Technical Note No 70

Thermal and moisture performance of cavities in building envelopes

The use of air cavities in wall construction is commonplace and may provide an improvement in performance, as well as providing a more robust design. The air cavity may increase the overall thermal resistance of the wall. It may also provide a means of removing moisture from the wall, through drainage and/or ventilation. Typical examples are the cavities in a rainscreen system or a brick/block wall.

This Technical Note describes the thermal and moisture performance of different air cavities within wall constructions. This Technical Note should be read in conjunction with:

TN 33 Breather membranes and vapour control layers in walls
TN 46 Introduction to building envelope energy transfer

Introduction

There are two main sources of moisture that have to be considered when designing a wall. These are water from the external environment, usually in the form of rainwater, but may also include the diffusion of moisture from a wet surface, and moisture vapour diffusion.

In temperate climates such as that found in the UK, the air in the internal environment usually contains more moisture than the outside air. Therefore moisture vapour will tend to migrate outwards through the construction.

Water penetration resistance

There are two main approaches to water penetration resistance. They are:

- Face sealing
- Secondary defence

Face sealed systems rely on the outer skin of the construction alone to prevent water penetration. If there is any moisture ingress past the external skin, there is no provision to allow the water to drain back to the outside.

An alternative approach to water penetration resistance is to provide a secondary defence. This usually takes the form of a cavity behind the external face of the wall. The cavity allows moisture that passes the external face to drain back to the outside through openings in the outer surface. The cavity may also have sufficient openings to allow ventilation, for increased moisture removal.

Moisture transfer

A drained and/or externally ventilated cavity may also be beneficial in the removal of any moisture that migrates through the wall from the warm moist internal environment.

The amount of moisture diffusion through the wall can be reduced by incorporating a correctly detailed vapour control layer (VCL) as close to the internal surface as possible (see TN33 – Breather membranes and vapour control layers in walls). This however is not a guarantee that moisture will not accumulate within the wall construction as this method relies on the VCL being installed without gaps and holes, which is difficult to achieve at junctions and around penetrations. Water vapour may also be trapped by other materials with a higher vapour resistance within the wall.

![Figure 1 Principles of cavity construction](image-url)
does get past the internal VCL to be safely removed to the outside. If such a cavity is not used then there is the risk that moisture vapour will be trapped within the wall where it may condense and the water cause damage to adjacent materials.

Classification of air cavities

Air cavities may be classified according to a number of different factors. These include the position of the cavity in relation to the main insulation layer, and the size of the openings in the outer surface.

Cold cavities

Cold cavities are located to the cold side of the main insulation layer. Because they are cold the moisture content should be kept low to reduce the risk of condensation forming. A VCL on the warm side of the insulation will reduce the moisture content in the cavity. Alternatively they should be ventilated to the outside to remove moisture and keep the moisture level close to outside levels.

Warm cavities

Warm cavities are located to the warm side of the major insulation layer. The cavity surfaces will be warmer than those of a cold cavity and the risk of condensation very much less. A vapour control layer may still be required to the internal face of the cavity in order to keep it dry.

Externally ventilated cavities

BS 5250 classification

The following classifications are taken from BS 5250: 2002 - Code of practice for control of condensation in buildings.

Vented air space

Cavity or void that has openings to the outside air placed so as to allow some limited, but not necessarily through, movement of air.

BS EN 6946 classification

The following classifications are taken from BS EN ISO 6946: 2007 - Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

Unventilated air layer

An unventilated air layer is one in which there is no express provision for air flow through it.

An air layer having no insulation layer between it and the external environment but with small openings to the external environment shall also be considered as an unventilated air layer, if these openings are not arranged so as to permit air flow through the layer and they do not exceed:

- 500 mm² per m length for vertical air layers;
- 500 mm² per m² of surface area for horizontal air layers.\(^1\)

Note - Drain openings (weep holes) in the form of open vertical joints in the outer leaf of a masonry cavity wall are not regarded as ventilation openings.

Slightly ventilated air layer

A slightly ventilated air layer is one in which there is provision for limited air flow through it from the external environment by openings of area, \(A_v\), within the following ranges:

- \(> 500 \text{ mm}^2 \text{ but} \leq 1500 \text{ mm}^2\) per m length for vertical air layers;
- \(> 500 \text{ mm}^2 \text{ but} \leq 1500 \text{ mm}^2\) per m² of surface area for horizontal air layers.\(^1\).\(^1\)

Well ventilated air layer

A well ventilated air layer is one for which the openings between the air layer and the external environment exceed:

- 1500 mm² per m length for vertical air layers;
- 1500 mm² per m² of surface area for horizontal air layers.\(^1\).

1) For vertical air layers the range is expressed as the area of openings per metre length. For horizontal air layers it is expressed as the area of openings per square metre area.

Thermal resistance of air cavities

A still air layer in a cavity construction will add to the overall thermal resistance of the element and therefore reduce the U-value. The contribution that the cavity makes will depend on the level of ventilation between the cavity and the external environment and the direction of the heat flow.

Unventilated air layer
Design values of thermal resistance are given in table 1. The values under “horizontal” apply to heat flow directions up to 30° from the horizontal plane. The table is taken from BS EN ISO 6946: 2007.

<table>
<thead>
<tr>
<th>Thickness of air layer [mm]</th>
<th>Direction of heat flow</th>
<th>Upwards [m²K/W]</th>
<th>Horizontal [m²K/W]</th>
<th>Downwards [m²K/W]</th>
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<td>0.16</td>
<td>0.18</td>
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<td></td>
</tr>
</tbody>
</table>

Note – Intermediate values may be obtained by linear interpolation.

Table 1 Thermal resistance of an unventilated air layer

The values given in the table 1 apply to an air layer which:

- is bounded by two faces which are effectively parallel and perpendicular to the direction of heat flow and which have emissivities not less than 0.8;
- has a thickness (in the direction of heat flow) of less than 0.1 times each one of the other two dimensions, and not greater than 0.3 m;
- has no air interchange with the internal environment.

Note - A single thermal transmittance should not be calculated for components containing air layers thicker than 0.3 m. Rather, heat flows should be calculated by performing a heat balance (see BS EN ISO 13789: 2007, Thermal performance of buildings — Transmission and ventilation heat transfer coefficients — Calculation method).

If the above conditions do not apply, the procedures given in Annex B of BS EN ISO 6946: 2007 should be followed.

Slightly ventilated air layer

The effect of ventilation depends on the size and distribution of the ventilation openings. As an approximation, the total thermal resistance of a component with a slightly ventilated air layer may be calculated as:

\[
R_T = \frac{1500 - A_v}{1000} R_{T,u} + \frac{A_v - 500}{1000} R_{T,v}
\]

Where

- \(R_{T,u}\) is the total thermal resistance with an unventilated air layer
- \(R_{T,v}\) is the total thermal resistance with a well-ventilated air layer

Well ventilated air layer

The total thermal resistance of a building component containing a well-ventilated air layer shall be obtained by disregarding the thermal resistance of the air layer and all other layers between the air layer and external environment, and including an external surface resistance corresponding to still air.

The surface resistance is defined in national standards. For a vertical surface with horizontal heat flow the internal and external surface resistance is 0.13 m²K/W and 0.04 m²K/W respectively.

U-values

The U-value of a cavity construction will vary depending on the type of cavity present, and its location with respect to the main insulation layer.

The values stated below are 1-dimensional U-values and therefore do not include the additional heat loss due to brackets, fixings and cavity ties that may be present in the construction. The constructions are considered to be vertical with horizontal heat flow.

Cold cavity construction

This type of air cavity will not change the layered U-value of the construction significantly because the cavity is to the cold side of the main insulation layer (Figure 2).
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Figure 2  U-value of a layered construction with a cold cavity

For the above example;

\[ U_{\text{unventilated}} = 0.32 \text{ W/m}^2\text{K}; \]
\[ U_{\text{slightly ventilated}} = 0.33 \text{ W/m}^2\text{K}; \]
\[ U_{\text{fully ventilated}} = 0.35 \text{ W/m}^2\text{K}. \]

An area of openings of 1000 mm\(^2\) is assumed for the slightly ventilated situation.

Warm cavity construction

This type of air cavity will significantly change the layered U-value of the construction (figure 3). This is because the cavity is to the warm side of the main insulation layer meaning the thermal performance of the insulation layer will be disregarded when the cavity is fully ventilated.

Figure 3  U-value of a layered construction with a warm cavity

For the above example:

\[ U_{\text{unventilated}} = 0.32 \text{ W/m}^2\text{K}; \]
\[ U_{\text{slightly ventilated}} = 0.56 \text{ W/m}^2\text{K}; \]
\[ U_{\text{fully ventilated}} = 2.07 \text{ W/m}^2\text{K}. \]

An area of openings of 1000 mm\(^2\) is assumed for the slightly ventilated situation.

Ventilation performance of cavities

A sealed cavity will have no provision for drainage or ventilation so will not improve the performance of the wall in terms of being a secondary defence against water penetration and vapour diffusion.

A cavity that is not either vented or ventilated presents a serious risk of moisture collection. As a comparison an insulating glass unit requires hermetically sealing and the provision of a desiccant in order to remain condensation free.

The higher the level of possible ventilation in a cavity, the more moisture may be removed from it.

Liquid water will be removed by;
- Drainage
- Evaporation

Moisture vapour will be removed by;
- Diffusion
- Mass transfer.

A fully-ventilated cavity will provide the most reliable means of removing moisture in the cavity. The air movements will remove moisture vapour that has migrated from the internal environment, encourage evaporation of any liquid water and promote drying of the cavity.

A vented cavity will have less capacity to remove excess moisture. It relies on the diffusion of water vapour in the cavity. Its performance will therefore be dependent on the vapour resistance of all materials to the cold side of the cavity and the size of the openings between the cavity and the external environment. The lower the vapour resistance and the larger the openings, the higher the rate of transportation will be.

The removal of moisture in a vented cavity may be increased by using a wider cavity. This will improve the air circulation by

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convection as there will be relatively lower frictional forces to resist the air movements.

Figure 4  Convection in a wide cavity

There may be an increased risk of material damage with vented compared to ventilated cavities. This is because moisture is likely to remain in the cavity for longer periods of time. It is for this reason that the NHBC requires a ventilated cavity to be used with a timber framed wall.

**Cavity width**

In order to achieve the desired performance, a minimum cavity width must be maintained. The CWCT 'Standard for systemised building envelopes' states minimum cavity widths for different configurations of rainscreen system. These dimensions shall not be reduced by more than fifty per cent at fire barriers and support rails.

The NHBC give advice on cavity dimensions for external masonry walls. Their advice states that increasing the cavity width for full cavity insulation from 50mm to 75mm or more greatly reduces the risk of rain passing through the cavity. A nominal cavity of 50mm is always required on the outside of partial cavity insulation. Cavities in timber framed walls should be ventilated to avoid damaging the timber.

The NHBC also give guidance on minimum cavity dimensions for insulated render systems. For timber and steel framed backing walls a cavity of at least 15mm should be provided between the wall and the insulation to allow any moisture to drain away. Where the backing wall is timber framed the cavity should also be ventilated. Care should be taken as this will have a considerable impact on the U-value of the wall. Further information on insulated render systems can be found in CWCT Technical Notes 59 and 60.

It is important that designers and contractors are aware that the minimum cavity dimension is the absolute minimum. Building irregularities, insulation, and framework must never compromise the cavity gap.

The minimum acceptable air gap should be such as to allow any water passing the outer skin of the construction to flow down the back face of the without wetting the insulation or backing wall.

A breather membrane may be placed on the cold side of any cavity insulation in order to protect it from direct wetting. The membrane should be carefully selected so as not to inhibit the migration of water vapour outwards through the wall.

**Cavity partitioning**

Careful consideration should be given to the design of the cavity, especially where other aspects of the wall performance have to be taken into account. A common example of this is where fire barriers have to be placed within the cavity to limit the spread of fire.

A vented cavity will usually only have openings at the bottom of each storey or compartment. Therefore any suitable fire barrier may be used, providing each compartment has such openings.

A ventilated cavity allows through movement of air, meaning openings are required at the top and bottom of the cavity. The design of the cavity/fire barrier therefore becomes more significant. If a single cavity is required an intumescent fire barrier may be used which will allow the cavity to remain open prior to a fire. Alternatively the cavity may be completely closed at the fire barriers with ventilation opening provided above and below the closer.

**Internally ventilated cavities**

Warm cavities that are not externally ventilated may also have openings to the internal environment. This will allow warm moist air into cooler parts of the wall. Although this is a warm cavity, the surfaces will be cooler than those of the room, and therefore there will be an increased risk of condensation.
The risk of condensation will be minimised if there are sufficient openings so that the cavity is fully ventilated to the inside. This will ensure that the surfaces of the cavity are as close as possible to the internal surface temperatures.

A typical example of this type of cavity would be that created behind an internal fit out. This may be of particular concern if the fit out is carried out by a different contractor to that responsible for the rest of the wall.

Figure 5 Warm cavity created by internal fit out

For the example shown above it is possible that the additional thermal insulation provided by the internal fit out could reduce the temperatures behind it to below the dewpoint. Condensation will then form in the cavity, where it may damage surfaces and floor coverings etc.

The risk of condensation will be especially high if the original internal surface acts as a vapour control layer. This will prevent the passage of water vapour thus increasing the local vapour pressure in the cavity. This in turn will require a higher minimum surface temperature in order to avoid the water vapour condensing.

References


CWCT TN46 Introduction to building envelope energy transfer, CWCT, 2004
