# Smoke Ventilation of Common Access Areas of Flats and Maisonettes (BD2410) - Final Factual Report

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## Executive Summary

The project *Smoke Ventilation of Common Access Areas of Flats and Maisonettes and their Relationship to the Provision of Compartmentation and Means of Escape Procedures* was undertaken as part of the ODPM Fire Safety Framework Agreement. The main project objectives were to assess the performance of smoke ventilation/control measures for common access corridors and stairs in flats and maisonettes and provide recommendations in support of revisions to Approved Document B.

A Steering Group drawn from industry, Government and other enforcing bodies has overseen the project and advised on the scenarios and smoke management measures to investigate.

There were three main components to the project, the first comprised an extensive review of previous and current research and worldwide practice. This identified the range of smoke management methods in use, and provided information on their relative advantages and disadvantages. From this review a selection of natural and mechanical ventilation schemes was drawn up for further study by physical and numerical modelling.

The second component of the project involved a series of over 70 experiments with a 1/5$^{th}$ scale physical model of a six storey building, with a fire inside a first floor dwelling and various arrangements of lobbies, corridors and stairs. These experiments, conducted mainly with a fixed fire size, door opening conditions and ventilation settings, showed that simultaneously protecting the stair from smoke and maintaining good conditions inside the adjoining corridor was not possible by natural smoke management schemes. By a careful setting of the air flow rate, mechanical smoke extraction from the corridor, coupled with adequate provisions for replacement air, was able to maintain a stratified smoke layer in the corridor while limiting the amount of smoke entering the stair. By either mechanical extracting from the corridor at a sufficiently high rate or by using naturally ventilated smoke shafts, it was possible to protect the adjoining stair from smoke ingress, but generally at the expense of smoke filled conditions inside the corridor.

The third component of the project involved over 500 numerical simulations of the relative performance of a wide range of smoke management schemes. This supported the findings from the physical modelling study, and extended the scope of the modelling programme to examine larger fire sizes and door openings (akin to a firefighting situation), to include alternative natural wall venting and smoke shaft geometries, to study a wider range of mechanical smoke extraction schemes and to assess the relative performance of stair pressurisation. Furthermore, the influence of adverse wind (or building stack) pressures was examined.

The project has highlighted that, if exposed to smoke from a dwelling fire for more than a short duration, the adjoining common corridor / lobby can be expected, in general, to become smoke filled. While external wall vents to the lobby / corridor may in some circumstances maintain tenable conditions inside these spaces (by virtue of creating a stratified smoke layer), in general a specially engineered mechanical solution would be

required in order to maintain tenable conditions. This could be in the form of either a smoke extraction scheme or a pressurisation scheme with protection extended into the common corridors.

Smoke protection to a stair adjoining a common lobby / corridor can be achieved quite effectively by a naturally ventilated smoke shaft located in the lobby / corridor. This serves to draw smoke from the corridor and depressurise the corridor relative to the adjoining stair. Alternatively, air/smoke can be mechanically extracted from the corridor and, provided replacement air provisions are made, the stair can be protected from smoke ingress. Stair pressurisation, with air/smoke relief from the corridor, provides an alternative means of mechanically protecting the stair. The mechanical schemes can be designed according to non-fire pressure differential and open door air speed criteria, and in general will be more robust with respect to adverse wind and building stack pressures than naturally ventilated smoke shafts. Both the mechanical and natural (smoke shaft) stair protection schemes will not, in general, maintain tenable conditions inside the lobby / corridor if exposed to smoke for any appreciable duration.

Some of the findings in respect to conditions inside a corridor, ventilated by natural or mechanical means, have been supported by an analytical study of smoke propagation in a corridor adjoining a fire compartment.

The findings from the review, modelling studies (physical and numerical) and supporting analytical work have collectively provided evidence for making recommendations for amendments to Approved Document B. These are not included in this report.

The details of the work undertaken in the project and the main results and findings are included as a series of appendices. It is important to note that these appendices should be read in the context of providing supporting evidence for the recommendations to Approved Document B, and do not constitute design guidance in themselves.

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## Contents

Appendix Fi – Selected 'visibility distance' contours for CFD 'corridor' scenarios; 0.25 MW fire; 0.1m door gap to dwelling & stair

Appendix Fii – Selected 'visibility distance' contours for CFD 'corridor' scenarios; 1 MW fire; 0.5m door opening to dwelling & stair

Appendix Fiii – Selected 'visibility distance' contours for CFD 'corridor' scenarios; 2.5 MW fire; 0.78m door opening to dwelling & stair

Appendix G – References for Appendices A to F

Appendix H – Summary of final report on the smoke management of corridors in residential apartments

## Introduction

The project Smoke Ventilation of Common Access Areas of Flats and Maisonettes and their Relationship to the Provision of Compartmentation and Means of Escape Procedures was undertaken as part of the ODPM Fire Safety Framework Agreement. It was led by BRE with participation also from consortium partners the University of Ulster and Buro Happold.

The main objectives were to:

- review current methods for smoke ventilation/control for common access corridors and stairs in flats and maisonettes;
- assess the performance of selected smoke ventilation/control measures;
- consider the common access areas and how they relate to the need to provide compartmentation and their effect on Means of Escape procedures;
- provide recommendations, in the form of draft amendments, in support of Approved Document B.

By addressing the above objectives it was intended that the requirements for smoke ventilation in common areas of flats and maisonettes be better understood, and the rationale for, and performance of, alternative smoke management measures be better documented. The project was to consider the initial stages of a fire, where occupants from the fire dwelling, and perhaps also neighbouring dwellings, would be making their escape, and also later stages where firefighting operations may have commenced or evacuation from other building storeys be required.

A Steering Group drawn from industry, Government and other enforcing bodies has overseen the project and advised on the scenarios and smoke management measures to investigate. This helped ensure the project remained focussed on the needs of the UK and its Building Regulations.

The project was to achieve its objectives by reviewing the literature and practice in the UK and worldwide, by undertaking physical scale experiments, by performing numerical simulations and by analytical study as appropriate. It was, in some respects, an extension of the study undertaken in a recent Government funded project to assess the performance of naturally ventilated smoke shafts for controlling smoke for fire-fighting operations within fire-fighting shafts [1]. The focus of this earlier study was, however, more towards commercial buildings rather than residential.

## Project summary

The first component of the project was an extensive review of previous and current research and worldwide practice. This identified the range of smoke management methods in use, and provided information on their relative advantages and disadvantages. Appendix A contains an extended summary of the review. The review assisted in the selection of natural and mechanical ventilation schemes for further study by physical and numerical modelling, and provided important information when drafting the recommendations for Approved Document B.

Meetings with the Steering Group drawn from industry, Government and other enforcing bodies has overseen the project and advised on the scenarios and smoke management measures to investigate. Together with the findings from the review, this allowed the set of smoke management schemes and geometries to investigate within the project to be defined.

The four following geometries were considered in the physical and numerical modelling studies:

- A fire compartment opening onto a lobby, which in turn opened onto a stair.
- A fire compartment opening onto a corridor, which in turn opened onto a lobby and then a stair.
- A fire compartment opening onto a corridor, which in turn opened onto a stair.
- A fire compartment opening directly onto a stair.

The geometries where a fire compartment opened onto a lobby or corridor, which in turn opened onto a stair, were included in the physical modelling study. All geometries except for the fire compartment opening directly onto a stair were included in the numerical modelling study. Full details of the dimensions, fire sizes, door opening conditions etc are given in Appendix B (physical modelling) and Appendix C (numerical modelling).

The smoke management measures studied included:

- External wall vents of cross-sectional area 0.5 $m^2$, 1 $m^2$ and 1.5 $m^2$, located either at high or low level.
- Naturally ventilated smoke shafts of cross-sectional area 0.25 $m^2$, 0.5 $m^2$, 0.75$m^2$, 1 $m^2$, 1.5 $m^2$ and 3 $m^2$, with either open or closed bases. In the results presented, a single smoke shaft was considered, located either at one end of the corridor / lobby or (in the corridor geometries) at the centre, with the vent into the shaft located on the end / side wall. Various sizes of ventilation openings (from the lobby / corridor into the shaft) were investigated
- Mechanically powered extraction from the corridor / lobby, with the vent into the exhaust shaft located as for the naturally ventilated smoke shafts (i.e. at one end

 

of the corridor / lobby or (in the corridor geometries) at the centre, with the vent into the shaft located on the end / side wall).

- Mechanically powered smoke exhaust ventilation from the ceiling of the corridor, balanced with floor level makeup air. For the corridor there were three ceiling exhaust vents, while for the (shorter) lobby there were two only.
- Pressurised stairwells, with air supply at top of the stair and an opening of 1 $m^2$ at the base of the stair. This simple arrangement was chosen for numerical convenience to allow comparison of its performance and the required (mechanical) effort against that of the alternative natural and mechanical measures, and does not represent a particular proposed pressurisation method.

While all the above were included in the numerical study, the physical modelling was restricted to external wall vents, 1.5 $m^2$ and 3 $m^2$ natural smoke shafts, and mechanically powered extraction into shafts at the ends of the corridor.

Appendix B provides details of the physical scale modelling study, which was performed using a 1/5$^{th}$ scale model of a six storey building with a fire inside a first floor dwelling. These experiments, conducted mainly with a fixed fire size, door opening conditions and ventilation settings, showed that simultaneously protecting the stair from smoke and maintaining good conditions inside the adjoining corridor was not possible by natural smoke management schemes. By a careful setting of the air flow rate, mechanical smoke extraction from the corridor, coupled with adequate provisions for replacement air, was able to maintain a stratified smoke layer in the corridor while limiting the amount of smoke entering the stair. By either mechanical extracting from the corridor at a sufficiently high rate or by using naturally ventilated smoke shafts, it was possible to protect the adjoining stair from smoke ingress, but generally at the expense of smoke filled conditions inside the corridor.

Appendix C provides details of the numerical modelling study, where the full range of smoke management measures was examined in over 500 scenarios. The BRE computational fluid dynamics (CFD) fire model JASMINE was used for this work, which supported the findings from the physical modelling study, and extended the scope of the modelling programme to examine larger fire sizes and door openings (akin to a firefighting situation), to include alternative natural wall venting and smoke shaft geometries, to study a wider range of mechanical smoke extraction schemes and to assess the relative performance of stair pressurisation. Furthermore, the influence of adverse wind (or building stack) pressures was examined. Appendices D to F then contain a comprehensive set of CFD results, in the form of smoke' visibility distance' contours, lobby / corridor temperatures and other information.

In the majority of the experiments and simulations, a steady fire has been assumed, and the work has been conducted to yield steady-state conditions. Furthermore, a fixed open door gap from the fire compartment to the adjoining lobby / corridor and into the stair has been assumed. This was a suitable approach for the purpose of comparing the performance of the range of smoke management options under smokey conditions. However, it should be stressed that the steady-state scenarios, with fixed door gaps /

openings, were designed to provide a relative measure of the performance of alternative smoke management schemes under, arguably, onerous conditions and NOT to generate predictions for any actual 'real-life' scenarios. Limited transient analyses, both with the physical scale model and in numerical simulations, confirmed that the steady state results were representative of conditions that would be found after some 5 to 10 minutes if the fire size and door opening conditions remained fixed.

The main findings from the physical and numerical studies are included under 'main findings and concluding remarks' below.

Appendix G lists all the references for the review and the reports of the physical and numerical modelling studies (Appendices A to C).

Appendix H contains a summary report from the University of Ulster on the analytical assessment of corridor smoke ventilation. This provided additional information when drafting the recommendations for Approved Document B.

## Main findings and concluding remarks

The various aspects of the project, considered as a whole, produced the following main findings:

- If exposed to smoke from a dwelling fire for more than a short duration, the adjoining common corridor / lobby can be expected, in general, to become smoke filled. In the absence of appropriate smoke management measures, neighbouring corridors / lobbies and stairwells can also be expected to become smoke filled. For this reason, smoke containment, provided by the provisions for compartmentation and by smoke-rated fire doors, plays a pivotal role in the overall smoke management strategy for flats and maisonettes. Furthermore, the concept of limited travel distances and the ‘preferred option’ of two escape paths, including the provision for two stairs, is important.

- Subject to an extended exposure to smoke from a dwelling fire, relatively smoke free conditions can, nonetheless, be maintained throughout the common corridors and lobbies by appropriately engineered mechanical solutions. These include direct pressurisation of the corridors / lobbies (generally in combination with pressurising the stairs) with air/smoke relief from the dwellings, or by smoke extraction directly from the corridor / lobby by specially designed systems. The latter could include, for example, distributed ceiling exhaust vents or cross-corridor ‘smoke dispersal’ by means of supply and extract at opposite ends. However, both of these methods require careful fire safety engineering design.

- While a high level of smoke control can be achieved using the measures above, it was found that smoke containment provisions, augmented by ‘relatively’ straightforward smoke ventilation measures, could offer a good level of smoke protection to the stairs, and a limited amount of protection to the adjoining corridor / lobby.

- Natural smoke venting into vertical smoke shafts, in the absence of adverse wind or building stack effects, can protect the stair very well, albeit at the expense of generally leaving the corridor / lobby smoke filled if exposed for more than a short duration. External window vents did, on average, provide some improvement to conditions inside the vented corridor / lobby compared to smoke shafts, but at the expense of less effective protection of the stair.

- Suitably designed mechanical ventilation systems can provide protection to the stairs that is, in principal, resilient to adverse wind and building stack effect pressures. This can be achieved by either depressurising the corridor / lobby relative to the adjoining the stair (extracting air/smoke from the corridor / lobby) or by directly pressurising the stair with air/smoke relief from the corridor / lobby. Tenable conditions inside the adjoining corridor / lobby are not in general maintained if exposed to smoke for more than a short duration. However, by a judicial choice of extraction rate, a depressurised corridor scheme may be able to prevent smoke migration into the stair while at the same time maintaining some degree of smoke stratification in the corridor.

- The 'cold-flow' (non-fire) performance requirement of the above mechanical ventilation systems for either depressurising the corridor or for pressurising the stair could be defined in terms of appropriate closed-door pressure differentials and open-door air flow speeds that were broadly compatible with those currently in BS 5588 Part 4. Indeed, the numerical simulations indicated that in non-firefighting situations there could arguably be scope to reduce the design criteria. However, it should be noted that the 'cold-flow' CFD simulations did not precisely replicate the conditions required when commissioning according to BS 5588 Part 4, and that any design criteria should include compensation for adverse wind and stack pressures etc.

- Increased performance to protect, say, a firefighting stair when exposed to more severe smoke and thermal conditions can be achieved by increasing the cross-sectional area of a natural smoke shaft or by elevated 'cold-flow' design criteria for a mechanical system.

The findings from the physical and numerical modelling studies, together with those from the analytical assessment and the review of worldwide practice and experience, have contributed to the drafting of recommendations for amendments to Approved Document B, not included in this project report. It is important to stress that in drafting these recommendations the 'global picture' was considered, and that findings from individual parts of this project (included in the Appendices) should not themselves be treated as elements of any design guidance.

## References

1. Harrison, R. and Miles, S. *Smoke shafts protecting fire-fighting shafts: their performance and design*. BRE Project Report No. 79204, 2002.

 