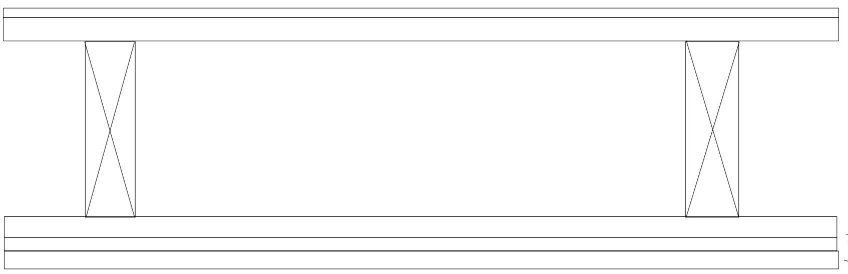


Figure 5 Typical timber floor construction upgraded with an additional ceiling

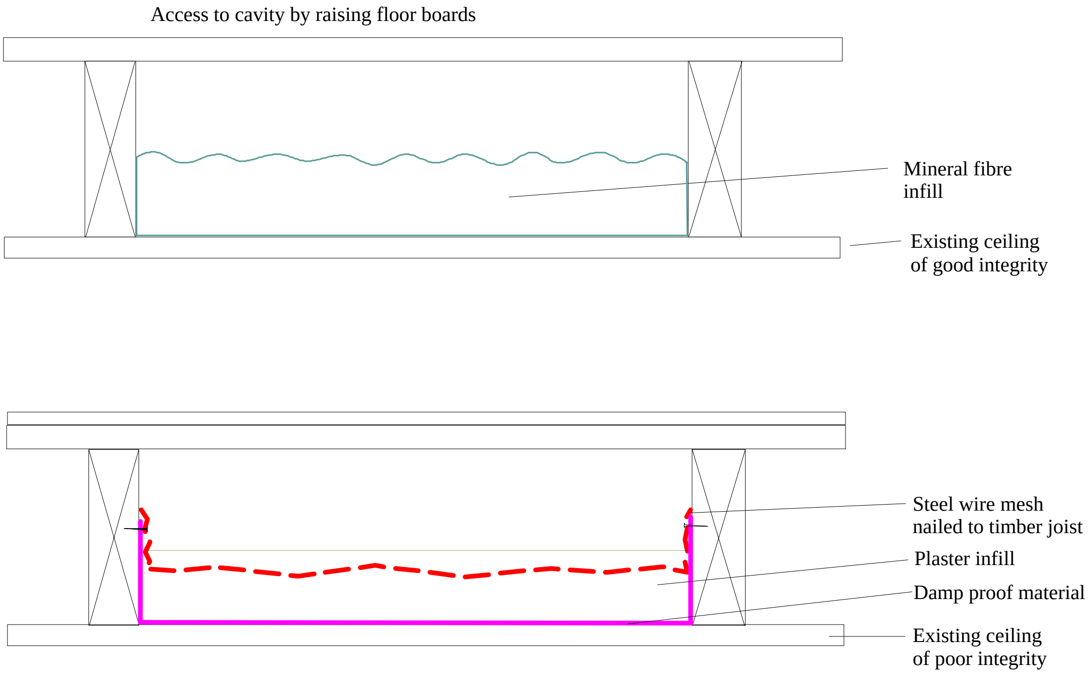


Figure 6 Floor upgraded with partial filling of mineral fibre or lightweight plaster

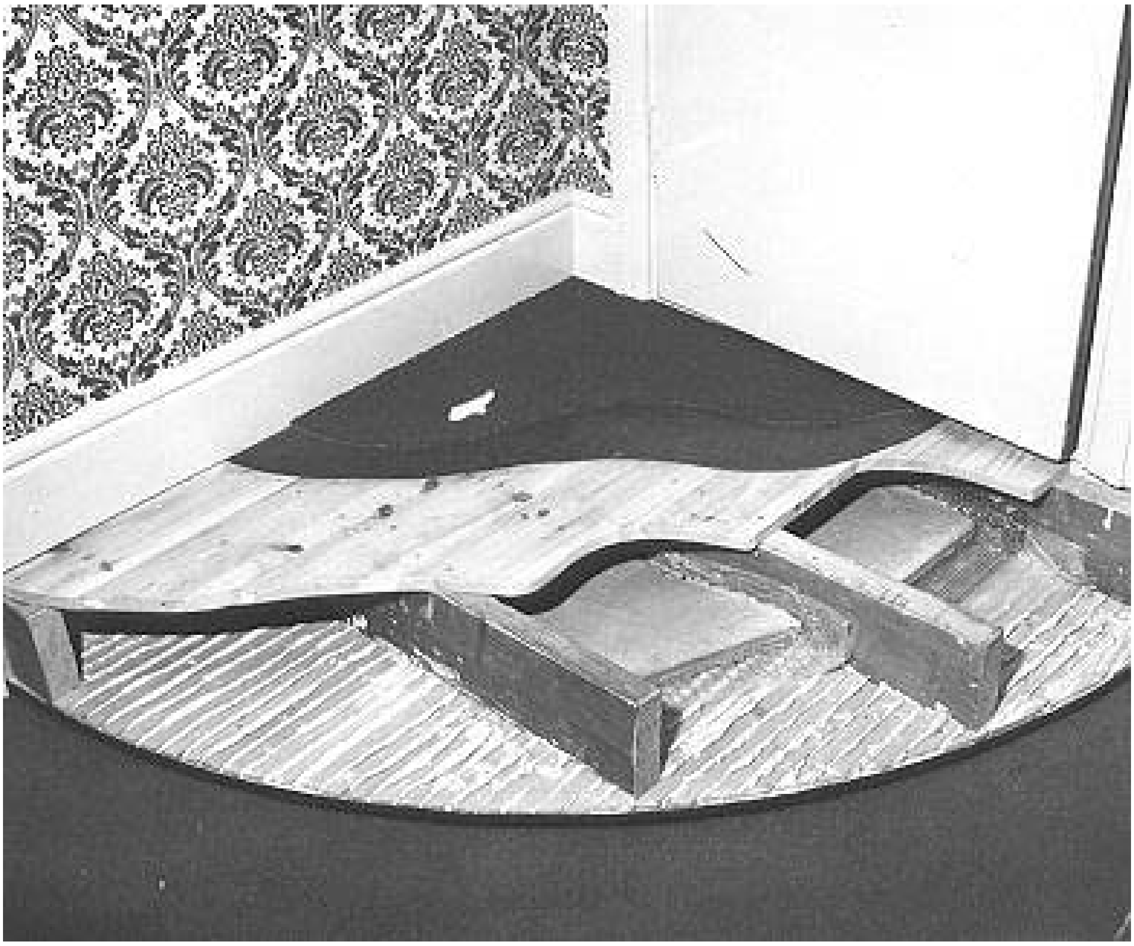


Figure 7 Example of floor with poor lath and plaster ceiling upgraded with additional plaster ceiling

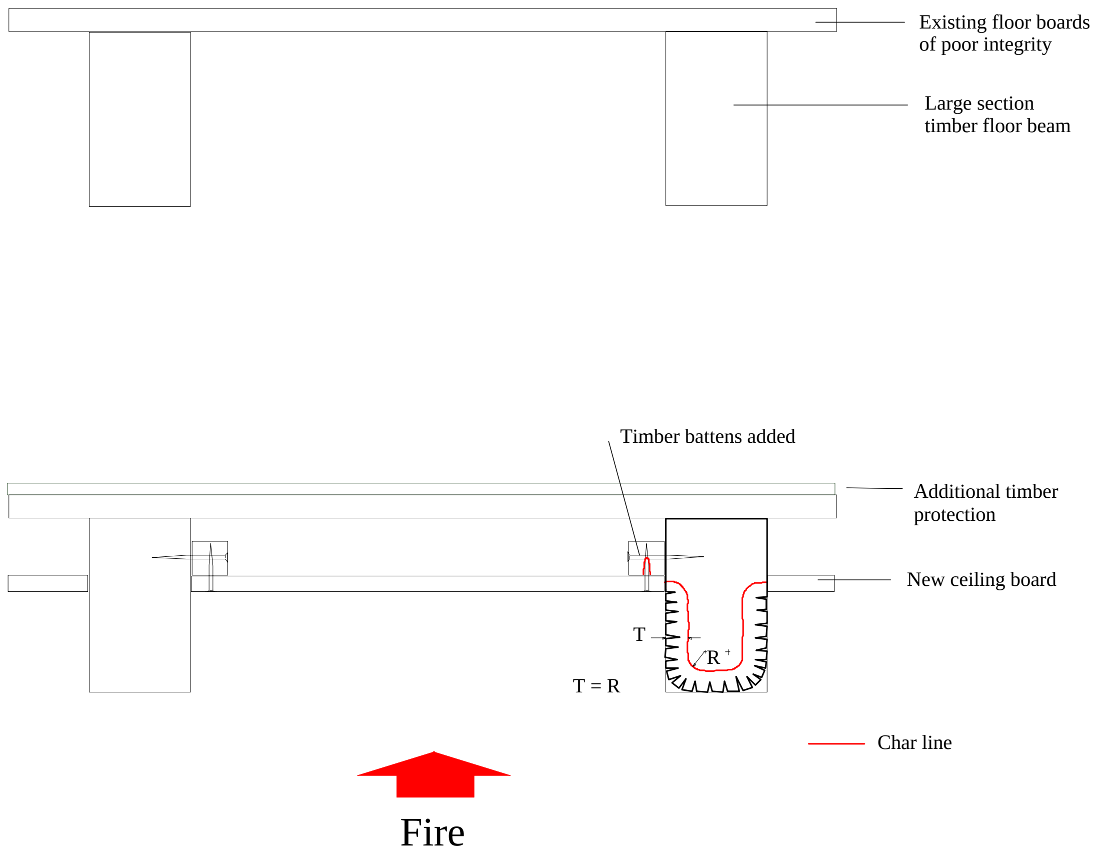


Figure 8 Upgrading a floor having large timber beams by adding inset ceiling

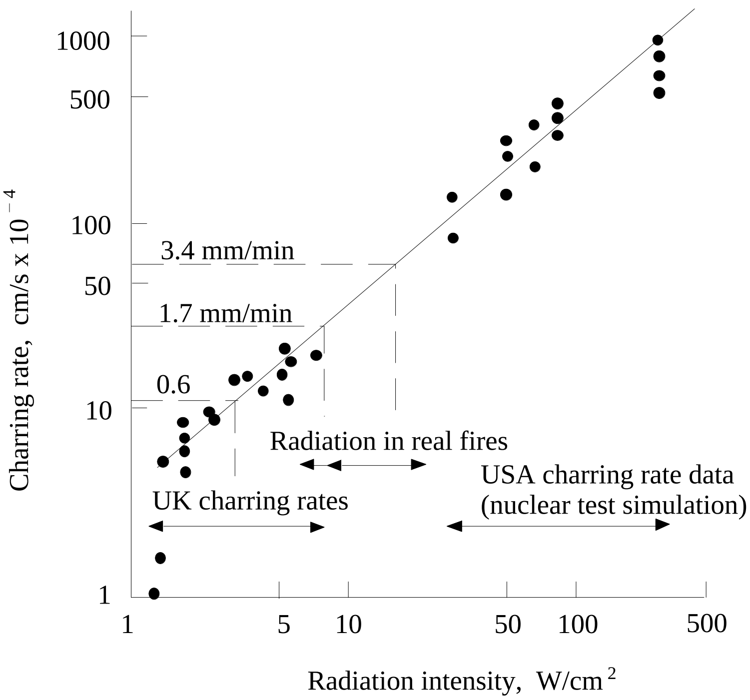


Figure 9 Charring rate of timber versus radiation intensity

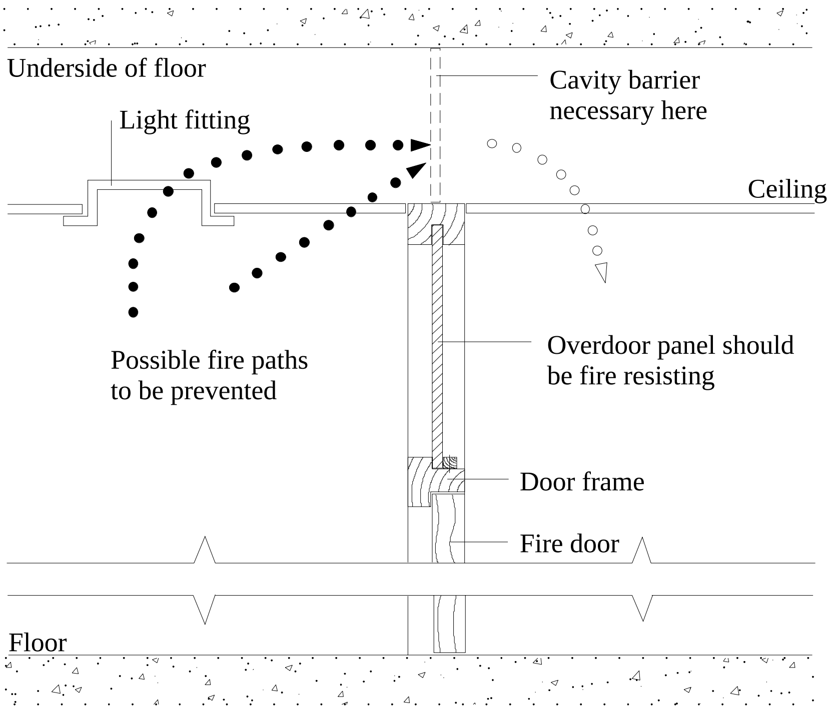


Figure 10   Importance of cavity barriers

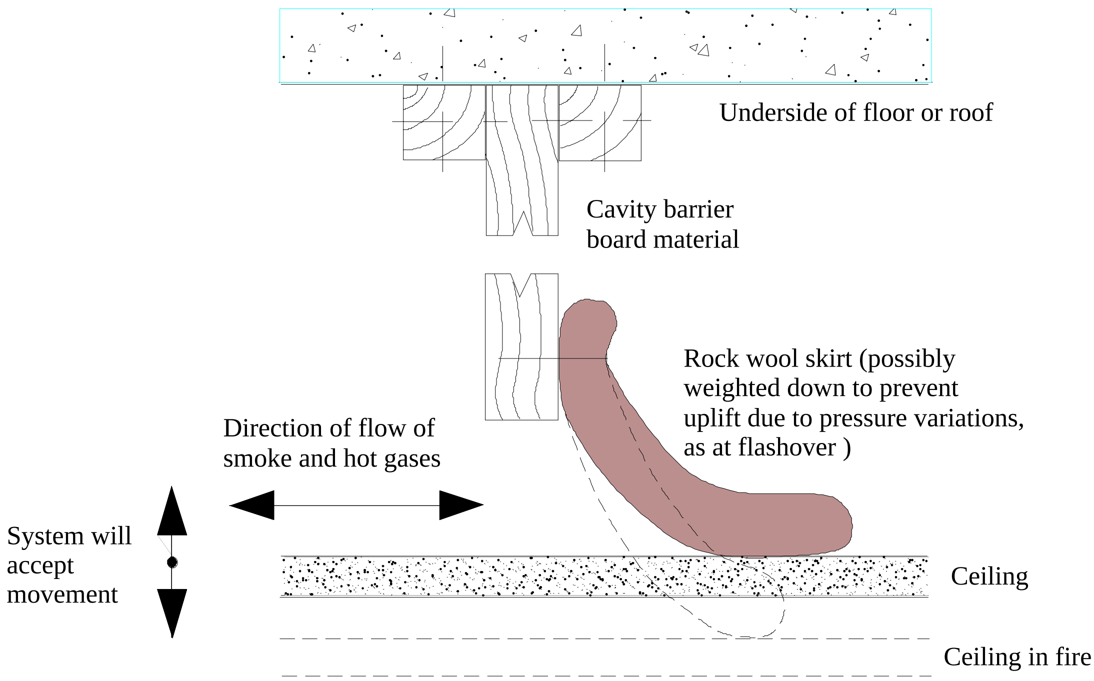


Figure 11   Ceiling cavity barrier with rock wool skirt

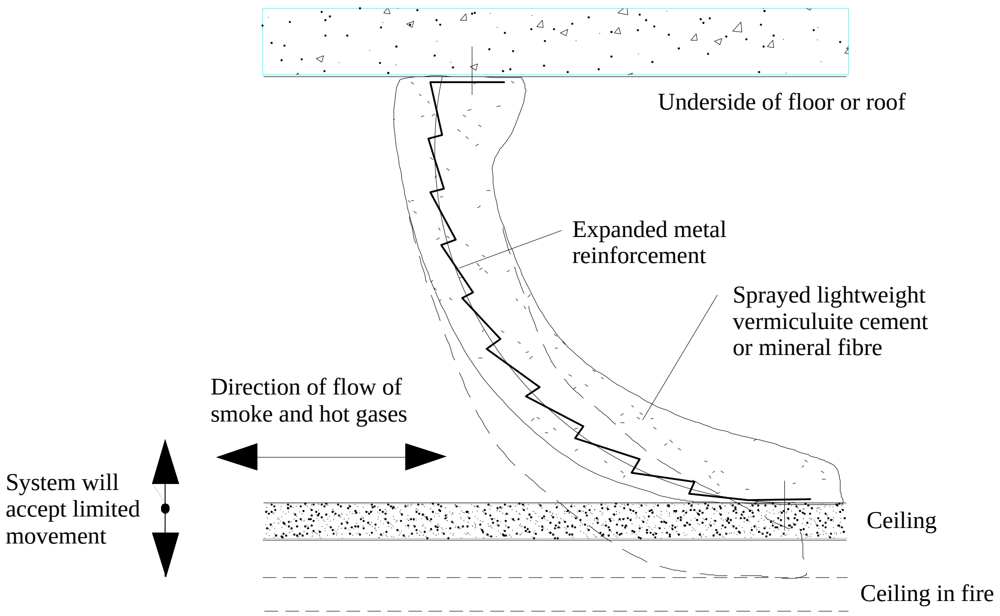


Figure 12 Ceiling cavity barrier using sprayed fibre on expanded metal

Figure 13 Fire door with hold-open device released by fire detection

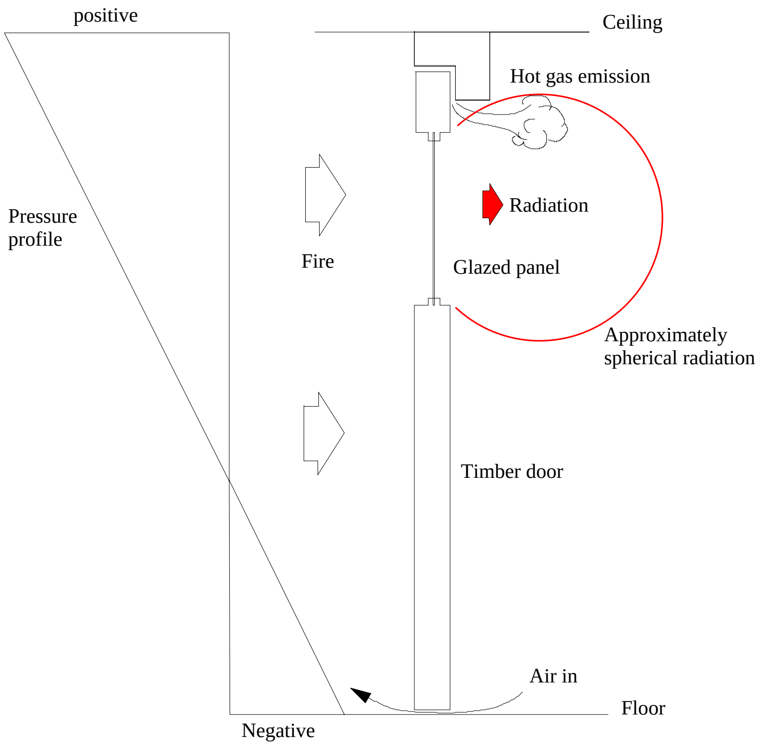


Figure 14 Pressure profile and fire transfer mechanisms for a glazed timber door

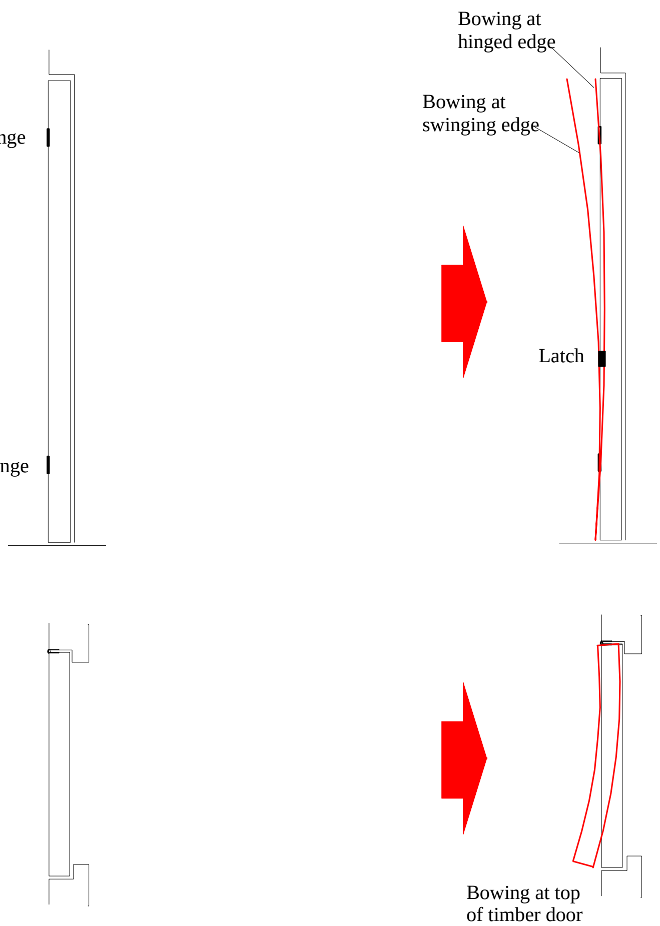
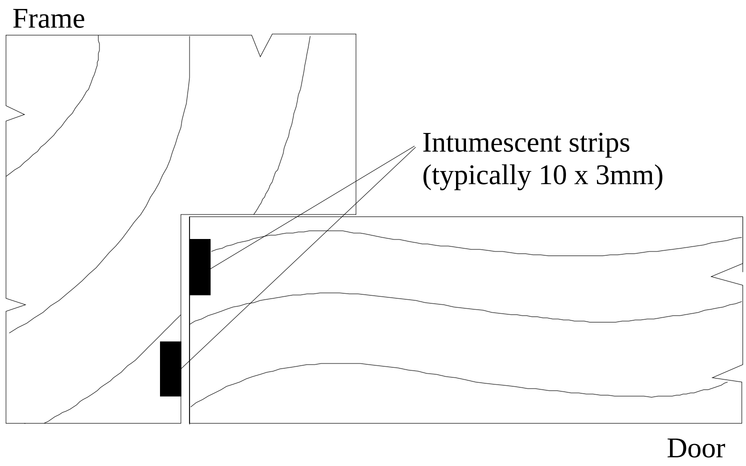


Figure 15 Bowing of a timber door exposed to fire on one side



Intumescent strip requirements

FR 30/20	strips not essential
FR 60/45	strips in door edge or frame
FR 30/30	strips in door edge or frame
FR 60/60	strips in door edge and frame

Figure 16 Use of intumescent strips for improving the fire resistance of a timber door set

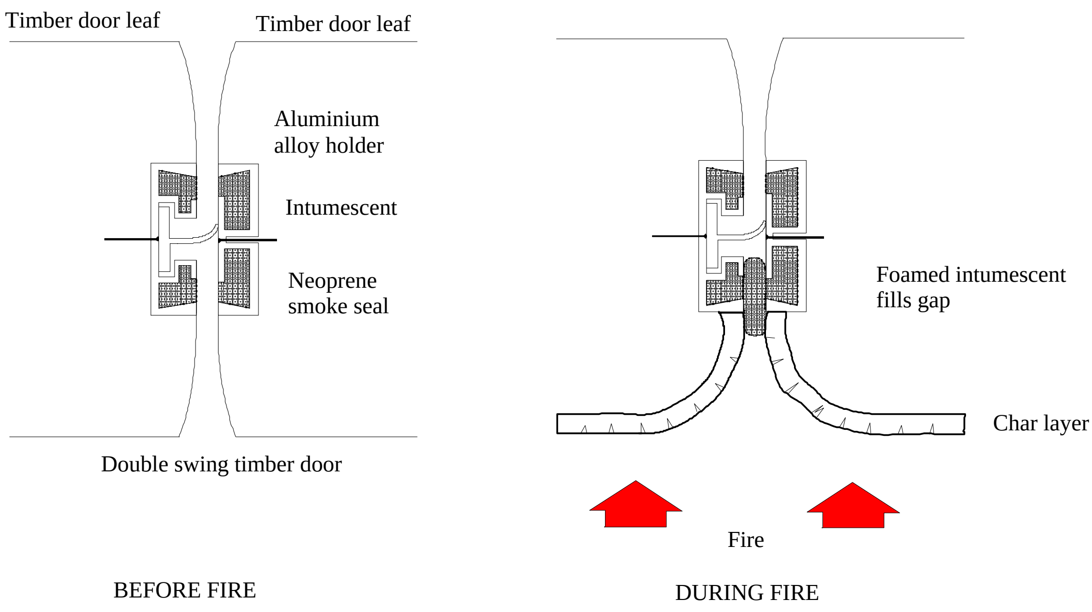


Figure 17 Example of heat and smoke seal for double swinging doors

Figure 18 Mahogany door with moulded panels

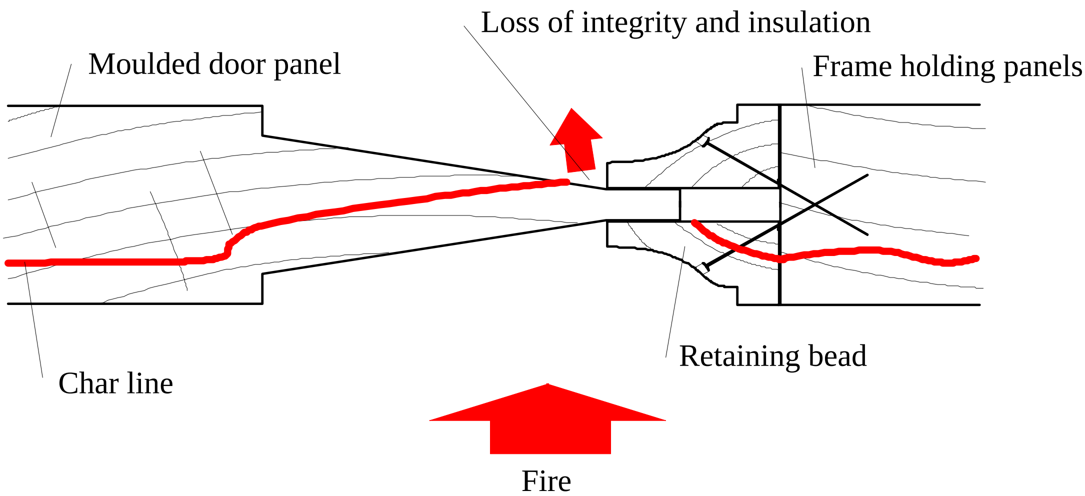


Figure 19   Loss of fire integrity in timber door panel

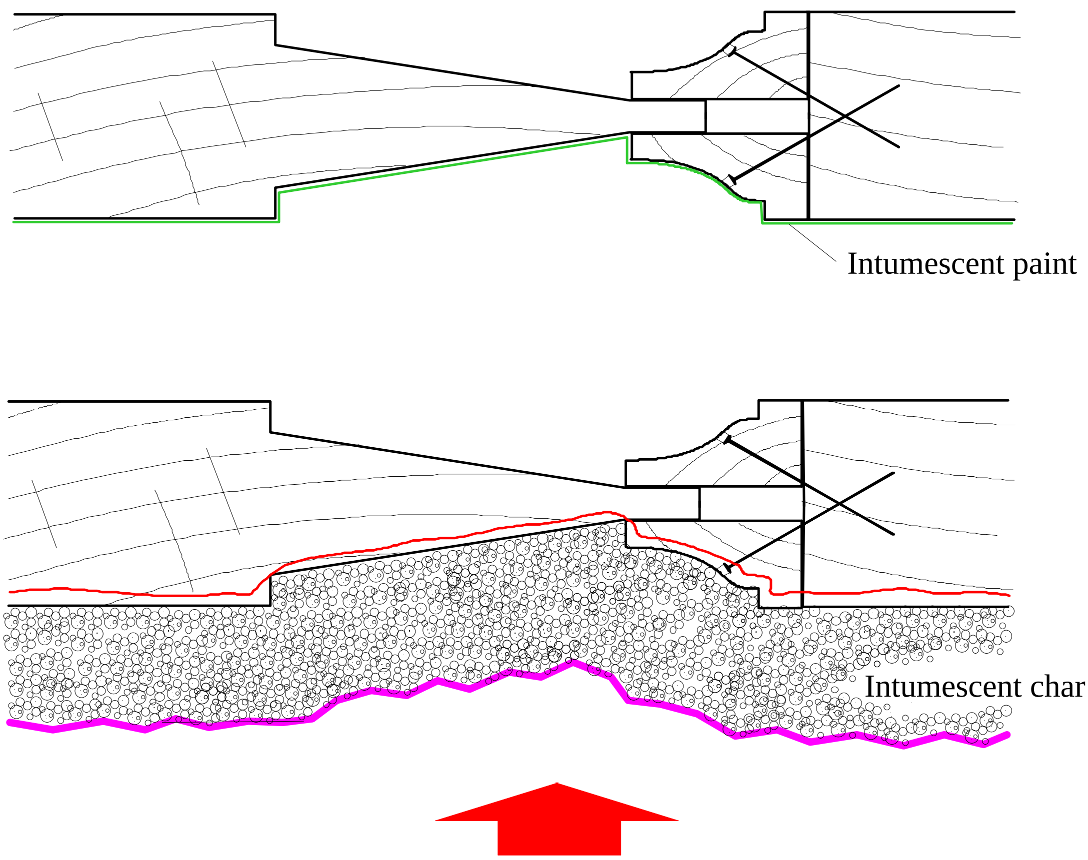


Figure 20 Use of intumescent layer for upgrading fire integrity and insulation

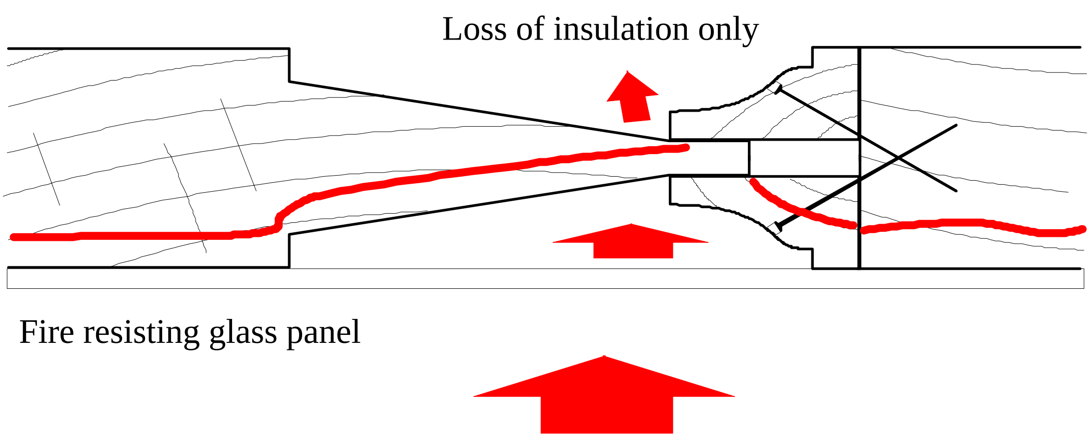


Figure 21 Use of fire resisting glass to upgrade the fire integrity of a timber door panel

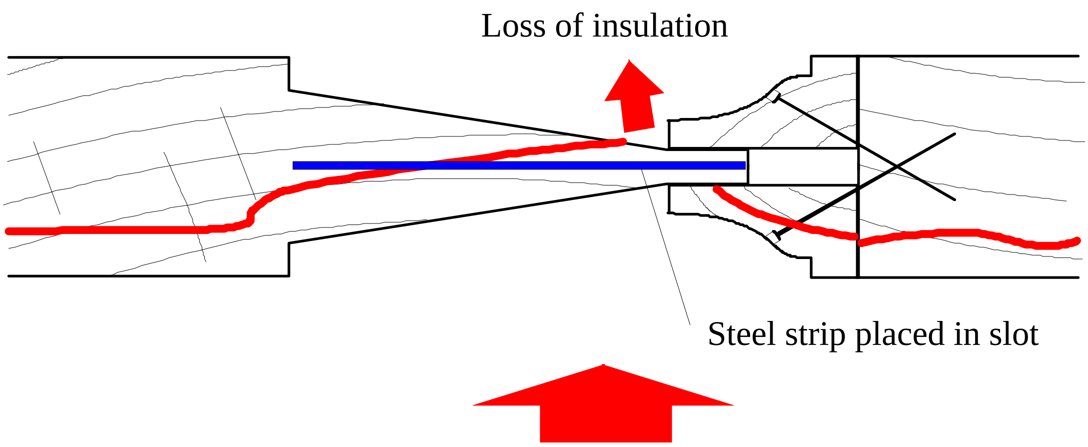


Figure 22 Use of an inserted steel strip to upgrade the fire integrity of a timber door panel

Figure 23 Example of beauty of door paneling which must be retained

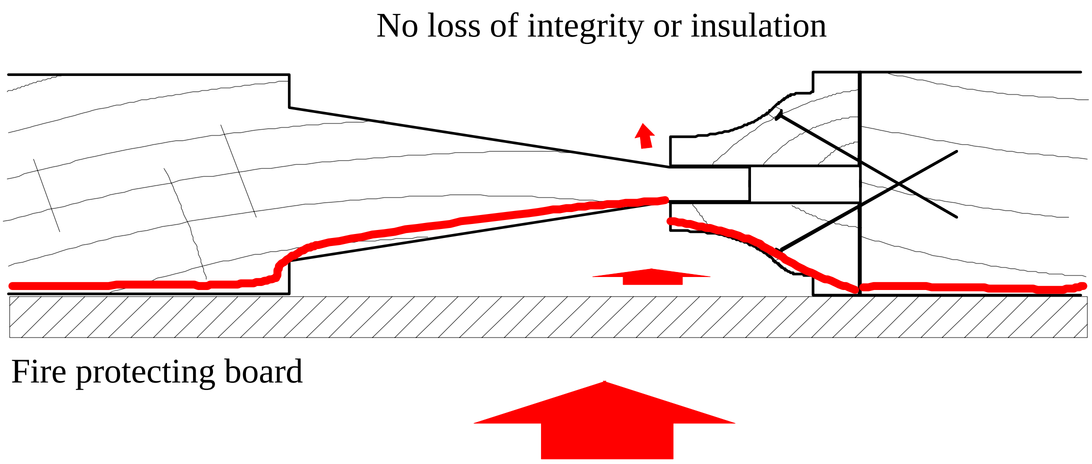


Figure 23 Upgrading a timber door with fire-resisting board protection

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