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S E M I N A R

WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

5 NOVEMBER 1980

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I N D E X

WEATHERTIGHTNESS AND WATER PENETRATION IN BUILDINGS

R A Hazelwood

UNDERSTANDING THE PITCHED ROOF

INTRODUCTION

At our laboratories we have been involved over many years in testing of pitched roof components and in improving their design. As was recounted at the SCI meeting in 1979[1], it is fair to say that although we feel we have learnt a great deal, there is still plenty of scope for increased understanding of why a pitched lapped roof works so well.

RELIABILITY v. WORKMANSHIP

It is generally recognized that pitched roofs have proved more reliable than flat roofs, and it is interesting to consider why this is so.

Whilst there are probably many reasons, I believe the principal advantage of a pitched roof is its tolerance of indifferent workmanship. In particular it employs a multilayer approach to resisting weather penetration. If reliance is put in a single, completely (you hope) impermeable layer, then it must be perfect. If, alternatively, there is a second line of defence, with means to carry water away, then it will be more reliable.

From this discussion it may be thought that I refer to the use of underlay or sarking, and indeed I do, but I also refer to the effect of the lapped joints themselves, to which I will return.

In testing and designing tiles, we do not rely on the underlay to resist driving rain. The underlay's prime function is to resist any powdery snow which is known to penetrate roofs without underlay. It is then essential that the consequent melt water can be safely conducted to the eaves. To this end BS5534[2], the code on "Slating and Tiling" recommends special underlay support at the eaves, counterbattens over boarded sarking and other important details. A second less well recognized function of an underlay is to reduce air flow through the roof. By so doing, the likelihood of leakage of the primary layer of slates, tiles, etc. is much reduced and, less obviously, the wind uplift on the roof is distributed between the two layers[3]. It is believed that this effect plays a major part in allowing many of us southerners to continue to deal out tiles over our roofs like cards, with no fixings to hold them down to the battens.

Whilst distinguishing between practices north and south of the border - which are in part due to the differences in climate - I would like to question the Scottish practice of using boarded sarking. At one time, I believed that this would be superior to bitumen felt underlay. I am now less sure. It seems that it may be too efficient in reducing loft ventilation, with a consequent sensitivity to condensation. In contrast, a lapped felt underlay laid with a sag between rafters, gives many ventilation paths which fortuitously self seal under windy conditions to give ventilation only when needed, in times of light wind. It is an active ventilation controller, albeit crude. It is also cheaper !

CONDENSATION

This discussion has brought me to the issue of condensation. The increasing concern with this problem implies changes in building practice. Whilst I don't think most of these changes have arisen above the loft space, the boarded roof may be more sensitive to the changes lower down.

In my view two major changes are:-

1. Better sealed houses. The efforts of the "SAVE IT" campaign, of those testing the air tightness of windows, and those raising fuel prices, have all indirectly encouraged the 3 gallons of water vapour produce daily[4] to head for the loft.

2. Better insulated ceilings. This change gives colder lofts, more prone to condensation unless adequately ventilated.

VENTILATION

BS5250[4] whose recommendations are now likely to be incorporated into the Building Regulations, asks for eaves ventilation gaps equivalent to a continuous slit 10mm wide each side (roof pitch over 15°). Two things are not yet clear to me - firstly I have not found out on what basis this number is specified (although it seems sensible) and secondly I do not know if it is adequate in practice. I would welcome any information or practical experience which you may be able to provide.

Eaves to eaves ventilation must rely on the wind as a driving force. In contrast, eaves to ridge ventilation can also call on the two "stack effects". Firstly, even with ceiling insulation, the loft air is likely to be warmer than outside air, especially on a calm clear night. Secondly, damp air is lighter than dry air. Both give rise to a "chimney" effect, driving warmer, moist air out through a ridge vent.

Whilst this flow is likely to be small compared with wind driven flows, it is available just when needed - on the aforesaid calm nights. However, it needs an entrance and exit at different heights, best provided by ridge and eaves ventilators. The wind driven ventilation is also likely to be improved, particularly for conditions with wind incident on a gable end, because ridge pressures are almost universally more negative than those under eaves.

LAP DESIGN

As discussed earlier, the design of the tiles, particularly single lap, low pitch tiles, involves an understanding of the potential leakage mechanisms through the gap[1]. Capillary leakage can be overcome by "anti-capillary devices", principally the chambers formed between the underside ribbing and the top surface of the lower tile.

These ribs also serve to provide the multilayer design referred to earlier. Any water spray driven by wind through the gaps at the external edge of the lap is caught by secondary ribs and returned by gravity to the external roof surface.

AN IMPROVED DRIVING RAIN INDEX

The true simulation of all aspects of the roof environment is so complex as to be effectively impossible. It is however possible to simulate the various potential leakage mechanisms and perform comparative tests between different roofing systems. The remaining difficulty is to decide which mechanisms are important and what weather conditions produce them. Is it the effect of short intense storms, or do long term damp winter conditions play a part ? I believe they do.

BRE Digest 127 1971[5] gives both yearly and hourly indices. Whilst both have some relevance, the hourly figures are preferable in that they record intense storms. However, analysis of the table shows that if the year is arbitrarily divided into winter (October to March) and summer (April to September) only 5 stations out of 23 had their worst storm in the winter. Summer storms are more likely to be followed quickly by drying conditions and it is felt that this index is not therefore ideal.

At the same time, it seems likely that since wind pressure is proportional to wind speed squared (V^2) an index of rainfall rate (R) x V^2 would be more appropriate than the RV index used in Digest 127.

We are therefore paying the Met. Office to re-analyse their data to give the worst storms using three different indices RV, RV^2 and RV^3. RV^3 may well be appropriate to wall or window leakage[1]. Results so far (9 stations) giving the worst storm in each year, have been further analysed to show how the storms thus selected differ depending on the criterion used. For Plymouth, over thirty years, the seven worst storms selected by the RV index comprise only two winter storms (2W) but five summer storms (5S). For RV^2 the ratio is reversed, 5W - 2S, whilst for RV^3 it becomes 6W - 1S. This trend is apparent in all 9 stations' data.

The extreme value given for Plymouth in July 1957 by Digest 127 ranks first in the list by a large factor but is twelfth in the RV^3 ranking. The wind direction in this storm was east (90^o) whereas the directions of <u>all</u> other worst storms for RV lie between 150^o and 240^o, i.e. broadly southerly, which makes sense for severe conditions at Plymouth on the south coast.

We therefore believe that an RV^2 index is more representative of winter storms.

CONCLUSIONS

1. Pitched roofs are likely to be more tolerant of indifferent workmanship than flat roofs and hence more reliable.

2. Felt underlay may give more appropriate ventilation then boarded sarking, as well as being cheaper.

3. There is an advantage to be gained from eave to ridge ventilation to avoid condensation particularly on calm nights.

4. RV^2 may well be a better index of driving rain than RV.

RAH/BK
24.9.80.

REFERENCES

1. Rain penetration mechanisms in lapped pitched roofs.
R.A. Hazelwood. Chemistry and Industry Aug. 1979.

2. Code of Practice for Slating and Tiling.
BS5534, Part 1 1978.

3. Principles of Wind Loading on Tiled Roofs and their Application in the British Standard BS5534. R.A. Hazelwood
Journal of Wind Engineering and Industrial Aerodynamics 6 (1980),

4. Code of ...... control of condensation in dwellings.
BS5250 1975.

5. An index of exposure to driving rain. R.E. Lacy
BRS Digest 127, 1971.

WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

D Armour

ROOF LEAKAGE AND ROOF FAULTS

The primary function of a roof, in our climate at any rate, is to provide a watertight covering to the building below. In doing this it should not only present a surface which cannot be penetrated by water, but also shed water as quickly as possible.

It appears then that the pitched roof must be the most logical and functional shape to employ. However, where large complex buildings are concerned flat roofs become the only practical and economic form. Both types of roof can experience failure, but the types of failure occurring in pitched roofs are in general better understood by architects and builders, are easier to avoid, and often less expensive to rectify.

FAULTS IN PITCHED ROOFS

These include faults developing in the supporting roof timbers due to fungal or insect attack, corrosion

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of fixing nails, overloading caused by a new and heavier roof covering, etc.

Clay tiles may laminate through frost action, or be damaged by frost crystallisation if underfired.

Slates may become detached through the corrosion of the fixing nails, or by breakage at the nail holes due to a rubbing action caused by wind.

Cracking or corrosion of rigid roof sheets is often brought about by poor fixing practices. Holes may have insufficient clearance to allow movement of sheets due to temperature, moisture absorption, etc. Fixings may corrode due to contact between dissimilar metals. Cutting and drilling will expose uncoated metal in coated sheets, and so on.

Due to the limited size of most pitched roofs and the often fairly small areas of defects, sometimes only individual slates or tiles, the cost of remedial work is often comparatively small and we shall turn our attention to defects in flat roofs where costs of remedial work are liable to be much higher.

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FLAT ROOFS

Basic Construction: Although flat roofs may consist of a great many layers of different materials the basic and most simple form consists of four layers. These are :

1. A roof covering (eg asphalt, felt and chips etc).
2. Insulation (eg polystyrene, fibre board).
3. A vapour barrier or vapour check.
4. A structural roof (eg timber, concrete, etc).

Traditionally then layers can be arranged to form a 'Cold Roof'. See Fig 1. This has a ventilated air space between the roof deck and the insulation. Alternatively the 'Warm Roof' type of construction can be used where the structural deck lies in the warm region of the building with the insulation above the structural deck.

The efficiency of all insulating materials is dependent on their remaining in a dry condition. In a Cold Roof the ventilation provided is designed to evaporate any moisture which may have passed the vapour barrier or check via holes for light drops or other perforations of the barrier. In much of Scotland however for half the year there is as much chance of the outside air

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introducing moisture into the roof through the ventilators, as there is of removing moisture. So one would hesitate to recommend a Cold Roof type of construction. It has also the additional problem that the above ceiling area is not likely to be uniformly ventilated. 'Dead' areas are likely to exist where moisture will not be readily removed. These will produce cold spots on ceilings and condensation is likely to occur below these spots.

In the Warm Roof (see Fig (b)) the whole load-bearing construction lies in the warm region. Everything below the heat-insulating layer is exposed to the internal temperature of the building. If, for the sake of appearance an under ceiling is required, then this should have a minimum insulation value and be as permeable as possible. A complete vapour barrier is placed between the insulation and the deck.

One of the main causes of trouble with flat roofs has been connected with high temperature variations in the water-proof roof membrane. It has always been obvious that if these variations could be reduced then the life of the membranes would be prolonged, and fewer faults were likely to develop. This has led to the

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introduction of the Inverted or 'Upside-down' Roof. (See diagram). The development of a closed-cell type of expanded polystyrene which will not absorb water has made this type of roof construction possible. In the Inverted Roof the Roofing Membrane which could be asphalt or built-up felt is laid directly on the structural deck, and the membrane also forms the vapour barrier. The insulation consisting of loose-laid expanded polystyrene slab is laid on top of the membrane and held in position and protected by a 50mm layer of gravel or by pre-cast concrete paving slabs.

COMMON FAULTS IN FLAT ROOFS

In April 1978, a paper by Mr P H Wilson of the Scottish Laboratory of the BRE quantified the types of faults being frequently encountered in investigations by the BRE. Those most commonly found were:

1. No, or inadequate vapour barriers or vapour decks.
2. Inadequate provision for movement of supporting structure.
3. Entrapped moisture between layers or in screeds
4. Inadequate flashings, etc.

Some investigators of failures like to categorise these as being design faults, faults in materials or

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faults in workmanship. We have normally found that things are seldom as clear cut as this. It is usually not possible to place all the blame on to one person. In most cases there is some measure of inadequate workmanship, some rather poor design details, and often a wrong selection of material. In some cases there is a lack of detailing by designers who may depend on the ingenuity of the workman to provide a proper barrier to moisture penetration.

There is some merit in a "belt and braces" approach to design, where the designer assumes that he is going to get something a little less than one hundred percent perfect workmanship. Where he designs in such a way that his construction will still function perfectly, even if the quality of workmanship is merely average.

It seems that architects and other designers are often not fully conversant with the various effects and their relative magnitude which can affect a flat roof. The main effects which should be kept in mind are :

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(a) The higher degree of thermal insulation demanded today may mean considerably higher temperatures in a membrane overlying the insulation, with a consequently greater softening of the bituminous materials.

(b) The considerable pressures which can be set up by the expansion of air, or an air and water vapour mixture immediately under or within the layers of a waterproof membrane.

(c) The considerable time needed to dry out materials in Scotland; this is frequently underestimated, so that materials are used in construction which are barely surface dry, and still contain considerable amounts of moisture.

(d) It is nearly always safe to assume that people will walk on any roof. Frequently after the roofers have departed other trades will walk over their completed work. There is thus an obvious danger of splits and cracking of the membrane, particularly where blisters have formed. The membrane may be punctured by stones being treaded down into it or by tools and other material taken on to the roof.

(e) Different movement of the various materials which make up the roof 'sandwich'. Some have

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considerable moisture movement, in the case of felts this may be greatly different when measured along as against across the sheet. Insulation boards may also show considerable moisture movement causing overlying felts to tear or winkle along the line of joints in the insulation board.

(f) The necessity of mechanical fixings to hold down roofing materials to a troughed deck. Mopping on bitumen and hoping to stick materials to a troughed metal deck is at best providing only a partial bond, due not only to the troughing, but to the rapid cooling of the bitumen.

In many cases the lack of understanding of the basic requirement for a successful roof extends also to the contractor and his workmen. Too often unskilled labour is employed to construct a standard built-up felt roof under the impression that such a roof is merely a case of pouring on some bitumen and rolling out the felt.

Too often bitumen is applied too cold, or it is applied to a surface which is dirty or wet.

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In many cases materials are used which already contain a good deal of moisture. A tarpaulin used to cover insulation boards will not prevent them soaking up water from damp ground.

Moisture is too readily trapped between successive layers of felt and within porous insulation or porous timber decking. If a partly completed roof gets wet from rain, snow or otherwise it is very difficult to dry it out completely, except in the very best of dry summer weather, unprotected roofs in this country are always likely to get wetter than drier.

The great care necessary to bond to the previous days work is often not fully appreciated. This applies particularly to asphalt roofing, but to other types also.

In an ideal world flat roofs would never be pierced to accommodate pipes, roof-lights, ducts, etc. The difficulty of preserving the integrity of the water-proofing around these can be considerable, moreover it demands slow careful work which is time consuming and apt to aggravate the workman who is trying to

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"get on with the job". Workmanship tends to deteriorate and poor workmanship is often undetected due to inadequate supervision.

Traditionally, particularly in the West of Scotland the waterproof membranes employed on flat roofs have been largely asphalt or multi-layer bituminous felt systems.

More recently the plastics industry have produced a range of sheet polymeric materials designed for use as single layer systems. The main polymers used are plasticised PVC, PVF, polychloroprene, polyisobutylene and chlorosulpphonated polyethylene. The membranes are of thin plastic and are often supplied bonded to their sheet materials such as asbestos sheet to give more dimensional stability and to simplify handling.

The main problem with these materials lies in the jointing. The joints are normally sealed by adhesive or by heat welding, and since in a single layer system there is no second line of defence, the joints must be perfect. So, as in many single-layer systems we are looking for perfect workmanship.

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If joints are a major problem in roofing membranes, it would appear logical to try and do without them. Jointless coverings have been available for many years in the form of a great many proprietry roofing treatments, which could be loosely referred to as "roofs in a tin". Many of the older ones consist of bituminous emulsion or cut-back bituminous which are painted on to the roof in several coats. The coats are usually reinforced with a fabric or mesh often of glassfibre.

In a wet area such as the West of Scotland the drying time required between coats can be the main problem, and many of these membranes are very vulnerable to damage until fully cured. In most cases they are given a measure of mechanical strength by trowelling on a sand-bitumen mixture, and may also be given a light colour to resist solar heat absorption. Again then jointless coverings demand a high degree of care and workmanship, and in effect good weather conditions or adequate protection while being laid.

In conclusion one cannot avoid saying that in roofs, as in much else, the client tends to get what he pays for. All types if well designed, adequately

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detailed, and if the workmanship is good will resist water penetration. They will not however all have the same life or demand the same amounts of maintenance.

References: BS Code of Practice CP144 'Roof Coverings'.

Built-up Roofing - Information techniques and specification by Felt Roofing Contractors Advisory Board 1977.

Building Research Station Digest No 144:1972 Asphalt & Built-up Felt Roofings - durability.

BRE Digest 8. Built-up Felt Roofs.

DOE Advisory Leaflet 79. Vapour Barriers.

DA:SM

a) COLD ROOF

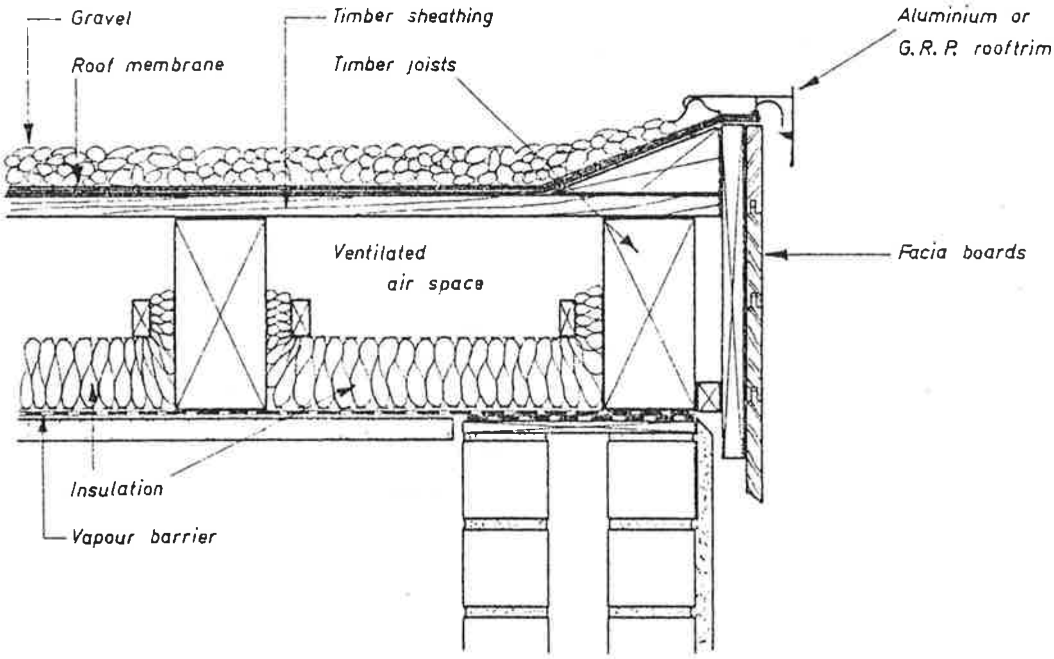


fig 1 One way ventilation

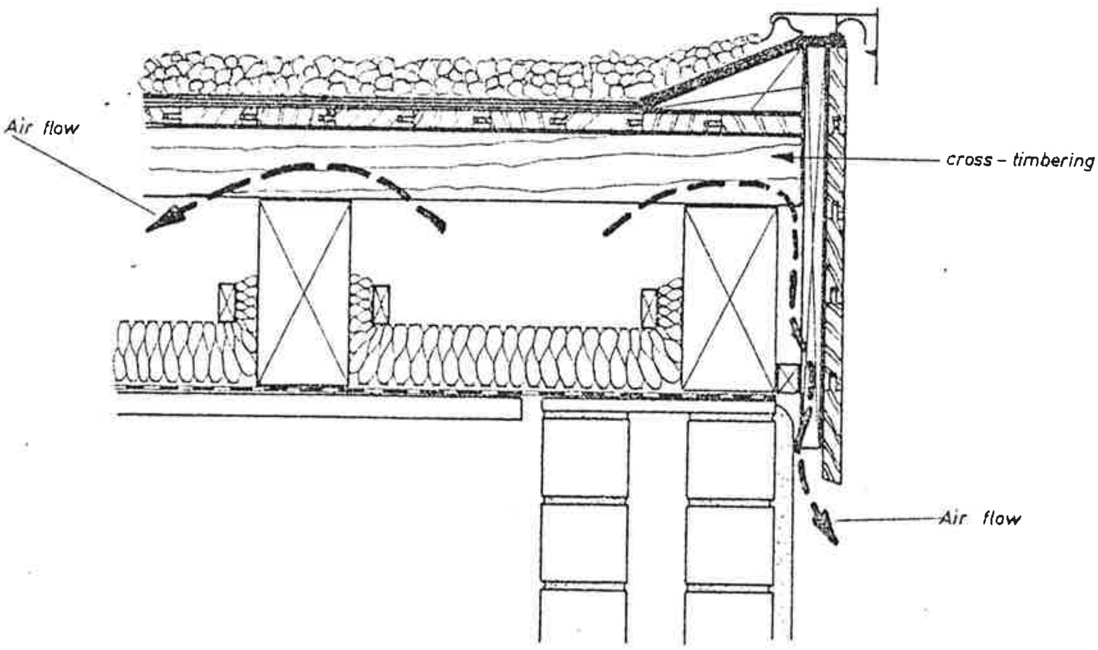
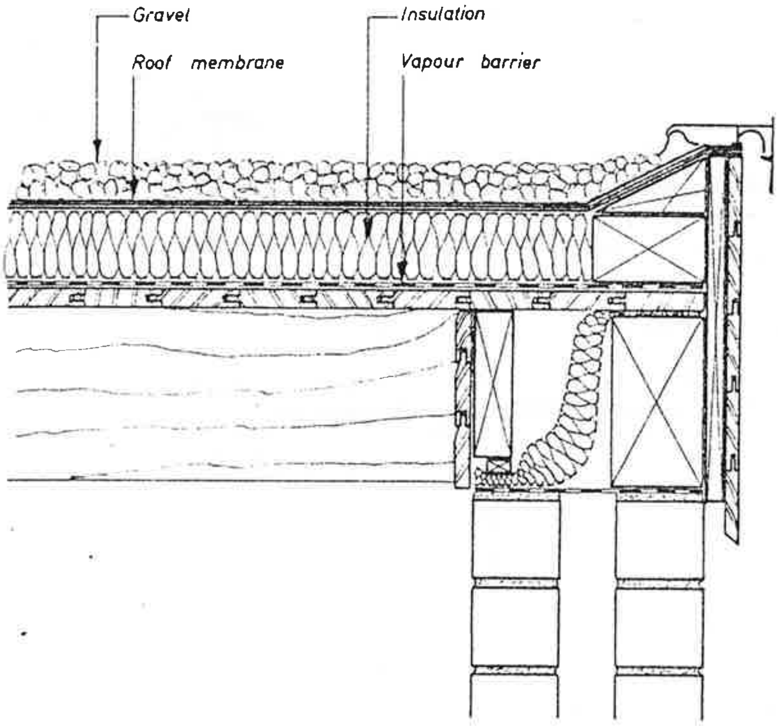
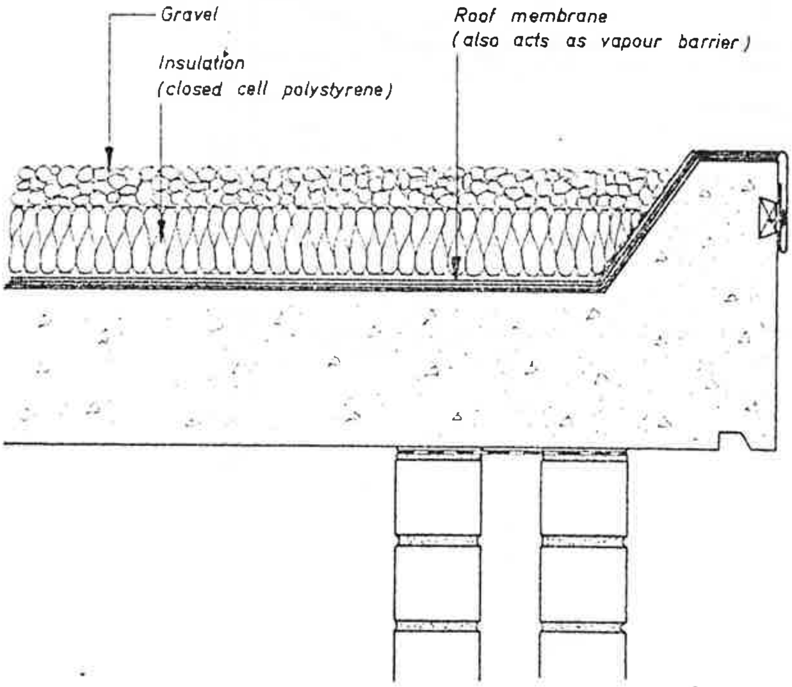


fig 2 Two way ventilation

b) WARM ROOF



The Inverted Roof



WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

ROOF CONSTRUCTION : FLAT ROOFS : GEOMETRIC LAYOUT

J Y Campbell

Flat roof construction is often used as a means of sealing the top part of the weather envelope of many structures. Sometimes the technique is successful, but more often than not a complete barrier to water penetration is not achieved.

This inadequate performance is a subject which, over the years, has prompted investigations by various authorities. One common factor running through these investigations has been the feeling of dissatisfaction with the high incidence of failure of the end product.

There would seem to be three main reasons for this situation:

(i) Inadequate materials to accommodate the effects of thermal and structural movement and the effect of sunlight

(ii) Poor design details

(iii) Poor workmanship by building contractors.

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It is the purpose of this part of the proceedings to look at the geometric layout of flat roofs and to assess if the correct approach is made at the design stage.

One of the first aspects which has a bearing on the topic is the topic of flat roofs itself! The dictionary definition of flat is "having a horizontal surface". This statement, when translated into geometric terms, conjures up a plane only in two dimensions. Thus unwittingly, at the outset, we may present designers with a picture of a rectangular shape in the 'x' and 'y' planes, having apparently no important features in the 'z' plane. In fact the picture the designer could have in his mind is the shape shown in Fig 1. It is to be hoped, however, that he does not have the complete content of this photograph in his mind!

Nevertheless, it is a fact that the outcome of many designs more than occasionally results in problem roofs like the one in this photograph.

Where does the roof designer turn for guidance? In CP308, is the general statement, "Flat roofs should be designed to avoid ponding except that some degree

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of temporary accumulation of water during heavy storms may be permitted where the roof covering is specially designed to remain watertight under such conditions". In the same Code of Practice the following guide lines are given for roof layout. "Flat roofs may be designed to drain in two ways either :

(i) Towards the outer edges

(ii) Towards channels or outlets within the roof area.

In both cases falls are required and minimum values are indicated in CP143 and CP144. Falls can be provided by tilting the roof or building up from a level roof construction. In the latter case falls should not be excessive in order to avoid costly screeds or firring". How helpful is the last sentence? These guidelines are not very tight and it is little wonder that problems sometimes ensue.

Some two years ago, in an attempt to find out the extent of geometric irregularities in completed roofs, a survey was carried out for the BRE by the MACDATA Unit of Paisley College. The main remit was to establish the degree of surface irregularity that typified various types of flat roof construction and, thereby, to determine the minimum overall fall required

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to nullify the effect of localised adverse falls and to ensure effective roof drainage.

The results of this survey are to be found in the Autumn 79 edition of the publication "BRE News". Briefly, the survey identified six roof types and five examples of each were surveyed. The roof types were:

(i) Plywood deck on timber joists.

(ii) Wood wool slabs on timber joists.

(iii) Wood wool slabs on steel joists.

(iv) Fibre insulation board on steel deck system.

(v) Insulating material on pre-cast concrete units

(vi) Insulating material on cast-in-situ concrete.

Most of the roofs had built up bitumen felt as weather-proofing except the in-situ concrete roofs which had mastic asphalt. The buildings were located in Central and West Scotland.

The main conclusion drawn from the study was that many of the roofs did not meet the minimum recommended fall of 1 in 80 as suggested in CP144 and two thirds of the roof had falls shallower than 1 in 100. Localised low spots, inadequate falls adjacent to drainage outlets and poorly located outlets frequently gave rise to ponding even in cases where falls of 1 in 80 or better had been achieved.

Subsequent model tests and calculations indicated that to offset the effects of surface irregularities and to give a final minimum local fall of 1 in 80 then the overall design fall should be based on 1 in 40 as a minimum. This conclusion amply justifies the statement in the proposed code of practice for the design of flat roofs which says "To ensure a minimum fall in the membrane of 1 in 80 it will be necessary to control the deflections and inaccuracies in the supporting structure or to provide for additive falls to offset their effect".

Without these precautions to offset ponding then the risk of water entering the building will be greater. Further, should leakage occur in the ponded area then naturally the quantity of water entering would be greater than that which would have entered through a properly drained surface.

Examples of poor layout and shallow falls are shown in the following figures and associated sketches. The accompanying descriptions to the figures highlight the faults.

Notwithstanding the fact that materials, workmanship and components can all have a bearing on the problem, if the geometric design is basically inadequate then the roof will have little chance of performing properly.

Fig 1 "Typical 'flat' roof?"

Fig 2 Low point adjacent to drainage outlet - lack of accuracy in setting out plane of roof?

Fig 3 "Good falls and bad". Adverse fall to only drainage outlet.

Fig 4 "Flat" roof being repaired (not for the first time!).

Fig 5 Contoured plan of roof in Fig 3.

Fig 6 "Impossible escape" - Edge of roof at gutter higher than adjacent roof area.

Fig 7 Poor drainage channel to almost impossible drainage outlet.

Fig 8 Low points adjacent to drainage channel.

Fig 9 Good built in roof falls.

Fig 10 Contoured plan of roof in Fig 8

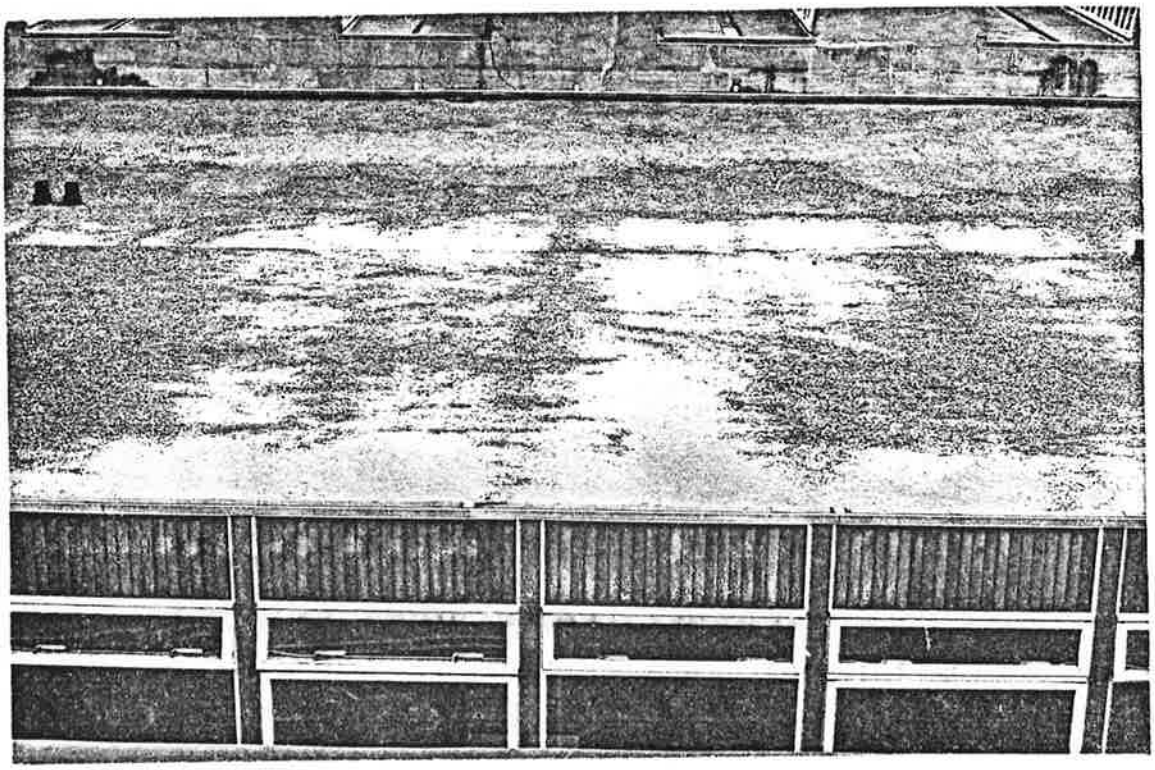


Fig 1

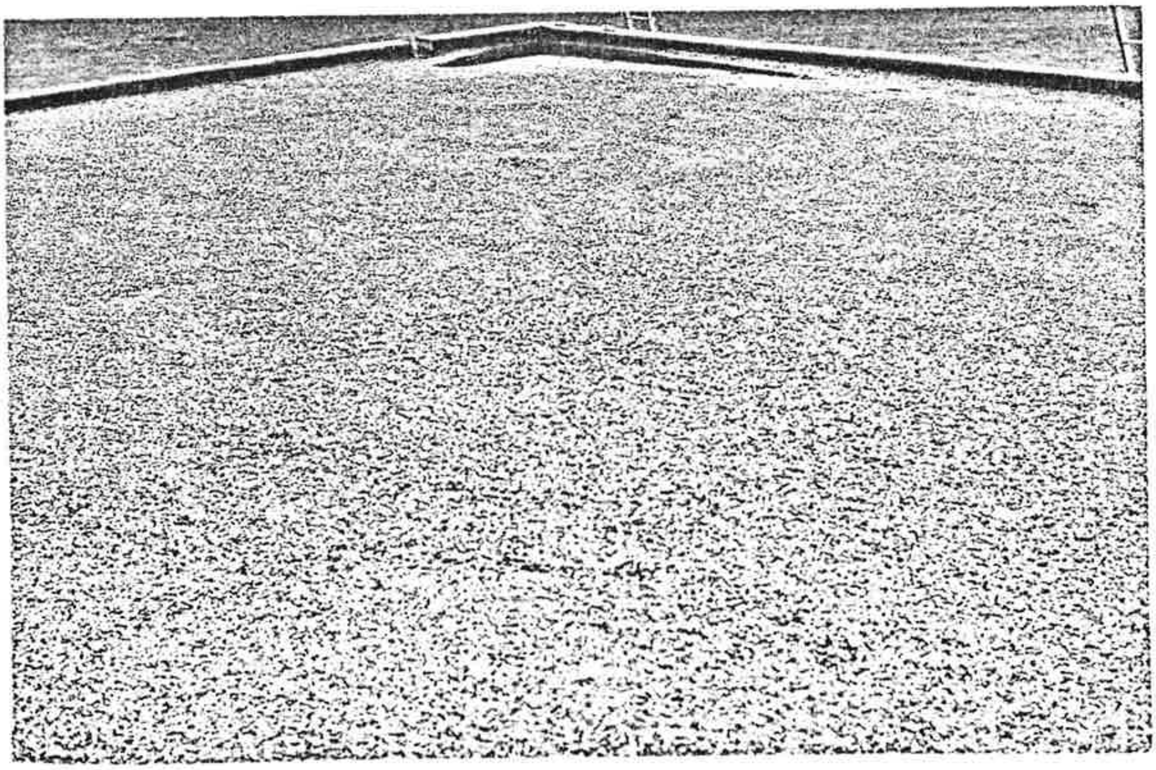


Fig 2

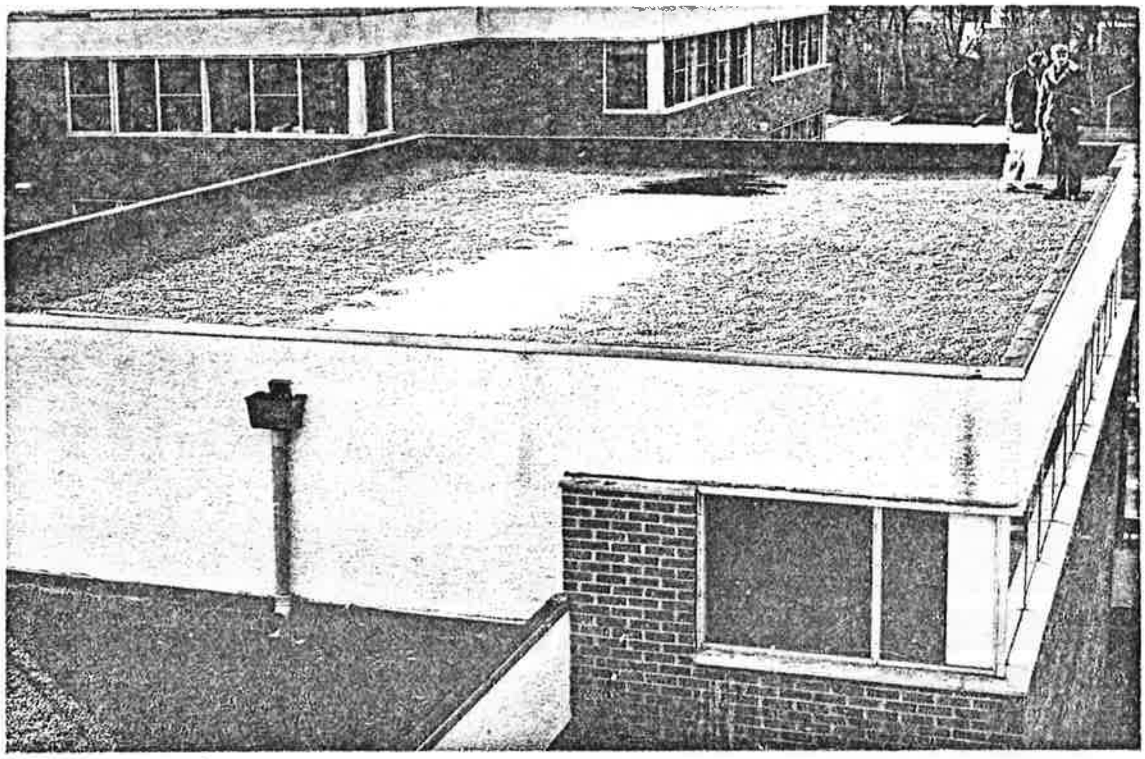


Fig 3

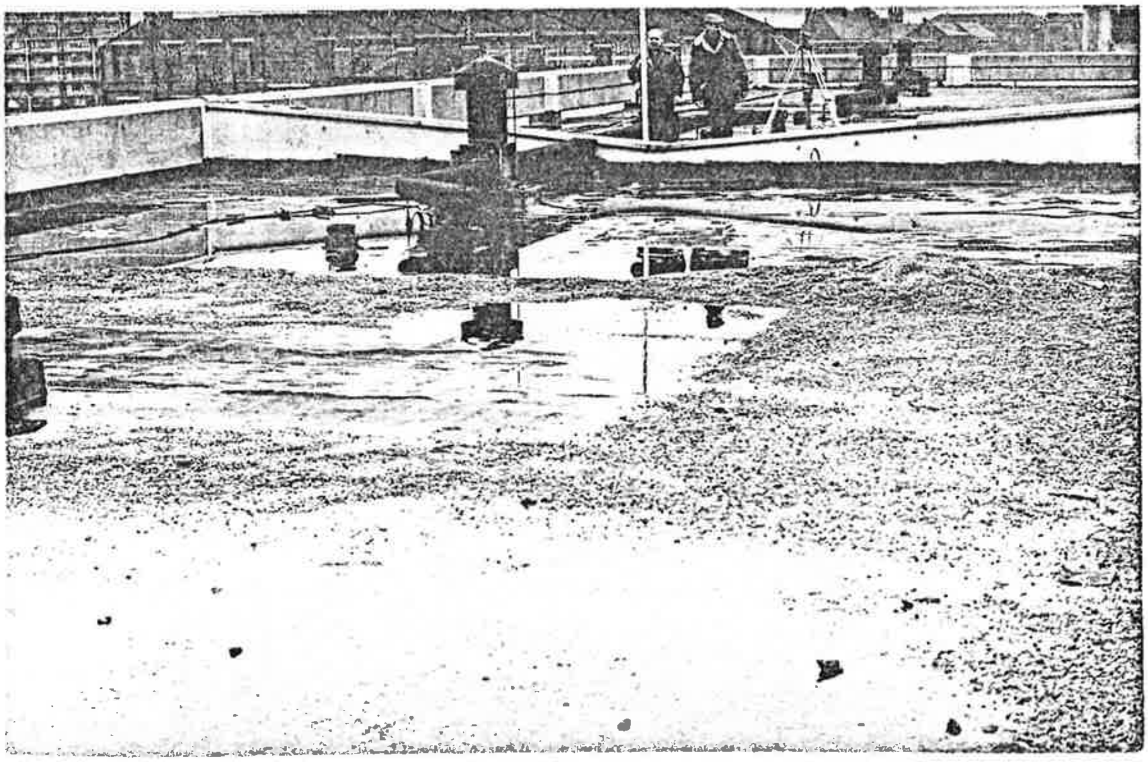


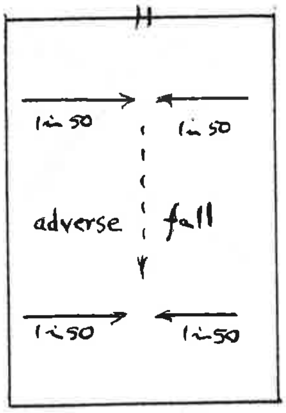
Fig 4

Ref D4

Type Metal Deck

Area 147 m^2

Constructed 1975



approx. falls

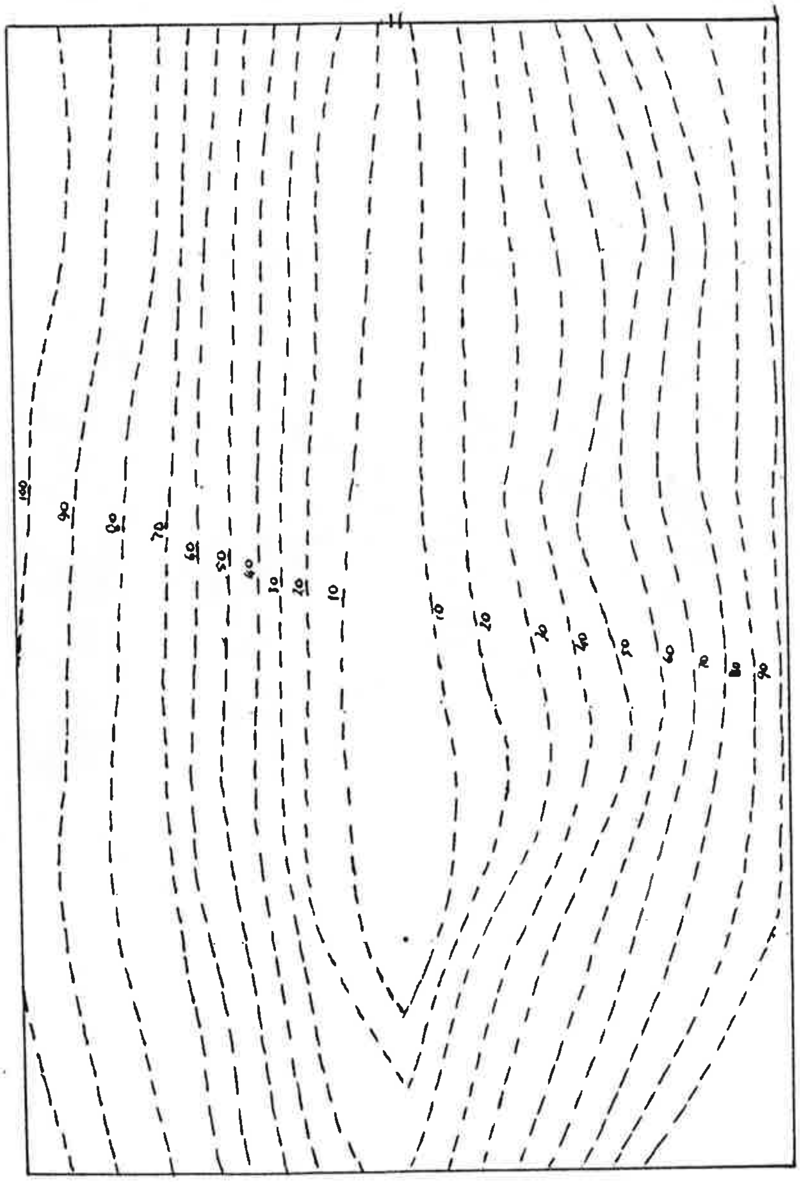


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Fig 5

ROOF D4

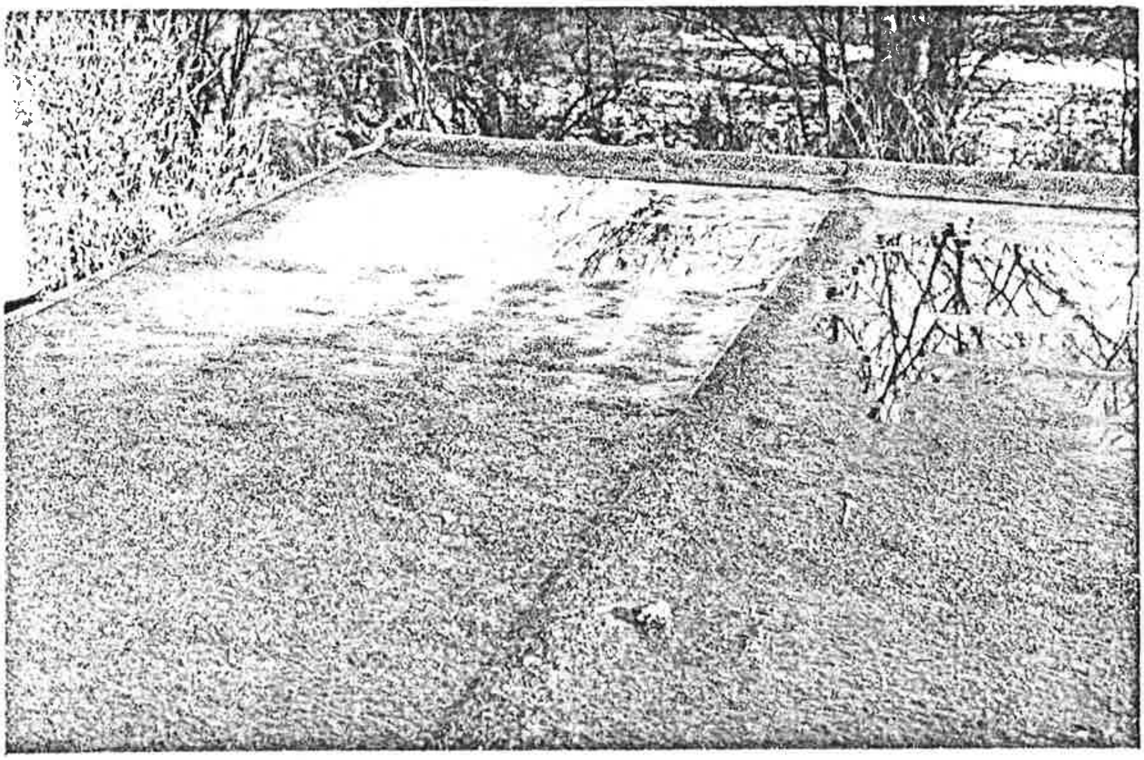


Fig 6

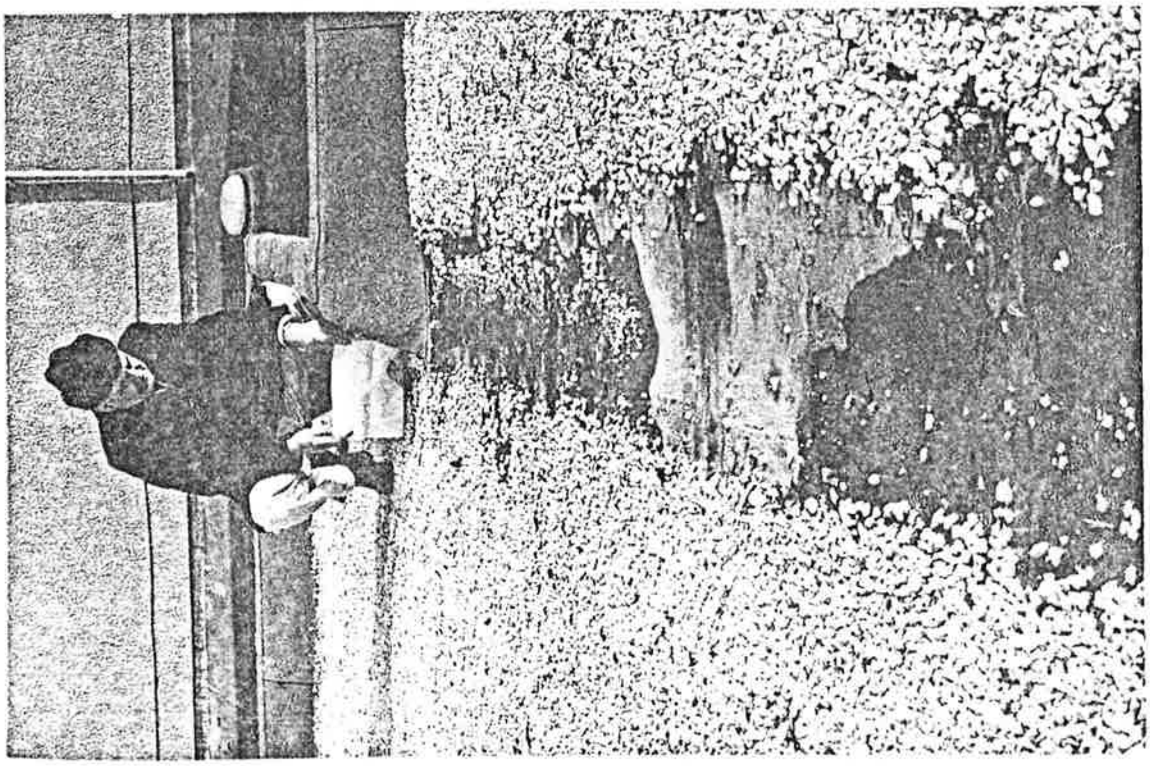


Fig 7

Fig 8

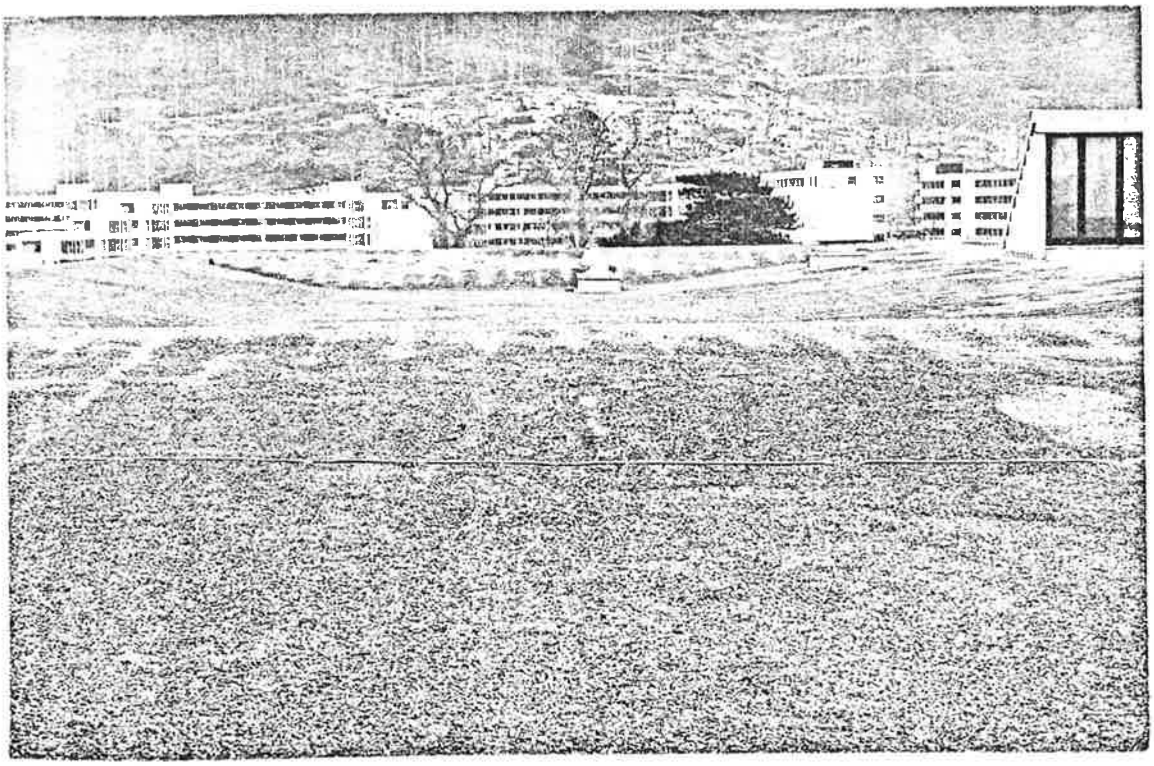


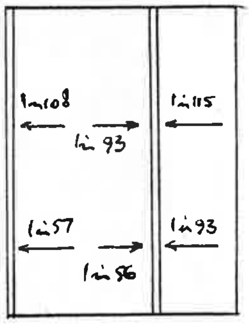
Fig 9

Ref C 3

Type Wood Wool Slabs + Steel Joists

Area 241 m^2

Constructed 1971



av. approx. falls

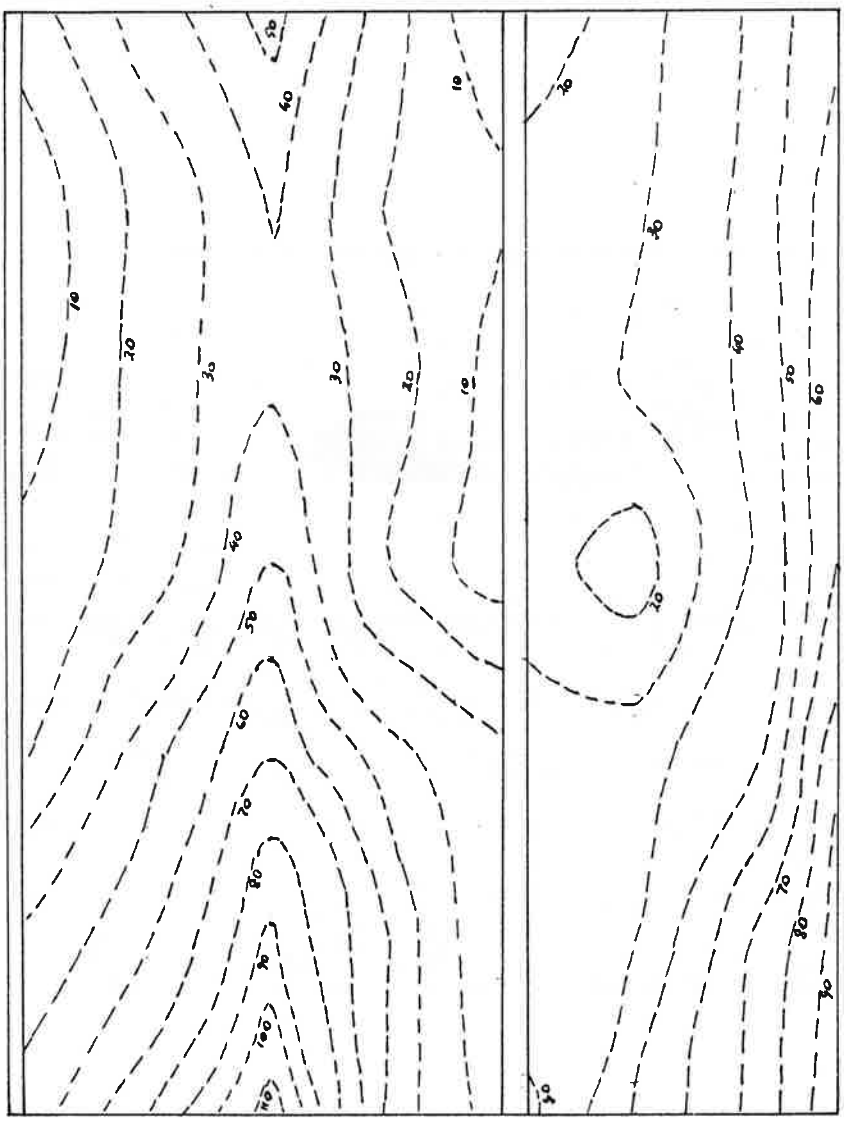


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Fig 10

ROOF C3

WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

I Buchan

FLAT ROOF MEMBRANE SYSTEMS

1. A ROOFING SYSTEM IN SCOTLAND normally includes

   (i) membrane protection and surface treatment,

   (ii) a membrane consisting of one or more layers joined to be compositely waterproof,

   (iii) thermal insulation

   (iv) vapour barrier, and

   (v) roof structure/deck.

   In some cases, prefabricated decking incorporating all features (i) to (v) is used in lieu of putting on each layer on site.

2. THE PRINCIPAL CATEGORIES OF MEMBRANE FAILURE OR DEFECTS have been diagnosed by R L Bonafont of Ruberoid as given in fig 1 (reproduced below) of his paper 'Application of Performance Concept in Evaluation, Specification and Selection of Roofing Materials' April 1977.

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A summary of these categories is given in paragraphs 3 to 7

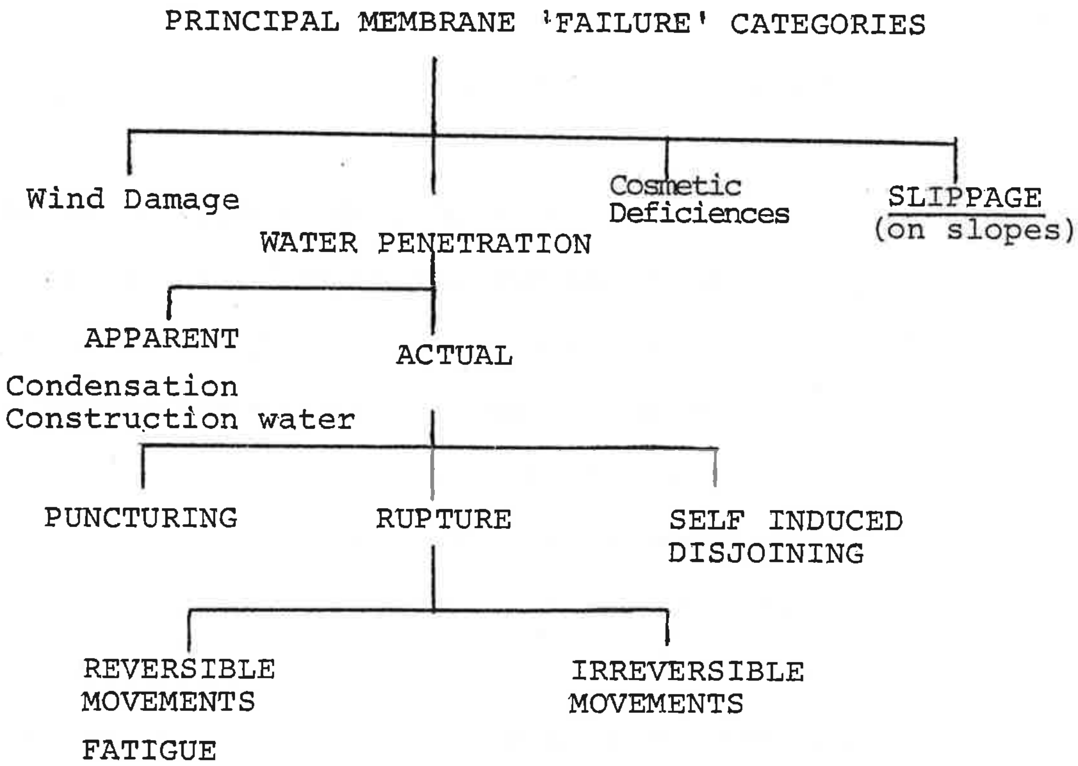

FIGURE 1.

3. High winds are prevalent in Scotland and the membrane requires (i) a high interply strength and peel strength between membrane and substrate insulation, and (ii) nail holding strength.

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Poor adhesion of layers due to a low bitumen temperature or to the presence of water during construction should be avoided.

4. Slippage of membrane on vertical upstands may occur if the membrane is not mechanically anchored or if the hard 115/15 bitumen is destroyed by overheating on site. (115°C is the softening point and 15 is the hardness penetration value as determined by BS tests).

5. Cosmetic deficiences such as wrinkling, surface crazing, membrane blisters and surface disintegration are indicative of possible future failures.

6. Water penetration may be apparent as condensation or water entrapped within the membrane during construction or by an incomplete vapour barrier.

   Water penetration may be real, due to puncturing of the membrane by animal action (pecking by birds) or by hail stones but the puncturing is more likely to be caused during construction by excessive foot and wheel barrow traffic, material stacking, roof alterations and maintenance after construction

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or subsequent abuse by building tenants using the roof for sporting/leisure activities. The membrane fails frequently due to sharp point loads especially if the insulation is soft.

Water penetration can occur at and close to gutters when these are of flimsy construction and are used as walkways. Special strengthened walking zones should be provided and marked out.

7. Structural failure of a membrane which is indicated normally by teasing or by folding suggests that the tensile strength and elasticity of the membrane are inadequate to cope with diurnal strate movements and building movements arising from thermal shock due to insulation or blown hot air, vibration of the roof deck, settlement etc. Ice formation and clay layers at low points also stress the membrane. Oils, petrols and other liquids may also attack the membrane.

8. THE TRADITIONAL SCOTTISH FLAT ROOF had a rigid structure with little thermal insulation and two or three layers of bituminous felt, asbestos or glass fibre sheet using bitumen adhesive covered with a single stone layer 13 mm size. Such

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roofing systems have lasted up to 40 years and more without trouble but generally about 38% of such roofs have failed during a possible 20 year life.

9. THE MEMBRANE SHEETS WERE AND STILL ARE MANUFACTURED TO BS 747 and an independent investigation of the degree of quality assurance given by such bituminous sheets indicated that the sheets made by the larger British manufacturers were of good uniform quality backed by excellent control procedures during manufacture and distribution for identification. The British manufacturing industry test for (i) the constituent materials viz bitumen, sand, filler, felt, asbestos, glass fibre (ii) production control of sheet and (iii) verification of sheet characteristics after production in accordance with BS 747, using professional chemists and engineers.

10. The manufacturing industry and the flat roof contractors association provide an extensive literature service for the use of BS 747 materials indicating how the sheets should be used for different types of structure and thermal insulation.

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11. The Building Research Establishment provides authorative publications on BS 747 sheet membranes and roofs and there is a British Code of Practice for flat roofs CP144 using BS 747 membranes.

12. The Construction Industry Training Board train annually 100 membrane layers at three training centre, one of which is Glasgow.

13. It can be seen that the BS 747 membrane system established for concrete roofs and strong timber roofs with little insulation is still adequate for some of today's building works and there is still a big demand for felt, asbestos and glass fibre bituminous sheets. However it is generally considered that only glass fibre and asbestos BS 747 roofing materials should now be used in high class roofing membrane in association with other roofing membrane materials as discussed in paragraphs 14 to 17

14. INTRODUCTION OF HIGH THERMAL INSULATION AND HIGH PERFORMANCE ROOFING MEMBRANE.

About 1969, new insulation boards made of low density plastic were introduced and this thermal blanket caused tensile failures of fully bonded BS 747

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membranes particularly over joints in the insulation. The British manufacturing industry researched the problem, pointing the way to the use of :

(i) existing glass fibre bituminous sheet BS 747

(ii) polyester base bituminous sheet, and

(iii) ventilated layer

when high thermal insulation was specified.

15. There is extensive well illustrated technical literature on the polyester base bituminous roofing materials being produced in the UK. These UK high performance roofing materials are produced on the same equipment as BS 747 felts and use bitumen as adhesive to other membranes. In terms of thickness there are two classes. (a) 1.4 to 1.8 mm (b) 3 to 3.5mm, class (a) incorporating high grade polyester of mass $125g/m^2$ while class (b) has 350 g/m^2 polyester.

Whereas existing BS 747 systems can only elongate about 4%, the polyester based system can elongate about 40%. The tensile strength is also much greater as is the Mullen Burst Strength which is a measure of the resistance to puncturing by a point load on an area of less than 1000 mm^2.

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16. The testing procedures for the high performance polyester bituminous material are more extensive and demanding than for BS 747 felts and more statistical control is necessary as the cost of the polyester etc is several times that of BS 747 felts.

17. Several years use of high performance polyester base two layer systems and of three layer systems having mixed BS 747 and UK high performance material layers have been successful to date.

18. COLD APPLIED LIQUID LAYER

There are occasions on industrial premises when the fire risks attendant upon the use of hot bitumen boilers are not acceptable eg whisky, explosives etc.

A layer of polyester fibre is placed on the insulation (or on the surface that has failed) and a cold polyester resin giving a 2.5 mm thick light grey layer is sprayed on. The system is waterproof after eight minutes, fully cured after 24 hours and the material has similar characteristics to the high performance polyester roofing described in paragraph 17.

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19. OTHER MEMBRANES

There are other proprietary membranes made of polypropylene and polyethylene base in lieu of polyester base.

Again, some manufacturers have gone for a high performance ie high elasticity by modifying the original bitumen with addition of rubber (SBR).
There are several manufacturers now using glass fibre or polyester as base with SBR bitumen.

Other manufacturers in Europe add polypropylene (APP) to the bitumen during manufacture and the finished APP sheet may contain glass fibre and/or polyester. This APP bitumen is more brittle than SBR bitumen or ordinary bitumen at low temperatures.

20. A further type viz polymeric sheet is particularly resistant to petrols and oils, foot traffic and fire. The polymeric sheet is homogeneous (without a base) but contains reinforcing fibres in the pitch compound for stability. Adhesion of polymeric sheets to other sheets may require special attention.

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21. To summarise, there are several options for a flat roof membrane on a flexible roof construction bearing in mind the requirements of para 1 to 7 viz:

(a) A mixture of BS 747 glass fibre roofing sheet and polyester based bituminous high performance roofing sheets - 3 layers.

(b) Two layers of polyester based high performance bituminous roofing sheets, with or without vapour escape sheet.

(c) A cold liquid polyester layer

(d) Polymeric sheeting with BS 747 glass fibre - 3 layers.

(e) SBR and APP proprietary systems.

(f) Single-layer proprietary systems (not discussed in this paper).

Schemes (a) and (b) are the most popular at the present moment, but the other schemes (c) to (f) may be more applicable in particular conditions.

Acknowledgement is made to the Director, Building Research Establishment, Dr R Bonafont of Ruberoid and Mr B Holden of Anderson & Son Ltd for information and data used in this report by the Author.

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WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

D Armour

WATER PENETRATION THROUGH OR INTO WALLING

Where an outer wall consists of two leaves with a cavity between, complete penetration by water to the inner face should not occur. The whole purpose of the cavity is to prevent this happening and theoretically only the outer leaf should be affected by rain penetration.

Where wet or damp areas appear on the inner face of a wall the first thing to look for is signs that the damp area dries out and re-appears within a few hours of rain falling on the wall. If such is the case then water penetration seems likely.

If signs of damp only appear when the building is occupied, and tend to vanish when it is not, for instance at holiday times, then the cause is most probably condensation.

Although evidence of damp on internal wall finishes may cause the occupants of buildings most concern,

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in the long term dampness which penetrates only as far as the cavity, and is not evidenced on the internal face of the wall, may cause serious damage which can be very expensive to repair.

RAIN AND WATER PENETRATION THROUGH WALLS

In many cases rain can penetrate through cracks in brickwork, pass across the cavity and create a wet inner leaf. If the cracks are fine ones then the water will be drawn through by capillary action and the passage of water is much more likely than with wide cracks. Wide cracks may however allow the passage of wind-driven rain if air is able to pass on through the inner leaf.

CRACK DEVELOPMENT AND WATER PENETRATION

Cracks in brickwork are most likely to develop due to expansion of new brickwork, although they can also occur due to ground movements, movement of supporting structural frameworks and other causes.

If the outer leaf of a cavity wall allows moisture to reach the cavity through cracks which have developed or otherwise, then the first line of defence is breached,

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and the integrity of the whole wall as far as water penetration is concerned depends on detailing and workmanship.

Wall ties must be clean and slope downwards towards the outer leaf.
Cavities must be free of mortar droppings and other debris, particularly where such debris reaches the level of damp proof courses or fills cavity gutters.
An additional hazard can occur with filled cavities if the insulation material is capable of transmitting moisture, or where water could run across the top of foam fill or through voids in the filling.

Cracks likely to permit water to enter the cavity are most likely to occur at or near quoins due to rotation of a short return caused by the expansion of two elevations of brickwork linked by the short return. This expansion is likely to occur when brickwork is newly built and is a property of the new bricks. It is most likely to produce a crack starting at dpc level and extending upwards cracking through stretchers in alternate courses

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Where brick in-fill panels are used in a concrete frame, again there is a tendency for the new brickwork to expand, but here the movement is resisted by the concrete frame which may have a tendency to shrink. Since the brickwork is restrained by the frame it tends to bow outwards and tensile cracks develop. This type of crack generally starts at the bottom of a panel of brickwork and extends vertically upwards. If there is a dpc at the bottom of the panel, then the brickwork may oversail the material below.

MOVEMENT JOINTS IN BRICKWORK

As mentioned above, brickwork tends to move through various factors other than loading. The main factors producing movement are:

(i) Sulphate attack on the mortar joints.

(ii) Drying shrinkage of the mortar

(iii) Uptake of moisture by the bricks themselves

(iv) Thermal movements.

The magnitude and seriousness of these movements vary widely and in many cases can be largely reduced by taking certain precautions.

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(i) Sulphate attack on mortar joints. Ideally this should not occur if suitable precautions are taken. It can however create expansions of a high order, but is not likely to be serious if bricks are kept dry. Normally it is not allowed for in the design of movement joint.

(ii) Drying shrinkage of mortar. This can be minimised by avoiding very strong Portland cement mortars. Sometimes a temporary toothed construction joint is incorporated, filled in the first instance with a very weak mortar, and later raked out and re-filled. This is generally the only allowance made for drying shrinkage of mortars.

(iii) Moisture movements are of two kinds. First an initial moisture expansion when the dry bricks from the kiln gradually take up moisture and reach a stage of moisture equilibrium with the moist atmosphere. This initial take up of moisture may cause a moisture expansion of about 0.1% or twice that in severe cases in an individual brick. However the walling will not move as much, and its expansion may be about 0.6 that of the individual brick.

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Later moisture movements due to variations in humidity are of a much smaller order. Partly this is due to the very humid climate in the UK at all times. However, during a long period of drought, movements of the order of about one tenth those experienced during the initial take-up of moisture may be experienced.

(iv). Thermal movements. In brickwork the thermal coefficient of expansion varies from 5 to 9 $x\ 10^{-6}$ per Cdeg. Since most brickwork suffers some restraint the lower value is generally used.
Since brickwork is weak in tension and generally is subjected to some restrain, it will tend to crack with falling temperatures. It has been suggested by Smith and others than movement joints are required at about 12m intervals in brickwork and should accommodate a movement of 3 to 4 mm.

WATER ABSORPTION OF BRICK WALLING

All over Scotland we see frequent examples of cracked and disfigured renderings. In the vast majority of cases this is due to sulphate attack.

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It is important to understand two things at the outset:

1. The sulphates which attack brickwork usually come from the bricks themselves. Therefore sulphate attack occurs in clay brickwork and hardly ever with concrete or calcium silicate bricks.

2. The sulphates which attack brickwork are in solution in water. Therefore if there is no water, there is no sulphate attack. The water may originate from construction processes (bricks built wet, or walls becoming wet before copes or roofs are put on, etc.). Or the water may penetrate into the brickwork through defective water barriers, cracks in rendering etc.
However the water enters the brickwork, it dissolves sulphate salts, and the solution reacts with the tricalcium silicate in the Portland cement mortar or rendering causing it to expand and soften.

Sulphate attack is generally a gradual process, and seldom becomes either very unsightly or dangerous in periods shorter than two years.

Recently, we have had two very severe winters in Scotland. These have given us an insight into the damage that can be produced by frost. Many walls which were quite old,

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and had survived undamaged for many winters suddenly showed signs of frost attack. Bricks had their faces pushed off, renderings were dislodged, copings of bricks on edge disintegrated, etc.

Again it is essential to appreciate that frost causes damage by freezing water contained in the pores of a permeable material and causing that water to expand. This expansion exerts pressures internally which the material is not strong enough to resist. Since water absorption causes both sulphate attack and frost attack, the two may often occur together. Frost attack however can be much more severe and can damage brickwork more quickly, and is frequently found during the first winter in the life of brick walling.

To avoid frost attack several obvious steps suggest themselves.

(i) Introduce as little water as possible into brickwork during the construction process.

(ii) Protect new brickwork from the elements. certainly until it is pointed or rendered.

(iii) Try to avoid cracks in rendering, ie use weak mixes rather than strong ones, do not continue renderings across joints between bricks and concrete frames etc.

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(iv) Try to shed rainwater off the brickwork by use of damp-proof courses, adequate drips on copes, cills. Use dry-dash renderings rather than wet. Re-point joints in older buildings when required etc.

THE FUTURE

It seems to me that there are one or two points we shall have to watch very carefully:

1. The advent of a whole host of 'miracle' joint sealants each with their easy application devices.
2. The use of filled cavities, which automatically prevent heat reaching the outer leaf of brickwork.

It seems to me that these two factors have to be watched carefully. We must detail adequately and not rely over-much on some sealant material to fill up cracks - a material of probably uncertain durability and difficulty of replacement.

We must also try to keep the outer leaf of brickwork as dry as possible, since it is certainly going to become very cold in winter. To do this it, or the applied rendering, must shed the rainwater and dpc's must be effective.

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WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

T F Provan/ J D Younger

WATER PENETRATION THROUGH WINDOWS AND DOOR JOINTS

INTRODUCTION

This paper is entitled Water Penetration through Windows and Door Joints, but will concentrate on Water Penetration through window joints since this has been a major area of interest of the Macdata Fluids Group. It will be appreciated that doors can be considered as large windows and water penetration through doors can therefore be considered in a similar manner to water penetration through windows. The general practice of positioning doors on the less exposed walls of a building affords doors a degree of protection which is not generally possible with windows.

Problems of water penetration associated with windows fall into three categories:

(i) Penetration between window frame and the adjacent wall

(ii) Penetration between window frame and the opening light.

(iii) Penetration between the glass and the glazing frame.

Problems arising in the first category can occasionally be due to the selection of a window design which is not appropriate to the degree of exposure experienced, but are more generally due to faults in detailing or construction as discussed in earlier papers.

The occurrence of the majority of problems arising in categories (ii) and (iii) can be reduced by testing windows and glazing systems and comparing their test performance with recommended performance levels.

COMPONENT PERFORMANCE TESTING OF WINDOWS

The penetration of a building by airborne moisture is dependent on two climatic factors, wind and rain, and it is impossible to dissociate these two factors. It is difficult to define let alone reproduce, the precise interaction of these two factors on a building. The test methods available do not attempt to reproduce natural weather conditions on the window, rather they attempt to give consistent results of the windows performance which can be related to natural conditions.

The principal test method used at Macdata is defined in BS 4315 : Methods for Resistance to Air and Water

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Penetration : Part 1: Windows and Gasket Glazing Systems : 1968. The pressure difference at which gross leakage occurs and the air infiltration rate are used to determine the particular grade of exposure.

GRADES OF EXPOSURE

The British Standard Institution's Draft for Development 4 : 1971 : Recommendations for the Grading of Windows, states that three grades of exposure should be recognised which are defined in terms of the maximum 3-second gust speeds to be expected in the particular area. The 3-second gust speed is provided by meteorological data and is defined as the maximum speed averaged over a 3-second period on a once in 50 year probability. The recommended grades of exposure are given in Table 1.

Exposure	Maximum 3-second Gust Speed (m/s)
Sheltered	40
Moderate	45
Severe (a)	50
Severe (b)	(55) *

TABLE 1 : GRADES OF EXPOSURE

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* Normally the upper limit for severe exposure should be taken at 50 m/s. The higher speed of 55 m/s is an assumed upper limit and is rarely necessary unless specified.

The test method and the recommendations for the grading of windows are not perfect, but experience of testing windows at Paisley in the past ten years shows a significant improvement in the gradings achieved.

SELECTION OF SAMPLES FOR TEST

BS 4315 recommends that a minimum number of three units per thousand should be tested unless otherwise agreed between the purchaser and supplier.

In Scotland, the practice to date has generally been for one sample from a given type to be supplied by the manufacturer and provided this is satisfactory the purchaser accepts the results as applying to the complete batch. If not satisfactory, further samples are provided until the required exposure category has been obtained.

This procedure is only valid provided that reasonable quality control exists in the manufacturing process and provided reasonable care is taken on site in handling. This is clearly demonstrated in Fig 1 which illustrates non-repeatability characteristics for three similar type windows tested prior to 1971.

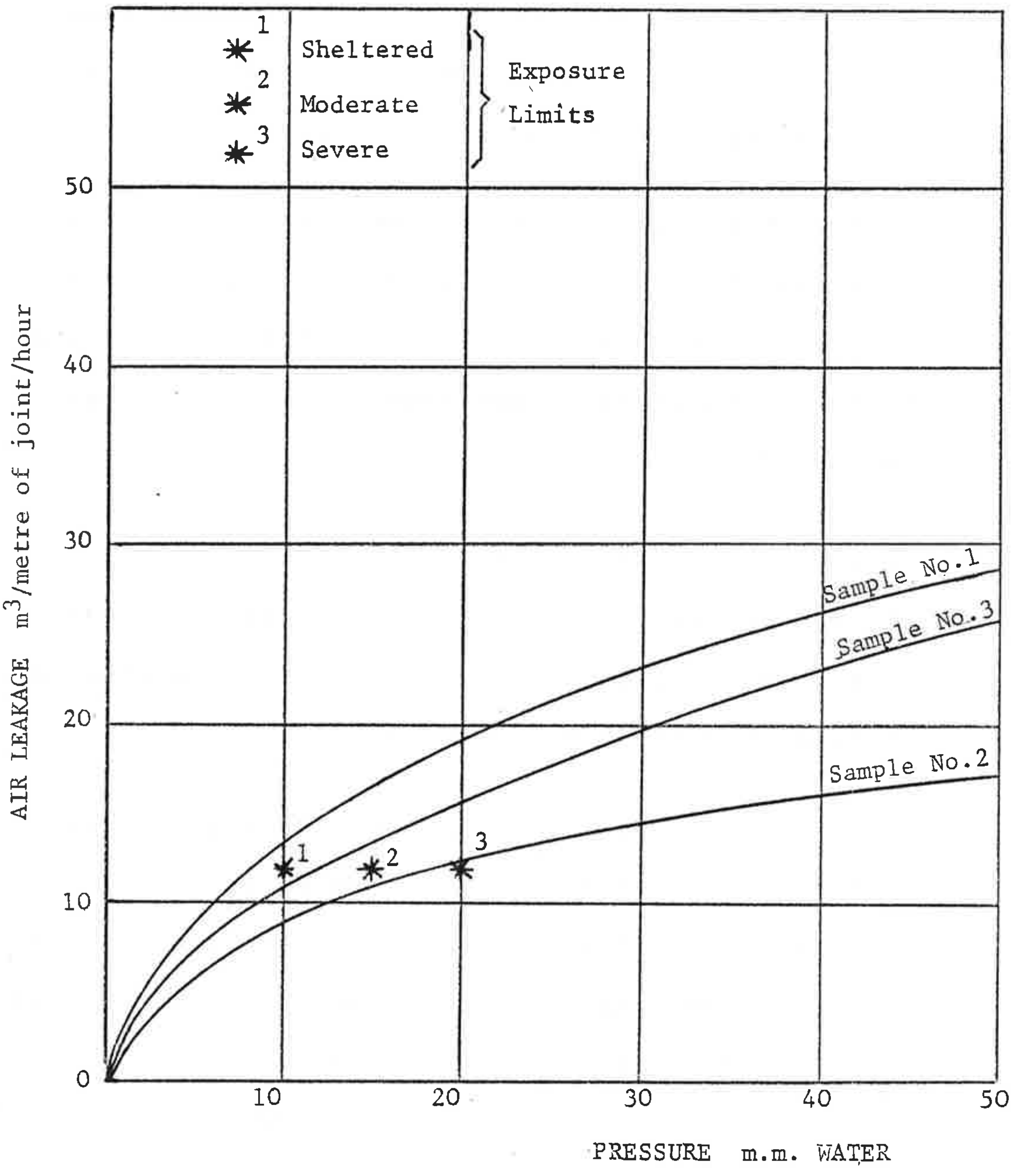


FIG. 1 : AIR PENETRATION FOR SIMILAR WINDOWS

DESCRIPTION OF SAMPLES TESTED

The distribution of the samples provided for test are given in Table 2 which indicates that over the past decade 534 windows have been tested at Paisley of which 59% were of the Horizontal Pivot type and 27% were of the Side, Top or Bottom Hung type. It is also worth noting that 78% of all windows tested were Timber framed.

Type	No. of Tests	Material	No. of Tests
Horizontal Pivot	316 (59%)	Timber Metal Aluminium P.V.C.	275 (87%) 31 (10%) 8 (3%) 2 (1%)
		Total	316 (100%)
Side Hung Top Hung Bottom Hung	144 (27%)	Timber Metal Aluminium P.V.C.	116 (81%) 10 (7%) 6 (4%) 12 (8%)
		Total	144 (100%)
Vertical Pivot	19 (4%)	Timber Metal Aluminium	16 (84%) 2 (11%) 1 (5%)
		Total	19 (100%)
Horizontal & Vertical Slider	47 (9%)	Aluminium	47 (100%)
Sash & Casement	8 (1%)	Timber	8 (100%)
TOTAL	534 (100%)		

TABLE 2: DISTRIBUTION OF TESTS

OVERALL PERFORMANCE ANALYSIS

The overall performance of the 534 windows tested at Paisley are tabulated in Table 3 and shown graphically in Fig. 2. These indicate that there has been a steady improvement in performance since the inception of B.S. 4315. In the period from 1970 to 1978, the statistics indicate that there has been an increase in windows suitable for

(a) severe exposure from 21% to 53%

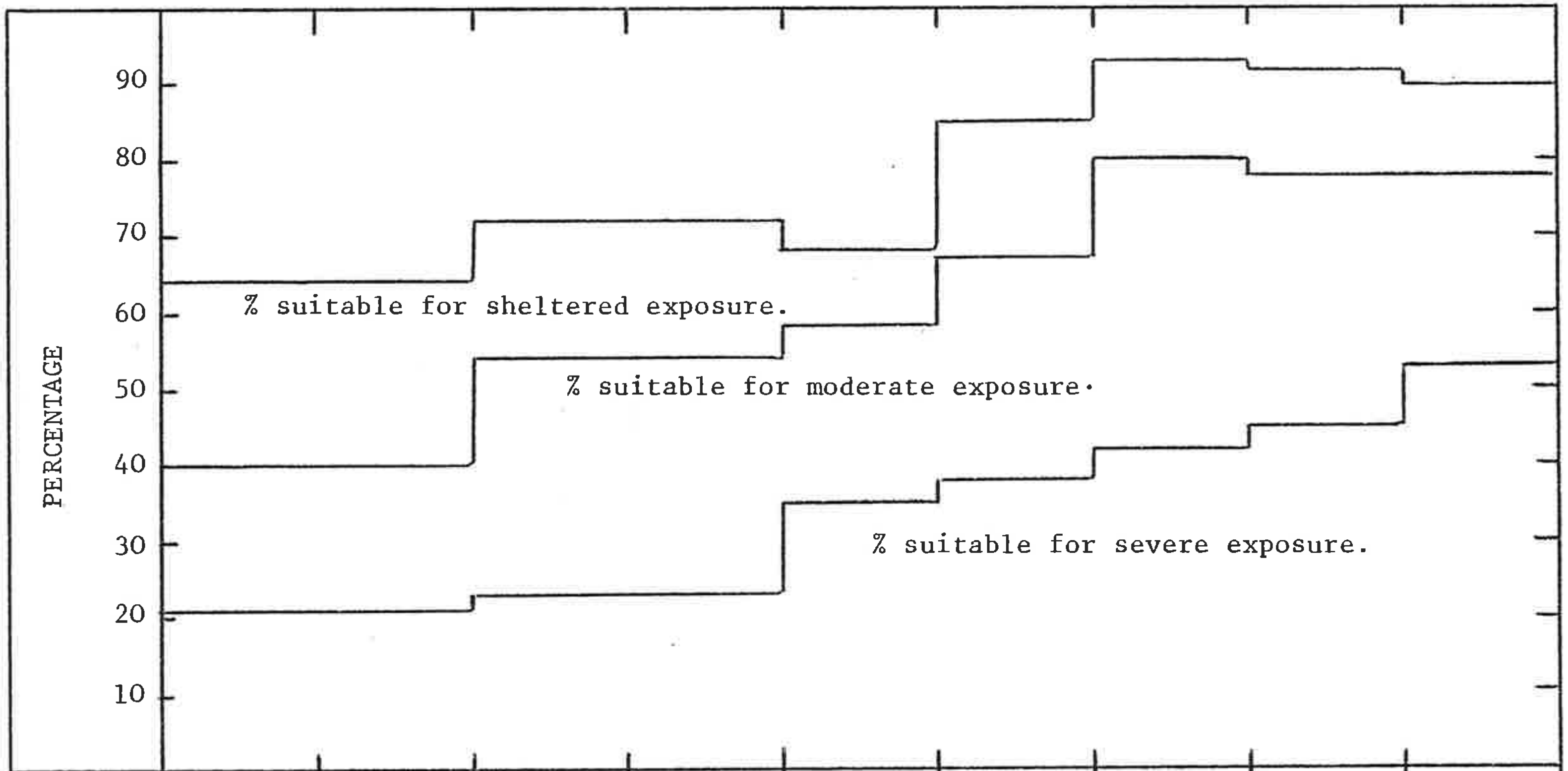
(b) moderate exposure from 40% to 78%

(c) sheltered exposure from 64% to 90%

and a decrease in windows unsuitable for any exposure from 36% to 10%.

Year	Exposure Suitability				Total
	Severe	Moderate	Sheltered	None	
	No. of Tests				
≤ 1971	21 (21%)	40 (40%)	64 (64%)	36 (36%)	100 (100%)
1972-3	14 (23%)	33 (54%)	44 (72%)	17 (28%)	61 (100%)
1974	22 (35%)	36 (58%)	42 (68%)	20 (32%)	62 (100%)
1975	28 (38%)	49 (67%)	62 (85%)	11 (15%)	73 (100%)
1976	43 (42%)	82 (80%)	96 (93%)	7 (7%)	103 (100%)
1977	34 (45%)	59 (78%)	70 (92%)	6 (8%)	76 (100%)
1978	31 (53%)	46 (78%)	53 (90%)	6 (10%)	59 (100%)
TOTAL	193 (36%)	345 (65%)	431 (81%)	103 (19%)	534 (100%)

TABLE 3: PERFORMANCE ANALYSIS



YEAR	1970	1971	1972	1973	1974	1975	1976	1977	1978
WINDOWS	100		61		62	73	103	76	59

FIG. 2: PERFORMANCE ANALYSIS

EFFECT OF WEATHERSEALS AND TOP FIXINGS

The improvement in performance over the years is undoubtedly due to a greater awareness by architects and manufacturers of the deficiencies in design shown up by the introduction of B.S. 4315. Prior to 1970, very few windows incorporated a weatherseal. Top fixings on horizontal pivot type windows were uncommon. At the present time, both these features are fairly standard and there has been a marked improvement in performance. This is clearly illustrated in Tables 4 and 5 and in Fig. 3.

Type	Exposure Suitability				Total
	Severe	Moderate	Sheltered	None	
	No. of Tests				
ALL WINDOWS					
(a) with w/s	186 (43%)	326 (75%)	399 (92%)	33 (8%)	433 (100%)
(b) without w/s	7 (7%)	19 (19%)	32 (32%)	69 (68%)	101 (100%)
HORIZONTAL PIVOT					
(a) with w/s	104 (41%)	187 (74%)	239 (94%)	14 (6%)	253 (100%)
(b) without w/s	5 (8%)	15 (24%)	23 (37%)	40 (63%)	63 (100%)
SIDE,TOP,BOTTOM HUNG					
(a) with w/s	58 (49%)	92 (78%)	103 (87%)	15 (13%)	118 (100%)
(b) without w/s	1 (4%)	1 (4%)	4 (15%)	22 (85%)	26 (100%)

TABLE 4: EFFECT OF WEATHERSEALS

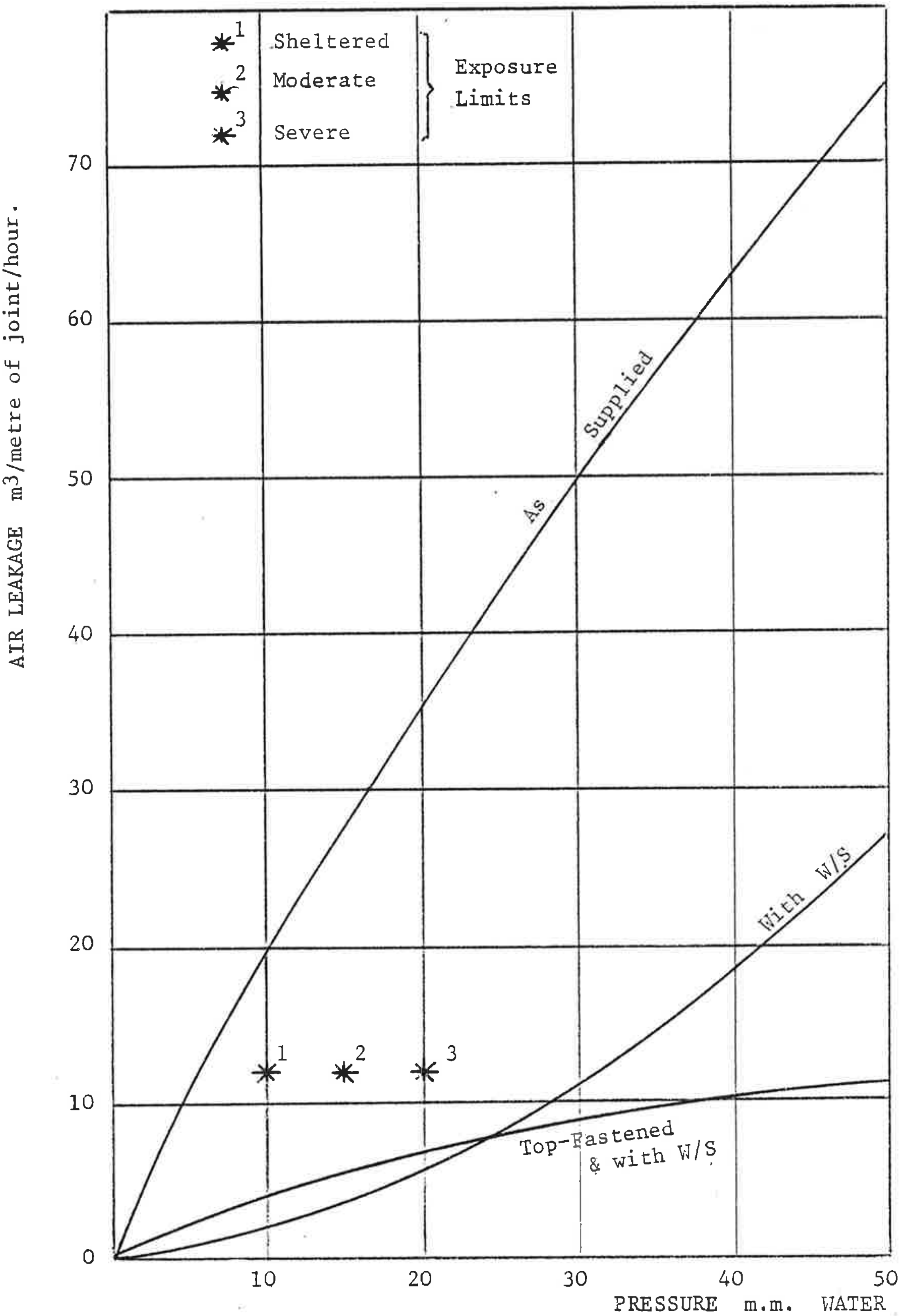


FIG. 3: EFFECT OF WEATHERSEAL & TOP-FASTENING

Horizontal Pivot	Exposure Suitability				Total
	Severe	Moderate	Sheltered	None	
	No. of Tests				
(a) with top fixing and w/s	68 (51%)	114 (85%)	130 (97%)	4 (3%)	134 (100%)
(b) w/s only	36 (30%)	74 (62%)	110 (92%)	10 (8%)	120 (100%)
(c) top fixing only	3 (17%)	8 (44%)	12 (67%)	6 (33%)	18 (100%)
(d) without top fixing or w/s	2 (5%)	6 (14%)	10 (23%)	34 (77%)	44 (100%)

TABLE 5: EFFECT OF TOP FIXINGS AND WEATHERSEALS ON HORIZONTAL PIVOT WINDOWS

CONCLUSIONS

The existing test method (BS 4315) and the recommendation for the grading of windows (DD4) have been criticised over the years. The above results, however, show a marked improvement in window performance and design, with a consequent saving in maintenance costs.

The imminent introduction of the new test method (BS 4368), will hopefully remove some of the criticisms of the present test method.

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WATER PENETRATION THROUGH WINDOWS AND DOOR JOINTS

T F Provan/J D Younger

References

1. BS 4315 Methods of test for Resistance to Air and Water Penetration.
Part 1. Windows and Gasket Glazing Systems.

2. Draft for Development 4 : 1971. Recommendations for the Grading of Windows. BSI.

3. Building Research Establishment Current Paper 49/77. "The repeatability and reproducability of test results on windows and wall span elements and the expected results". J F S Carruthers & C J Newman.

4. Building Research Establishment Current Paper 31/78 "The Performance of Timber Based Doors" - I S McIntyre.

5. BS 5368 : 1976. Methods of Testing Windows.

Part 1 Air Permeability Test EN 42
Part 3 Wind Resistance Tests EN 77

WATERPROOF COATINGS AND JOINT SEALANTS

1. Waterproof coatings

Waterproof coatings are defined as liquid applied materials which either set or cure to produce an impervious layer. The curing may involve a chemical reaction or simply the loss of solvent or water from a solution or an emulsion. The materials may be applied by either brush, roller or spray and may arrive on site as a ready to apply material or can involve the mixing of 2 or more components.

The waterproofing system may consist of several layers of the same material or of different materials. Sheets of reinforcement may be laid onto the wet layer or chopped reinforcement may be incorporated into the material. The reinforcement may be of glass, terylene, hessian, asbestos or metal fibres.

Table I lists the main types of materials available with examples of each type. The list is not exhaustive as there are many products on the market which are only defined as being liquid plastics or liquid rubbers.

Included in the table is the group of materials known as water repellants which should not really be included in a list of waterproof coatings as they do not normally provide a continuous coating and will not prevent the passage of water under pressure. However they do have a useful application in weatherproofing walls and have been included because of this.

British Standards exist only for Group I and materials a and b of Group 5. Very few of the remaining products are covered by Agrement certificates.

There are many different applications for waterproof coatings in buildings. Some of the materials may be used in several applications but others are only suitable for a particular application.

Table II gives a list of the main applications.

Table I Types of waterproof coatings

Group		
1.	Bituminous -	a) hot applied b) solution c) emulsion
2.	Modified Bitumens -	a) modified with elastomers b) modified with polyurethane c) modified with epoxides
3.	Elastomers -	a) Neoprene b) Hypalon c) Neoprene/Hypalon
4.	Plastics	a) PVC b) Polyurethane c) Epoxy/polyurethane d) Acrylic e) Polyester
5.	Water repellants - disturb adhesion of water at their surfaces (non-wetting)	a) Silicones b) Siliconates c) Complex Aluminium Stearates

Table II

Applications for waterproof coatings

		Material Groups
1.	Damp proof membranes for concrete structures	1 and 2
2.	Tanking of basements	1 and 2 preferably with reinforcement
3.	Weatherproofing of walls	1 and 5
4.	Flooring a) floor covering	4
	b) protection of concrete floors	3 and 4
5.	Roofing and repairs to roofs	1, 2, 3 and 4 preferably with reinforcement
6.	Injected damp proof courses	5

Failures and causes of complaints

1. Failures in design : in adequate detailing or detailing that is impossible to attain with the particular material used

2. Workmanship faults : failure to achieve complete coverage
   failure to prepare substrate adequately
   failure to comply with instructions

3. Failures due to pin holing : the loss of solvent from solutions or emulsions often results in pin holing of the waterproof layer. It is for this reason that two or more layers are invariably applied allowing each coat to dry before the next is applied

4. Failures due to inadequate adhesion : failures caused by wet substrates - failures caused by dirty substrates

5. Failures due to blistering of the waterproofing: caused by moisture or solvent trapped in the substrate expanding due to high temperatures

6. Failures due to mechanical damage: impact damage
   indentation damage
   abrasion damage

7. Failures due to splitting of the waterproofing:
   cracking of substrate
   movement at joints in substrate

8. Failures due to inadequate durability

Advantages of poured waterproofing systems

Although problems can occur with waterproof coatings they do have certain advantages over other forms of waterproofing in particular circumstances such as : many of the systems do not require specialist applications and can be installed by normal site labour. Some of the more complex systems used for r-ofing, flooring and tanking however do need specialist contractors.

: in general a jointless waterproof covering is achieved although special arrangements will usually have to be made where the material passes over joints where movements is likely to occur

: complex shapes can be waterproofed which would be difficult or impossible with sheet waterproofing materials

: with waterproofing systems containing reinforcement it is possible to provide additional layers of reinforcement in areas where the highest stresses are likely to occur.

However to avoid problems it is essential that before any system is used that it is checked that the product is suitable for the particular application.

It should be checked whether the material is covered by a British Standard, Code of Practice or an Agrement Certificate. If not then it is necessary to check that the product has been adequately tested for its proposed use.

The following gives a list of requirements that may have to be checked depending upon the proposed use of the product.

General requirements

- Waterproofing properties versus likely head of water
- Adhesion to the substrate
- Tolerance to moisture in the substrate
- Tolerance to surface imperfections in the substrate
- Tolerance to dust and dirt on the substrate
- Curing or setting time under adverse conditions of temperature and humidity
- Tolerance to sudden changes in atmospheric conditions such as rain or frost
- Chemical compatibility with the substrate and other materials with which it will be in contact
- Expected life of the product

Specific Requirements

Vertical walls : resistance to clump

Damp proof membranes : resistance to impact
resistance to traffic

Tanking : penetration resistance to backfilling operation - if protection is not provided

Flooring : resistance to traffic - pedestrian
rubber tyres
steel wheels
resistance to indentation - static
dynamic
resistance to impact - domestic
public
factory
resistance to chemicals and cleaning - domestic
public
factory
resistance to slippage

Roofing : resistance to traffic - pedestrian
vehicles
resistance to indentation - static
dynamic
resistance to thermal shock
resistance to movement of the substrate

2. Joint Sealants

A sealant is defined as a compound, applied to a joint in an unformed state, which constitutes a seal by adhering to appropriate surfaces within the joint. Sealants may be non-setting or they set or cure within the joint. The curing may involve a chemical reaction or simply the loss of solvent.

The sealant may be applied by either hand, gun, or pouring and may arrive on site as a ready to apply material or can involve the mixing of 2 or more components.

The main types of sealants classified according to the chemical make-up are:

- Oleo-resinous
- Bitumens and rubber-modifed bitumens
- Butyl rubber
- Acrylic resin
- Flexible epoxides
- Poly sulphide
- Silicone
- Polyurethane

British Standards exist for the quality control testing of the main groups of sealants and there is also a B.S. Code of Practice "Guide to the selection of constructional sealants". The following sections on Joint design considerations and causes of sealant failure are taken from that document.

3.5 Sealant geometry. Having considered the nature and causes of the movement at the joints, quantified the amplitude of the movement and having selected a sealant with suitable dynamic properties and of adequate movement accommodation, it is necessary to consider the seal geometry required to achieve satisfactory performance of the sealed joint.

The joint geometry, expressed as the ratio of width:depth of the sealant cross section, is related to the dynamic properties of the different types of sealant, with the object of minimizing the stresses induced in the sealant as a result of movement deformations.

The preferred width:depth ratios for the different sealant types are:

Elastic sealants	2:1
Elastoplastic sealants	2:1 to 1:1
Plastoelastic sealants	1:1 to 1:2
Plastic sealants	1:1 to 1:3

Notwithstanding these ratios, in narrow joints care should be taken to ensure that the depth of the sealant is adequate, i.e. for porous substrates they should be 10 mm min., for non-porous substrates they should be 6 mm min.

3.6 Sealant modulus. The modulus of a sealant at a stated degree of extension is a measure of the stiffness of the material; and for many sealants this will tend to increase markedly at low temperatures. Sealants having high moduli may impose excessive stresses on the substrates to which they adhere, and should therefore be avoided when specifying sealants for use with mortar and other materials prone to weak surfaces. It should also be noted that for such sealants with high recovery properties (i.e. negligible stress relaxation) the persistence of high stresses at the sealant/substrate interface will increase the likelihood of this type of failure.

3.7 Maintenance. When specifying a sealant the joint designer should give some thought to the need for maintenance and/or replacement of the sealant at some time during the expected lifetime of the building.

Lifetimes of the sealants themselves can only be estimated crudely on the basis of current experience of their performance in service, and on the assumption that design of the joint, erection of the jointed components and application of the sealant have all been correctly performed. (See figure listed below.)

Expected service life of sealant types.

Types of sealant	Expected service life
Oleo - Resinous Bitumen and rubber/bitumen bulyl	Up to 10 years
Acrylic (solvent) Acrylic (emulsion)	Up to 15 years

1 part polysulphide	)	Up to 20 years
1 part polyurethane	)	
Silicone	)	
2 part polysulphide	)	Up to 30 years
2 part polyurethane	)	

NOTE. Under favourable conditions the expected service life quoted above may be exceeded.

The amount of exposure to weather, which is a function both of the locations of the building or structure and the joint, and of the joint design, will also influence the effective life of the sealant in service.

In choosing between butt and lap joint designs, the designer should bear in mind that although the stresses imposed on the sealant will be lower for a lap joint, to accommodate a given amplitude of movement, there may be more difficulty in applying the sealant, and in removing and replacing it should this prove necessary, than for the equivalent butt joint solution.

3.8 Causes of sealant failure. If the appropriate sealant is selected according to the principles set out above; and the materials are correctly stored before use, and applied to the joint following the guidelines laid down in section the sealant should perform adequately throughout the service-life. Although it is not possible to give service-lives precisely, the values quoted in 3.7 are representative of past experience, their reliability clearly depending on the periods of time during which the various sealants have been in common use in the building industry.

Premature sealant failure is of two broad types, though in practice evidence of both kinds may often be seen on close inspection of a failed joint seal.

Adhesive failure occurs as a result of a rupture within the bond at the interface between the sealant and one or more of the joint surfaces to which it has been applied.

The reasons for adhesive failure may be one or more of the following:

(a) inadequate preparation of the joint surface before application of the sealant: the joint surfaces must be dry, clean, and free of loose particles or dust. The presence of water (liquid or ice), oil or grease, or of dust will impair adhesion of the sealant to the joint surface. This may not be apparent at the time of application; however, when movement causes the joint to open, the stresses generated at the interface are likely to manifest any weakness of adhesion. Once the sealant has become detached from the surface, even over a small area, the failure is likely to increase progressively, until eventually water and air are able to pass through the joint.

(b) incompatibility between sealant and substrate: it is essential to use an appropriate primer on many surfaces, such as concrete, and particularly with curing (elastic or plastoelastic) types of sealant. This is done in addition to (not as an alternative to) the correct surface preparation referred to above.

In this context, it may be appropriate to refer to difficulties encountered in glazing where timber window frames have been given an exterior wood stain finish instead of a conventional paint coat. The presence of preservative or water-repellent in such treated timber can give rise to adhesion failures. It is possible, however, that the primary cause of such failures is excessive moisture movement of the timber, since exterior wood stains represent a less effective barrier to ingress of water or water vapour than does the conventional paint coat. With such glazing details, it is desirable to use an elastic ot plastoelastic sealant as a capping, in addition to the plastic glazing or bedding compounds, to prevent failure from this cause.

(c) weakness of the surface in contact with the sealant: The surfaces of materials such as concrete may have a layer of weak material ('laitence') which is unable to withstand the tensile forces produced at the interface with the sealant when the joint opens. This is not properly an adhesive failure of the sealant (rather a 'cohesive failure' within the material of the adjoining component in the joint). However, the effect is similar to those already described and can best be prevented by adequate surface preparation, including priming as recommended by the sealant supplier.

Cohesive failure. A failure within the body of the sealant may occur if the tensile forces during extension of the material as the joint opens are sufficient to literally pull the sealant apart. This is most likely to occur if a sealant of inadequate movement accommodation has been chosen; or if dimensional variations between a number of ostensibly identical joints are such that joint widths beyond the capability of the sealant have occurred.

Cohesive failures may initiate from small cracks in the external surface of the sealant, and effective and careful 'tooling' of this surface is essential in applying the sealant to the joint. Crazing or cracking of the surface exposed to weather may occur in certain types of sealant as a result of ultra-violet radiation from sunlight.

Although excessive extension is the most probable cause of cohesive failure, (certainly with sealants which are predominantly elastic in character), subjection of stress-relaxing sealants to excessive compression can lead ultimately to cohesive failure. A fold of material may then be extruded out of the joint: if the sealant is held in this state for long periods (e.g. in a prolonged spell of hot weather) considerable stress relaxation will occur, so that the sealant surface is unable to resume its original shape, and a cohesive failure initiates.

This type of failure is also likely to occur in elastic or plastoelastic sealants which fail to cure, or which cure over a prolonged period after application to the joint. During this period movement may occur at the joint - either reversible movement as a result of thermal or other changes, or an irreversible movement, such as occurs with 'settlement' of a newly constructed building. In either case irreparable damage may be done to the sealant.

A related failure, though not strictly a cohesive failure, may be referred to here. Certain slow curing or predominantly plastic sealants may be prone to 'slump' so that flow of the material out of the confines of the joint occurs under the influence of gravity. This may occur in both vertical and horizontal joints in vertical surfaces - indeed there is some evidence that such sagging can be more often a problem in such horizontal joints. To avoid such failures it is important that the maximum recommended joint width for the sealant used should not be exceeded.

4. Classification and Grading of Sealants - UEAtc Common Directive

4.1. General

In view of the above, a number of classifications and gradings are necessary and possible.

4.2. Classification according to the total deformation the sealant can tolerate (amplitude)

A_1 : total deformation up to 5%

A_2 : total deformation up to 15%

A_3 : total deformation up to 25%

A_4 : total deformation up to 35% (Note: since no experience is available on sealants of class A_4, it is not possible to specify the requirements and methods of assessment for this class).

Note: If deformation can occur in several directions at once (e.g. expansion and shear), it is necessary to assess the lowest tolerated deformation at the design stage.

4.3. Grading of sealants according to elastic recovery

R_1 : elastic recovery $\leq$ 10%

R_2 : elastic recovery $>$ 10 to $\leq$ 40%

R_3 : elastic recovery $>$ 40 to $\leq$ 70%

R_4 : elastic recovery $>$ 70 to $\leq$ 90%

R_5 : elastic recovery $>$ 90%

4.4. Grading of sealants according to the shear modulus

M_1 : shear modulus $\leq$ 0.1 MPa

M_2 : shear modulus $>$ 0.1 to $\leq$ 0.25MPa

M_3 : shear modulus $>$ 0.25 to $\leq$ 0.5 MPa

M_4 : shear modulus $>$ 0.5 MPa

4.5. Grading of sealants according to slump resistance

S_1 : slump resistant up to a joint width of 20mm

S_2 : slump resistant up to a joint width of 40mm

This applies to both horizontal and vertical joints

4.6. Grading of sealants according to their resistance to direct contact with water

E_o : not resistant to direct contact with water

E_1 : resistant to direct contact with water after hardening

E_2 : resistant to direct contact with water even before hardening

5. Grading of sealants according to Chapter 4, Section 4

Grading of sealants for use in external walls is done by means of five letters, each letter being followed by an index number resulting from the classifications outlined in Chapter 4, Section 4.

A : Amplitude of movement of the joint or total deformation the sealant is capable of tolerating

R : Elastic Recovery of the sealant

M : Shear Modulus

S : Slump resistance of the sealant

E : Resistance to direct contact with water

For instance, a sealant with the following properties:

- total deformation tolerated : 25%
- elastic recovery: between 40% and 70%
- shear modulus : between 1 and 0.25 MPa
- slump resistant up to a joint width of 40mm
- resistant to direct contact with water, even before hardening

would be graded : A_3, R_3, M_2, S_2 and E_2

As regards selection of sealants according to the function of the joints, see guide-lines in Appendix 2.

THE AGRÉMENT BOARD

Assessment of Products for the Construction Industry

CERTIFICATE NO. 77/512

Valid until 1st January 1981

CI/SfB | | Yu6 |

Rentokil Ltd
Felcourt
East Grinstead
Sussex RH19 2JY

Rentokil Silicone Injection Damp Course System

Couche d'étanchéité pour murs par injection de silicone

Part I Certification

1 Product

This Certificate renews and extends Certificate No 76/420, and relates to the Rentokil Silicone Injection Damp Course System, a system involving the injection of a silicone resin solution into existing brick or stone walls, to form a damp-proof course, and then replastering where necessary.

2 Marketing

The system is marketed and installed by Rentokil Ltd and manufactured by Thomas Ness Ltd.

3 Use

The system is for use in providing a barrier against rising damp in:

(1) Existing solid walls of brickwork, blockwork or stone (excluding flint) up to 600 mm thick or in cavity walls with individual leaves not exceeding 340 mm thick, where there is no damp-proof course or where the existing damp-proof course has failed.

(2) Existing stone walls of rubble-filled construction of any thickness, where there is no damp-proof course.

4 Assessment

In the opinion of The Agrément Board, the system is satisfactory for this purpose. In solid or conventional cavity constructions it provides an effective means of preventing rising damp. In rubble-filled cavity constructions, the variable nature of the infill may prevent a totally effective treatment, but the reported incidence of failure is small and rectification by retreatment is often achieved. The replastering system is effective in limiting damage to subsequent redecoration due to soluble salts retained in the walls.

5 Building regulations

5.1 In the opinion of The Agrément Board, the position of the Rentokil Silicone Injection Damp Course System, when used in the context of this Certificate, with regard to the various building regulations, is as follows:

5.2 The Building Regulations 1976 and the Building Regulations (Northern Ireland) 1977 — it can satisfy the requirements of Regulation B1 (Fitness of materials) and C6 (Protection of walls against moisture), in so far as action to meet these requirements might, in certain circumstances, be necessary in the case of an existing building.

5.3 The Building Standards (Scotland) Regulations 1971 to 1975 — it can satisfy the requirements of Regulations B1. (Selection and use of materials) and G7. (Resistance to moisture from the ground), in so far as action to meet these requirements might, in certain circumstances, be necessary in the case of an existing building.

5.4 London Building (Constructional) By-laws 1972 — use of this system for damp-proofing would be subject to the approval of the District Surveyor in respect of By-laws 4.11 (Materials for damp-proofing) and 5.05 (Protection from damp).

6 Conditions of certification

6.1 The quality of materials and method of installation have been examined by The Agrément Board and must be maintained during the period of validity of this Certificate. If this condition is not complied with, this Certificate may be withdrawn.

6.2 Where reference is made in this Certificate to any Act of Parliament, Regulation made thereunder, Statutory Instrument, Code of Practice, British Standard, manufacturer's instruction or similar publication, it shall be construed as reference to such publication in the form in which it is in force at the date of this Certificate.

6.3 In granting this Certificate, The Agrément Board makes no representation as to the presence or absence of patent rights subsisting in the product and/or as to the legal right of Rentokil Ltd or their approved contractors to market, install or maintain the product.

The Agrément Board, a non-profit distributing company limited by guarantee and registered in England No 878293

P O Box No 195, Bucknalls Lane
Garston, Watford, Herts WD2 7NG
Tel: Garston (STD 092 73) 70844

THE AGRÉMENT BOARD
Assessment of Products for the Construction Industry

CERTIFICATE NO. 79/695

Valid until 1st December 1982

CI/SfB t4

Sika Ltd
Watchmead
Welwyn Garden City
Herts AL7 1BQ

Sikaflex 1a Building Sealant

Mastic à base de polymère

Readers are advised to check that this Certificate has not been withdrawn or superseded by a later issue, by referring either to the Board's 'Abstracts and Index' or contacting the Board direct [telephone Garston (STD 092 73) 70844].

Part I Certification

1 Product

This Certificate relates to Sikaflex 1a, a polymer-based building sealant.

2 Marketing

The product is manufactured and marketed by Sika Ltd.

3 Use

Sikaflex 1a has been assessed for use on aluminium, concrete or wood substrates in buildings, to fill and seal joints in vertical surfaces which may be liable to a total deformation of up to 25%.

4 Assessment

4.1 In the opinion of The Agrément Board, the product is satisfactory for this purpose.

4.2 Sikaflex 1a has been assessed by The Agrément Board as having an ARMSE classification $A_3R_5M_4S_2E_2$. An explanation of this classification can be found in the Appendix.

5 Building regulations

5.1 In the opinion of The Agrément Board, the position of Sikaflex 1a, when used in the context of this Certificate, with regard to the various building regulations, is as follows:

5.2 The Building Regulations 1976 (as amended) and the Building Regulations (Northern Ireland) 1977 — it can satisfy the requirements of Regulation B1 (Fitness of materials) and can be used in a construction to satisfy Regulation C8 (Weather resistance of external walls).

5.3 The Building Standards (Scotland) Regulations 1971 to 1979 — it can satisfy the requirements of Regulation B1. (Selection and use of materials) and can be used in a construction to satisfy Regulation G8. (Resistance to moisture from rain or snow).

5.4 London Building (Constructional) By-laws 1972 — there are no requirements in these By-laws relating to the use of this product.

6 Conditions of certification

6.1 The quality of materials and method of manufacture have been examined and found satisfactory by The Agrément Board and must be maintained to this standard during the period of validity of this Certificate. If this condition is not complied with, this Certificate may be withdrawn.

6.2 Where reference is made in this Certificate to any Act of Parliament, Regulation made thereunder, Statutory Instrument, Code of Practice, British Standard, manufacturer's instruction or similar publication, it shall be construed as reference to such publication in the form in which it is in force at the date of this Certificate.

6.3 In granting this Certificate, The Agrément Board makes no representation as to the presence or absence of patent rights subsisting in the product and/or as to the legal right of Sika Ltd to market, install or maintain the product.

The Agrément Board, a non-profit distributing company limited by guarantee and registered in England No 878293
PO Box No 195, Bucknalls Lane, Garston, Watford, Herts WD2 7NG
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THE AGRÉMENT BOARD

Assessment of Products for the Construction Industry

CERTIFICATE NO. 79/646

Valid until 1st August 1982

CI/SfB (47) Ps1

Evode Roofing Ltd
Common Road
Stafford, ST16 3EH

The Evode System of Roof Waterproofing

Système d'étanchéité pour toiture

Readers are advised to check that this Certificate has not been withdrawn or superseded by a later issue, by referring either to the Board's 'Abstracts and Index' or contacting the Board direct [telephone: Garston (STD 092 73) 70844].

Part I Certification

1 Product

This certificate renews Certificate No 76/362 and relates to the Evode System of roof waterproofing, a cold-applied liquid bituminous system.

2 Marketing

The system is manufactured, marketed and installed by Evode Roofing Ltd.

3 Use

The Evode System has been assessed for use on limited access flat (not less than 1°) or pitched roofs laid either:

(a) as a waterproofing layer on roof decks complying with BS Code of Practice 144 : Part 3 : 1970 (Roof coverings — Built-up bitumen felt) with the exception of expanded polystyrene;

(b) as a maintenance and remedial system over slate, bituminous, asbestos cement and sheet steel roof coverings provided the substructure is stable.

4 Assessment

4.1 In the opinion of The Agrément Board, the Evode System is suitable for these purposes provided:

(a) it is not used without adequate protection (see Part II 'Design Data', '5 Resistance to foot traffic') on soft substrates where point loading other than pedestrian traffic associated with maintenance operations is envisaged,

(b) the Evodex material is not used without adequate protection (see Part II, 'Design Data', '5 Resistance to foot traffic') on hard substrates where impacts are likely to occur,

(c) the system is installed by operatives employed by Evode Roofing Ltd.

4.2 Subject to the conditions above, the material can accept without damage the foot traffic and light concentrated loads associated with installation and maintenance operations. If damage should occur, repairs are easily carried out.

4.3 When used on appropriate decks in conjunction with suitable materials (see Part II, 'Design Data', '6 Fire resistance') the roof will achieve an EXT AA fire rating when tested in accordance with BS 476 : Part 3 : 1958 (External fire exposure roof tests).

5 Building regulations

5.1 In the opinion of The Agrément Board, the position of the Evode System of waterproofing, when used in the context of this Certificate, with regard to the various building regulations, is as follows:

5.2 The Building Regulations 1976 (as amended) and the Building Regulations (Northern Ireland) 1977 — it can satisfy the requirements of Regulation B1 (Fitness of materials), and is capable of being used to satisfy Regulations C10 (Weather resistance of roofs) and E8(4) and (6) (Separating walls — junctions with roofs). When used on an appropriate substructure using particular materials it is capable of being unrestricted under Regulation E17. (Roofs).

5.3 The Building Standards (Scotland) Regulations 1971 to 1979 — it can satisfy the requirements of Regulations B1. (Selection and use of materials),G8. (Resistance to moisture from rain or snow) and when used on an appropriate substructure using particular materials it is capable of being unrestricted under Regulation D18. (Roofs).

5.4 London Building (Constructional) By-laws 1972 — the system can only be used in conditions where it would achieve an EXT.AA rating when tested in accordance with BS 476 : Part 3 : 1958 and when the District Surveyor is satisfied as to its durability and suitability [By-law 6.02 (j) External covering of roofs]

6 Conditions of certification

6.1 The quality of materials and method of manufacture have been examined by The Agrément Board and must be maintained during the period of validity of this Certificate. If this condition is not complied with, this Certificate may be withdrawn.

6.2 Where reference is made in this Certificate to any Act of Parliament, Regulation made thereunder, Statutory Instrument, Code of Practice, British Standard, manufacturer's instruction or similar publication, it shall be construed as reference to such publication in the form in which it is in force at the date of this Certificate.

6.3 In granting this Certificate, The Agrément Board makes no representation as to the presence or absence of patent rights subsisting in the product and/or as to the legal right of Evode Roofing Ltd to market, install or maintain the product.

The Agrément Board, a non-profit distributing company limited by guarantee and registered in England No 878293
PO Box No 195, Bucknalls Lane, Garston, Watford, Herts WD2 7NG
Tel: Garston (STD 092 73) 70844

Part II (Contd)

Design Data

1 General

The Evode System is satisfactory for use on limited access flat or pitched roofs laid either:

(a) as a waterproofing layer on roof decks complying with CP 144 : Part 3 : 1970 with the exception of expanded polystyrene.

(b) as a maintenance and remedial system over bituminous, asbestos cement and sheet steel roof coverings provided the substructure is stable.

2 Practicability of installation

2.1 Installation of the Evode System must be carried out at temperatures above freezing point. Evodex and Evode Thinners/Cleaner 507 are inflammable and Evodex Primer is highly inflammable; full precautions must be taken to avoid naked flames and sources of ignition.

2.2 Expansion joints must be constructed where necessary in accordance with the manufacturer's instruction, especially at joints liable to movements greater than ± 1.0 mm.

3 Weathertightness

3.1 When installed correctly, the Evode System is impervious to water and water vapour and will provide a satisfactory weathertight surface.

3.2 Normal good practice in respect of the provision of vapour barriers and/or ventilation of existing insulation must be followed to prevent condensation.

4 Adhesion

The adhesion of the Evode System is sufficient to resist the effects of wind suction likely to occur in practice when applied to all the substrates listed above.

5 Resistance to foot traffic

5.1 The Evode System can accept without damage the limited foot traffic and light concentrated loads associated with installation and maintenance operations.

5.2 For heavier traffic reference should be made to CP 144 : Part 3 : 1970 and measures taken accordingly (see also Part I, 'Certification', '4 Assessment').

6 Fire resistance

6.1 When laid over a steel deck underdrawn with insulation board, the Evode System incorporating Evode Paste 1 will achieve an EXT.S.BC rating when tested to BS 476 : Part 3 : 1958 (Fire tests on building materials and structures — External fire exposure roof tests).

6.2 When used in conjunction with Evode Silverfilm finish and laid on asbestos insulation boards the Evode System with Evode Paste 1 will achieve an EXT.S.AA rating.

7 Durability

The Evode System, when used in conjunction with Evode Silverfilm finish, will remain effective as a roof waterproofing for a period of at least 15 years. This period could be considerably extended if maintenance is carried out every five years.

8 Maintenance

Maintenance can be easily carried out by Evode Roofing Ltd and consists of coating the surface of the existing waterproofing with either Evode Paste 1 or Evodex, and applying a finish all in accordance with the original specification.

Part III Technical Investigations

The following is a summary of the technical investigations carried out on the Evode System of roof waterproofing.

1 Tests

As part of the assessment resulting in the issue of the previous Certificate No 76/362, tests were carried out to determine:

- impact resistance
- effect of light concentrated loads
- tensile strength
- system to substrate bond impact resistance
- effect of deck movement
- resistance to thermal shock
- flexibility
- resistance to water pressure
- water vapour permeability
- effect of solar heating
- effect of ageing.

2 Other investigations

2.1 A re-examination was made of the data and investigations on which the previous Certificate No 76/362 was based. The conclusions drawn from the original data remain valid.

2.2 Regular factory inspections have been carried out to ensure that quality is being maintained. Return visits were made to the original sites which were visited as part of the assessment for Certificate No 76/362.

2.3 Existing data relating to the performance of the system under fire conditions were examined.

2.4 Approximately 1.5 million sq. metres of the Evode System have been laid since the issue of Certificate No 76/362 and no failure of the System has been reported to the Board.

On behalf of The Agrément Board.

23rd July 1979

Director

THE AGRÉMENT BOARD
Assessment of Products for the Construction Industry

CERTIFICATE
NO. 79/652
Valid until 1st August 1982

CI/SfB (43) Vu5

Acoustic Chemical Co Ltd
Bradley Mill
Bradley Lane
Newton Abbot TQ12 1LZ

Unique Protective Coating

Enduit protecteur pour béton

Readers are advised to check that this Certificate has not been withdrawn or superseded by a later issue, by referring either to the Board's 'Abstracts and Index' or contacting the Board direct [telephone: Garston (STD 092 73) 70844].

Part I Certification

1 Product

This Certificate renews Certificate 74/243 and relates to UPC, a colourless surface protection for concrete floors.

2 Marketing

UPC is manufactured and marketed by Acoustic Chemical Co Ltd.

3 Use

UPC is for use as a protective treatment for new or existing concrete floors, in industrial situations.

4 Assessment

In the opinion of The Agrément Board, UPC is satisfactory for this purpose. It waterproofs and improves the wear and chemical resistance of concrete floor surfaces.

5 Building regulations

5.1 In the opinion of The Agrément Board, the position of UPC, when used in the context of this Certificate, with regard to the various building regulations, is as follows:

5.2 The Building Regulations 1976 (as amended), the Building Regulations (Northern Ireland) 1977, The Building Standards (Scotland) Regulations 1971 to 1979 and the London Building (Constructional) By-laws 1972 — there are no specific requirements in these regulations relating to the use of this product.

6 Conditions of certification

6.1 The quality of materials and method of manufacture have been examined by The Agrément Board and must be maintained during the period of validity of this Certificate. If this condition is not complied with, this Certificate may be withdrawn.

6.2 Where reference is made in this Certificate to any Act of Parliament, Regulation made thereunder, Statutory Instrument, Code of Practice, British Standard, manufacturer's instruction or similar publication, it shall be construed as reference to such publication in the form in which it is in force at the date of this Certificate.

6.3 In granting this Certificate, The Agrément Board makes no representation as to the presence or absence of patent rights subsisting in the product and/or as to the legal right of Acoustic Chemical Co Ltd to market, install or maintain the product.

Part III Technical Investigations

The following is a summary of the technical investigations carried out on UPC concrete surface protection.

1 Tests

As part of the assessment resulting in the issue of the previous Certificate, No 74/243, tests were carried out to determine:

- flash point,
- resistance to heat
- resistance to chemicals, including:
  - degradation due to chemicals
  - staining due to chemicals
  - washability with caustic soda solution,
- resistance to abrasion,
- adhesion to concrete substrate,
- slip resistance,
- effect of artificial weathering,
- coverage rate,
- practicability of application.

2 Other investigations

2.1 A re-examination was made of the data and investigations on which the previous Certificate was based. The conclusions drawn from the original data remain valid.

2.2 Regular factory inspections have been carried out to ensure that quality is being maintained.

2.3 A user survey and visits to established sites were conducted to evaluate performance in use.

2.4 No failure of the product in use has been reported to the Board.

On behalf of The Agrément Board

23rd July 1979 Director

WEATHERTIGHTNESS & WATER PENETRATION OF BUILDINGS

E Downey

It is clear from perusal of the other contributions to this Seminar that problems relating to Weathertightness and Water Penetration are responsible for a very large proportion of the troubles experienced by the occupants of new buildings. It has been the writer's sad experience to visit prestigious modern buildings of designs which compare favourably with any in the world and to see water running down walls or dripping on to expensively carpeted floors. It is easy to understand the exasperation of the occupants of such buildings and their perplexity over why it should be difficult in this day and age to construct a weathertight building.

Surely the minimum requirement for any building should be that it is free from water penetration. It does not seem to be an unduly onerous requirement that the building should also be draughtproof. Why is it, therefore, that after centuries of constructing buildings which were waterproof and with modern technology relating to sealants and draught excluding

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devices available to us we find it difficult to construct satisfactory buildings today.

In the preceding papers attention has been paid to the details of roof and wall construction, the necessary requirements for satisfactory windows and doors and the properties of joint sealants and waterproof coatings. Most of this information, although not often presented in a single event such as this seminar, has been available to designers and it is doubtful if many architects and engineers will have heard in any of the papers anything that is entirely novel. It would seem therefore that problems arise from the fact that available information is simply not applied in designs or that where it is, the construction may fall short of the designers' expectations in such a way that problems may arise.

In a survey conducted by the Building Research Establishment it has been found that most building faults are not caused, as might be expected, by poor workmanship but they in fact arise as a result of bad design. It is the writer's experience also that this is the case. Almost invariably this manifests itself

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in one of the following ways:-

1. The designer has not given sufficient thought to specific details.
2. The designer has relied upon a standard of workmanship and adherence to tolerances which are not normally achievable.
3. New materials or processes have been adopted in the design which are incompatible with other features.

To illustrate the above points; few people concerned in the construction industry will have failed to come across the situation where a detail which is satisfactory in general will not work in the particular case. The flashing which is satisfactory over an opening but which does not take account of the necessary corner detail, the window seal which is perfect but which stops altogether at the hinge and the dampproof course which is of a shape that is entirely satisfactory provided no joint is required in the material.

It is an unfortunate fact of life that it is no longer reasonable to assume that any construction will be carried out by craftsmen who will lavish loving care in the execution of their work. Indeed, it is a certainty that construction work carried out under

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prevailing economic conditions, subject to our weather in the United Kingdom will be carried out at best to the minimum standard that will meet the specification. It is essential therefore that the designer avoids the type of problem mentioned in paragraph 2 above by catering for such standards. It is, in the writer's opinion, futile to detail to tolerances of the odd millimetre the method of insertion of an expensive and precisely manufactured metal framed window in a reinforced concrete surround, when in practical terms that surround cannot be constructed to such fine tolerances. Provision must be made for such shortcomings in the profile of cast insitu concrete , brick and concrete components. It is imprudent to rely upon the use of sealants to provide primarly weathertightness of a building where literally miles of joints are involved. Assuredly at some point either the configuration of the joint or the standard of application will provide the circumstances where a failure must inevitably occur.

The third category of failure may be typified by the situation where the level of insulation in a flat roof is increased without regard being given to the effect of the consequently increased temperatures on roofing

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materials. Similarly, timber windows with a stained finish instead of painted will be subject to moisture movement of a much higher order. If such a finish is adopted and it has great merit, it is necessary to appreciate that movements of a higher order will occur and provide for these. If a building is to be clad in a material which is to be attached to the structural frame, it is necessary either to ensure that the movements due to thermal, moisture and ageing effects will be comparable in the materials of the cladding and the frame, or alternatively that the differential movement involved is catered for.

It would be possible to fill a book with further examples of such problems without covering every possible detail which could give rise to trouble and with no certainty whatever that such a list would be studied and committed to memory by all designers. It is necessary therefore to try to provide some system which might be followed in the design of a building in such a way that the types of pitfall referred to are either eliminated or at least very substantially reduced.

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few days been spent considering the details of the design. By any standards the expenditure of this time at the design stage is a cost effective exercise.

Nothing that has gone before in this paper could be regarded as remarkable in its novelty or subtle in its concept, indeed there is nothing suggested which would fall outwith the bounds of commonsense on the part of the designer. Nevertheless, under the present day pressures referred to, it is an undeniable fact that many design organisations and firms do not seem to be able to devote the detailed attention to their work which would be required to materially reduce the incidence of failures. The only way in which the situation will be improved is if the responsible partners or managers in design organisations create an atmosphere in their offices whereby detailed attention becomes the norm. Some design offices as a matter of routine carry out exhaustive investigations into all materials and products to be used, including where appropriate laboratory testing. This work is of low cost in relation to any structure but may save very large sums if carried out and due regard given to the results. It may take many years for the benefits of such a change of emphasis in any design organisation to be

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felt but these benefits will assuredly accrue not only to the designer but to his clients and to the economy at large if the effort is made.

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WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

WEDNESDAY 5 NOVEMBER 1980

P R O G R A M M E

0900-0930	REGISTRATION
0930-0940	INTRODUCTION "Scale of Problem" J F S Carruthers, Head of Components Division, Building Research Establishment Princes Risborough Laboratory
0940-1030	ROOF CONSTRUCTION (a) Pitched Roofs Dr R A Hazelwood (Redland Technology) (b) Flat Roofs D Armour (MACDATA) J Campbell (MACDATA)
1030-1050	COFFEE
1050-1115	ROOF CONSTRUCTION (b) Flat Roofs (continuation) I Buchan (MACDATA)
1115-1140	WALL CONSTRUCTION Cladding, Brickwork and Blockwork D Armour (MACDATA)
1140-1215	DISCUSSION
1215-1330	LUNCH
1330-1420	WINDOW AND DOOR JOINTS J Younger (MACDATA) T F Provan (MACDATA)
1420-1500	WATERPROOF COATINGS & JOINT SEALANTS J O May, Head of Materials Division The Agrement Board
1500-1520	COFFEE
1520-1550	WEATHERTIGHTNESS & WATER PENETRATION OF BUILDINGS E Downey (MACDATA)
1550-1630	DISCUSSION

WEATHERTIGHTNESS AND RAIN PENETRATION OF BUILDINGS

SEMINAR : 5 NOVEMBER 1980

LIST OF DELEGATES

Mr J F Munro
Bullen & Partners

Mr A Heron
Clydebank District Council

Mr K Gavin
CPC (UK) Limited

Mr S J Thompson
Edinburgh District Council

Mr John F McDonald
Schlegel (UK) Engineering

Mr D Swanson
Scottish Gas

Mr C McKenzie
Scottish Gas

Mr I Sandiman
Ove Arup & Partners

Mr R A Sykes
T Harley Haddow & Partners

Mr W Peden
Edinburgh District Council

Mr W Watt
Edinburgh District Council

Mr W McGillvray
Parry & Hughes

Mr J Maxwell
Lochaber District Council

Mr G H McConnell
Fife Regional Council

Mr S Leith
Paisley College of Technology

Mr A Clow
CSA (Buildings Division)

Mr J Proctor
CSA (Buildings Division)

Mr R Jacques
CSA (Buildings Division)

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Mr A K McDonald
Stirling District Council

Ms Judith Moores
Assist

Assist

Mr M Toulson
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Dumbarton District Council

Mr W Symington
Dumbarton District Council

Mr S Hannah
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Mr D M Mackenzie
Paisley College of Technology

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Riach & Hall, Edinburgh

Mr J King
Cumnock & Doon Valley District C

Mr A C Morris
Cumnock & Doon Valley District C.

Mr J R Southern
BRE, East Kilbride

Mr George High
BRE, East Kilbride.

Mr Taylor
King Main & Ellison, Troon

Mr P McCafferty
ASSIST.

WEATHERTIGHTNESS AND WATER PENETRATION OF BUILDINGS

5 November 1980

QUESTION FORM

Name ______________________________

Organisation ______________________________

Q.1 ______________________________

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Q.2 ______________________________

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Q.3 ______________________________

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Additional question forms will be available should they be required.