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Ventilation and Conservation

Prepared for Historic England by
Dr Brian Ridout, Ridout Associates Ltd

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Front cover: Cast iron grille intended to provide ventilation to the void beneath a suspended timber ground floor in a 19th-century building (©Historic England).

SUMMARY

This report discusses the relationships between timber decay and ventilation. Among architects and other building professionals, the accepted wisdom is that even a little air movement is better than none. Therefore, holes will be made into any kind of cavity with the intention of providing ventilation. The result can be very disfiguring and damaging and has prompted the questions:

- Can air actually be made to flow in small cavities?
- What would we expect small air movements to achieve?

Many building professionals will be surprised that there is any need for further research on ventilation. Therefore, some historical information is presented to show how our faith in air movement has developed.

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CONTACT DETAILS

email: Conservation@HistoricEngland.org.uk

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1 INTRODUCTION

Historic England has been investigating the relationships between timber decay and ventilation for several years. For architects and other building professionals the need to ventilate cavities has become almost a mantra. Holes will be made into any kind of cavity and the accepted wisdom is that even a little air movement is better than none. The result can be very disfiguring and damaging and has prompted the questions: Can air actually be made to flow in small cavities, and what would we expect small air movements to achieve?

The results from the preliminary investigation have encouraged Historic England to expand its investigations into cavities vented to the exterior, including wall cavities, roofs and sub-floor voids.

Many building professionals will be surprised that there is any need for further research on ventilation. Therefore, some historical information is presented to show how our faith in air movement has developed.

2. WHY DO WE THINK THAT AIR MOVEMENT PROTECTS TIMBER?

Belief in the benefits of natural ventilation now pervades building conservation. At first sight this belief does not seem to be unreasonable. ‘Hygienists’ of the 19th century showed that ventilation dispelled condensation and invigorated a building’s occupants, while mycologists in the 19th and 20th centuries claimed that air movement discouraged fungus growth – particularly dry rot. A draughty buildingwas a healthy building.

The idea that ventilation is beneficial for the occupants of a building is not in dispute. But the notion that it prevents timber decay is more questionable. Belief in this idea developed during the 19th century. In 1878, Henry Simpson writing in *The House - Health Lectures for the People* stated:

> *“Spaces must be left under the floors, on the ground level, if they are of wood, or they will soon decay; and they ought to be well ventilated with some of the various contrivances as ventilating bricks etc those are now so common.”*

The ventilating bricks he refers to seem to have been first patented by John Burridge, who published a book in 1825 with the somewhat ponderous title *Improvements in Civil Architecture* ‘proving the necessity, utility and importance of ventilation to render wood equally durable as walls’. Burridge, in turn, acknowledges and develops ideas first expounded by Ralph Dodd in his 1815 book *Practical Observations on the Dry Rot in Timber.*

Our modern belief that ventilation protects timber, therefore, has a pedigree that dates back at least to 1815, but in the days of Dodd and Burridge there was no general acceptance that 'dry rot' was caused by fungi that required water. The important point was that ventilation circulated air around the timber and not that it kept the timber dry. Burridge, for example, writes:

> *'The durability of wainscots (whether against dry or wet walls) would always be increased by ventilation, and this might easily be done by boring small ornamental holes at regular intervals, a little above floors and near ceilings in cornice borders, which would allow a gentle current of air.'*

However, by the end of the 19th century it was firmly accepted that 'dry rot' was caused by water-requiring fungi, and by the mid-20th century it was well known that the source of water had to be significant and continuous. Now the floor vents advocated by Simpson, and the little holes advocated by Burridge, not only had to supply air, they had to supply enough, and at a suitable humidity, to dry the sub-floor or wall void (if it was wet enough for decay) and keep it dry. This expectation was unrealistic, but the idea of cavity ventilation was so entrenched that nobody noticed. Ventilation became even more problematical when research in Dundee, *Studies of the domestic dry rot fungus Serpula lacrymans with relevance to the management of decay in buildings* (Technical Conservation and Education Division, Historic Scotland, Edinburgh, 2012) found that small air movement stimulated the growth of dry rot, thus demonstrating, contrary to accepted wisdom, that a little air movement was not better than none at all.

Nonetheless, architects and building professionals are wary of not ventilating cavities. Even the manufacturers of waterproofing membranes corrugate surfaces applied to walls and claim that this allows air movement. However, nobody really knows if air flows in these situations. Fashion and commerce encourage ignorance and the result is frequently wasted time and money. Too often the assumptions about air movement and associated benefits lead to unnecessary damage to the building and the risk of unforeseen decay.

3 VENTILATING SMALL CAVITIES INTO ROOMS: A LABORATORY ASSESSMENT

A ventilation study was commissioned by English Heritage and the Office of Public Works in Dublin to investigate air movement in a small vertical cavity vented by holes formed top and bottom. The practical work was undertaken by the School of Mechanical, Aerospace and Civil Engineering at the University of Manchester.

3.1 Method

Air movement in small cavities, even if something is added to make the flow visible, will generally be concealed by the opacity of the enclosing materials. This research therefore used a 2m x 2m test rig with a light aluminium frame. The front was formed from transparent acrylic plastic with good optical properties and the back from medium density fibreboard. The cavity was 50mm wide to replicate the void behind a wall lining. Flow was visualised with minute glass spheres, and modelled using computational fluid dynamics.

3.2 Results

The test cell was run with different sizes and configurations of inlet and outlet vents (for example, Figure 1). Figures 2 and 3 are typical of the results obtained.

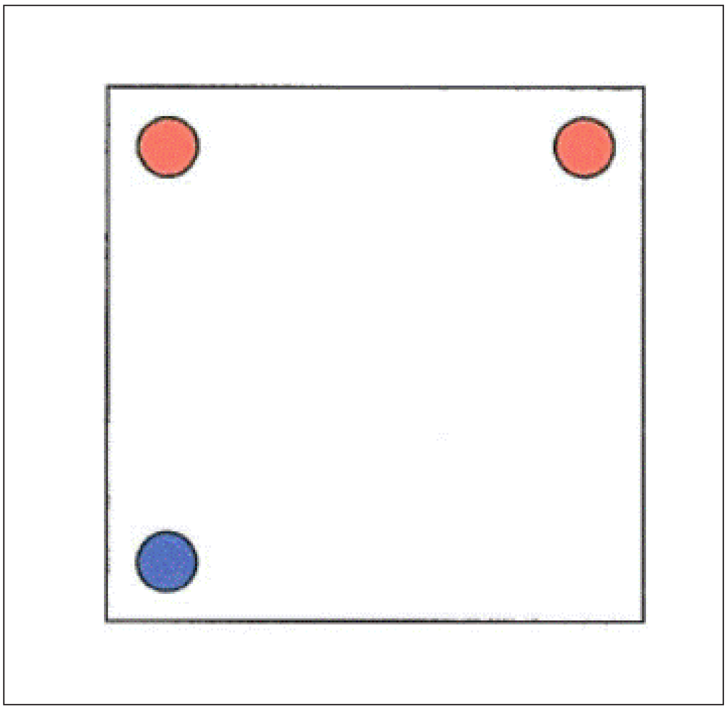

Figure 1: Position of inlet vent (blue) and outlet vents (red). Vents 110mm in diameter and void set at 50mm depth.

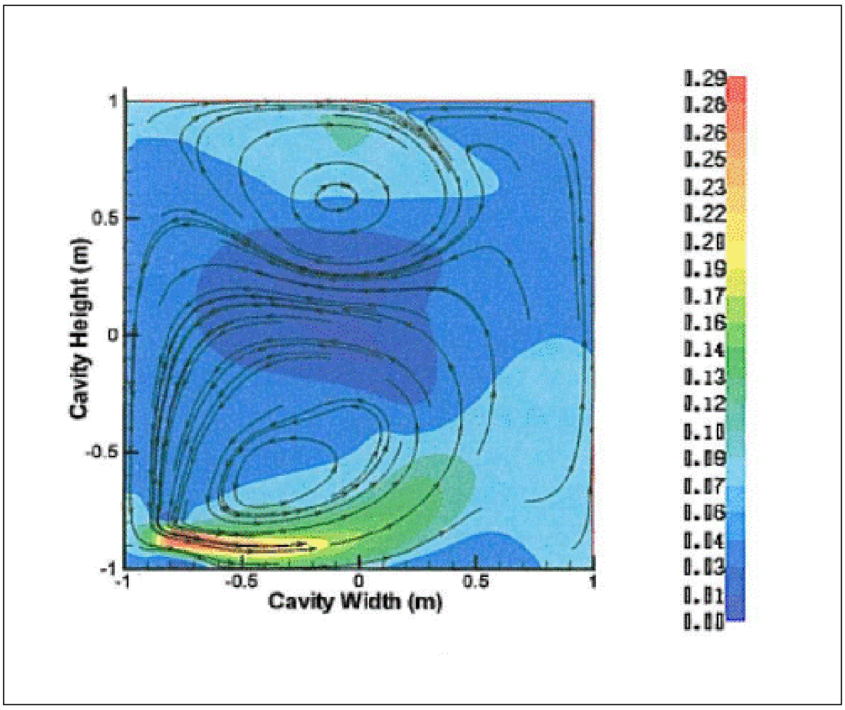

Figure 2: Stream trace for Inlet Velocity 0.3 – 0.4 m/s, with the Velocity Contour coloured by Velocity Magnitude. Inlet in the bottom left corner.

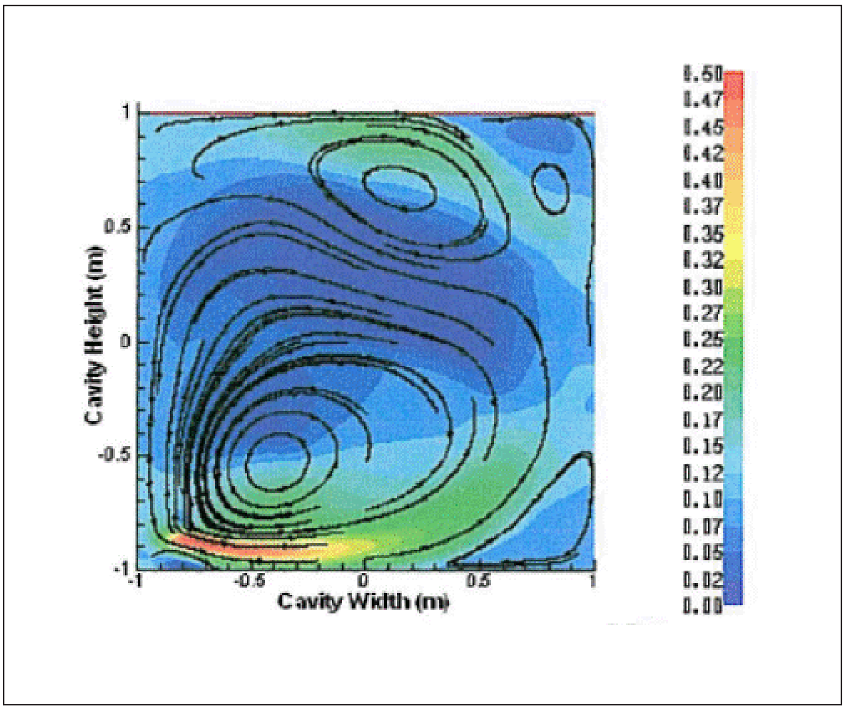

Figure 3: Stream trace for Inlet Velocity 0.9 m/s, with the Velocity Contour coloured by Velocity Magnitude.

3.3 Discussion

Results from a range of vent configurations and air speeds showed that air does not take a direct course through a cavity at low air velocity, even though there were no obstructions within the void. Counter currents, stagnant areas and vortices were all formed, and increasing the air speed at the inlet did not remove the turbulence but generally made the air flow more unstable.

As stated in the introduction, a major reason for undertaking this research was a desire to question the widely held perception that making a hole in the top and bottom of a wall lining (or other internal void) would encourage air to flow. The results of the laboratory assessment allow this perception to be evaluated:

- The Thermal Comfort Standard (IS07730) recommends that in 'normal thermal comfort environments' the air velocity should be less than 0.25 m/s. In winter this should be less than 0.15 m/s. The later is probably the lowest limit detectable by human sensory cells. This means that, unless we want a draughty room or use forced ventilation, the environment in a wall cavity within the room will be static, or approaching that shown in Figure 2. An input air flow of around 3m/s was needed before air would take a direct path through the cavity. This would be unacceptable within a building, even if it could be contrived.

- The generally perceived reason for ventilation is to keep a cavity dry, but if there is free water within the wall surface then the rate of vapour removal is proportional to the square root of the air speed. But the air speed in the cavity, as indicated by Figure 1, is mostly below 0.1 m/s so that the drying effect, assuming there is water that is removable, must be very small.

- If the air does manage to remove any moisture from the wall, it is more likely to circulate around in the void rather than exit at the top of the cavity, and it may even accumulate in the stagnant zones.

3.4 Conclusions

These results indicate that a poorly thought out ventilation scheme might easily have unexpected consequences, and that making a few holes into internal voids is unlikely to achieve anything useful.

4 VENTILATING CAVITIES TO THE EXTERIOR

Our conclusions that significant airflow is required before air will move through a cavity has important consequences, but our investigation also produced other conclusions that are relevant to ventilation from the exterior.

1. **Large holes don't always mean better airflows** – in the context of heritage buildings this is reassuring as large visible holes are intrusive.

2. **Distribution of openings is far more important than opening siz**e – the results seem to suggest that horizontal spacing of openings 1 metre apart would play a major part in eliminating stagnant air pockets, although they still are not completely absent. However, few ventilation schemes would be installed at 1m intervals and the results would be unsightly.

3. **An arrangement of openings at top and bottom encourages air flow from the top of the wall cavity to the bottom. This is because the induced wind pressure at low level is less than at high level due to ground level friction effects** – this is an interesting conclusion because it means that cavity wall ventilation is practical, but the ground friction effect has serious implications for sub-floor ventilation.

4. **Shelter of the wall in relation to the incident wind velocity will have a major effect upon the resultant wind velocity within the wall cavity** – for simplicity, clear terrain was assumed for our investigation, but this may not always be a valid assumption in reality. It certainly imposes considerable constraints on sub-floor vents concealed by shrubs and flower beds.

5. **It would appear that presence of a temperature gradient across the wall layers (adiabatic system) does not induce a significant convective air movement component in comparison to an isothermal system. It is suspected that the influence of convection might be greater on a taller wall cavity.** In a low velocity regime, the convective component has a proportionately greater effect. At higher incident wind velocities, the wind induced pressure component dominates.

4.1 Historical illustration: Cavity walls

The question of wall cavity ventilation seems to have been first argued 150 years ago and is still a topic for contentious debate, which is now augmented by the marketing of cavity wall insulation.

The first reference to cavity walls seems to be in William Atkinson's 1805 book, *Views of Picturesque Cottages with Plans*. Here he stated that a hollow wall saves the cost of materials. But he also perceived as a further advantage, that the trapped air would act as an insulating layer. This idea was taken up by an anonymous contributor to *The Builde*r issued 28th January 1860:

> *"Air is a poorer conductor than stone, and costs nothing save the box or hollow in the wall which holds it, and this is only a question of slightly increased labour in construction, an dnot a question of material, for the same amount of materials may be made stronger if hollow than if solid. Here we come to the great and common mistake which too often renders hollow walls no better than solid ones, viz., instead of absolutely confining the stratum of air, and isolating it from the outer atmosphere, they permit it to change, to escape when heated, and make room for fresh air from without; in short, to circulate, in which case they are worse than a single wall. Many attempts are made, especially in the country, to prevent the dampness of brick or stone houses by making hollow walls, and they generally fail because the contained air is not absolutely confined. Dampness does not come from without, through the wall, but is deposited from the air within when it comes in contact with the walls, which have been made cold simple because they are not thorough non-conductors. The greatest care should be taken to stop all holes, however small, especailly between the outside atmosphere and the enclosed non-conducting stratum."*

The author believed that wall cavities must be sealed because any air movement would be likely to introduce moisture into the cavity. He did not believe that moisture could penetrate the outer wall.

This concept was challenged by 'WR' in the edition dated 24th February 1860 whose experience indicated that water would certainly penetrate the outer wall and should be allowed to escape by means of weep holes at the base of the cavity.

"Having to erect several houses in a situation much exposed to severe south-west storms from the sea, and the bricks procurable being excessively porous, the hollow-wall expedient was resorted to – (half-brick outer wall, a 2-inch hollow, and a 9-inch inner wall) – the two tied together with wrought-iron cramps). At the line of the chamber window-cills, however, two through-courses were improperly introduced. The work advanced, and was completed during the fine part of the season. Just previously to the return of the wet season the plaster seemed quite dry; but immediately afterwards a band of damp appeared on the inside of all the chamber-walls having a south-west aspect. As the season advanced the damp increased, so that the whole of the south-west walls became literally drenched with wet, from the line of the upper cills down to the ground floor: even the floors half-way across the rooms were quite wet.

On visiting the work, a question or two disclosed how the specification had been departed from in building the walls: the through-courses at the upper cills were the cause of the whole mischief. They were immediately cut out; the separation between the outer and inner walls rendered complete; frequent openings, the thickness of a joint, made in the outer walls at the bottom where the hollow work commenced; and since then (not twelve months ago) 'the storms have not ceased to beat upon the houses,' but damp has certainly ceased to penetrate to the inner walls in the very slightest degree.

If the rain penetrated the 16-inch solid work, must it not also penetrate the 4½-inch outer wall? and it would have ceased to penetrate the inner wall if no openings had been left at the bottom?"

William Peachey, writing in the edition for March 3rd 1860, took the theme further and advocated ventilation at the top and at the bottom of the cavity.

> *"Several years since I introduced in the erection of a small detached house a 12-inch hollow wall, constructed with a 4½-inch brick wall inside and outside, leaving a space of 3 inches between, and tied together with 12-inch headings at convenient distances, to make the work secure. Small air-grates were inserted at the bottom and top of the wall, to give a current of air through the walls. I found it answer very well, and since then a number of houses have been built in the same manner: one especially I may name, that has been rebuilt by the side of a brook, in a very damp situation, – so damp that it was impossible to keep paper upon the walls of the house previously standing upon the same spot. I have taken the trouble to inquire at this and several houses if they find any damp at any time in any particular place, and the answer is in the negative. I therefore infer that the above experiment is successful, and that the damp does not find its way through the headers, neither does the admission of a current of air cause the inner portion of the wall to become damp; but, on the contrary, I think the admission of air would keep it dry; care, however, should be taken that a course of headers is not put under the windowsills, or the damp will find its way through them, especially if the sills are not properly throated. If I am in error I shoud be very glad to be set right."*

Thus it would seem that different observers reached different conclusions and there was no agreement about the benefits of cavity walls except perhaps that they reduced the quantity of bricks required. However, having constructed a cavity, ventilation became a question for debate.

4.2 Sub-floors

Our investigation of sub-floor ventilation is ongoing, but the results presented above do provide some interesting indications. If ground friction limits air flow at ground level then for many situations we must add bedding plants and perhaps a few shrubs to the problem. The incident air velocity at the sub-floor vent is likely to be low even if the vent is clear. If air bricks are spaced at 1.8m intervals, as usually recommended, into a large void containing joists and sleeper wall (even if honeycombed) all of which impose friction, then it is optimistic to expect much air flow. More will be achieved if the floor above is uncarpeted with gaps between boards that allow a stack effect up through the building, but if there is sufficient air flow in this situation to avoid dead spaces and vortices in the void, then the building would be very draughty. Sub-floor vents mostly gained popularity as part of the Victorian initiative to make buildings healthy for people and draughts were acceptable. Certainly Dodd, Burridge and others (see Historical overview above) thought that air movement would protect timber, but this was not because they thought it would keep it dry.

Most building professionals will still look at dry rot (for example) beneath a floor and blame it on lack of ventilation, but dry rot needs a wood moisture content that is near fibre saturation (mc 28%–30%) to thrive and this moisture content has to be sustained. Low speed swirling air currents from air vents, even if air flow was possible, would not stop the fungus and might stimulate it.

Expected air velocities within a range of sub-floor void types were modelled by TRADA in the 1980's. Using 225mm x 150mm airbricks set at 1m intervals. The general conclusion for all floors was that air velocities were low in 10% of the sub-floor space and that this figure should probably be increase to 20% to include friction from the floor structure. This figure does not seem to be too bad, until we note that their criterion for low air speed was 0.005m/s. At least 20% of the air was essentially static and presumably this figure would rise considerably if it was raised to the 0.25m/s threshold above which air movement can be perceived as a draft.

Most professionals believe that ventilators should not become blocked and it is clear that if the ventilators are serving a useful purpose then they should remain open. However this problem requires investigation because wall or floor infill insulation must significantly affect air flow. If, however, air flow is normally so slow that the affects are insignificant, then blocking the vents may not matter provided that the insulation does not trap moisture.

5 CONCLUSIONS

The objective of ventilation is to remove excess moisture, frequently condensation, resulting from building usage. This may be valid in modern impervious building constructions, but is it relevant to historic buildings?

Timber buffers humidity so that a traditional enclosed roof space (for example) may produce a very stable environment. The large surface area of wood can easily absorb any excess moisture rising from the rooms below, even if there is a new kitchen or bathroom. Wood moisture contents might rise by a percent or two but this could not cause decay under normal circumstances.

Ventilation to the exterior, however, will introduce moist air into the structure for most of the year. At best this will achieve nothing, whilst at worst it will cause environmental instability in a structure that may have survived safely for several hundred years. The vents also allow easy entry of pest creatures including furniture beetles that will easily colonise any modern timbers used for repairs.

If the structure is actually damp then the results may be equally unsatisfactory. For example if outside air with an average humidity of 60–70% percolates into a damp sub-floor void then it will cool and its relative humidity will rise as its temperature drops. The amount of water the air can then absorb will be very small unless air movement is considerable. The normal result, if air moves at all, will be slowly moving damp air rather than static damp air. This will have little effect on any decay organisms and may assist them by spreading fungus spores and insect pheromones. The most important part of the remedy must be to find out why the sub-floor is damp and to remove the source of moisture.

Ventilation will only be useful in special circumstances where the following requirements pertain:

- There is excess moisture.
- The moisture is finite and can be removed.
- The method of ventilation will allow air circulation throughout the void.
- The relative humidity and speed of the air allows it to absorb the excess moisture.
- The damp air within the cavity can be exchanged for drier air outside of the cavity.

If roof or sub-floor timbers are sound and dry then attempting to ventilate them is meaningless and may cause problems that were not there before. However, if insulation is added to improve energy efficiency, this will affect the hygric balance to some degree and can sometimes have unintended consequences. Historic England is currently investigating this through a programme of laboratory- and site-based studies.

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