

Full Fill Cavity Wall Insulation in Areas of Very Severe Exposure to Wind-driven Rain



A preliminary investigation into the impact of wider cavities on the possibility of rain penetration in new build masonry cavity walls

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Note: This document may be revised from time to time to take account of improvements and amendments to test and assessment methods and material innovations. Readers are advised to contact the British Board of Agrément to check the latest edition.



Housing research & guidance

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The purpose of this investigation was to understand whether increasing the width of cavities in new-build masonry walls – alongside an accompanying increase in the thickness of full fill cavity wall insulation to meet higher energy efficiency standards – might affect resistance to rain penetration.

An investigation was undertaken using a non-standard adaptation of the standard BBA masonry cavity wall Water Resistance test rig, creating conditions more severe than any weather experienced in the UK, with a wall where the jointing between the bricks is considerably worse than would be expected in real life.

There is no previous experience of the behaviour of insulation systems under these non-standard test conditions and the findings of this investigation have no bearing on the continuing certification or suitability of existing cavity wall insulation systems.

Executive summary

Since the 1980s, cavity wall insulation has been installed in many new homes during construction. In the light of widespread experience of rain penetration in 1989-91, NHBC introduced restrictions on the use of full fill cavity insulation, and similar restrictions were subsequently introduced into Approved Document C to the Building Regulations (England & Wales). At that time the standard cavity width was 50 mm.

As energy efficiency standards have improved over the years since, standard cavity widths have increased in order to accommodate greater thicknesses of thermal insulation, and it is now common to see cavities 100 mm and wider in new homes. Given the increased distance that rainwater would need to travel, it would seem possible that with these wider cavities the potential for rain penetration could be reduced. By testing various types of insulant materials in a laboratory test rig, this project set about investigating the resistance to rain penetration of fully filled masonry walls with wider cavities. The aim was to provide a sound basis for any possible future changes to the NHBC Standards and Building Regulations relating to cavity wall insulation.

Following some initial calibration testing, test walls were constructed to replicate typical 1990s construction. Unlike the standard BBA test wall which has been in use for over 40 years, these test walls included a window opening. The standard BBA test wall is deliberately built to be a highly permeable construction, making it a very harsh test. However, inclusion of the window openings further accentuated the test conditions. Subjected to this much more severe test regime, with water blown into the rig under pressure for a three-week period, rain penetration was found to occur. Although the clear cavity wall leaked a little, the problem was much more severe for the 1990s specification test wall sample which included full fill insulation.

The next phase of testing involved testing a range of materials using the same test regime, but in a wall construction with a wider cavity and current detailing around the window opening:

- blown-in mineral wool (MW)
- blown-in expanded polystyrene (EPS) beads (bonded)
- built-in glass mineral wool (MW) batts
- built-in rock mineral wool (MW) batts
- built-in expanded polystyrene (EPS) boards.

Results of the tests were:

1. All three of the built-in materials completed the test with no rain penetration occurring during the three-week period.
2. The blown-in expanded polystyrene (EPS) beads also completed the test, although a temporary minor damp patch was observed on the 'inner leaf' of the test wall at one stage.
3. In the case of the blown-in mineral wool (MW), water penetration was observed during the course of the test.

The testing was limited insofar as there was only a single test per type of material, and therefore the results must be regarded as indicative and should not be seen as conclusive. However, the results do suggest that built-in materials may offer greater inherent resistance to the passage of rainwater in new build construction. Any failures are more likely to occur around openings owing to unsuitable detailing, or because of installation issues. Therefore, careful initial consideration of the suitability of the building is needed, as required by the BBA Assessment and Surveillance Schemes for Approved Assessors and Installers of Cavity Wall Insulation.

Project Partners and the Steering Group



Housing research & guidance



The project scope was agreed, and the work programme was overseen, by a Steering Group coordinated by the BBA and drawn from a range of interested parties, including the NHBC Foundation, key industry bodies and house builders.

The BBA would like to thank the following organisations for their valuable contribution to the project:

NHBC Foundation

APA – Aircrete Products Association

BDA – Brick Development Association

Bovis Homes Limited

BPF – The British Plastics Federation (EPS Division)

CBA – The Concrete Block Association

MIMA – The Mineral Wool Insulation Manufacturers Association

Redrow plc

Introduction

Background

There is an increase in the demand for and the use of full fill cavity wall insulation in the UK. This is due to climate change predictions, the UK government's commitment to meeting the Kyoto Protocol to reduce greenhouse gases emissions, and the need to conserve energy, supported and driven, at the UK level during the outset of this investigation, by the Code for Sustainable Homes, Fabric Energy Efficiency Standard, Carbon Compliance and the ever-tightening energy requirements of the relevant national Building Regulations.

New homes registered with NHBC are designed, specified and constructed in accordance with the NHBC Standards. For decades, the NHBC Standards have placed restrictions on the use of full fill cavity wall insulation in areas exposed to wind-driven rain, because of the risk of rain penetration from the outside to the inside of the wall.

Current limitations for walls up to 12 metres in height are summarised in the table in Appendix 6.1 – A of the NHBC Standards 2013⁽¹⁾. A key requirement is that in Very Severe exposure locations fair-faced masonry with full cavity insulation is not permitted at all. A range of other restrictions also apply. Restrictions based on wall construction and exposure zone are also in the guidance contained in Approved Document C to the Building Regulations (England & Wales) and in the domestic Technical Handbook to the Building (Scotland) Regulations. Further guidance also appears in BRE Report 466 : *Understanding Dampness*⁽²⁾, and driving rain is also addressed in British Standards such as BS 8104 : 1992, and more recently BS EN ISO 15927-3 : 2009⁽³⁾.

The current project and its scope

First introduced when the standard cavity width was 50 mm, the current guidance has been effective in controlling the risk of rain penetration. However, with improving energy efficiency standards, cavities have grown wider, and widths of 100 mm and above are increasingly common. A question has therefore arisen as to whether walls with a wider cavity and fully filled with insulant could present a reduced risk; if so, should current restrictions be reconsidered?

With this need to balance the demands of energy efficiency and carbon reduction, whilst maintaining robust standards for preventing harmful water penetration through external masonry walls in areas of very severe exposure, the NHBC Foundation outlined a project scope to generate some new data on the subject, thus providing a sound basis for the possibility of future changes to the NHBC Standards and Building Regulations relating to cavity wall insulation.

The project scope was:

- to consider the resistance to water penetration performance of fair faced cavity masonry walls with full fill insulation in areas of very severe exposure to wind driven rain
- to provide reassurance in the continuing technical basis for current product testing and certification scheme(s) used to assess the resistance to wind-driven rain in insulated masonry cavity walls (eg BBA Certificates)
- to consider the performance of typical current masonry construction in terms of cavity widths, inclusion of openings and detailing, in comparison with the type of masonry construction common in the early 1990s, at which time NHBC introduced restrictions on the use of full fill insulation
- to establish if full-fill cavity insulation (blown-in and built-in) can be used to achieve satisfactory weatherproofing performance in areas of very severe exposure to wind-driven rain and, if so, whether there are any limiting conditions on materials or design in relation to current construction.

(1) Now NHBC Standards 2016 Chapter 6.1, Table 2.

(2) BRE Report 466 : *Understanding Dampness*; Trotman, Sanders and Harrison (BRE Bookshop 2004).

(3) BS EN ISO 15927-3 : 2009 Hygrothermal performance of buildings. Calculation and presentation of climatic data. Calculation of a driving rain index for vertical surfaces from hourly wind and rain data.

Factors affecting the rain penetration through masonry cavity walls

The following factors are understood to have an effect on a wall's resistance to rain penetration:

- the type of brick
- the composition of the mortar
- the mortar joint, its profile and finish
- the thickness of the outer leaf of masonry
- the width of the cavity
- whether the cavity is fully or partially filled with insulation
- the type and thickness of any cavity insulation
- design features in the wall and local practice
- the quality of workmanship achieved on site
- the orientation of the exposed wall and the weather conditions – rainfall, wind speed and direction
- local topography, which may affect the local exposure conditions
- the height of the wall.

The standard BBA test specification

Introduction

The BBA's method used for the testing of both blown-in and built-in cavity wall insulation systems is described below. This is the standard test method used for Agrément Certificates and has shown to be effective for over 40 years. As an accelerated test, it is intended to provide data on the anticipated performance of a system, over the lifetime of a building in which it is installed, in a matter of weeks. The wind pressures applied during the test are static (ie constant for the length of each test period) rather than fluctuating as would be the case in service. These conditions are generally accepted, by their nature, to be extreme and are designed to ensure that cavity wall insulation systems are sufficiently robust to withstand all exposure zones in the UK, given correct specification and installation.

Overview

The test wall is filled and then subjected to water spray and air pressure of increasing severity over a 15-day test period. The appearance and spread of any dampness on the 'inner leaf' is monitored and the flow of water from the 'cavity' measured.

Apparatus

The test apparatus for the standard test used by the BBA is shown in Figures 1 and 2 and comprises two cavity walls, back to back, the 'outer leaf' of each wall forming the sides of a pressure chamber. Each wall measures 3 m x 3 m and has a nominal cavity width of 65 mm. A sparge pipe is positioned at the top of each wall so that a water spray can be applied at points approximately 150 mm from the top of the 'outer leaf'. Air pressure in the chamber can be raised to a maximum of 500 Pa.

Each cavity wall is constructed with an 'outer leaf' of fletton bricks laid frog upwards in a 1:6 (cement : sand) mortar with a plasticising additive, and an 'inner leaf' (indicating leaf) of aircrete blocks of nominal dry density 650 kg·m⁻³ (the subject of a current BBA Certificate). The 'inner leaf' is constructed with a 1 : 6 (lime : sand) mortar to allow easy removal of the blocks for observation and for the removal of the cavity fill.

Figure 1 The outer leaf of a standard BBA test wall



Wall ties are used at normal spacings (ie 450 mm vertically, 900 mm horizontally in a staggered pattern) and the 'inner leaf' is whitewashed to permit rapid identification of any damp penetration.

Wall ties are of the butterfly type conforming to BS 1243 : 1978 *Specification for metal ties for cavity wall construction*.

Three viewing windows are set into the 'inner leaf' to observe adequacy of fill of the insulation. Side panels are fitted to facilitate extraction of the fill.

The sparge pipe is 3 m in length (the full width of the wall) and has holes of 1.0 mm approximate diameter at nominal 100 mm spacings. The spray rate is variable from 0.4 l/min to 4.4 l/min and is controllable to within 0.1 l/min.

Provision is made for the collection of water that has leaked into the cavity and for measurement of the flow rate of this leakage to an accuracy of 0.1 l/min.

Photographic equipment is provided to record the spread of dampness, images are time and date marked to allow easy identification of photographs.

Test wall calibration

Not less than 28 days after construction of the 'outer' leaf and not less than 7 days after construction of the inner leaf, the procedure used to calibrate the wall (cavity empty) is commenced (see below). On the day before calibration is to be carried out, the pump is set to run overnight to wet the walls.

C.3 – 500 Pa pressure – week 3 conditions

Care is taken to ensure that the short cavity flow-out tube is fitted to feed the cavity flow cylinder. The air pressure is adjusted and set at 500 Pa using the control unit. The spray rate on the external leaf is adjusted to give a cavity leakage in the range 1.4 ± 0.1 l/min. The spray rate is then adjusted, if required, until the cavity flow remains within the required range for at least half an hour. This is confirmed manually by collecting the water flow over a sufficient period of time using a suitable measuring cylinder.

C.2 – 250 Pa pressure – week 2 conditions

Care is taken to ensure that the short cavity flow-out tube is fitted. The fan is turned on manually and the air pressure set at 250 Pa using the control unit. The spray rate on the external leaf is adjusted to give a cavity leakage in the range 0.8 ± 0.1 l/min. The spray rate is then adjusted, if required, until the cavity flow remains within the required range for at least half an hour. This is confirmed manually by collecting the water flow over a sufficient period of time, using a suitable measuring cylinder.

C.1 – Zero pressure – week 1 conditions

Care is taken to ensure that the long cavity flow-out tube is fitted. The spray rate on the 'outer leaf' is adjusted to give a cavity leakage in the range 0.3 ± 0.1 l/min. The spray rate is then adjusted, if required, until the cavity flow rate remains within the required range for at least half an hour. This is confirmed manually by collecting the water flow over a sufficient period of time using a suitable measuring cylinder.

The calibration procedure is carried out in reverse, to ensure that the higher leakage required for week 3 conditions can be achieved.

The spray rates used to achieve the leakage rates at zero, 250 Pa and 500 Pa are recorded. These are then the test conditions for weeks 1, 2 and 3 of the water resistance test.

If any damp patches appear on the 'inner' (indicating) leaf of the wall during calibration, appropriate action is taken to establish the cause and to remove the problem.

Following calibration, the walls are allowed a minimum of 48 hours to recover before installing cavity wall insulation.

Test procedure

The test duration comprises three five-day periods. Water spray and air pressure are applied as shown in the table below for a period of 6 hours each day.

Day	Spray rate (l/min)	Air pressure (Pa)
1-5	as in C.3	zero
6-10	as in C.2	250
11-15	as in C.1	500

For each test day, the following observations are made:

- start time
- pressure reading after 0, 2, 4 and 6 hours
- spray rate after 0, 2, 4 and 6 hours
- cavity flow after 0, 2, 4 and 6 hours
- appearance of any dampness on the inner leaf.

Photographs are taken at the beginning of each spraying period and at two-hourly intervals throughout, even if dampness has not appeared. Care is taken to identify each photograph with the time at which it is taken.

Figure 2 Water Resistance Facility (Front View)

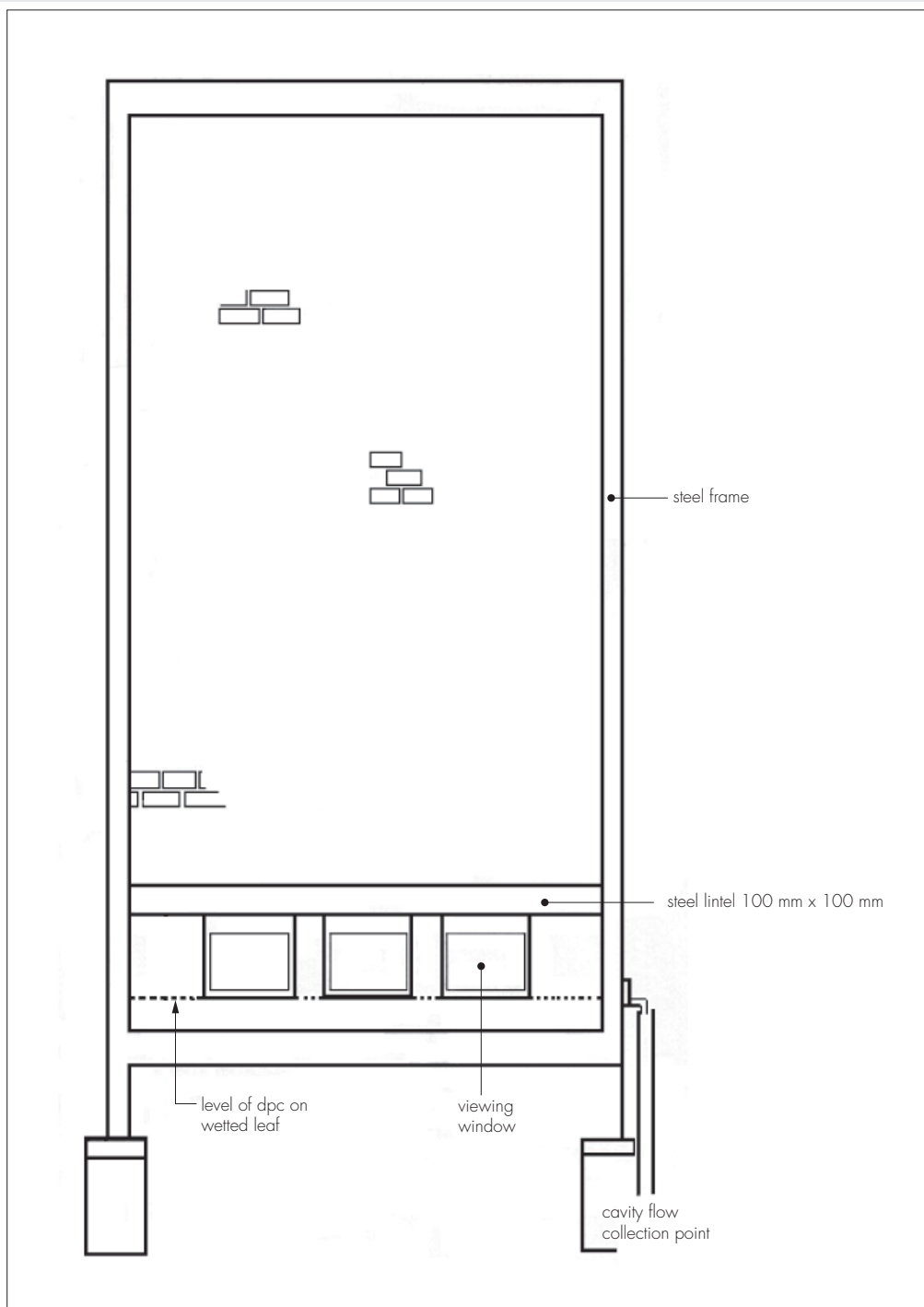
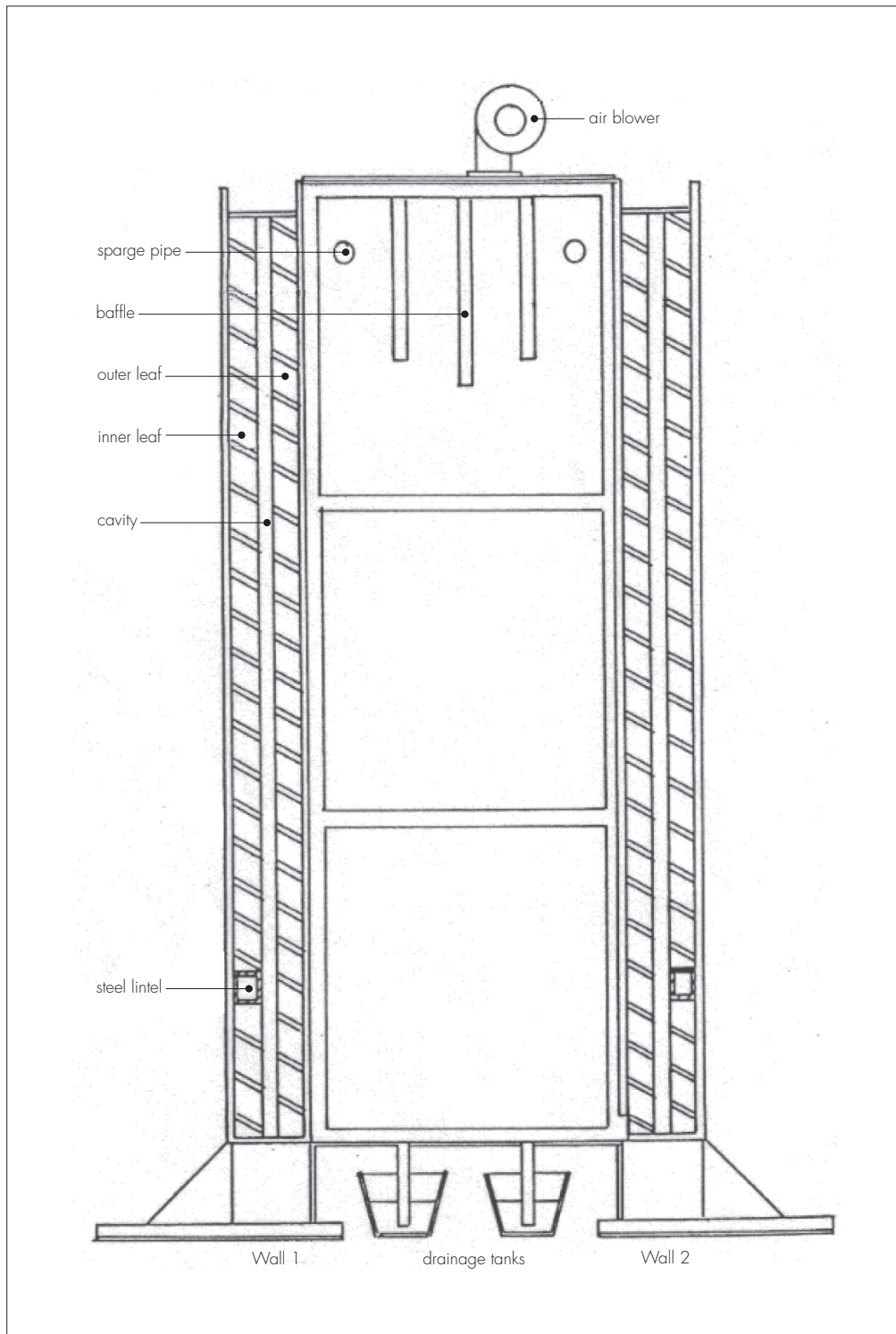


Figure 3 Water Resistance Facility (side view showing section through the rig)



Calibration test for current masonry walls

The BBA Water Resistance test was developed over 40 years ago and has become the industry standard for testing cavity wall insulation, owing to the severity of the test conditions used. In this period, the BBA has carried out hundreds of tests on the insulation materials listed below, with some of them tested at cavity widths of 40 mm:

- built-in glass mineral wool (MW) batts
- built-in rock mineral wool (MW) batts
- built-in expanded polystyrene (EPS) boards
- blown-in glass mineral wool (MW)
- blown-in rock mineral wool (MW)
- blown-in expanded polystyrene (EPS) beads (loose and bonded)
- blown-in polyurethane (PU) foam.

Although the test was well established and had been used extensively, the Steering Group sought reassurance that the severity of test did actually represent conditions encountered in reality. For this reason, it was decided that typical masonry materials in current use should be used to verify the severity of the test conditions used for the standard BBA Water Penetration test.

Wall details

A calibration test was set up using masonry walls typically used in areas of very severe exposure, built to a current specification and generally in accordance with the NHBC standards, with the exception of the recessed mortar joints. As the BBA Water Penetration rig has two walls, this provided the opportunity to test two different materials for the outer leaf. Following consultation with the Steering Group, the materials chosen were clay brickwork and reconstituted stone. Clay brickwork was chosen because it is so commonly used throughout the UK, and reconstituted stone because it was considered likely to be a material less resistant to rain penetration.

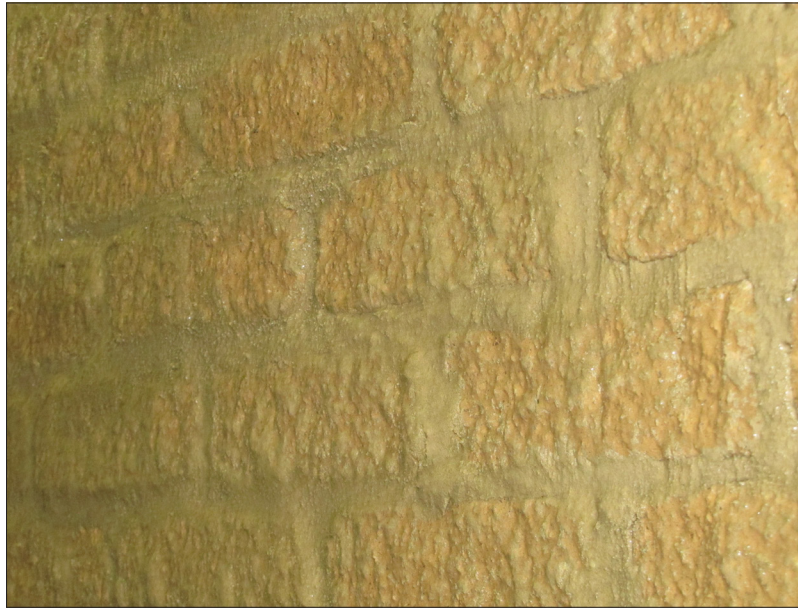
Wall 1: Brick outer leaf – Cattybrook Brunswick Farmhouse Mixture, with mortar in accordance with Designation (iii) to BS EN 1996-1-1 : 2005 and NHBC Standards. Mortar joints – a slightly recessed square joint (1 to 2 mm) was employed, which would not normally be acceptable to NHBC, but agreed by the Steering Group as the most vulnerable type that would ever be used in areas of very severe exposure.

Figure 4 Brick outer leaf



Wall 2: Stone block outer leaf – Bradstone EnviroRebastone, with mortar as above. Mortar joints – flush, as recessed joints were not possible owing to the uneven nature of the stone face.

Figure 5 Stone outer leaf



Results

The calibration test was run as per the standard calibration procedure for a water penetration test. In order to examine the comparative permeability of the two walls constructed as detailed above, two tests were conducted:

Test 1 – The inlet flow rate (ie simulated rain) onto each wall and the air pressure applied were both varied whilst the outlet flow rate (ie water penetrating the wall) from each was recorded.

Test 2 – A fixed water flow of 4 litres per minute (l/min) was applied to both walls whilst the air pressure applied was varied. Again, the outflow was recorded.

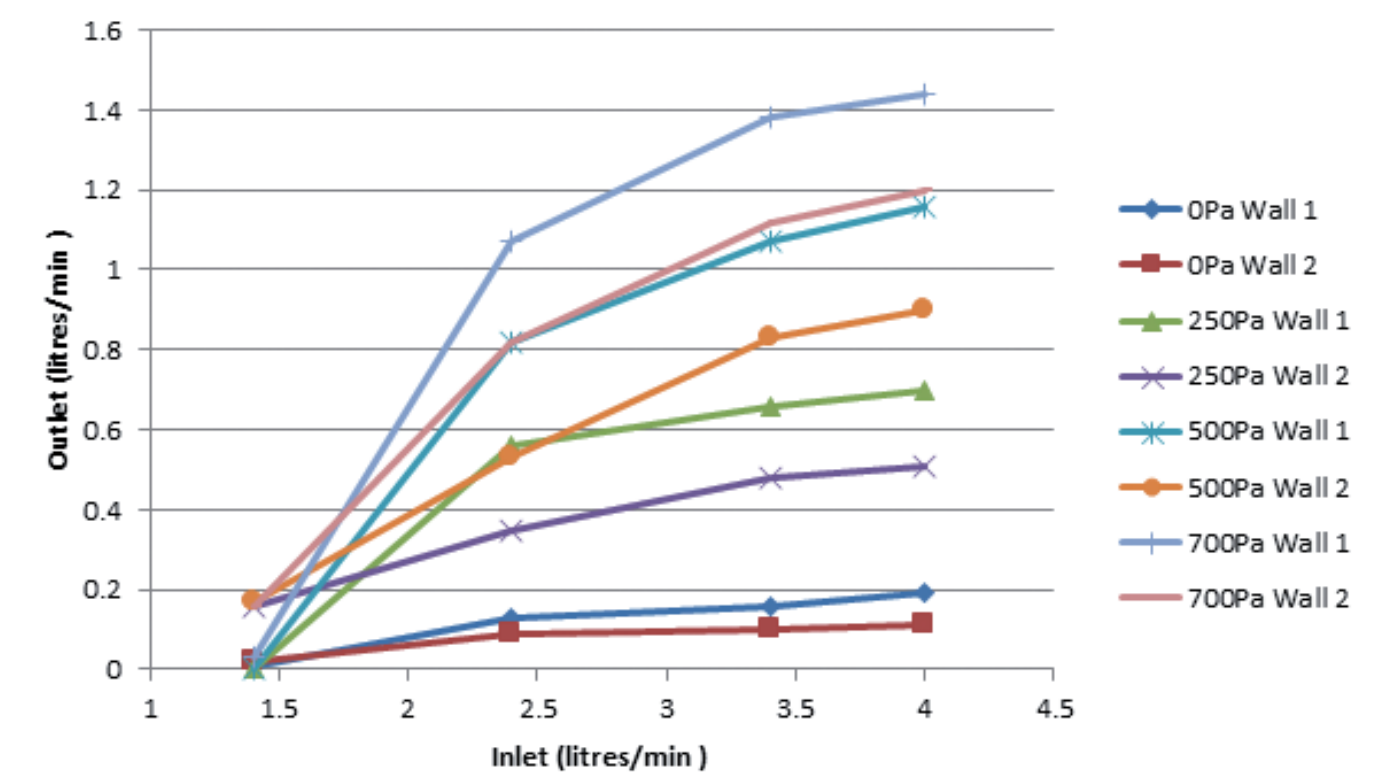
The results are given below.

Graph 1

This table and graph show how the outlet flow rate (water penetrating into the cavity) varied at different inlet flow rates (water sprayed onto the outer face of the wall) and pressures.

Inlet flow rate (l/min)	Air pressure (Pa)							
	0 Pa		250 Pa		500 Pa		700 Pa	
	Wall 1	Wall 2	Wall 1	Wall 2	Wall 1	Wall 2	Wall 1	Wall 2
	Outlet flow rate (l/min)							
1.4	0.01	0.02	0.00	0.16	0.00	0.17	0.03	0.16
2.4	0.13	0.09	0.56	0.35	0.82	0.53	1.07	0.82
3.4	0.16	0.10	0.66	0.48	1.07	0.83	1.38	1.12
4.0	0.19	0.11	0.70	0.51	1.16	0.9	1.44	1.20

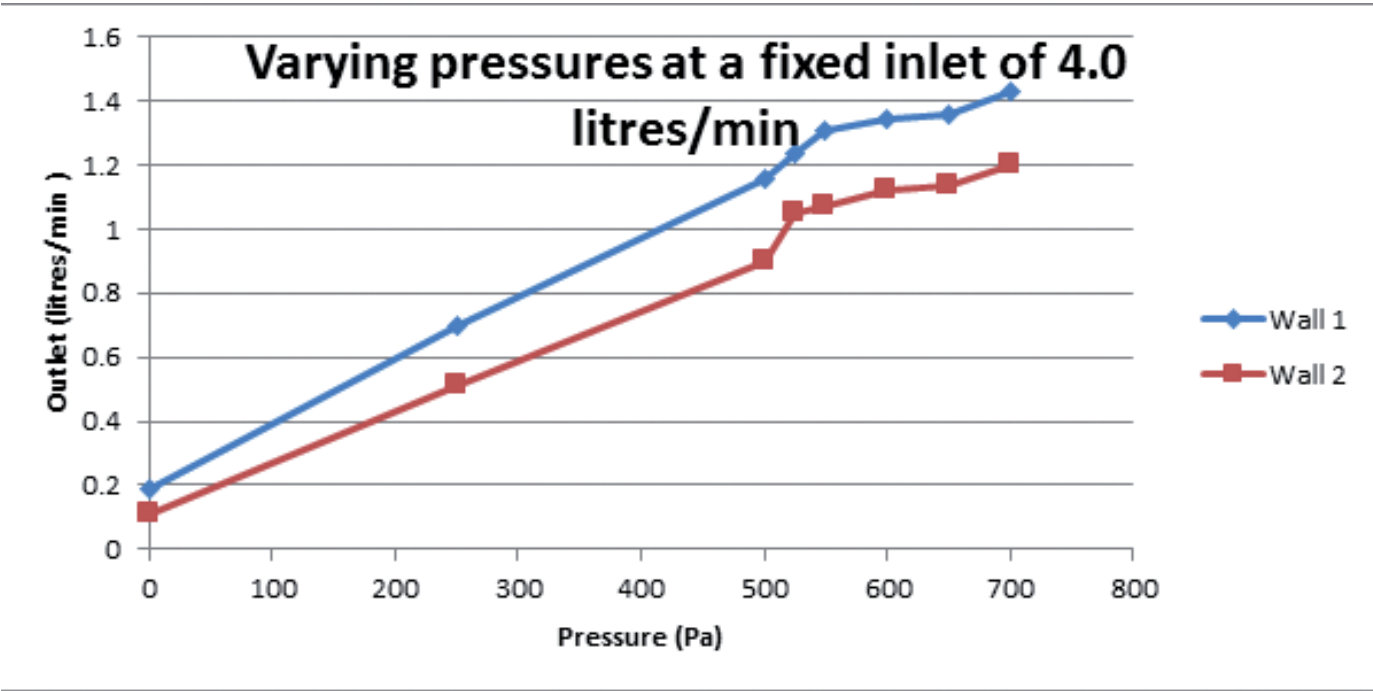
Water penetration at varying inlet flow rates and pressures



Graph 2

This graph shows how the outlet flow rate varies at a fixed inlet flow rate and different pressures. The inlet flow (ie simulated rain) was fixed at 4.0 l/min at each pressure.

Pressure (Pa)	Outlet flow rate (l/min)	
	Wall 1	Wall 2
0	0.19	0.11
250	0.70	0.51
500	1.16	0.90
525	1.24	1.05
550	1.31	1.07
600	1.35	1.12
650	1.36	1.14
700	1.43	1.20



Current masonry wall calibration — conclusion

For the standard BBA test, the most extreme conditions in week 3 are set to a wind pressure of 500 Pa and an outlet flow rate of 1.4 l/min, ie the water entering the cavity. Typically, this would require an inlet flow rate of between 2.4 and 4.0 l/min, depending on the age and condition of the test wall, as the test walls can become less porous with use.

In the calibration testing for the current masonry wall, for wall 1 an outlet flow rate of 1.38 l/min was achieved at a pressure of 700 Pa and an inlet flow of 3.4 l/min. When the inlet flow rate at 700 Pa was increased to 4.0 l/min, the outlet flow rate achieved was 1.44 l/min.

For wall 2, an outlet flow rate of 1.2 l/min was achieved at a pressure of 700 Pa and an inlet of 4.0 l/min. It can thus be concluded that the standard BBA test parameters are more severe than those that are likely to be achieved in a good quality current wall (with either a clay brick or a reconstituted stone outer leaf). It is worth adding here that an inlet of 4.0 l/min is the maximum the rig can produce in order to maintain an even spray rate across the wall. The wind pressure of 700 Pa is the maximum safe pressure at which the rig can be operated, hence these parameters were not exceeded.

Graph 1 shows that once the wall has become saturated, the increase in the inlet flow rate on the wall remains directly proportionate to the outlet flow rate only up to a point, after which the addition of further water has progressively less effect.

Graph 2 demonstrates that an increase in wind pressure has a significantly greater effect than the inlet flow rate in influencing the outlet flow rate, ie water penetrating into the cavity.

On the basis of this calibration exercise, the Steering Group concluded that the standard BBA test parameters were appropriate for the test programme. The deliberately highly permeable nature of the BBA standard walls was appropriate for simulating very severe exposure to wind-driven rain and can be correlated to current standards in new build masonry walls.

Testing of a typical 1990s specification wall

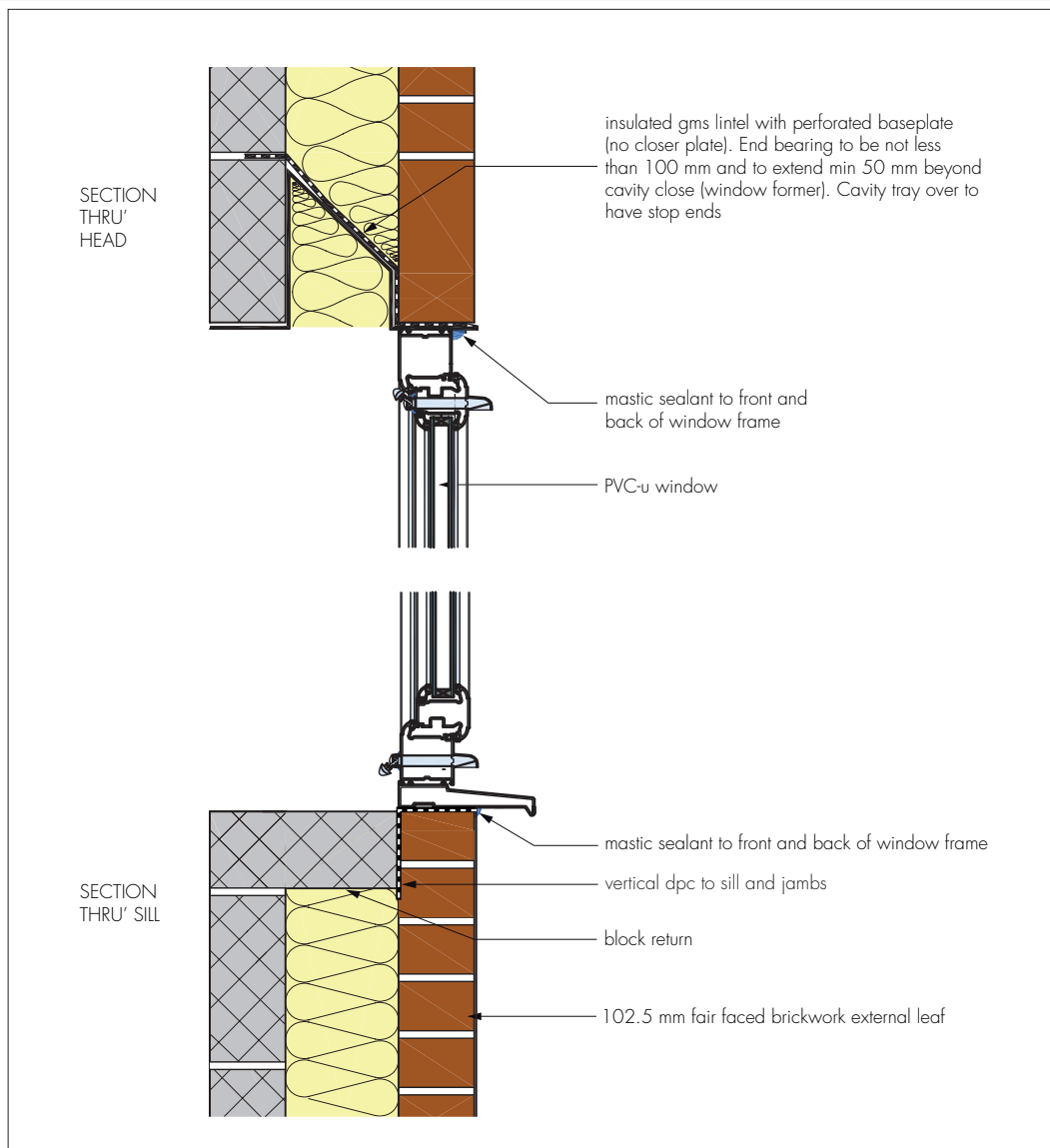
One feature of both the standard BBA test and the calibration testing of the contemporary masonry wall carried out for this project is that the test walls are plain walls without window openings, flue penetrations or other features. An NHBC 'Standards Extra' newsletter from September 1991 presented to the Steering Group summarised the nature of complaints relating to water penetration of fully filled cavity walls at that time, following a period of severe weather conditions. This showed that many of the water penetration claims investigated by the NHBC occurred around features in the wall, for example windows, doors and flue pipes. For this reason, it was agreed that the next stage of the project would involve the testing of a wall which would include a window opening and be built in accordance with a typical 1990s specification.

Wall details

Both walls in the test rig were constructed to the standard BBA criteria with these exceptions:

1. A cement mortar was used for the blockwork leaf instead of the standard lime: sand mortar.
2. A 900 mm wide by 1200 mm high window was installed centrally in the wall with a 1500 mm long steel lintel above the window
3. A cavity tray with stop ends (folded at the ends to form a stop) was used
4. The sill and jamb reveals were closed by way of a block return.

Figure 6 1990's test wall specification (Courtesy of Bovis Homes Ltd)



Test wall calibration

Since the area of brick wall that was directly subjected to the simulated rain would be reduced by the presence of the window, the expected outflow resultant from the regular input levels of water was reduced as shown below:

Regular figure (l/min)	Adjusted figure (l/min)
1.4	1.1
0.8	0.7
0.3	0.3

Insulation

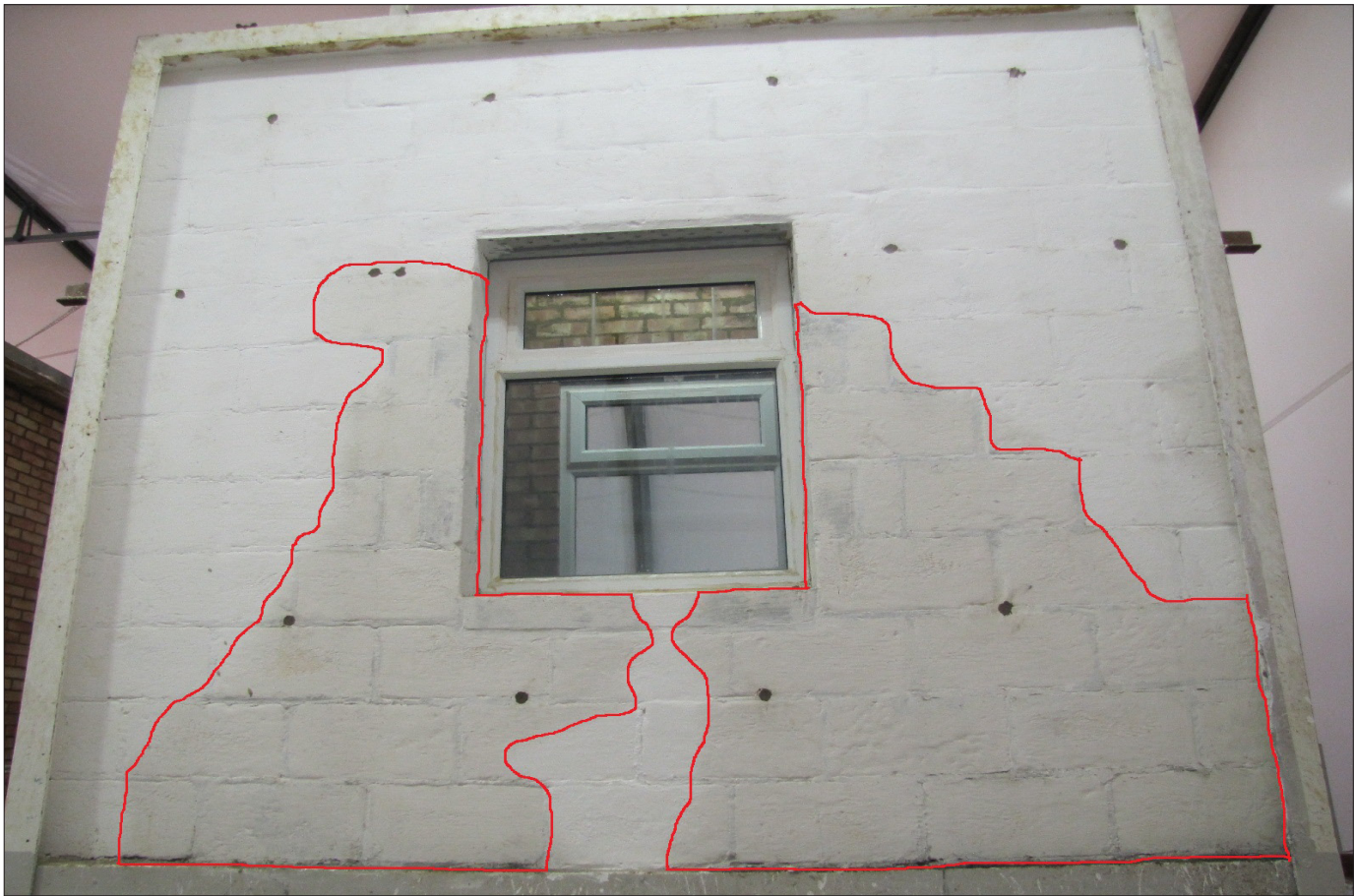
For the purposes of comparison, one wall (Wall 1) was tested with a clear cavity whilst the other (Wall 2) was filled with blown-in mineral wool insulation, which was considered to be the most representative full fill insulation material from the time. The specific products used in the 1990s are no longer available, but the closest alternative available today was used for this test. The material was installed in accordance with practice common during the 1990s at an installed density of 24 kg·m³ (as opposed to the current 18 kg·m³).

Testing

Wall 1 (Clear Cavity): no areas of moisture emerged until the final day of the test, when two small areas appeared to the left and slightly below the window feature.

Wall 2 (Filled Cavity): in the latter part of day 1 of week 1 of the test, damp areas began to emerge in mortar joints on the left hand side of the window detail. On day 2, these recurred and were mirrored by similar areas to the right of the window. The area of moisture expanded throughout the testing until, by the end of the final week, two broad arcs of dampness spread from either side of the window to the base of the rig. Figure 7 shows the two damp areas outlined in red. The black spots are the injection holes for the insulation.

Figure 7 Wall 2 at end of test



Dismantle

Wall 1 (Clear cavity): nothing exceptional was noted. The area behind the damp areas showed no particular features to explain the transmission of water. The only possible explanation for these damp areas is perhaps the presence of the window opening, unidentified issues with the associated detailing and the severity of the test conditions.

Wall 2 (Filled Cavity): inspection of the cavity showed that the insulation had been installed to a good standard of consistency, apart from two very small voids which were found below and to either side of the window feature, but the transmission of moisture could not be attributed to these. No other feature suggesting an explanation for the transmission of moisture was observed.

Upon dismantling of the test rig, the insulation was found to have been installed at a significantly higher density than the target density of $24 \text{ kg}\cdot\text{m}^3$.

Conclusion – 1990s test

The test showed that the presence of a typical window feature design from the time, in combination with full fill cavity wall insulation, replicated water penetration consistent with some of the warranty claims that NHBC experienced in the early 1990s.

The BBA and the Cavity Wall Insulation industry are also aware of the fact that features such as windows, doors, flue pipes etc incorporated into walls can accentuate any weaknesses in the construction and lead to water penetration. It is therefore a requirement in all blown-in Cavity Wall Insulation Agrément Certificates that a detailed survey of the property is carried out to establish:

- the construction ie type of brick and block, composition of the mortar and thickness of the outer leaf of masonry
- the mortar joint, its profile, finish and condition
- the width of the cavity across the construction on all elevations
- the condition of the cavity ie presence of rubble, mortar snots, wall tie condition
- the condition of the property in general eg presence of existing damp, damage, leaking gutters etc
- any remedial work necessary
- design features in the wall and local practice
- the orientation of the exposed wall and the weather conditions – rainfall, wind speed and direction
- local topography.

The above is documented in a site assessment report, and a decision is taken on the suitability of the property to be filled. The installing team are also required to verify the above before proceeding with the installation process, and are not permitted to continue with the installation of blown-in insulation if the property does not in all respects comply with the requirements of the Certificate and established industry best practice.

Testing of current specification walls with wider cavities

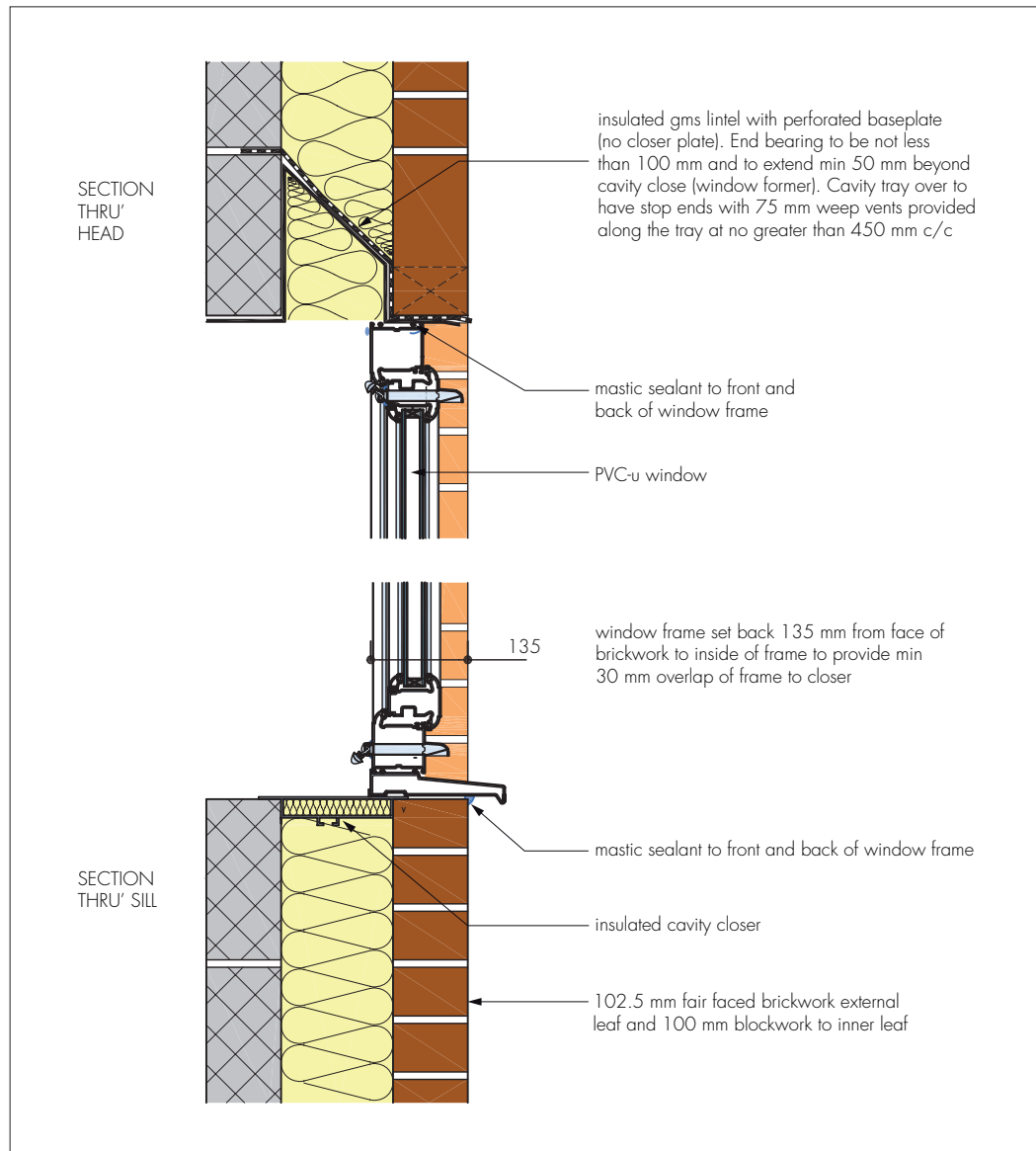
Taking into account the issues observed in the 1990s test specification, the Steering Group agreed that it was worthwhile pursuing further testing with a window opening included, while recognising that this made the test considerably more onerous than that normally carried out for Certification. This testing was to reflect current cavity wall constructions, but does not have relevance to the current certification, which is well established and has been shown in practice to confirm that systems are satisfactory for their intended purpose in practice.

Wall details

Both walls in the test rig were constructed to the standard BBA criteria with the following exceptions:

1. A cement mortar was used for the blockwork leaf instead of the standard lime: sand mortar.
2. Cavity width – 125 mm, being a sensible minimum width going forward with regard to the thermal requirements in the latest Building Regulations.
3. A 900 mm wide by 1200 mm high window was installed centrally in the wall with a 1500 mm long steel lintel above the window
4. A cavity tray with stop ends
5. Weep holes (with full height vents), as required by NHBC Standards.
6. Insulated cavity closer – proprietary, purpose designed for use in very severe exposure zones (without welded corners).

Figure 8 Current test specification (Courtesy of Bovis Homes Ltd)



Insulation

The test programme was to cover the following insulation materials, which were agreed by the Steering Group to cover the full range of materials covered by the project scope:

- blown-in mineral wool (MW)
- blown-in expanded polystyrene (EPS) beads (bonded)
- built-in glass mineral wool (MW) batts
- built-in rock mineral wool (MW) batts
- built-in expanded polystyrene (EPS) boards

Calibration

Once again, owing to the presence of the window the expected outflow resultant from the regular input levels of water flow would be reduced. Accordingly, a new figure for the expected output was calculated by reducing the regular figures proportionally to the reduction in active wall area. This gave (to one decimal place):

Regular figure (l/min)	Adjusted figure (l/min)
1.4	0.9
0.8	0.5
0.3	0.2

The expected calibration figure was adjusted accordingly in the computer file and the wall calibration run to those parameters.

Results

Blown-in mineral wool (MW):

- the first blown-in mineral wool (MW) insulation material showed no water penetration in week 1 of the test. In week 2, some damp patches appeared along the left hand side jamb of the window on wall 1 (see Figure 9). On wall 2, a damp patch appeared to the right hand side of the wall, but independent of the window. During week 3, the damp patches grew in size (see Figure 10)
- no obvious issues were noted during the dismantling of the wall, ie there were no building defects and the fill appeared to be even and consistent throughout with no voids. However, subsequent density measurements showed that the insulation was installed at an average density significantly higher than the density certified for the product. This higher density was not uniform throughout the cavity, with variations being noted. Plugs of higher density insulation had formed, resulting in some surrounding areas of lower density, which may have provided paths for water penetration. This test was therefore not representative of the certified product and typical installations. Further testing of blown-in mineral wool insulation was discontinued at this point.

Figure 9 Damp area on wall 1



Figure 10 Damp area on wall 2



Blown-in expanded polystyrene (EPS) beads (bonded):

- the expanded polystyrene (EPS) bead insulation material saw no water penetration on wall 1 throughout the test. Wall 2 experienced a damp patch during day 3 of week 3, but this damp patch did not reappear during the remainder of the test (see Figure 11). Under the BBA's usual water penetration assessment criteria for full fill cavity wall insulation, this test result would not be deemed a failure when carried out on the standard wall configuration
- no obvious issues were noted during the dismantling of the wall, ie there were no building defects and the fill appeared to be even and consistent throughout with no voids.

Figure 11 Damp area on wall day 3 of week 3



Built-in materials:

- the three built-in materials tested, ie glass mineral wool (MW) batts, rock mineral wool (MW) batts and expanded polystyrene (EPS) boards, showed no water penetration to the internal leaf throughout their respective tests
- the expanded polystyrene (EPS) boards included a tongue and groove edge, and the external face of the boards also incorporated tapered flutes.

Overall Conclusions

The purpose of this investigation was to understand whether the widening of cavities in masonry cavity walls, fully filled with cavity insulation installed to enable the fulfilment of improving thermal standards, would have an additional benefit of providing greater resistance to the penetration of wind driven moisture to the inner leaf.

The investigation also set out to explore whether current new-build masonry walls with wider fully filled cavities may be less susceptible to rain penetration than walls built to a typical 1990s walls specification.

The investigation was undertaken using a completely novel adaptation of the standard BBA masonry cavity wall Water Resistance test rig. The adaptation was to include a window and associated features, which would serve to make the already very severe test conditions significantly more extreme than using the standard arrangement.

It is accepted that the exposure conditions in the standard BBA test presents the cavity wall insulation with an extreme level of exposure to wind driven rain. The conditions were established at these extreme levels in order to negate the need to include any features into the test area, and thereby to provide a reproducible test for insulation systems. The modification of the standard test conditions for this research project to include features added a new dimension to the testing, which further increased the severity.

Since investigations have not been made before, using the adapted rig, there is no experience of the behaviour of the insulation systems in this condition. The findings of this investigation have no bearing to existing certification for cavity wall insulation systems.

The test sampling was also small, at one test per material type. The results are therefore not statistically reliable and provide insufficient evidence to draw any firm conclusions. However, based on these tests and in the light of 40 years' existing BBA experience of testing insulated cavity walls, the following tentative statements can be made:

- the long-established BBA testing regime for cavity wall insulation materials and systems remains valid for all exposure zones in the UK
- the testing shows that current masonry wall design and detailing to current standards is inherently more resistant to water penetration than the common construction practice in the early 1990s
- built-in full fill cavity insulation can be used in fair faced masonry walls in areas of very severe exposure to wind-driven rain when incorporated in correctly-designed and built wall elements
- blown-in cavity insulation appears to be more sensitive to variations in installation processes and the individual design and build quality. Its suitability for use in very exposed locations will therefore depend on local factors. The use of these systems would require assessment on a case-by-case basis by a suitably-qualified and experienced individual
- increased cavity widths being used to meet more onerous U value requirements for walls are generally considered to reduce the risk of water penetration across the cavity, but design around openings is still critical to ensure robust performance. The innovation in components such as wall ties for better thermal bridging performance must be assessed for any adverse interaction with the insulation materials in terms of water transmission across the cavity
- the issues of control and monitoring of workmanship and correct specification on site continue to need careful consideration. For blown-in cavity wall insulation in particular, this requires close adherence to the requirements of the BBA Assessment and Surveillance Scheme for Approved Installers of Cavity Wall Insulation.