WATER PERMEANCE OF DOUBLE LEAF MASONRY WALLS WITH CAVITY INSULATION

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ABSTRACT Thermal insulation of double leaf masonry walls is desirable to improve their performance. Results of a program to examine the likelihood of rain penetration to indoors occurring when insulation is placed in the cavity are given. A proposal is made for a simple standard test of the ability of cavity insulations to resist the transfer of water across them under the conditions pertaining to a cavity wall. The research was funded by the GMI Council of Australia, which also arranged consultation with industry.

1. BACKGROUND

Several studies, e.g. Walsh et al. (1), Delsante (2), have indicated the considerable hot weather advantages in temperate climates of heavyweight construction such as can be provided by concrete slab-on-ground with double-leaf masonry walls. However, the latter need to be thermally insulated if low energy consumption for space heating is desired in cold weather. Increased thermal resistance can be achieved by adding insulation in any one of three locations: externally, in the cavity, or internally. Whilst insulation fixed on the outdoor side of the wall is the most attractive from a thermal viewpoint (especially for continuous heating), placing insulation in the cavity is likely to be the most cost effective means of increasing the overall thermal resistance of the wall to a satisfactory level.

Cavity masonry walls were developed early this century to overcome problems of rain penetration through masonry walls. Any water that penetrates the outer leaf can run down the back of it and be led back outdoors with the aid of suitable flashing, or allowed to run harmlessly to the ground. Since the introduction of insulation into the cavity may increase the risk of water being transferred from the outer leaf to the inner leaf, the performance of several cavity insulation systems has been examined in order to determine those systems which minimize this.

Since the 'energy crisis' of 1973, considerable attention has been given to satisfactory methods of insulating double leaf masonry walls, especially in the United Kingdom and Europe. Test methods have been developed to examine the risk of water penetration with insulation present, and the Building Research Establishment has carried out extensive field experiments, reported by Newman et al. (3,4). In these experiments water was applied to the gable ends of two-storey houses and the extent of damp patches on the decorated plaster on the internal leaf of concrete block was recorded. With retrofit fills (blown-in or injected after the walls are built) the performance of the walls was examined both before and after the insulation was placed. The outer leaf allowed much of the applied water to penetrate and run down the inside of the outer leaf and some of this was transferred across the cavity. Of the nine retrofit fills examined, four resulted in a significant increase in dampness compared with the unfilled cavity, four resulted in a slight increase in dampness, and one actually gave a decrease in dampness. With built-in fills (water repellent mineral wool slabs or expanded polystyrene boards incorporated at the time of construction of the walls), a range of performance similar to the retrofit fills was observed and it was established that dampness occurred by streaming or tracking of water at joints between the materials rather than by permeating

through the materials themselves. Guidance on good construction practice is contained in a publication prepared jointly by the British Board of Agrement and others (5).

2. EXPERIMENTAL

In order to distinguish effects arising from the properties of the individual masonry units, the properties of the built wall, and the properties of the various insulation materials, the masonry units were characterized first, then single-leaf walls built from these units were studied, and finally the various insulation systems were evaluated by placing them in a simulated cavity against the single brick leaves and subjecting them to water. Two different methods of doing this were adopted. In one method, water flowed through the walls under a simulated wind loading adjusted to give a specific rate of flow on the 'indoor' or insulation side of the single leaf. In the other, water was applied uniformly and at a constant rate of flow directly to the inside of the wall above the insulation and allowed to flow down to the simulated cavity holding the insulation. The rate of water flow chosen could be as high as might be expected to penetrate and run down the indoor side of the outer leaf on a very exposed site with a very permeable wall. Various criteria of performance were considered, all associated with the diversion of water from the indoor side of the brick leaf by the insulation in the simulated cavity.

3. PROPERTIES OF THE MASONRY UNITS

The water absorption properties of the six different masonry units used in the project were determined using the methods outlined in the relevant Australian Standard (6). The results are summarised in Table 1 and show wide variation in water absorption properties.

Table 1. MEAN BRICK AND BLOCK PROPERTIES

Description	Dry mass (kg)	Initial rate of absorption, IRA_2 (kg/m^2.min)	24 hour cold water absorption, CWA (%)	5 hour boiling water absorption, BWA (%)	Saturation coefficient CWA/BWA
Extruded clay brick, low absorption, 'smoke', 3 holes	3.36	0.22	5.36	5.76	0.93
Pressed clay brick, high absorption, 'brown'.	3.73	5.24	9.03	11.19	0.81
Stiff plastic pressed clay brick, 'red'.	3.39	1.49	3.92	5.52	0.70
Calcium silicate brick, 'white', 3 holes.	3.38	1.87	8.81	12.12	0.73
Concrete brick	4.21	0.75	4.77	not measured	-
Concrete block, 390 x 90 x 190 mm, 2 holes.	9.17	1.36	9.04	" "	-

4. PROPERTIES OF THE SINGLE LEAF MASONRY WALLS

Single leaf masonry walls with wire ties inserted to accept a second leaf of masonry were built with the six different types of masonry under investigation (three different types of clay brick, calcium silicate brick, concrete brick, and concrete block). The walls were 1800 mm high and 1190 mm wide (corresponding

to 21 high and 5 wide in standard bricks, or 18 high and 6 wide in modular bricks). Walls with ironed joints and with raked joints (as illustrated in Figure 1) were constructed for each case. The ironed joint is finished with a trowelling action and thus the surface of the mortar is more compacted. The raked joint leaves a horizontal 8 mm wide ledge on which water can lie. For all except the calcium silicate bricks, a 9:2:1 sand: lime: cement mortar was used with the sand consisting of 4 parts of washed sand and 5 parts of a brick sand (60/40 Baxter's Combine). The sieve analyses of the various sands are given in Table 2. For the calcium silicate bricks the manufacturer's recommended mortar consisting of 5 parts of washed sand to 1 part of cement plus a small quantity of "Mortarbond" was used and, in contrast to the practice on all the other walls, the extrusions of mortar on the indoor side were not trowelled off.

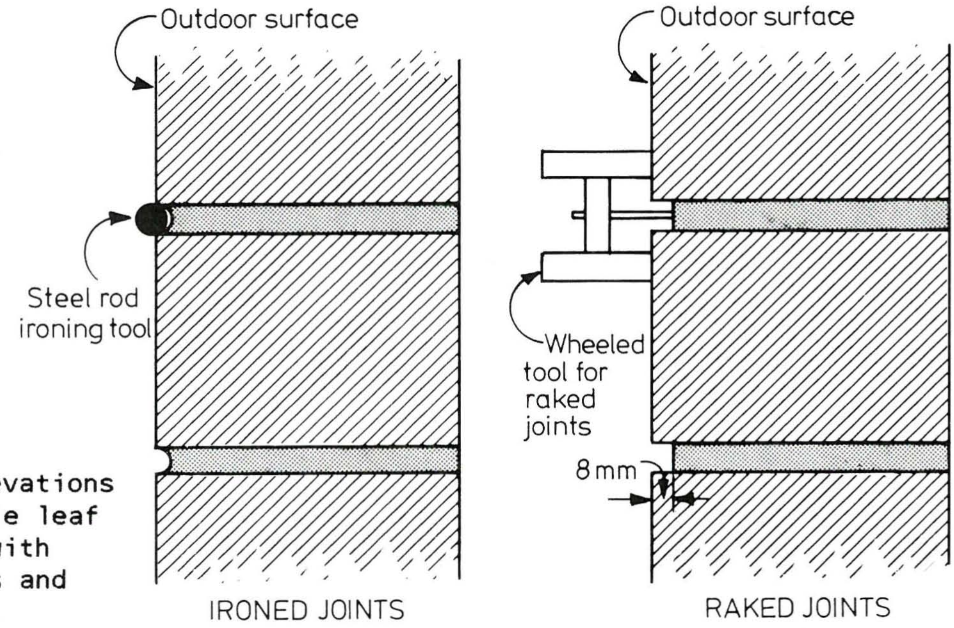


Fig.1 Sectional elevations through single leaf brick walls with ironed joints and raked joints.

Table 2. SIEVE ANALYSIS OF MORTAR SANDS

Type	Particle size (% by mass)					
	<0.42 mm	0.42-0.83 mm	0.83-1.65 mm	1.65-2.36 mm	2.36-3.35 mm	>3.35 mm
Washed sand	23	71	5	negligible	negligible	negligible
Baxter's combine, 60/40	49	22	22	5	2	negligible
4 parts washed, 5 parts Baxter's 60/40	35	49	13	2	1	negligible

The water permeance of each of these twelve different masonry walls has been determined using the pressure box rig depicted schematically in Figures 2 and 3. Initially, the performance of the wall at a fixed pressure of 300 Pa was observed (corresponding to a wind velocity of about 80 km/h). The sparge pipe at the top of the wall delivered about 3000 mL/min, sufficient to form a continuous film on the wall. It was found that most walls arrived at a steady value of rate of water penetration which could be readily measured by a float/displacement transducer arrangement connected to a chart recorder. The variation of rate of water penetration with variation in air pressure was also determined so that the pressure required to give a selected water permeance could be interpolated. A summary of the major results obtained is given in Table 3.

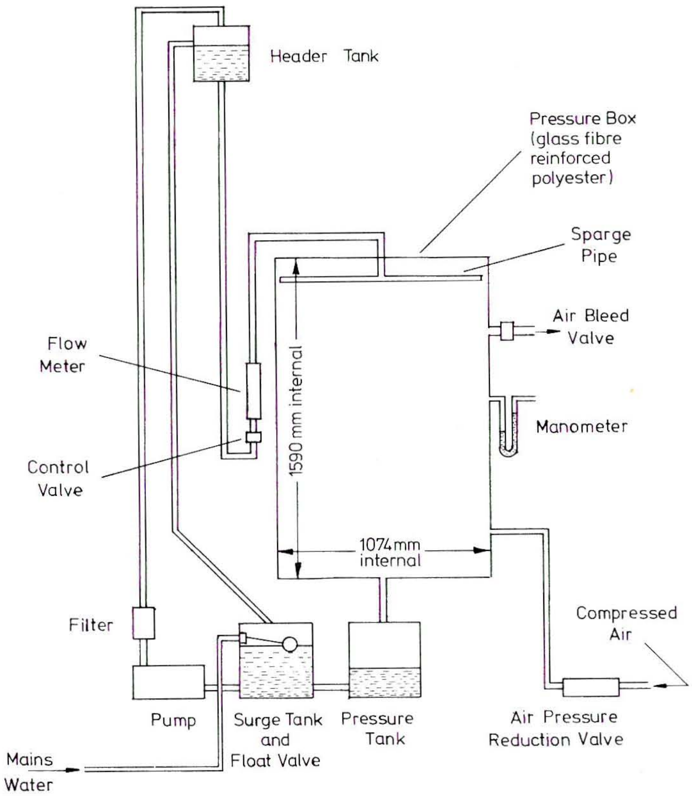


Fig. 2 Pressure box rig showing the water circulation system.

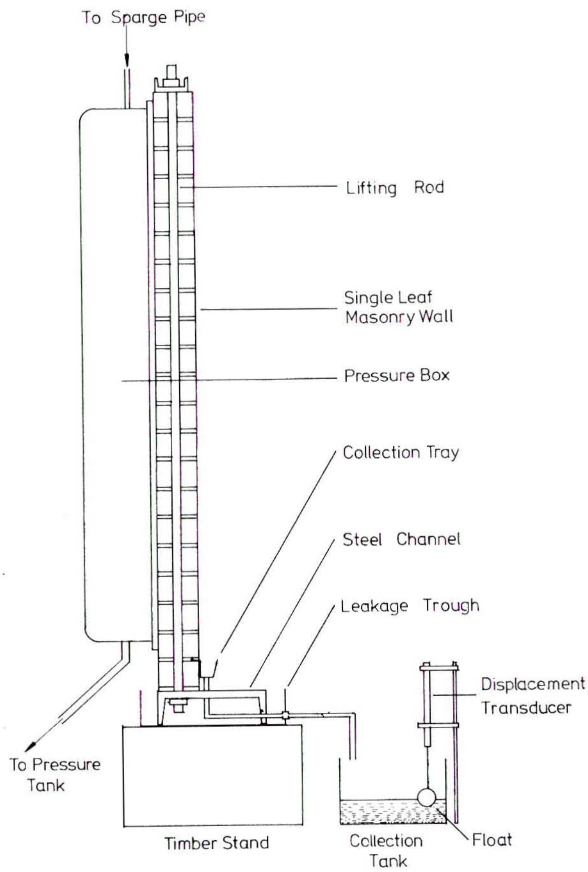


Fig. 3 Side view of the test wall and water penetration measuring system.

Table 3. PROPERTIES OF SINGLE LEAF WALLS

Masonry Type	Joint type	Wall No.	Time to first dampness at 300 Pa (min)	Water penetration rate per metre width		Pressure to give rate of 150 mL/min.m (Pa)
				at 300 Pa (mL/min)	at zero Pa (mL/min)	
Clay brick, 'smoke'	ironed	3	5	8.2	-	-
		4	3	8.7	-	-
	raked	5	1	44.6	-	-
" " 'brown'	ironed	15	5.7	146	41	300
	raked	16	2	500	160	0
" " 'red'	ironed	7	0.3	125	40	350
		8	1	110	36	500
	raked	9	0.5	230	41	180
		10	0.3	240		-
Calcium silicate brick	ironed	17	1.5	50	15	-
	raked	18	1.2	103	35	500
Concrete brick	ironed	13	1.5	47	15	-
	raked	14	1	50	25	-
Concrete block	ironed	11	2	120	47	-
	raked	12	0.2	300	140	-

Water always appeared at the back of the wall soon after the start of the experiment at the standard pressure of 300 Pa. Penetration usually occurred first at the mortar joints and spread from there. For the 'smoke' coloured bricks, which showed the lowest penetration rate, most of the water that penetrated did so on the lower half of the wall. In all other walls the penetration was fairly uniform over the wall. The raked joints always resulted in greater water penetration rates than the ironed joints, and in some walls this was very marked. Thus, the raked 'smoke' brick walls allowed 5.3 times as much water through as the ironed joints. Corresponding ratios for the other walls were 'brown' 3.4, 'red' 2.0, calcium silicate 2.1, concrete brick 1.1, and concrete block 2.5. Clearly, ironed joints are to be encouraged to reduce the risk of water penetration. However there was an even greater variation in water penetration rates among the different masonry types, e.g., ironed 'brown' was some 17 times greater than ironed 'smoke'.

5. THE INSULATION SYSTEMS

Six types of insulation were chosen for investigation, based partly on successful use overseas. They were

(a) glass fibre batts,
(b) expanded polystyrene (EPS) bead board,
(c) extruded polystyrene (extruded P/S) board,
(d) rock wool loose fill,
(e) expanded polystyrene beads, and
(f) urea formaldehyde foam insulation (UFFI)

The first three products have to be built in as the wall is constructed and may be used as a complete fill of the cavity, or as a partial fill of thickness less than the width of the cavity. The latter allows an air space to be retained between the insulation and the outer leaf, theoretically reducing the risk of water transfer across the cavity. The last three products are installed after the cavity masonry wall has been completed and are thus suitable not only for new work but also for retrofit in existing buildings.

6. EFFECT OF THERMAL INSULATION ON WATER TRANSFER ACROSS THE CAVITY

For ease of discussion, the four surfaces of a double leaf masonry wall may be numbered from 1 to 4 as shown in Figure 4, with surface 1 on the outdoor side.

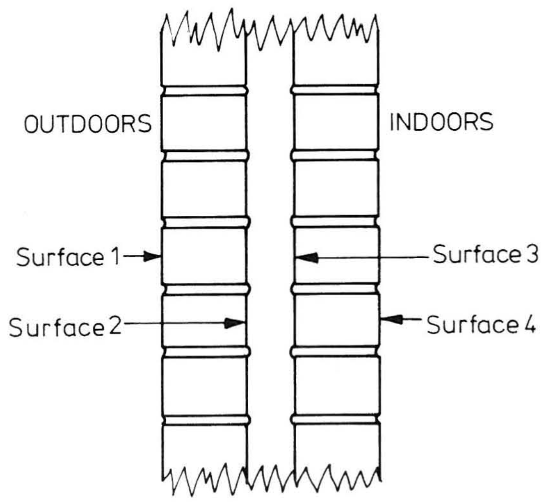


Fig. 4 Identification of the four surfaces in a double leaf masonry wall

The work described in the previous section established that with wind-driven rain, water penetration of the outer leaf usually occurs to such an extent that free water runs down surface 2, the magnitude of this at 300 Pa pressure difference varying from 8 mL/min.m to 500 mL/min.m for masonry walls examined here (i.e. 8 mL/min to 500 mL/min for one metre width of test area), or in area terms from about 5 mL/m^2.min to over 300 mL/m^2.min. If an insulant is placed in the cavity it must divert as little as possible of this water from surface 2.

If water is diverted from surface 2 it could

(a) be held in the interstices of the insulation,
(b) drain from the insulation at the bottom of the wall,
(c) reach surface 3, and
(d) pass through the masonry and reach surface 4.

In these studies, we have adopted the criterion for acceptance of a cavity insulation system as being that no liquid water should reach surface 3. On this basis, the cavity can be simulated by constructing a timber frame to hold the insulant being investigated, and using clear glazing to represent surface 3, the sides of the frame being clamped to the test wall. A suitable trough for collecting water draining from the insulation was placed at the bottom of the frame spaced some 2 mm from surface 2 so that water not diverted from that surface could flow freely past the trough. The rate of water flowing into the trough would quantify item (b) above, whilst item (a) could be measured by weighing the insulation system before and after test. Experience with testing a variety of insulant systems showed that in those cases where water did reach surface 3, rarely was it in quantities large enough to run down and be measured, so a separate collecting trough for that purpose was not necessary. Any water that did reach surface 3 could be observed through the glass or clear acrylic panel simulating surface 3.

Two modes of water application were used. Mode 1 was the application of water at a rate of 3000 mL/min.m by a sparge pipe at the top of surface 1 inside the pressure box and allowing it to penetrate the brickwork to surface 2 under the imposed air pressure difference chosen to give the desired flow rate on surface 2. Mode 2 was the application of water to surface 2 by a sparge pipe at the top of wall. Since considerably smaller flow rates were required in this case the water was arranged to impinge on a felt mat to obtain proper distribution across the width of the wall.

An idealized comparison of the rate of water flow on surface 2 in Modes 1 and 2 is depicted in Figure 5. In Mode 1, water is assumed to be flowing uniformly through the wall over the whole of the test area so that the rate of flow of water past a horizontal line at the top of surface 2 is zero and the rate of flow increases linearly down the wall. Let $\bar{Q}$ mL/min.m be the mean rate of flow. Then the rate of flow at mid-height will be equal to $\bar{Q}$ and the rate of run off at the bottom of the test area will be $2\bar{Q}$. In Mode 2 let the rate of application of water by the sparge pipe at the top of the wall be Q mL/min.m. This rate of flow will be maintained on the wall as one traverses down it, less the loss of water flowing into and through it. If a wall of low water permeability is chosen, this loss is likely to be negligible compared with the value of Q. If it is not negligible, the rate of application of water at the top of the wall is given by $Q = \bar{Q} + Q_a$ where $\bar{Q}$ is the desired mean rate of flow and $2Q_a$ ml/min.m is the total rate of flow through the wall.

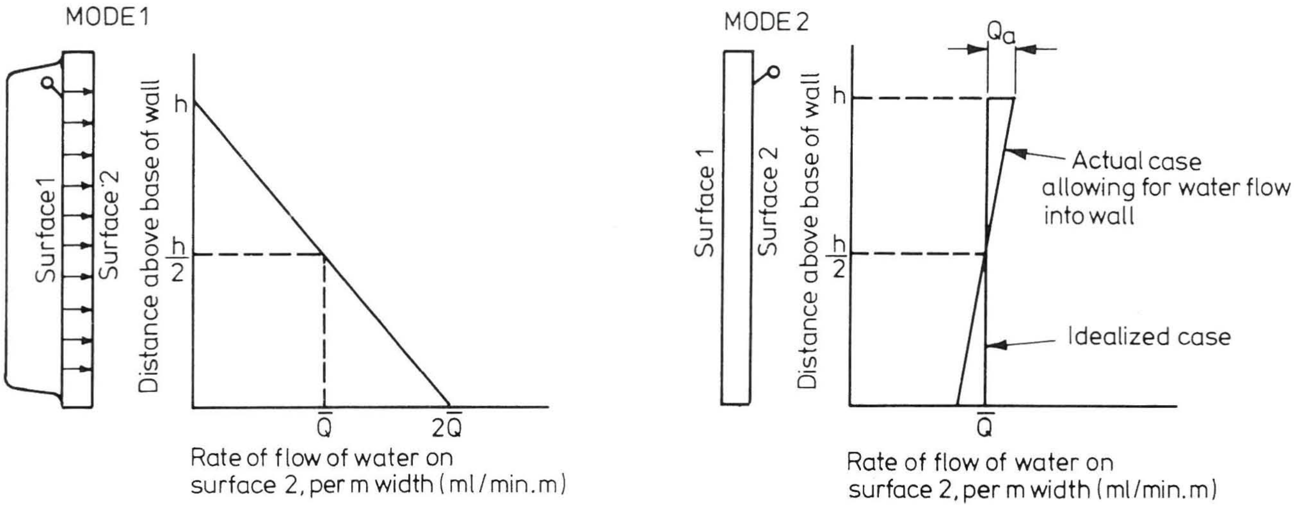


Fig. 5 Comparison of water flow rates past any horizontal line on surface 2 for water application by Mode 1 or Mode 2.

Diversion of water from surface 2 by insulants in a simulated cavity has been found to be very dependent on the flow-rate of water down surface 2. Although Mode 1 and Mode 2 tests are of different kinds, conditions in the two tests will be most closely alike not when the rates of run off at the bottom are equal but when the mean rates of flow (i.e. the rates of flow at mid-height) are equal, i.e. when the rate of run-off in Mode 2 is approximately half the rate of run off in Mode 1.

The results obtained in Mode 1 experiments are summarised in Table 4.

Table 4. WATER DIVERSION BY CAVITY INSULANTS, MODE 1
(i.e. Water applied to surface 1, under pressure and at 3000 mL/min.m)

Cavity fill type	Cavity fill material	Details	TEST NO.	WALL NO.	CAVITY WIDTH (mm)	Pressure on surface (Pa)	Water penetrating per metre width to surface 2: Estimated flow rate at mid-height, $\bar{Q}$ (mL/min)	Duration, t (min)	Total Flow, $V = \frac{2\bar{Q}}{1000}$ (L)	Time to first appearance of water on surface 3 (min)	Water diverted per metre width into cavity from surface 2: Drained from insul'n (mL)	Retained in insul'n (mL)	Total (mL)	Total (%)
1. Built in to cavity as wall constructed, (complete fill)	Low density glass fibre batt		54	18*	50	500	75	72 x 60	648	d.n.a.	900	375	1275	0.2
			55	8	"	500	75	72 x 60	648	"	0	210	210	0.03
		60 mm hydro-phobic	39	7	"	350	75	144 x 60	1296	"	0	not measured	-	-
	medium density glass fibre batt		49	8	30	500	75	72 x 60	648	"	0	150	150	0.02
			51	18*	"	500	75	72 x 60	648	"	0	100	100	0.02
	as above + foil	foil at surface 2	58	8	30	500	75	72 x 60	648	"	26 250	assume 77	26 327	4.1
	as above + foil	foil at surface 3	58	8	30	500	75	72 x 60	648	"	0	not measured	-	-
	Rockwool batt		38	9	50	250	75	144 x 60	1296	"	0	not measured	-	-
			57	8	50	500	75	96 x 60	864	"	0	" "		
	Extruded polystyrene board		52	8	30	500	75	72 x 60	648	"	0	0	0	0
2. Retrofit (pour or inject)	Expanded polystyrene beads		53	18*	50	500	75	144 x 60	1296	"	0	not measured		
	Tripolymer foam insulation		72	15	50	300	75	72 x 60	648	"	36 500	not measured	>36,500	>5.6

*mortar extrusions at surface 2 See Table 3 for wall no. identification d.n.a. = did not appear

It will be noted that the experiments were all done at a mean flow rate of 75 mL/min.m and in no test did water reach surface 3. However in two tests the total water diverted from surface 2 by the insulant was well in excess of 1% or 20 litres and this casts some doubt on those particular systems. In retrospect, the mean flow rate chosen, although higher than that which would be experienced by many masonry walls, was not high enough to be representative of the worst of the whole range of values that occur (see Table 3). In any event, experience gained with both Mode 1 and Mode 2 tests indicated that the simpler Mode 2 arrangement could be developed very satisfactorily as a standard test for cavity insulation systems, and that further work should be concentrated in that area.

Preliminary results obtained with Mode 2 tests, together with the results later obtained on single leaf walls and reported in Table 3, indicated that tests at successively increasing rates of flow were desirable, corresponding to increasing degrees of risk in practice. It was found that doubling the rate of flow at successive tests was not sufficiently discriminatory, but that trebling the rate of flow was. It was finally judged that the initial test should be at 100 ml/min.m. for a period of 24 hours. If no failure occurred during that time then the flow rate would be increased to 300 ml/min.m for a further 24 hours testing, and if there was still no failure, a further 24 hours testing at 900 ml/min.m. The permitted uses of cavity insulation would be restricted for materials that only pass the 100 ml/min.m test and be incrementally relaxed for materials that passed at the higher flow rates. A failure was deemed to be appearance of water at surface 3, but a further condition that there be an upper limit to the percentage of water by volume retained in the insulation should be considered.

Mode 2 tests were carried out on insulations that only partially filled the cavity as well as on those that completely filled it. With partial fills, the batts or boards were retained against surface 3 leaving a cavity between the insulation and surface 2, typically some 20 mm wide. In general, partial fills of this nature did not allow any water across to surface 3 and it is deemed that all such systems would perform well in the test situation. This is not to say that they would always perform well in the field situation, however, as will be discussed later.

Table 5 gives a selection of some of the results obtained for Mode 2 testing of complete fills, in most cases using the finally recommended flow rates. The loose fill rock wool made water repellent (or hydrophobic) was placed by hand as a suitable blowing machine was not available. It will be noted that the optimum density of placement would appear to be of the order of 60 to 70 kg/m^3 as higher densities performed less well.

On the basis of the results obtained (space limitations preclude a complete listing in Table 5), the best built-in complete fill systems were medium density (about 25 kg/m^3) fibre glass with water repellent treatment and expanded polystyrene board with shiplap edge treatment, whilst the best retrofit system was expanded polystyrene beads. The latter are very free-flowing with a low angle of repose which is an advantage in securing complete filling of the cavity but a disadvantage if there are any openings existing or subsequently required in the masonry. Adhesively bonded polystyrene beads overcome this difficulty, but are not yet commercially available in Australia.

Table 5. WATER DIVERSION BY CAVITY INSULANTS, MODE 2
(i.e. Water applied to surface 2)

Cavity fill type	Cavity fill material	Details	TEST NO.	Water applied per metre width to surface 2: Application rate, Q (mL/min)	Duration, t (min)	Total appl'd $V = \frac{Qt}{1000}$ (L)	Time to first appearance of water on surface 3 (min)	Water diverted per metre width into cavity from surface 2: Drained from insul'n (mL)	Retained in insul'n (mL)	Total (mL)	Total (%)
1. Built in to cavity as wall constructed (complete fill)	Medium density glass fibre hydrophobic batt	30 mm cavity	24	250	1440	360	d.n.a.	0	-		
				500	480	720	"	"	-		
				1000	1400	1440	"	"	-		
				2000	5700	11400	"	"	350	350	0.003
	Rock wool batts	50 mm cavity	28	100	1440	144	d.n.a.	0	-		
				300	4320	1296	"	"	-		
				900	450	405	2	23750	85	23835	5.9
	Expanded polystyrene bead board	shiplap edge (15 mm rebate)	32	100	1380	138	d.n.a.	0	-		
				300	1440	432	"	"	-		
				900	1440	1296	"	"	-		
2. Retrofit	Rock wool, loose fill	hydrophobic packed to 68.3 kg/m^3	30	100	1440	144	d.n.a.	0	-		
				300	1440	432	"	"	-		
				900	1440	1296	210	"	-		
		hydrophobic packed to 92 kg/m^3	29	100	6720	672	d.n.a.	0	-		
				300	1440	432	>600	"	-		
				900	1440	1296		18000	-	c.18000	c.1.4
		hydrophobic packed to 100 kg/m^3	31	100	1560	156	2	2028	-	c.2028	1.3
	Expanded polystyrene beads	no adhesive	10	340	1440	432	d.n.a.	0	-	negligible	
		" "	18	1000	1440	-	"	"	-	negligible	
	Tripolymer foam insulation	wall 15	33	100	1380	138	d.n.a.	0	not measured		
				300	1380	414	"	"			
				900	540	486	"	24000	" "	c.24000	4.9

N.B. 50 mm cavity unless otherwise stated. d.n.a. = did not appear

7. PRACTICAL CONSIDERATIONS IN THE PREVENTION OF WATER TRANSFER ACROSS CAVITIES

During the course of the work reported here the importance of avoiding flexible impermeable materials which could bear against surface 2 and cause a damming action was observed. Thus an attempt to flash between successive courses of glass fibre batts with a polyethylene film at horizontal joints was a failure. The 150 mm wide film was placed across the 50 mm wide batt with a 50 mm turn down on surface 2 and a 50 mm turn up on surface 3. This caused the water to bank up, flow along the horizontal portion of the flashing, and breach it at end joints. Aluminium foil facings had a similar damming effect with overtopping at the horizontal joints, in some cases.

British experience (3,4,5) emphasises the role that mortar extrusions at the horizontal courses play in diverting water into the cavity, particularly if they are in the neighbourhood of horizontal joints in built-in insulants. Hence, the recommendation for complete fill insulants is that the outer leaf of masonry should proceed ahead of the inner leaf so that all mortar extrusions on surface 2 can be easily trowelled off. Wire brick ties should be used and spaced in a vertical direction to accommodate the slabs of insulant between them. The inner leaf is built up until it is flush with the top of the insulant slab, the outer leaf then proceeds to two courses above the next row of ties, extrusions are removed from surface 2, and all mortar droppings removed from the top of the previous row of insulant slabs and ties before placing further insulation. In the case of partial fill insulants, however, the inner leaf needs to proceed ahead of the outer leaf so that the insulant slabs can be fixed to surface 3 (after extrusions have been trowelled off). It is still desirable that no extrusions be left on surface 2 but this is difficult to achieve in a narrow cavity of say 20 mm, and for this reason a minimum cavity of 50 mm is still recommended, necessitating an 80 mm initial cavity if 30 mm insulant is being used. This, together with the greater risk of mortar droppings accumulating in

the cavity, suggest that less risk may be associated with complete cavity fill than with partial cavity fill.

In general, the risk of water penetration occurring through double leaf masonry walls with cavity insulation will be less in Australia than in Europe because of the higher average temperatures prevailing in Australia's centres of population, leading to higher rates of evaporation of absorbed moisture.

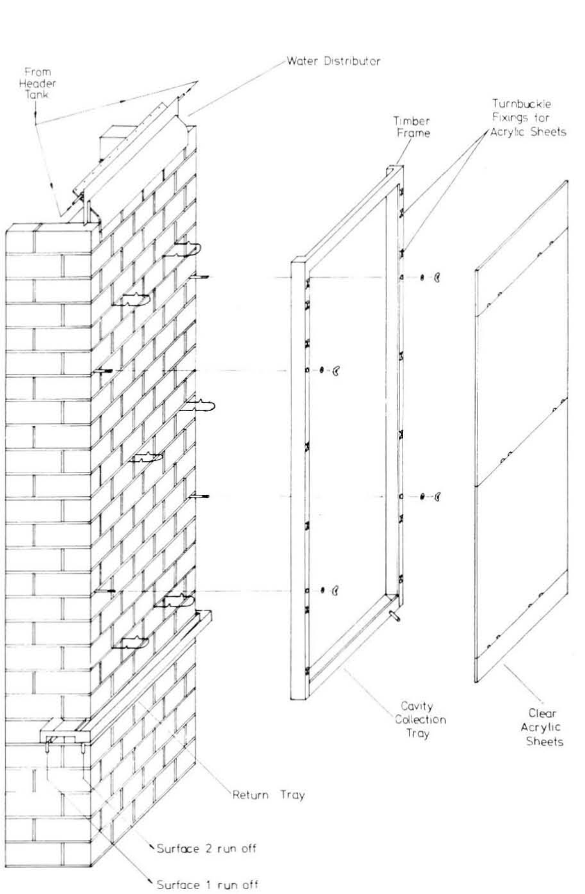
8. A STANDARD WATER DIVERSION TEST FOR CAVITY INSULANTS

There is considerable literature in the world on the measurement of water penetration through masonry walls, but not a great deal on the measurement of the effect of cavity insulation on the overall water penetration through double leaf masonry walls. In some cases, such as the Standard promulgated by the Bureau for the Quality Control of Cavity Fillings in the Netherlands (7) the Standard adopted does not identify or control the rate of water penetration to surface 2 and thus the results obtained depend in an unknown way on the characteristics of the brickwork. British Standard 6232 (8) offers an improved technique inasmuch as the test masonry wall is calibrated. It is a Mode 1 test but the application rates at zero pressure and 250 Pa pressure are adjusted to give mean flow rates (i.e. flow-rates at mid-height) on surface 2 equivalent to 34 ml/min.m and 117 ml/min.m respectively.

Arising out of the work reported here, and bearing in mind European experience with testing methods and thousands of installations in the field, the following tentative standard test proposal is made. A Mode 2 rig using the roughly trowelled off surface 2 of a masonry wall 1800 mm high by 1190 mm wide would be the test wall, as depicted in Figure 6. The distance between the vertical uprights containing the insulation system would be 1000 mm, and the height of the frame would be 1500 mm.

The water distribution system is indicated in Figure 7. A series of tests at mean flow rates increasing by a factor of 3 would be carried out as described earlier, commencing with 100 mL/min.m, and each of 24 hours duration. Water reaching surface 3 would be regarded as a failure and the insulant will be given a Class rating of 0, 100, 300 or 900 depending on which was the highest of the nominated flow rates passing the test. The higher the class, the less the restrictions on the use of the particular insulant system need be. A possible schedule of application rates and associated restraints is given in Table 6.

Consideration needs to be given as to whether any other parameter such as the uptake of water by the insulant, or measurement of the water draining from the insulant, needs to be taken into account in assessing the class of the insulant system. For investigatory and development work, a second test wall with mortar extrusions left on surface 2 rather than trowelling them off would be particularly desirable for the testing of retrofit fills, since the latter will often be required in walls where it has not been possible to obtain a smooth surface 2.



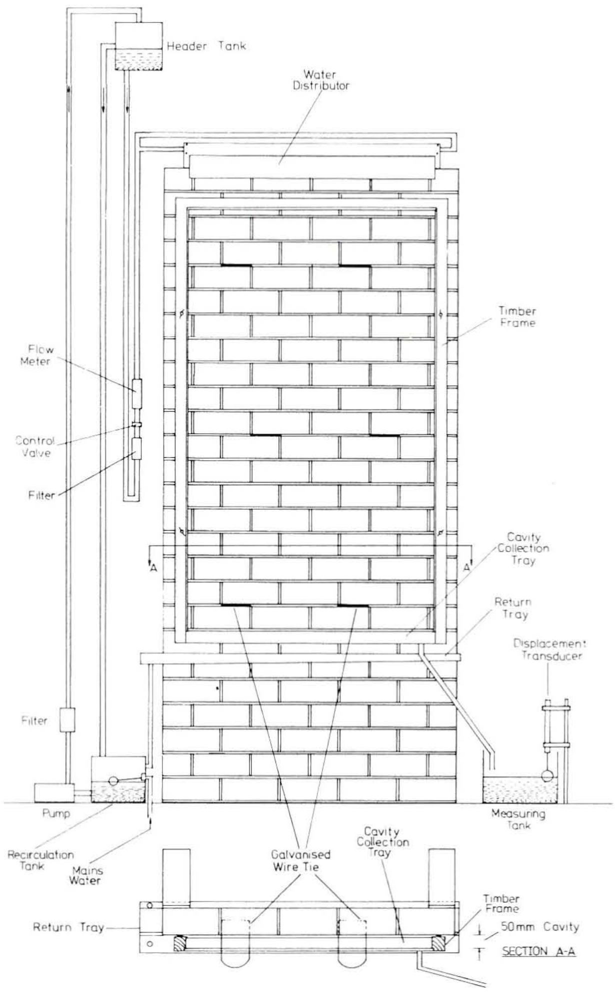


Fig. 6 Free-standing masonry wall and associated insulation retaining frame for Mode 2 standard test. Clear acrylic sheets provide surface 3.

Fig. 7 Schematic representation of the water distribution system and other details for Mode 2 standard test.

9. CONCLUSIONS

Considerable progress has been made in developing a simple test for determining the potential performance of masonry wall cavity insulation systems. More work is required to make decisions on some of the finer points of classification of insulant systems and a possible extension to retrofit fills in existing brick veneer houses.

10. ACKNOWLEDGEMENTS

The Brick Development Research Institute kindly measured the physical properties of the various masonry units used in this study. Assistance in the supply of materials was provided by several members of the masonry and insulation industries.

Table 6. PERMITTED USES OF CAVITY INSULATION PASSING WATER TEST AT THREE WATER APPLICATION RATES

Class rating (application rate in mL/min.m)	Permitted use
0	None
100	Terrain category 3 or 4 in single storey buildings with ironed joints.
300	Terrain category 3 or 4 in buildings up to 10 m high with ironed joints OR single storey buildings with raked joints.
900	Terrain category 1,2,3 or 4 in buildings up to 10 m high with ironed joints OR single storey buildings with raked joints

Note: Australian Standard 1170 (9) defines four terrain categories as follows:

Category 1 - Exposed open terrain with few or no obstructions and in which the average height of any objects surrounding the structure is less than 1.5 m.
Category 2 - Open terrain with well scattered obstructions having heights generally 1.5 to 10 m.
Category 3 - Terrain with numerous closely spaced obstructions having the size of domestic houses.
Category 4 - Terrain with numerous large high closely spaced obstructions.

For further details see AS 1170.

11. REFERENCES

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