‘Do Unprotected Small Diameter Service Penetrations in Fire Rated Constructions Hasten Gypsum Plasterboard Failure?’

Bill Hay

Iain Sanderson

Glasgow Caledonian University

University for the Common Good

Although within the UK and the Republic of Ireland Building Regulations are performance based, the prescriptive technical guidance documents which accompany these Regulations nevertheless remain a dominant influence on building design and construction.

These guidance documents, either explicitly or implicitly support sustainability. What is unclear is whether some of the fine detail within the guidance, which may have been developed decades ago, truly aligns with the development of innovative and sustainable building products.

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Many European Governments consider growth in the use of timber in building construction as an important factor in reducing greenhouse gas emissions.

In addition to traditional rectangular timber sections, engineered timber products have become popular as they offer a number of benefits.

Timber I-joists are one such product, which offer advantages such as: greater clear spans, which in turn offer design flexibility and construction economies; economy and sustainability in the use of forest products; structural economy, and construction economy as a result of lighter weight and improved performance in service.

‘Manufactured timber I-joists are more efficient than solid sawn timber joists under normal temperature conditions, but may not perform as well in fire if the Webs are thin, because of strength loss due to charring of the web.’

(Buchanan, 2001)

Floor and wall constructions containing I-joists are typically protected from fire by gypsum plasterboard. Therefore premature failure of the gypsum plasterboard would lead to direct exposure of the I-joist and precipitate structural failure.

In order that these products can optimise their sustainable potential, it is essential that such constructions can maintain their fire resistance for some prescribed period of time.

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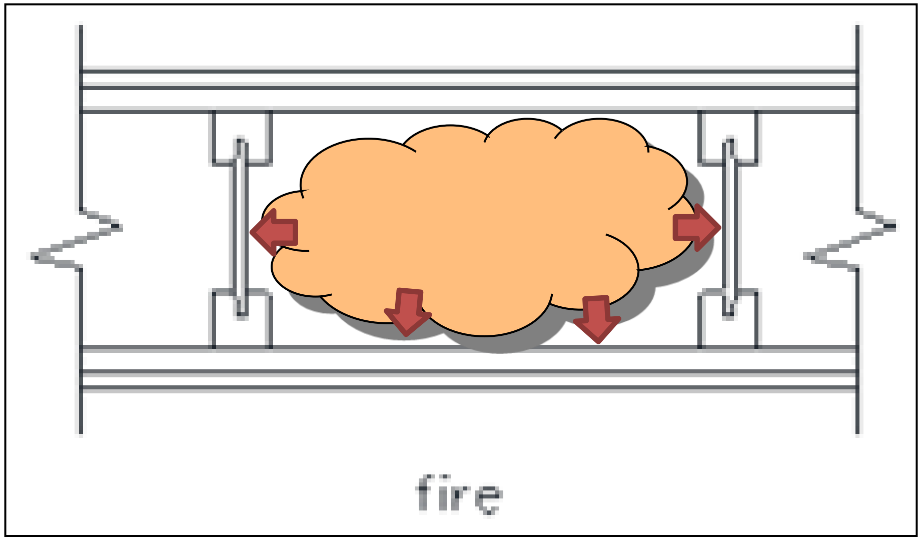
Building Regulation guidance documents in both the Republic of Ireland and the UK, require walls and floors which serve a fire separation, or compartmentation function to achieve specific periods of fire resistance depending on: building type, compartment size and building storey height.

Where penetrated by services, the penetration must not undermine this fire resistance. In the case of waste pipe penetrations this is often achieved by the use of an intumescent fire collar, which seals the penetration when heated.

However, both the guidance documents in the Republic of Ireland and the UK allow 40mm diameter waste pipes to penetrate these constructions without such protection; fire-stopping the annular space around the pipe is considered adequate.

Scotland is singular amongst these countries in additionally specifying a maximum number of waste pipes in close proximity and also a minimum distance between adjacent pipes.

The authors concern is that these unprotected service penetrations may allow hot gases to enter the construction cavity of a timber floor or wall. This could be detrimental to the timber members exposed within the cavity and also lead to heating of the rear face of the gypsum plasterboard protection, effectively meaning that the board is being heated both from the fire exposed side and from within the construction cavity simultaneously.



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As ‘fall-off’ of gypsum plasterboard is related to its dehydration, simultaneous heating from both sides could influence the time until: plasterboard failure, subsequent direct exposure of the I-joist to the fire, local structural failure of the I-joist due to this direct fire exposure, and hence premature failure in terms of fire resistance of the wall or floor in question.

There are two dehydration reactions associated with heating gypsum, the first is initiated at around 100^{o}C. There is wide variation in the literature as to the second dehydration reaction temperature; however Wakili and Wullschleger (2007) indicate a peak at around 200^{o}C.

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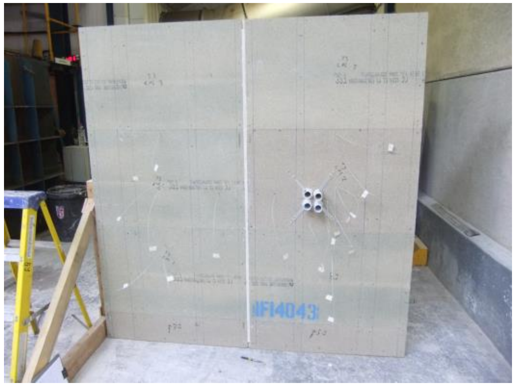
Reduced scale fire resistance tests.



In order to examine the effect of the limitations peculiar to Scotland three reduced scale fire resistance tests were conducted on 2 m x 2 m floor samples. The discussion in this paper relates only to the first test, which would be acceptable in all of the countries of the UK as well as the Republic of Ireland.

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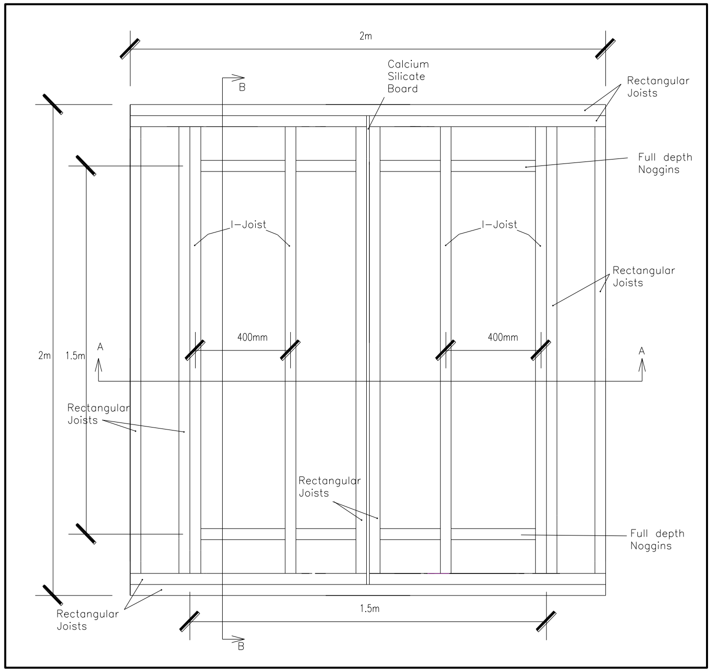
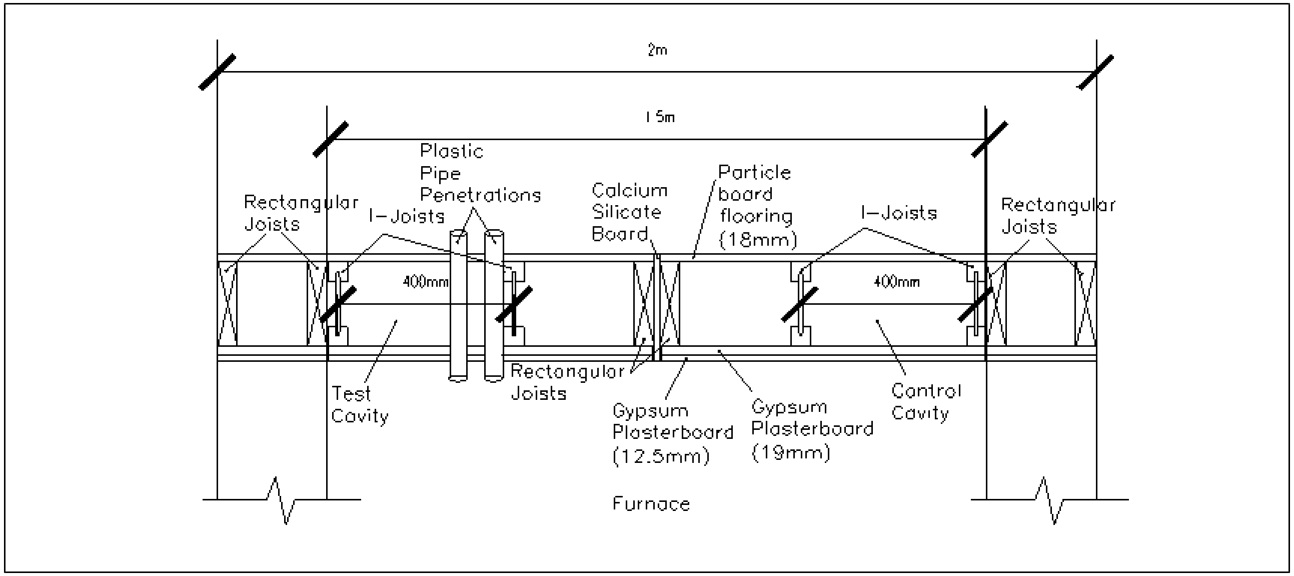
The floor sample consisted of 18 mm flooring grade particle board on 195 x 45 mm timber I-joists at 400 mm centres. The I-joists comprised 45 mm x 47 mm softwood flanges at the top and bottom, connected to each other by a 9 mm thick OSB web. The underside of the I-joists was lined with a base layer of 19 mm gypsum wallboard and a further layer of 12.5 mm gypsum wallboard. This specification was identified within an I-joist manufacturer’s technical manual as one providing 60 minutes fire resistance.



The samples contained both a ‘test’ cavity which was penetrated by plastic waste pipes and a ‘control’ cavity with no penetrations.



The pipe penetrations were tightly fitted within the apertures in the particle board flooring and gypsum plasterboard. The minimal annular space around the pipe penetrations remaining were then sealed with inert gypsum based plaster filler; this type of fire-stopping material being permissible in the guidance to the Building Regulations.

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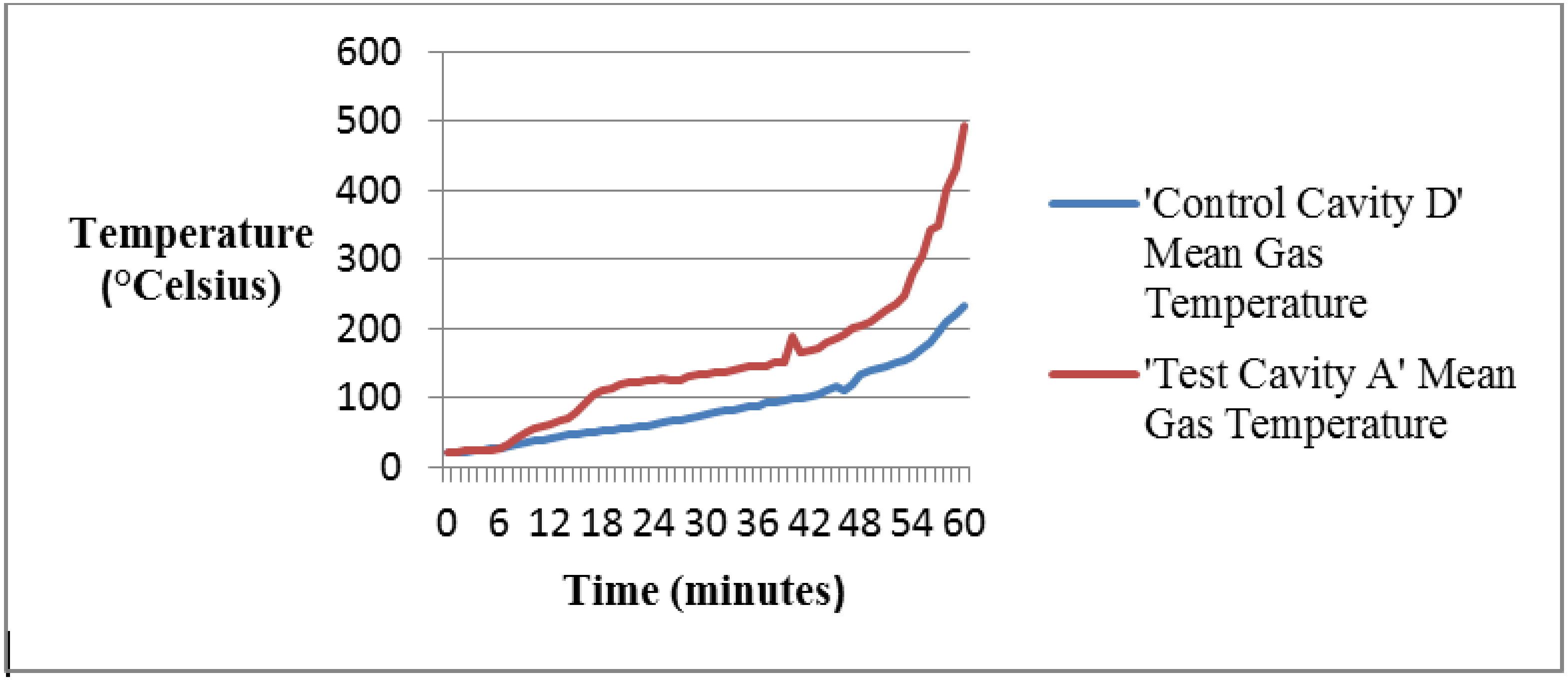
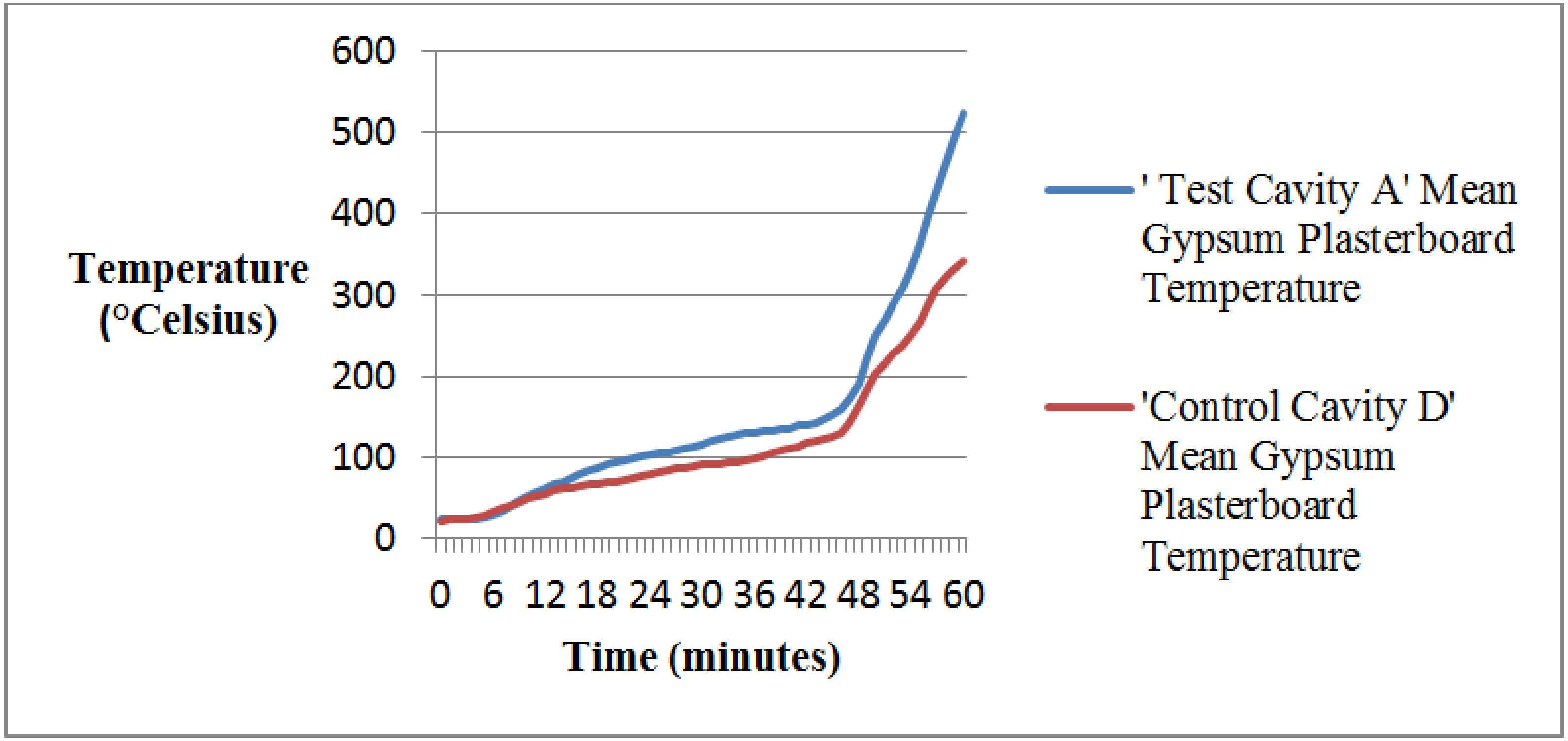
After 6 minutes the test cavity average gas temperature was consistently higher than the control cavity temperature, suggesting that the pipe penetrations did lead to increased temperatures within the construction cavity.



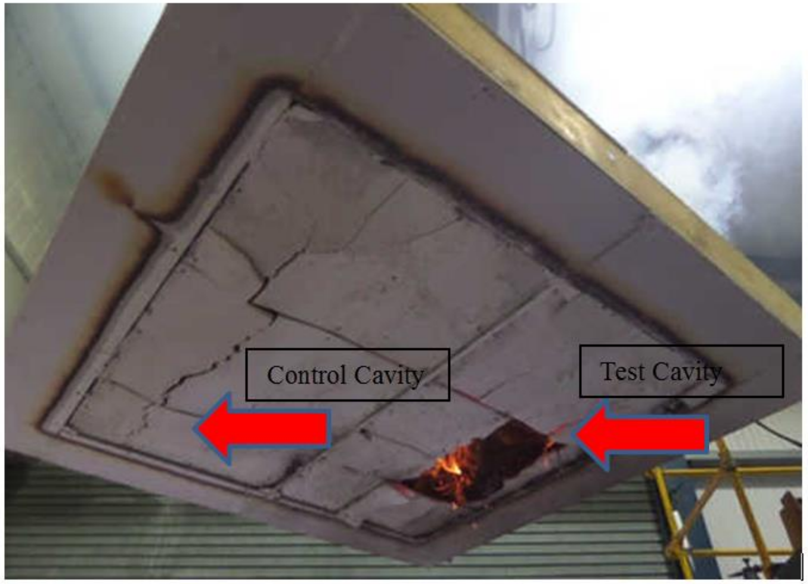
After approximately 12 minutes the test cavity's mean gypsum plasterboard temperature was consistently above that in the control cavity, suggesting that the inclusion of the pipe penetrations did lead to additional heating of the rear of the gypsum plasterboard.



By visual observation through the furnace window, after approximately 30 minutes the first layer of 12.5 mm gypsum plasterboard had predominantly fallen off; thereafter cracks appeared in the 19 mm inner layer of gypsum plasterboard.

Cracks eventually connected the apertures for the pipe penetrations to each other and to other cracks and a single larger hole developed. It seems probable that the proximity of the 40 mm diameter apertures for the pipe penetrations to each other, led to particular stress concentrations in the gypsum plasterboard.

The inner layer of gypsum plasterboard to ‘Test Cavity A’ failed to a greater extent than the inner layer gypsum plasterboard to ‘Control Cavity D’ as can be seen as the sample was lifted from the furnace.



It was noted that even before the pipe penetration apertures joined and formed a single larger hole some combustion was evident in the test cavity; flames appeared sporadically through the 40 mm apertures into the furnace. This sporadic flaming combustion was probably limited by the amount of oxygen available for combustion within the cavity and by the oxygen available within the furnace.

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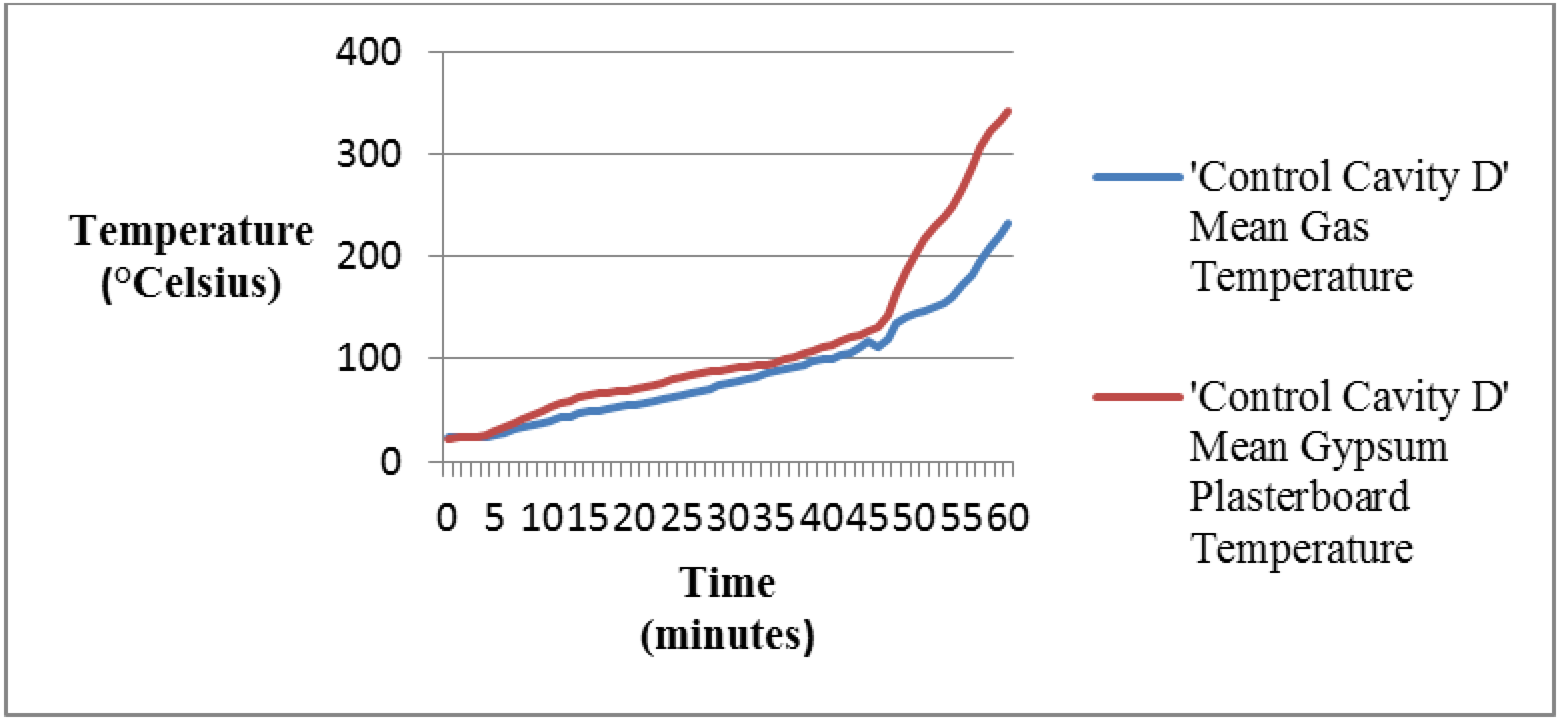
The mean gypsum plasterboard temperature in ‘Control Cavity D’ was consistently higher than the mean gas temperature; presumably due to conductive heat transfer through the gypsum plasterboard.



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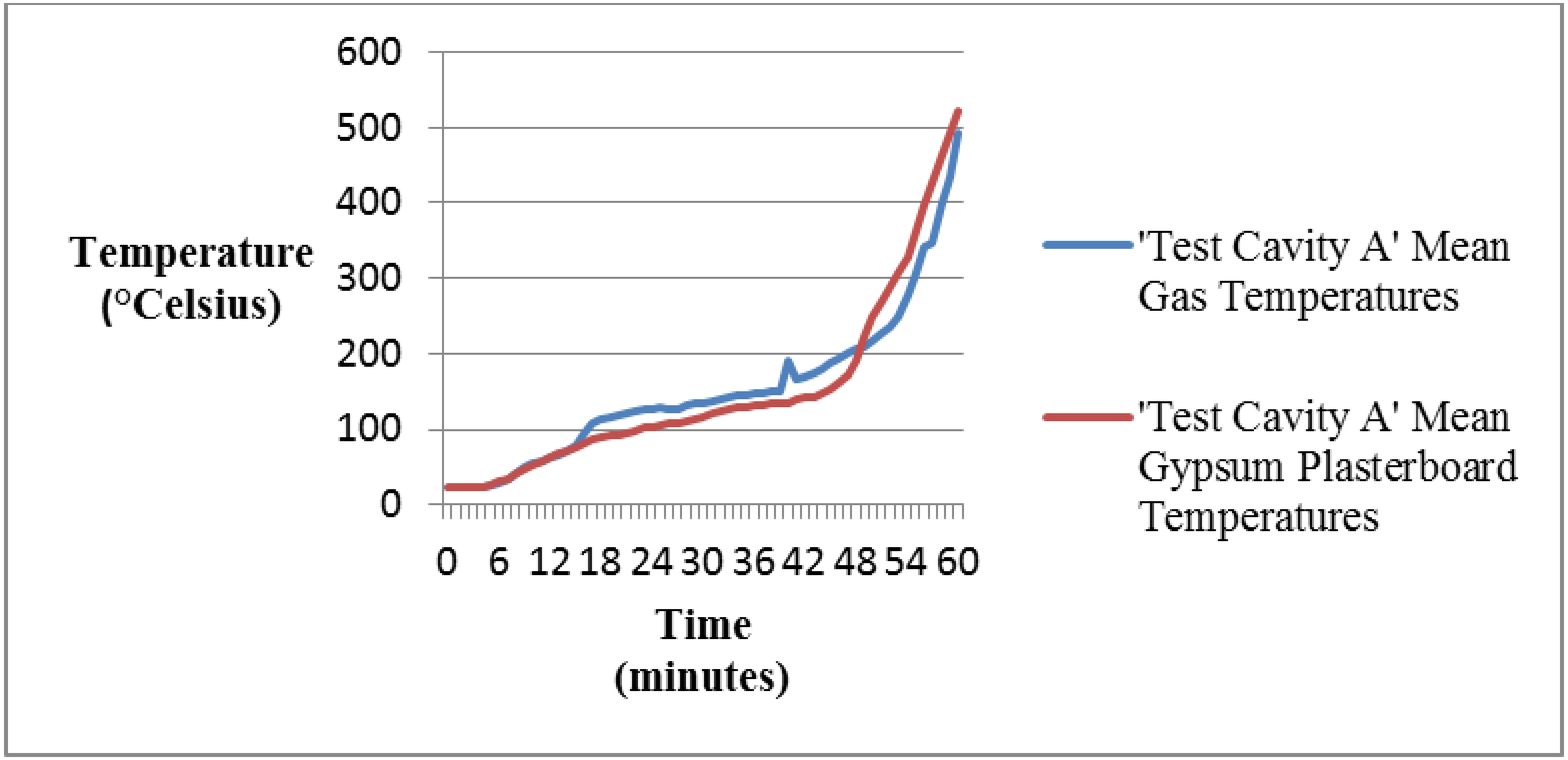
In the test cavity, for part of the test period the converse was true. This reversed towards the end of the test period when the gypsum plasterboard temperature exceeded the gas temperature, which approximates with the time that cracks between the penetration apertures joined, forming one larger hole in the inner layer of 19 mm gypsum plasterboard.



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Conclusions

The two indicative dehydration temperatures, 100°C and 200°C, were reached on the rear of the gypsum plasterboard to the test cavity containing service penetrations sooner than in the un-penetrated control cavity.

'Fall-off' of the inner layer of 19 mm gypsum plasterboard was more extensive to the test cavity containing the service penetrations than the control cavity with no penetrations.

Limitations and Future Work

The main limitation of the research discussed here was that the fire tests were at a reduced scale. This is pertinent as the volume of the construction cavity, which is a function of joist depth, span and the joist spacing, will have an effect on the rate at which the void increases in temperature. Additionally at reduced scale it was not possible to load the floor sample and as such the effects of deflection were excluded.

Although these experiments are indicative of a potential problem with building regulation guidance regarding unprotected service penetrations, further fire resistance tests require to be carried out which better represent realistic spans and loadings. These tests should utilise a full sized furnace and include loading of the floor specimens in order to determine whether failure would actually occur.

Thank you.