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OPEN-JOINTED RAIN SCREEN CLADDINGS

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The note reports on natural exposure tests on vertical joints in open-jointed rain screen cladding. This work, together with earlier complementary work by the Norwegian Building Research Institute on horizontal joints, enables design recommendations to be made.

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OPEN-JOINTED RAIN SCREEN CLADDINGS

by M R M Herbert

INTRODUCTION

As its name implies, the function of a rain screen is to screen and protect the inner part of a walling system from the weather. Well-known examples of this principle are the outer leaves of cavity walls, and tile hanging. Of recent years the term has been used to describe the external weather face or layer of cavity wall construction when made up of large, often thin, sheet materials.

Because of the difficulties and cost of forming filled weathertight joints between thin panels, the use of open-joint rain screens has attracted increasing interest in recent years. Following studies by the Norwegian Building Research Institute[1] this form of cladding has been widely used in Scandinavia, to a lesser extent in Canada, and on a limited number of buildings in the United Kingdom.

Broadly, the open-joint rain screen cladding system allows water to pass through the joints into a ventilated cavity from which it is then drained. Successful design therefore depends on preventing water which enters and drains within the cavity from reaching the inner leaf in sufficient quantities to cause damage.

Apart from providing weather protection in ventilated cavity cladding systems, the method is claimed to offer considerable advantages in cold climates because it allows much of the thermal insulation to be placed near the outside of the wall. The chances of impaired performance or damage due to interstitial condensation in the inner leaf or back-up wall are also said to be reduced, since any water vapour penetrating the vapour check is free to condense in or near the cavity from which it can subsequently be evaporated.

NORWEGIAN WORK

Tests by the Norwegian Building Research Institute [1] were made to examine the effect of joint width, cavity depth and exposure on the penetration of water through open joints in thin timber, asbestos cement sheet, and stone slab claddings. Laboratory tests on the 20 mm thick stone slab facings with a 20 mm cavity showed that only small quantities of water crossed the cavity with both horizontal and vertical joint widths up to 5 mm. Most of the water passing through the joint system ran down the back of the rain screen. Above this joint width the amount of water crossing the cavity became unacceptably large. With joint widths of 5 mm and below, the horizontal joint blocked with water, effectively preventing air movement through the joint, thus reducing penetration.

Similar results were obtained in both laboratory and natural exposure tests, on horizontal joints, in rain screens using 5 mm thick asbestos cement sheets fixed to vertical battens. Again, provided the joint widths did not exceed 5 mm, very little water crossed a 25 mm deep cavity, although large quantities ran down the back of the rain screen. A typical successful construction of this type is shown in Figure 1.

Horizontal joints wider than 5 mm did not block with water, but allowed droplets to be torn from the edge by the air stream and carried across the cavity. Limited laboratory tests on vertical joints in asbestos cement sheets showed that gaps over 2.5 mm width were penetrated by driving rain, which, together with some water from the joint edges, crossed the cavity in unacceptably large quantities and wetted a strip some 50 mm wide on the back-up wall.

NATURAL EXPOSURE RIG STUDIES

To extend the Norwegian work, natural exposure tests have been made by BRE on vertical open rain screen joints. The object of these tests was to find out the effect of varying the following factors on the water penetrating the joint, and on its subsequent behaviour in the cavity.

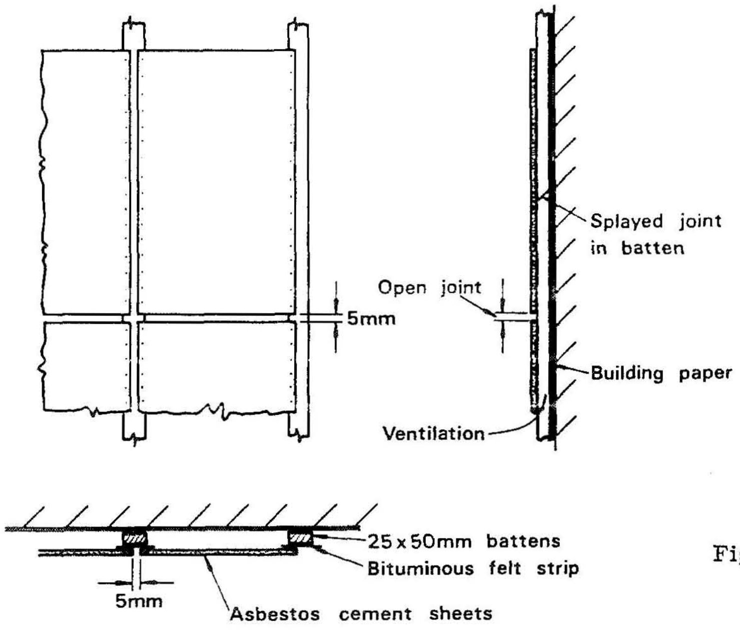


Figure 1 Typical open-joint rain screen cladding using asbestos cement sheets

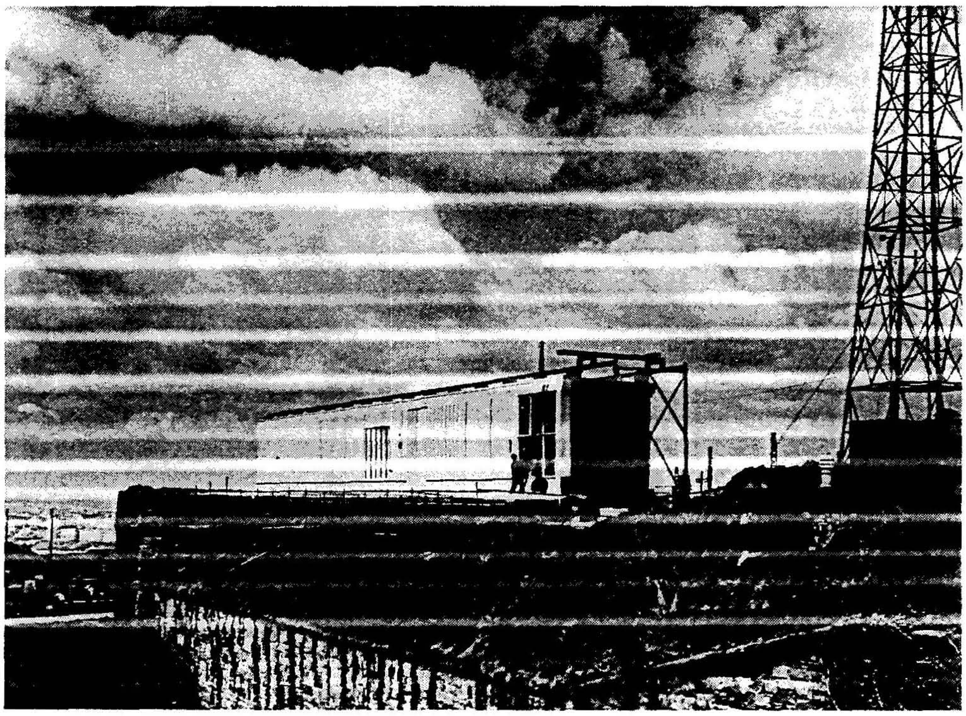
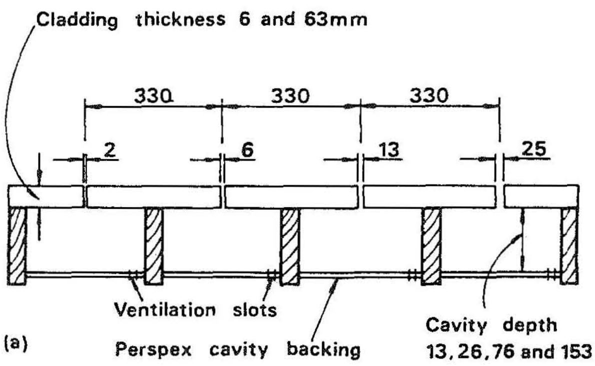


Figure 2 View of the natural exposure rig at Plymouth



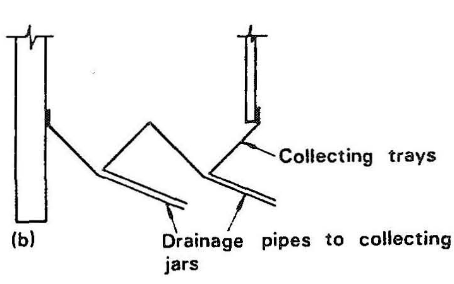


Figure 3(a) Horizontal section through typical test panel showing joint width, cavity depth and cladding thickness used in the BRE experiments

Figure 3(b) Vertical section showing method of collecting water which entered the cavity

1 Panel edge thickness

2 Cavity depth

3 Joint width variations

4 Ventilation of the cavity

5 The edge profile of the joints.

Figure 3 shows a typical panel used in the test and the variables examined in the principal experiment (1 to 4 above).

The natural exposure tests were made on a rig at Plymouth shown in Figure 2, over a period of many months' duration. During these tests the weather conditions were continuously monitored and daily readings were made of the amount of water which crossed the cavity or ran down the back of the rain screen panels. The extent to which the water droplets crossing the cavity spread out on the perspex inner leaf was also noted daily. Weather during these tests included days on which driving rain intensities of up to 20 mm per hour and wind speeds of up to 25 m per second occurred from a very wide range of directions. To represent the considerable volume of records, the maximum daily catches measured for the plain edge joints have been selected, and these are given in Figure 4. The maximum angles of spread, similarly, are given in Figure 5. Both Figures differentiate between sealed and unsealed cavities. The word 'sealed' here refers to the closing of ventilation holes on the perspex plate at the rear of the cavity. The catches resulting from the series of different edge profiles, without the baffles indicated in Figure 6, are given in Figure 7.

DISCUSSION OF RESULTS

It has been observed that water penetrates the walling system in two ways - water crossing the cavity and water running down the back of the rain screen; it is therefore convenient to take them separately for discussion.

1 Water crossing the cavity

The site observations show that, with two exceptions (n and j in Figure 4) the only factor which materially affected the quantity of water crossing the cavity was the variation of the joint width, the quantity of water crossing the cavity being approximately equal to the amount of driving rain reaching the face area of the joint. For practical purposes the amount of water passing through a given joint which would strike and run down the inner leaf of the wall can be estimated from meteorological records of wind speed and vertical rainfall using the methods suggested by Lacy[2].

After passing through the joint the droplets fan out or spread; the maximum angles of spread measured under both sealed and vented conditions are shown in Figure 5. This information can be used to determine the widths of shields or trays to prevent the droplets reaching the inner leaf. When using this information consideration should be given to providing a factor of safety to allow for exceptional weather conditions and unknown factors. Variation in the relative positions of the components due to inaccuracies in fixing must also be allowed for. An indication of the variation of joint widths likely to occur in thin asbestos cement sheet claddings is given in reference 3, and for heavy concrete cladding in reference 4. Observation shows that splashing by unintercepted water droplets can occur on the cavity backing. The extreme area affected could be in excess of 600 mm either side of the joint: the amounts however were very small and were usually removed within 24 hours by evaporation.

2 Water running down the back of the rain screen

It will be seen from the plots in Figure 4 that most water passing through the joints ran down the back of the rain screen. The effect of this form of penetration of varying the joint width was somewhat different for the thick and thin panels.

With thick panels, with the cavity sealed, variations of joint width made little difference to the quantity of water penetrating, and though the quantities were very small, there was a tendency for it to decrease with increase of joint width. However, when the cavity was ventilated, increase of joint width produced a marked and progressive decrease in penetration, 2 mm wide joints giving the maximum and 25 mm the minimum penetration.

With the thin panels, the effect of varying the joint width with the cavity ventilated, while similar in general pattern to that of the thick panels, was less well defined, 6 mm joints generally giving maximum penetration and 2 and 25 mm least. When backed by a sealed cavity,

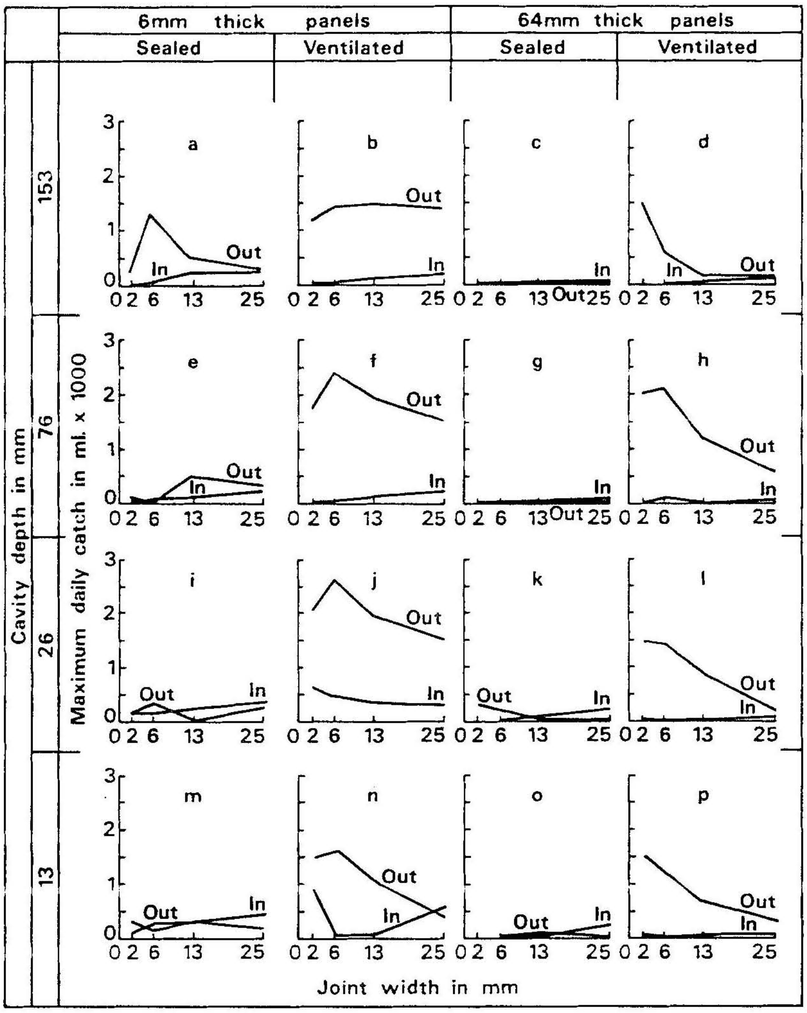


Figure 4 Maximum daily catches of water crossing cavity (in) and water running down back of rain screen (out) which were recorded under natural exposure tests

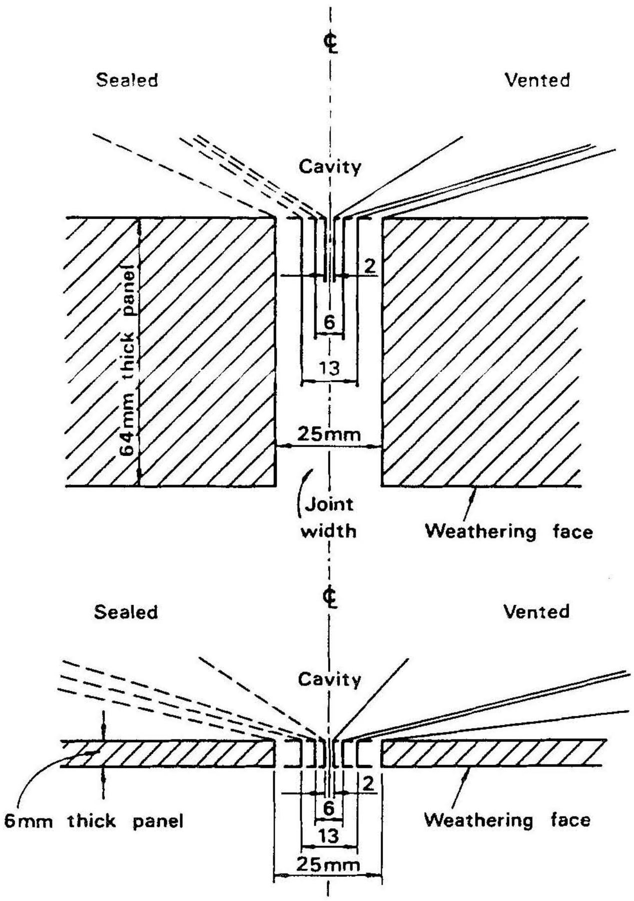


Figure 5 Scale diagram showing the maximum angles of spread of water passing through the joint and crossing the cavity

maximum penetration occurred with the 6 and 13 mm joints, 2 and 25 mm joints allowing only small quantities of penetration. Under the test conditions these quantities did not exceed 2 litre/h for any joint; however, under exceptionally severe exposure it is calculated that penetrations of up to 7 l/h could occur on a 3 m high joint.

Because, from calculation, nearly all the water crossing the cavity to the inner tray was driving rain, it follows that little driving rain was caught in the outer tray, and therefore that the majority of the water which ran down the back of the rain screen must come from water driven sideways on surfaces adjacent to the joint. From this it is to be assumed that the amount of water running down the back of the rain screen would be considerably reduced, or even virtually eliminated, by shielding the joint against side flow with external ribs, small corrugations, or similar features.

3 Effect of edge profiles

The effect of edge profiles on the water penetration through the joints was also examined. The edge profiles used are shown in Figure 6. Their behaviour both with and without baffles was studied.

The results are shown for comparison in Figure 7. When not fitted with baffles, with the exception of profile C, discussed later, the profiles had little effect on the amount of water which crossed the cavity, but did reduce the amount of water which ran down the back of the rain screen; those which included inclined grooves were more effective in this respect. The fitting of baffles reduced the amount of water crossing the cavity with profiles A and B, but made little difference to the remainder, possibly because the inclusion of inclined grooves reduced the effective lap of the baffles.

The lap profile (C) only allowed very small quantities of water to cross the cavity (a maximum daily catch of 5 ml in three years' exposure) and in this respect was consistently the best of all the profiles tested.

Laboratory studies intended to complement the site work are in progress but are not yet complete. For this reason, and also since the site studies were limited in scope for practical considerations, it is not yet possible to provide explanations for some of the observed behaviour patterns. This in turn means that design guidance at this stage can only be general in character.

DESIGN PRACTICE

The successful design of an open-joint rain screen as previously stated depends on preventing water which passes through the joints and drains down the back of the rain screen from reaching the inner leaf of the wall.

The Norwegian and BRE tests taken together suggest that if both the horizontal and vertical joints can be kept very small, below 5 mm for the horizontal and 2.5 mm for the vertical joint, with tolerances of a millimetre or so, very little water will cross cavities which are greater than 25 mm. However, to keep both horizontal and vertical joints simultaneously within these limits requires a high and probably impracticable degree of control.

The method shown in Figure 1, which has been widely and successfully used in Scandinavia and on at least one building in the United Kingdom, reduces the requirements for accuracy of the vertical joints and provides good ventilation of the cavity. Measurements taken on this building in the United Kingdom [3] showed that a mean joint width of 4.5 mm was achieved and although 12 out of 146 joint widths exceeded the recommended maximum of 5 mm by up to 4 mm, examination of the building after 5 years' use [5] showed no sign of water having crossed the cavity at these points. It should be stated however that the building was subject only to moderate exposure.

Although this series of tests was inconclusive in this respect, Scandinavian experience shows that a minimum cavity depth of not less than 25 mm should be maintained: consequently this depth should be increased if non-rigid insulating materials, which tend to bulge into the cavity, are used. In this cladding arrangement the extent to which the inner leaf of the wall should be protected against water crossing the cavity will depend on the accuracy with which the joint widths can be maintained, the sensitivity of the back-up wall to moisture and the severity of the exposure.

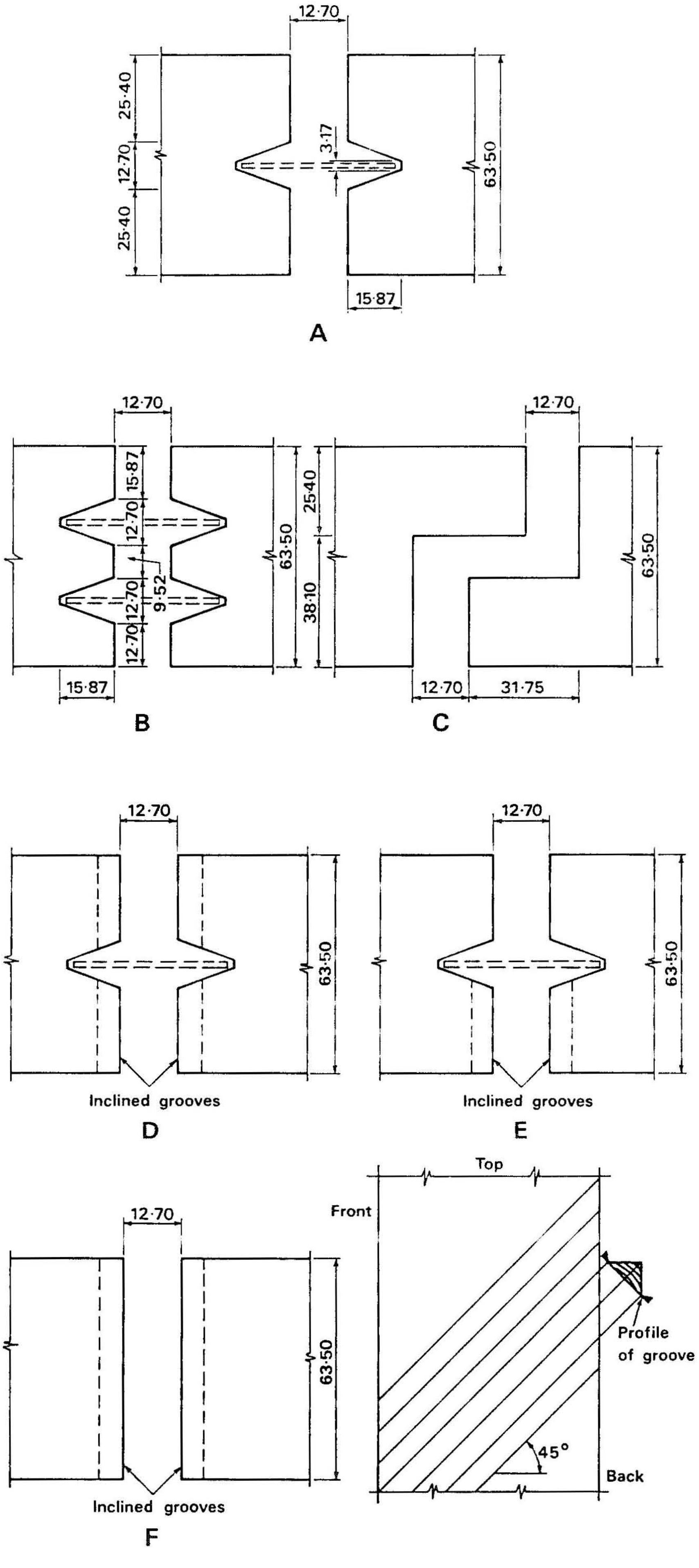


Figure 6 Detail of joints with profiled edges
(note inclined grooves stop at baffle in E)

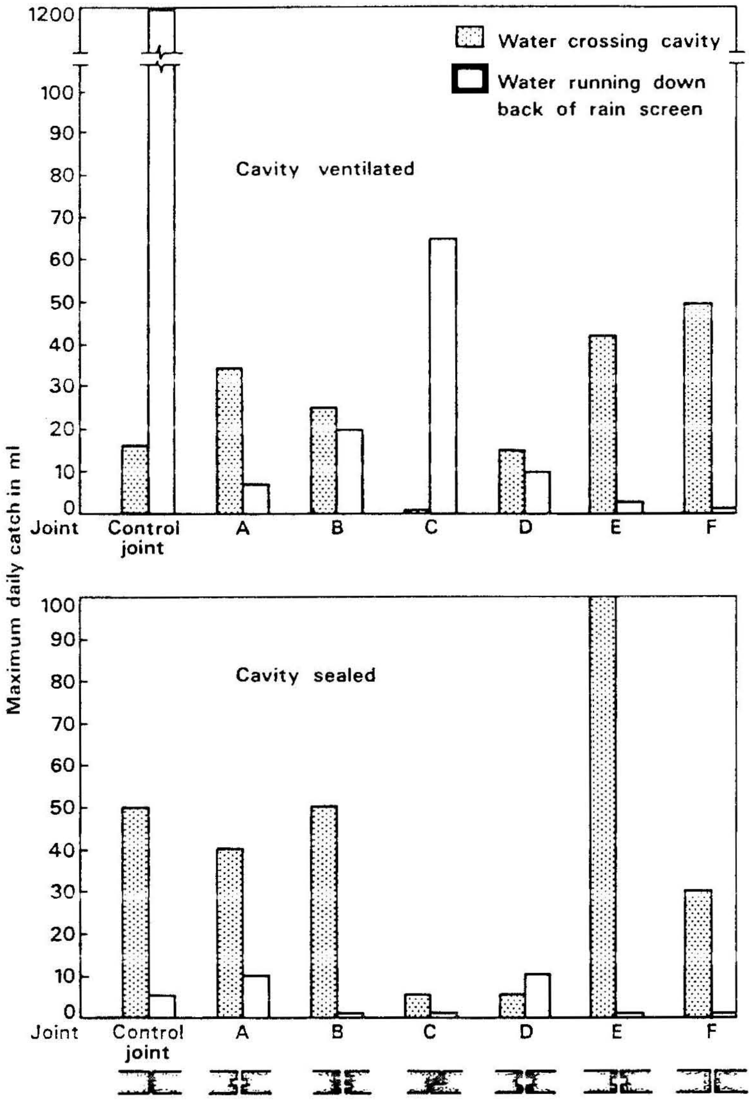


Figure 7 Comparison of maximum daily catches in joints with profiled edges without baffles

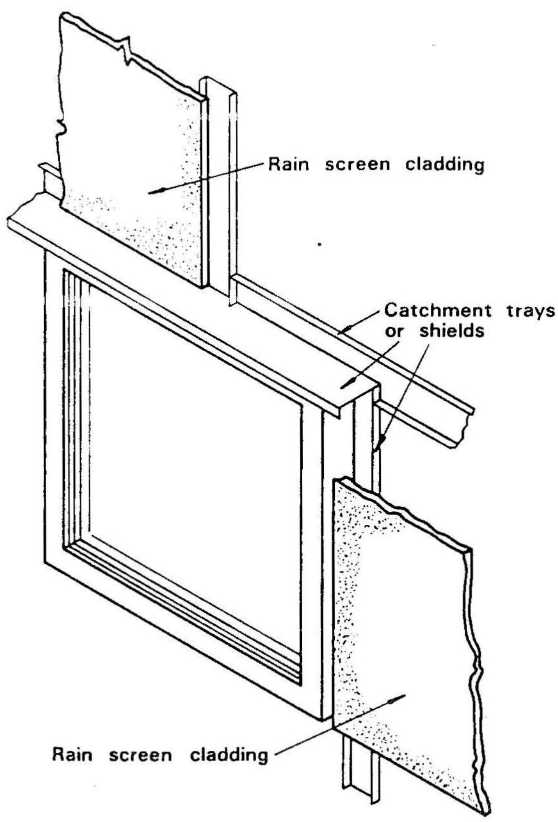


Figure 8 Suggested method of preventing water crossing the cavity by use of catchment trays around window openings

Because of limited UK experience with this kind of construction, when any doubts exist it is probably wise to protect the inner leaf with slaters' felt, building paper or similar material as shown in Figure 1.

When heavier materials such as concrete are used for the rain screen, the variations of joint width commonly experienced would normally prevent protection against water crossing the cavity being achieved solely by the use of closely controlled narrow joints. Consequently, either the inner leaf and its accompanying details must be designed to cope with water crossing the cavity, or the water must be prevented from doing so by other design features.

For vertical joints the BRE experiments show that the water passing through the joint which would cross the cavity can be caught at the back of the joint in catchment trays designed on the information given in Figure 5, or mainly trapped within the joint by edge profiles or baffles (see Figures 6 and 7). Similar details could be used at joints around window and door frames (Figure 8), using so-called 'secret gutters'.

The only horizontal joints tested were of the type shown in Figure 9. These provided protection to the inner leaf only under conditions of moderate exposure, penetration to the back of the cavity occurring where the flashing met the vertical stop end of the joint. This was due to water being blown along the flashing and building up sufficient quantities at the end to block the joint. However, in Canada[6] similar details have been used with success in joints 53 mm wide with weathered faces, and this fact may account for their reported good performance. Norwegian experience suggests that a catchment tray of the form shown in Figure 10 could be successful although this has not been tested.

As with all cavity wall construction, provision must be made for dealing with water draining down the back of the rain screen from either or both horizontal and vertical joints. Structural connections must therefore be designed to prevent water passing along them to the inner leaf, and projections into or through the cavity must be protected by flashings or trays. The back of the rain screen must allow water to drain down freely.

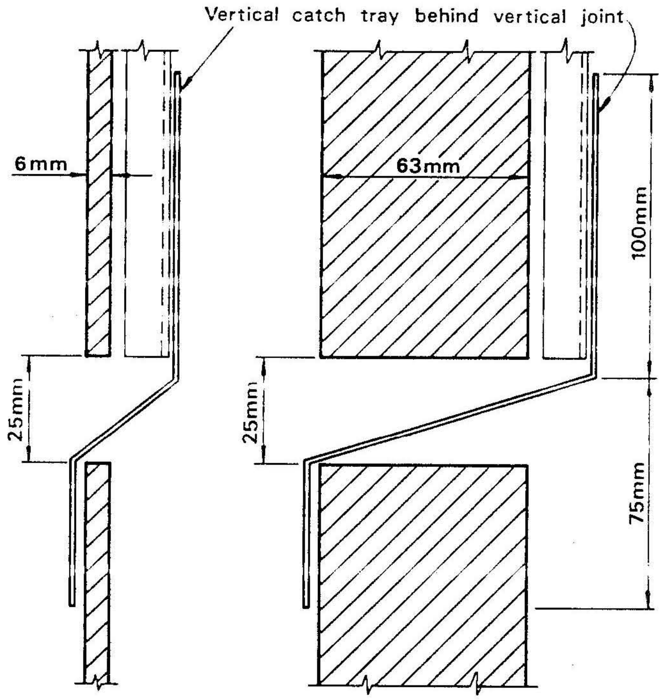


Figure 9 Horizontal joints tested

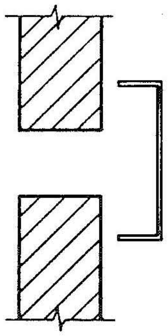


Figure 10 Catchment tray to prevent water crossing cavity at horizontal joints

The amount of water draining down the back of the rain screen from vertical joints is affected by air movements resulting from ventilation of the cavity, which in turn depends in part on its size and also on the width of joints. While drainage of water down the back of the rain screen is acceptable in this form of cladding there are clearly advantages in keeping this to a minimum, especially in tall buildings.

SUMMARY OF DESIGN RULES

It is important to realise that, however well they are designed and built, rain screen walls will allow some water to cross the cavity, and will also allow some water to drain down the back face of the screen. These two types of penetration have to be balanced in any design, for it appears that under some conditions they are inversely related.

It is possible to reduce water crossing the cavity to a minimum by having vertical joints of 2.5 mm and horizontal joints of 5 mm regardless of whether or not the cavity is sealed at the rear. Under normal site conditions this may represent an unreasonably severe discipline, and alternative widths therefore may need to be considered. In any alternative design the likely amounts of water crossing the cavity should be estimated by multiplying the maximum predicted driving rain by the area of the joint according to reference 2. If the backing wall is sensitive to this water, then it must be protected. The extent of protection can be gauged from data in this report and arrangements should be made to drain this water out of the building.

To conclude, the amount of water draining down the back face of the screen will normally be much more than that crossing the cavity. The amount can be estimated by data in this paper. To control this water it is necessary to make sure that the cavities are well sealed at the rear and provide cavity stops. In this way the volume of any one section of a cavity is kept down and pumping action by the wind reduced. Changes of pressure in the cavity due to suction effect on the leeward face of the building is also controlled. The amount of water may also be controlled by adjusting the designed joint width to greater than, say, 13 mm, by providing upstands, ribs or other features to prevent water from entering the joint from sideways flow, or by combinations of these features. Inclined grooves in the edges of thick panels will also help.

ACKNOWLEDGEMENTS

The project team included J Cronshaw, S Haines and R Whiting.

REFERENCES

1 Isaaksen, Trygve. Driving rain and ventilated sheathings with open joints. Report E 4023, Norwegian Building Research Institute.

2 Lacy, R E. Driving rain maps and the onslaught of rain on buildings. BRE Current Paper, Research Series No 54.

3 Herbert, M and Cronshaw, J. Width variations of cladding joints. BRE Current Paper CP 10/73.

4 Monks, W L. Tolerance in external joints between precast concrete panels on buildings. Technical Report TRA 405. Cement and Concrete Association, October 1967.

5 Gubas, G A. Open joint technique performance investigation. Cape Universal Products Ltd.

6 Norwegian Building Research Institute. Recent Canadian experience in wall designs. Report No 51C, p 227.