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external walls of large panel system dwellings

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This publication is one of a series being prepared as part of BRE's programme of investigation to assist local authorities and their consultants in appraisal, maintenance and repair of large panel system dwellings.

Other BRE publications on large panel system dwellings are:

Building Research Establishment. *The structure of Ronan Point and other Taylor Woodrow-Anglian buildings.* BRE Report. Garston, BRE, 1985.

Edwards M J. Weatherproof joints in large panel systems: 1 Identification and typical defects. *BRE Information Paper* IP8/86. Garston, BRE, 1986.

Edwards M J. Weatherproof joints in large panel systems: 2 Remedial measures. *BRE Information Paper* IP9/86. Garston, BRE, 1986.

Edwards M J. Weatherproof joints in large panel systems: 3 Investigation and diagnosis of failures. *BRE Information Paper* IP10/86. Garston, BRE, 1986.

Edwards M J. Weatherproof joints in large panel systems: 4 Flat roofs, balconies and deck accessways. *BRE Information Paper* IP15/86. Garston, BRE, 1986.

Morris W A and Read R E H. Passive fire precautions in LPS blocks of flats and maisonettes. *BRE Information Paper* IP18/86. Garston, BRE, 1986.

Reeves B R. *Large panel system dwellings: preliminary information on ownership and condition.* BRE Report. Garston, BRE, 1986.

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Contents

Summary

This state-of-the-art report examines the requirements for overcladding used to upgrade the performance of large panel system dwellings, and the solutions currently being used, and assesses the experiences of local authorities and the industry.

Overcladding is only one of the many options available to clients. However, it is expensive, and therefore any decision to overclad should be taken only after exhaustive study of the condition of the building and deficiencies in performance.

Background

Reason for report

This state-of-the-art report has been produced at a time when it appears that a small number of local authorities have completed, or are in the process of completing, the full or partial overcladding of large panel system (LPS) dwellings, and when many authorities are actively engaged in reaching decisions on whether and what to overclad. The range of solutions proposed is very wide, as is the range of costs.

This report is intended primarily to reduce the extent of repetitive technical studies carried out by officers within separate authorities, and, by summarising the experience of individual local authorities together with the relevant BRE and other research, to inform the decision-making process. It does not address in any degree of detail the economics of the decision on whether or not to overclad.

This report is addressed primarily to officers in the technical departments of local authorities, to provide a background discussion of some of the factors to be taken into account in any decision on whether or not to overclad, and does not assume a prior knowledge or experience of overcladding. Many of the questions raised in the report will in turn need to be raised with those who design and supply overcladding systems.

Each housing authority has its own particular housing stock and its own characteristic problems, and all of them are now faced with the difficult task of diagnosing the extent and causes of deterioration, and assembling and assessing their options. Overcladding may be one of the options to be considered.

Scope of report

The report is not a design guide to overcladding. Rather, it aims to provide: a comment on the characteristics of LPS dwellings which might influence their suitability for overcladding, a comprehensive review of the performance requirements for such cladding, the general types of options which are currently available, a summary of experience with selected application in use, a brief commentary on certain aspects of their likely performance, and some guidance on the kinds of question which need to be answered in order to decide what to specify. The report concentrates on the weather exclusion and durability of overcladding rather than thermal insulation, which is dealt with in more detail in other BRE publications[1]. It is confined to the overcladding of walls.

A separate BRE report will deal with the replacement of flat roofs by pitched roofs, which can be regarded as a special case of overcladding.

This report has been prepared for the most part from existing knowledge within BRE, from the experiences of some local authorities, and from a limited amount of experience of practical application. No new full-scale research programme was undertaken. Although every effort has been made to cover the more widely available techniques, for example by examination of manufacturers' published advertising literature and design guides, the coverage is by no means universal. Only a small sample of manufacturers or installers has been contacted.

Our researches so far have found only few examples of overcladding on LPS dwellings, although there have been some on high-rise blocks of more conventional construction. Despite the advertising by the cladding manufacturers, only relatively few buildings in the United Kingdom have been overclad, and not many of these are housing.

We have had reports from local authorities who have considered overcladding and have rejected the option outright. Some authorities have tried small-scale tests, and these are being evaluated by those authorities carrying out the trials. These trials are usually based on materials previously found to be generally acceptable to that authority. However, this is not always found to be the case, and some innovative systems are being tried.

Definitions

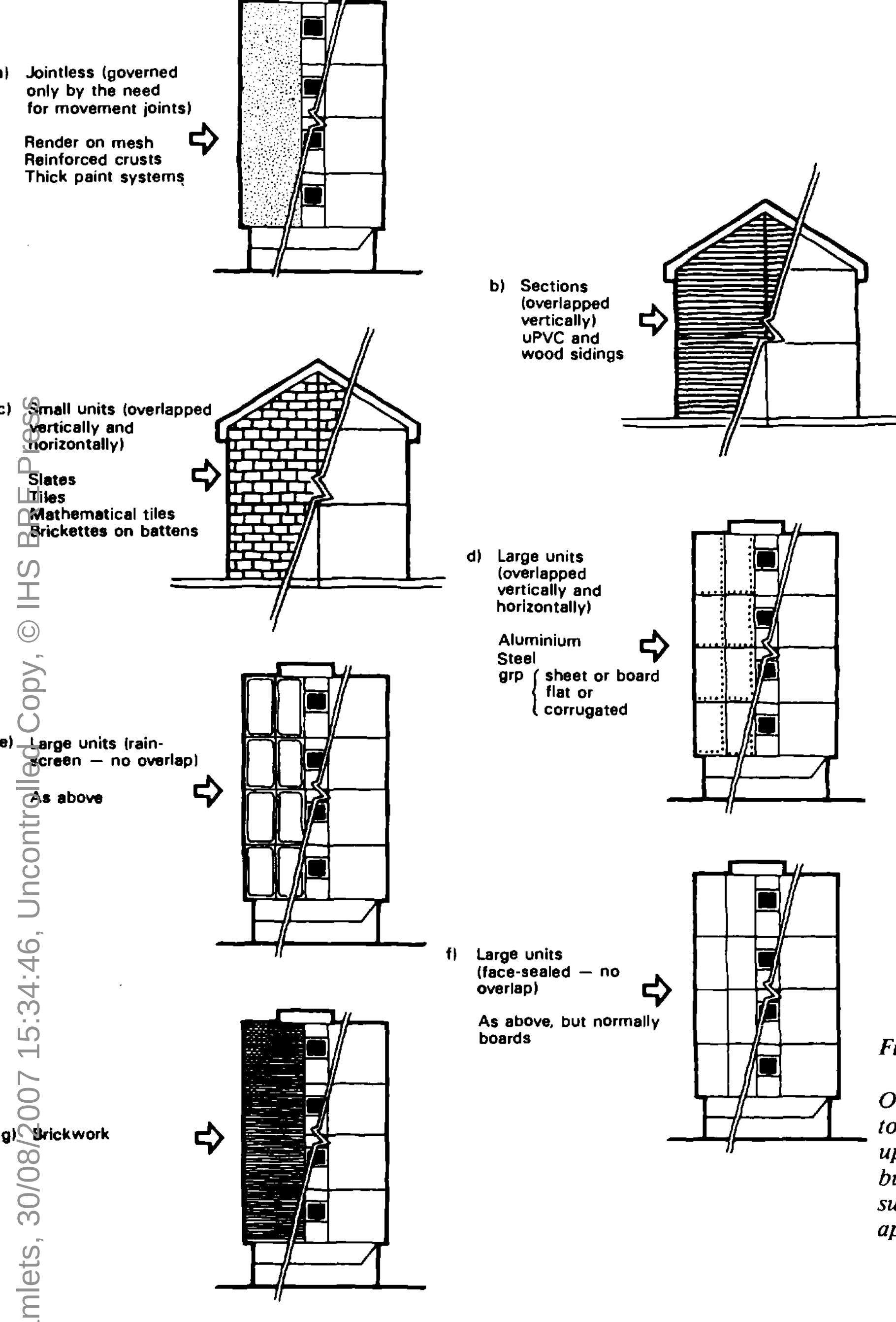
By 'cladding' we mean external vertical or near-vertical non-loadbearing covering to a structure.

By 'overcladding' we mean a completely new skin applied to the external walls of low- or high-rise dwellings of, in the present context, large panel construction (Figure 1). Overcladding may, and usually does, include additional thermal insulation over the outside of existing walls, but the primary aim is to provide a durable weathertight cover protecting the existing structure. Windows may or may not be included in the overcladding, and the overcladding may extend to the whole of the external walls, to particular elevations, or to parts of elevations as appropriate. Illustrations of overcladding are given in Figures 2 to 6.

The stock

In England and Wales there are 117 local authorities known to possess high-rise blocks of flats in large panel construction[2], and some have many of them, Sheffield for example. In Scotland there are 24 local authorities possessing high-rise blocks; Glasgow alone has 60 such blocks.

Of the 700 or so high-rise blocks (five storeys and over), and the 1000 or so low-rise blocks in large panel construction which have been identified and listed by Reeves[2], the proportion which has been renovated or overclad is unknown, but it is likely to



Amd 3
Note that vulnerable cladding as shown in (b) & (c) is not suitable in public access areas.

Figure 1 Generic types of overcladding

Overcladding is a completely new skin applied to the whole or part of the external walls, to upgrade the performance of the original building. While most cladding materials are suitable, care is needed in their choice and application

be small, judging from the difficulties faced by the research team in identifying examples to include as case studies. Examples are usually concentrated in a few authorities; for example Glasgow, Sandwell and Newham. In some authorities, some such dwellings are earmarked for demolition, largely on social grounds, or cost and suitability of repair, or have already been demolished. Nevertheless, of the 140 000 dwellings which were originally authorised for construction, a considerable proportion remain, and many of these are potential candidates for overcladding treatment.

Some 30 or more different large panel systems were used[2], not all of which are equally suitable for the full range of measures described in this report. Whenever possible, attention is drawn to features of systems which might inhibit the range of choice of solutions and techniques, although the major distinction is between low rise and high rise.

Interviews with local authorities

Before the study it was suggested to us that many authorities were actively engaged in, or were contemplating, the overcladding of their LPS buildings. We had hoped to collect this experience, and include it in this report, either as individual case studies or more generally. We have found it difficult to identify these authorities. Using the returns to the Department of the Environment on ownership of dwellings of non-traditional construction, we approached those authorities with large stocks of LPS dwellings, seeking information on their practices, and it is largely this information which has been drawn upon in producing this report.

Figure 2 Derelict Tracoba block at Sandwell

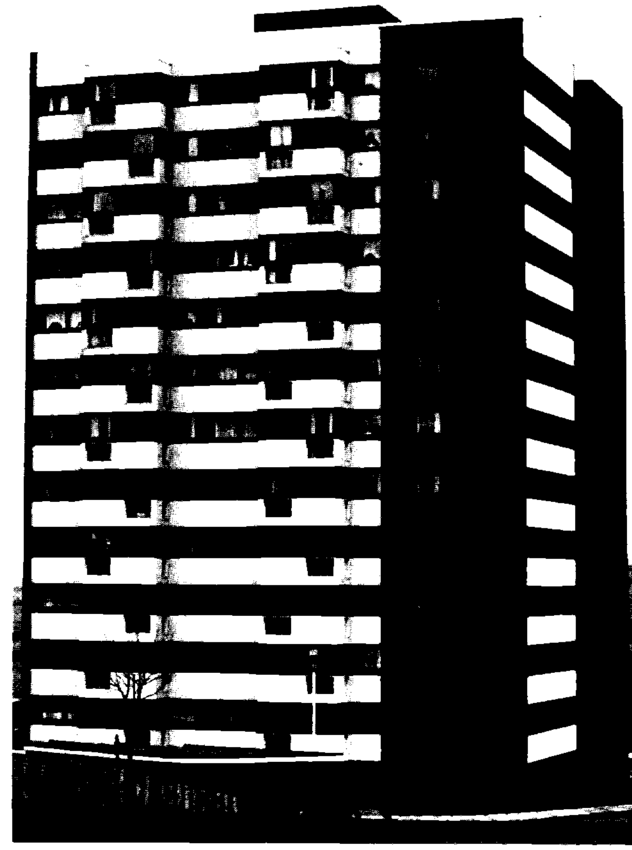


Figure 3 Block at Gateshead clad in aluminium and brick

Figure 4 Rendering over thermal insulation at Gateshead

*Structural deficiencies, rain penetration, condensation, deteriorating concrete and poorly insulated external walls are the main problems associated with large panel system dwellings. Options for the buildings' future range from full repair and modernisation to demolition. Some **(Figure 2)** stand derelict awaiting a decision and financial resources. Others have been fully or partially overclad **(Figures 3 and 4)** in attempts to solve particular problems*

Figure 5 Stenni panels on Smiths houses at Sandwell

*Not all LPS dwellings are high rise. Smiths houses have been fully overclad and externally insulated to improve their thermal insulation and appearance **(Figure 5)**. Overcladding has also been used to prevent further deterioration of the gable end walls of non-LPS dwellings **(Figure 6)***

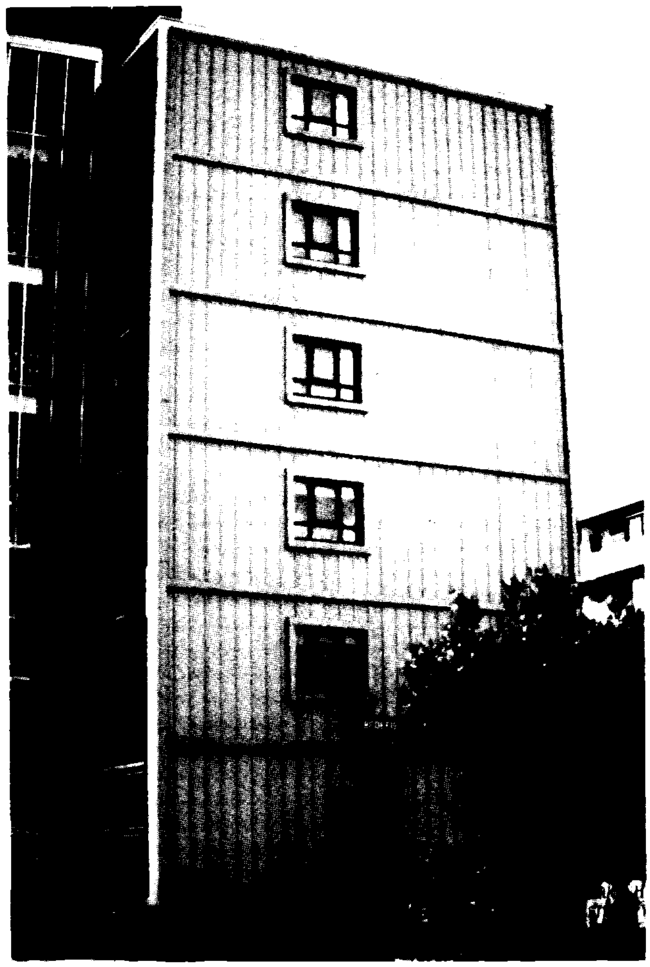


Figure 6 Partial overcladding on gable ends at Camden

Authorities who hold large stocks and were approached include:

Major owners in England and Wales
Barking and Dagenham, Birmingham, Bradford, Brent, Gateshead, Greenwich, Hillingdon, Hounslow, Islington, Lewisham, Manchester, Nottingham, Oldham, Salford, Solihull, South Tyneside, Tower Hamlets, Waltham Forest

Major owners in Scotland
Aberdeen, Dundee, Edinburgh, Glasgow

Other owners
Barnsley, Basildon, Bolsover, Chester, Chesterfield, Derby, Doncaster, Eastbourne, Enfield, Epping Forest, Kingston upon Hull, Knowsley, Leominster, New Forest, North Tyneside, Portsmouth, Warrington, Wirral

Of the 117 owners of LPS dwellings, we approached about half the total. We subsequently visited some of those with experience of overcladding to discuss their policies, problems and decisions. It soon became apparent that little actual overcladding of LPS buildings had been done and we had to widen the scope to overcladding on all types of housing. The response to the initial approach was:

Local authorities who had considered the option of overcladding: 28
Local authorities who had not: 32

In the group of authorities who had considered overcladding, the six situations shown in Table 1 had occurred.

Table 1 Numbers of authorities who considered overcladding

	LPS housing	Non-LPS housing
No of authorities with completed full or partial overcladding contracts	6	14
No of authorities who are considering overcladding or who have small-scale trials	2	2
No of authorities who have rejected overcladding	3	1

Note: These totals include double counting where an authority has both LPS and non-LPS

Subsequent discussions were held with most of the authorities referred to in Table 1.

In talks with local authority engineers and architects who have considered overcladding, it has been clear that the following range of options is current:

1 Ignore the fact that problems are occurring
2 Carry out essential repairs to make safe only
3 Carry out essential repairs plus some palliative renovation internally
4 Carry out essential repairs plus full internal renovation — heating, windows, etc
5 Carry out some measures to delay further deterioration externally (ie protective paint — there is some concern about this option; a paint system should ideally have a low resistance to water vapour diffusion but a high resistance to the diffusion of carbon dioxide)
6 Measures to increase life expectancy, eg by overcladding

or

7 Sell off to a private developer (who may form a housing association) in return for the ability to nominate a proportion of the future tenants
8 Decant tenants, secure site, and leave derelict
9 Demolish

Against these are the following considerations:

1 Extent of the problem
2 Financial resources
3 Technical resources
4 Effects of renovation — on tenant satisfaction
— on the building (both beneficial and adverse)
5 Local housing needs and pressures

Arguably the most important points are: is it certain that the causes of deterioration have been correctly identified, can satisfactory potential solutions be identified, (and can sufficient funds be expended to make a real impact on the problems)?

Reasons for choosing overcladding

This section reviews those aspects of performance which have been quoted by others as reasons for choosing overcladding.

Inadequate weathertightness of external envelope

Surveys carried out by BRE as well as the review[2] of consultants' reports on the condition of LPS dwellings provide some evidence of rain penetration through the panels, joints or windows of the external envelope, although this is by no means universal. Rain penetration is much more prevalent through face-sealed joints, and through traditional components, such as windows, doors and prefabricated infill panels (as well as through flat roofs).

When rain penetration through panel joints does occur, however, its source can be particularly troublesome to diagnose, as the water can percolate down through the many cavities in the external envelope before appearing on the inside of the building, perhaps some distance from the point or points of entry. Water trapped within the existing external envelope can cause serious damage to the fabric of the building, causing steel reinforcement to rust as well as saturating insulation and hence degrading its thermal properties.

There are normally two basic kinds of joints in the external envelope of LPS dwellings: two-stage (or open-drained) joints, and one-stage (or face-sealed) joints. Both kinds have been found to be repairable in the majority of cases[3,4], though some have given rise to problems. Whilst, therefore, overcladding is potentially an effective way of weatherproofing a facade, nevertheless, it will rarely be justified for that reason alone. Remedial measures applied to the joints have nearly always been found to be a cheaper solution, but even correct repairs may have limited life. Where rain penetration is a particular problem, it may thus be a question of whether it is more acceptable to effect one costly recladding, or several not-so-costly repair jobs. It would appear to be the presumed certainty of a permanent repair that is the major attraction to overcladding, but it is by no means universal experience that it will provide a certain cure.

Deterioration of concrete and external finishes

Many of the problems relating to LPS housing concern cracking, spalling concrete, and falling surface finishes (Figure 7). Overcladding has been considered as one means of providing protection against falling masonry. Some of the reasons for these defects are inherent in the design, manufacture and construction of the building, and can be exacerbated by weathering. In the past, remedial advice to owners has been very variable in quality, and even, on occasion, irresponsible. One authority reported that they were advised at one time that overcladding would, by excluding the weather, allow the carbonated concrete to revert back to normal and that reinforcing steels would recover their shiny as-new surface!

In many LPS buildings the concrete has spalled in some degree, following corrosion of the steel reinforcing bars. Such corrosion is usually brought about by the concrete losing its alkalinity over a period of time, by the process known as 'carbonation'. Exclusion of moisture by overcladding can be expected to reduce – though not to eliminate – corrosion of the steel in carbonated concrete.

The recent BRE report[5] *Carbonation depths in structural-quality concrete* examined carbonation in concrete of significantly different qualities by relating it to different methods of concrete production: prestressed precast, normally reinforced precast, and in-situ concrete. As might be expected, the 'higher-quality' concrete produced the lowest level and spread of carbonation. Further analysis produced figures for the average permeability constant K (a measure of carbonation depth and time) in relation to methods of production, making it possible to indicate the expected time when the mean depth of carbonation would reach a level at which loss of protection to a significant proportion of the reinforcement was likely to occur. For the concretes in the BRE sample, the mean value for K was 2.2 mm/$\sqrt{}$year, giving on average 80 years of protection to reinforcement with

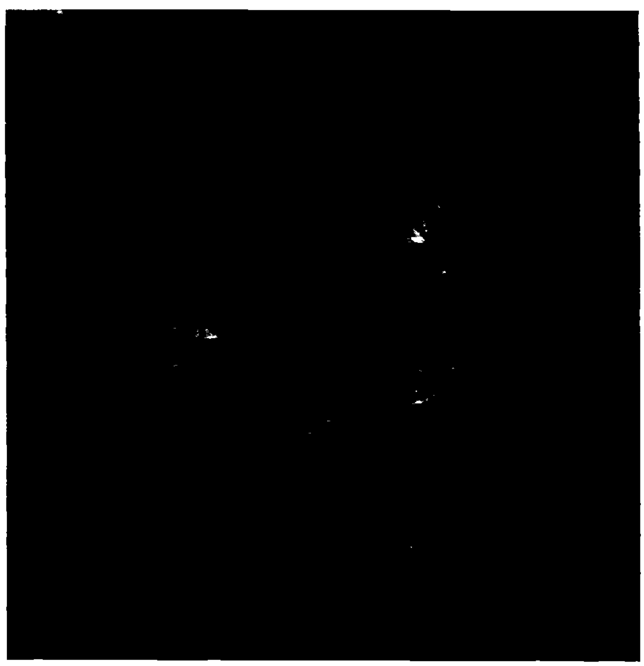


Figure 7 Corrosion of reinforcement causes cracking, spalling and falling surface finishes. Overcladding has been considered as one means of providing protection against falling masonry

20 mm of good-quality concrete cover. About 75% of normally reinforced precast concrete had an average *K* value below 2.2, and a substantial proportion of in-situ concrete had an average value in excess of 2.2, ie a quarter of the concrete used in LPS component manufacture, and much of the in-situ concrete cast around tie bars and fixings will have less than 80 years of protection in similar circumstances.

Corrosion may be accelerated by the presence of chlorides and may even proceed, albeit at reduced rates, where chlorides are present in relatively dry carbonated concrete.

Significant corrosion of reinforcing steel is usually first indicated by staining or marking, and then subsequent spalling of the concrete cover. Although the concrete can be cut out and a repair effected, the long-term durability of such repairs is unproved, and the prospect of an increased incidence of spalling, with increasing carbonation over time, may be seen as supporting the case for overcladding to exclude continued ingress of moisture to the original concrete cladding. In addition, following repair, any patch will usually show, and overcladding has been adopted by some owners as a means of masking unsightly repairs. When blocks have been strengthened to meet the DOE criteria on resistance to explosions, overcladding can also mask strengthening bolts and plates.

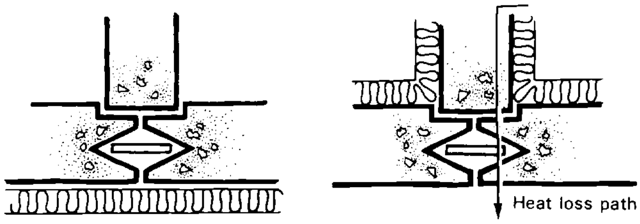
Improving thermal insulation

Addition of extra thermal insulation is often included in refurbishing contracts, and the opportunity to do so may be seen as favouring the adoption of overcladding as a remedy. The treatment of thermal insulation given in this report is not exhaustive and a more thorough treatment is given by Southern[1].

Many large panel systems were designed and constructed before the 1973 fuel price increases, and by today's standards may have unacceptable levels of thermal insulation.

There are two options available for upgrading thermal insulation levels in the walls of LPS construction – applying insulation to the inside or to the outside. Where there is a sound and weatherproof structure, or where the relatively simple replacement of weather seals in panel joints would ensure weathertightness, internal insulation may be achieved relatively simply and economically compared with external insulation and overcladding – a figure of 20% of the cost of overcladding including disruption payments to tenants has been reported. However, it is rarely possible to provide for a satisfactory elimination of cold bridges at junctions of the external wall with internal walls and floors (Figure 8).

Insulating the outside of the building enables the insulation to cover all such potential cold bridges (Figure 8(a)). It is expected that such insulation would be protected by overcladding.



a) Insulation on the outside of a building

b) Insulation on the inside of a building

Figure 8 *The addition of extra thermal insulation is often seen as favouring the adoption of overcladding. However, in some circumstances, applying insulation on the inside of the external wall may prove simpler or more economic, but it is rarely possible to eliminate cold bridges at junctions of the external wall with internal walls and floors*

Even with enhanced insulation, the risk of condensation within the dwelling will in any case remain in poorly heated dwellings; it may increase further if ventilation rates are reduced as a consequence of sealing gaps. The risk will again increase if new airtight windows and other energy conservation measures are employed. In addition, the introduction of a large amount of extra external thermal insulation may give a risk of interstitial condensation within the concrete structure, but this risk can be avoided by appropriate design.

Improving appearance

Many LPS buildings have not behaved as their designers had intended from the point of view of weathering. Uneven dirt deposition and stains along unpredicted routes for rain-water run-off (Figure 9)

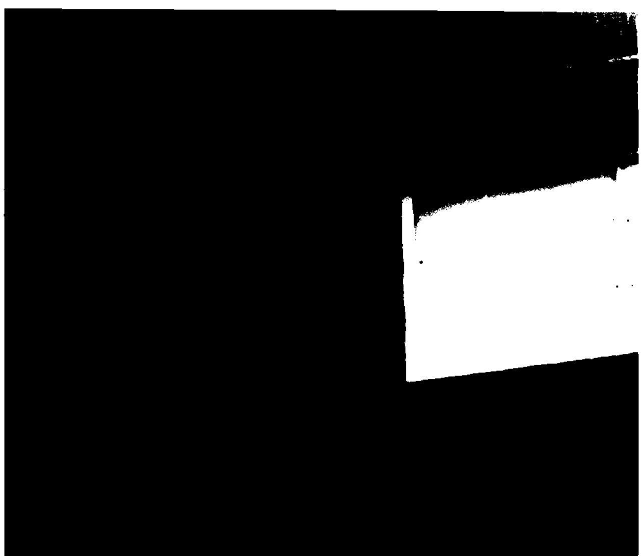


Figure 9 *Many LPS dwellings have weathered badly and have a drab appearance. This has helped to make some estates unattractive to occupants and difficult to let*

can mar appearance, and this too has been seen as an additional reason for overcladding.

In summary

Overcladding is seen as a means of restoring adequate technical performance to LPS dwellings, whilst at the same time improving their appearance and hence acceptability to occupants. When coupled with other measures in the field of housing management (landscaping, limited demolition, controlled access, etc) there is no doubt that it can provide both a visual and technical transformation for those estates which have become difficult to let.

Condition of the structure

Structural survey

Before any decision can be taken on the range of solutions which can be considered, it is essential to assess the condition of the building; in particular:

(a) Ascertain the type, extent and causes of the deterioration
(b) Make an accurate record of the present state of the building, to assess its present state, to predict its future state, and to compile a dossier to be used to monitor future performance
(c) Develop a prognosis

It should be understood that there is no easy way of ascertaining points (a) to (c) above. The causes of many building defects are notoriously difficult to establish, and a very thorough examination of the building is necessary.

There are two main problems:

(a) Is the structure safe? (and will it remain safe for a determinable period?)
(b) Is the structure strong enough to carry any or all of the proposed range of options, including overcladding?

The surveys should therefore give an idea of remaining life of the building in its present state, even if no change in the system is to be made.

A preliminary survey can be carried out by means of powerful binoculars, but this will not be sufficient to reveal the condition of hidden parts and the condition of the concrete in depth. A recent procedure, permitting closer inspection, is offered by some consultants who employ trained engineers who abseil down the face of the building. We understand that current costs are about £2000 for a 15-storey block. The visual inspection should be accompanied by spot checks of chloride content and carbonation. It is not sufficient to rely on typical values occurring in other examples of the system, since deterioration proceeds at varying rates.

Information together with photographs such as those relating to size and position of cracks, etc, should be carefully stored for future reference (eg Figure 10).

Irrespective of the particular solution to be adopted for the building, it will be necessary to obtain an accurate survey of the condition of the whole of the existing external walling, particularly identifying the existence and condition of the fixings, whether any exposed aggregate or other surface finish is becoming detached, whether any corrosion of reinforcement and consequential spalling of the concrete surfaces has begun, and if the existing fixings are suitable to take the extra load of any extra materials, for example those in an overcladding system.

Of particular concern is whether the existing concrete panels will be strong enough to accept fixings for overcladding and will continue to do so for 30 years, and if so, of what kind. Some assessment will also need to be made of whether any proposed solution will actually introduce any side effects, such as condensation within the concrete panels – it is conceivable that some potential solutions might actually reduce remaining life.

Hidden problems

Experience with LPS buildings and other types of prefabricated buildings suggests that the fixing together of the components is the most difficult site operation and one which is most often inadequately performed. However, as the strength of the finished building relies on these fixings, their adequacy and condition are of great importance.

Where structural connections and steel reinforcement are hidden within the components and structure, their

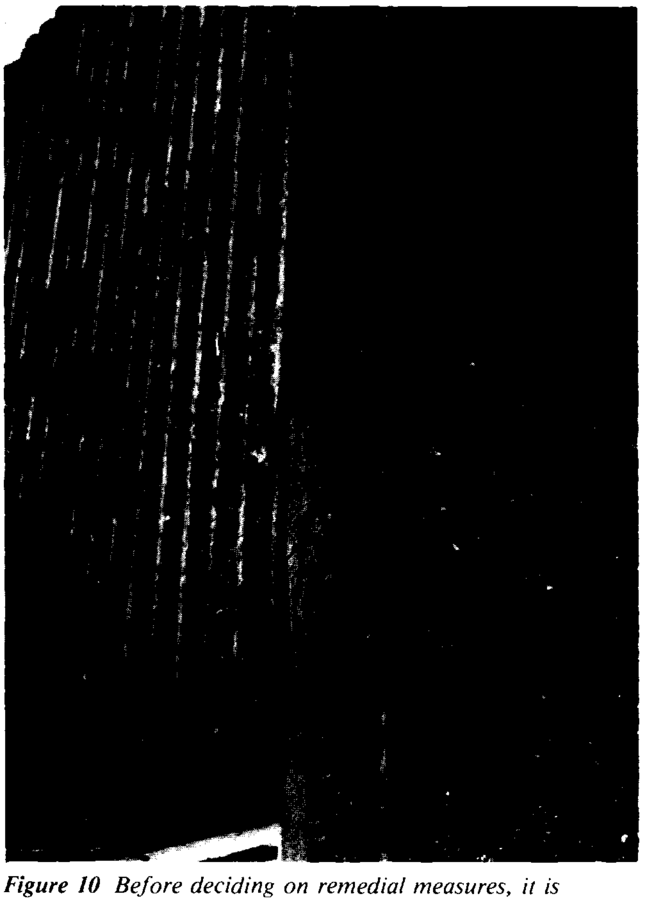


Figure 10 *Before deciding on remedial measures, it is essential to determine and record the condition of the building. Visual inspections and some testing are relatively easy. However, no non-destructive techniques are yet available to inspect hidden structural connections and reinforcement*

existence and condition will be virtually impossible to determine without elaborate measures such as the use of metal detectors and other scientific tools. Some small-scale testing of materials will be possible, but reference to published works on the condition of similar systems and the application of much 'engineering judgement' will be needed in order to reach a considered view on the present state of the building. A prognosis will be even more difficult, as information on rates of deterioration where carbonation and chlorides are present under varying conditions is lacking. No non-destructive technique is yet available which will allow detailed inspection of these hidden parts, and it may be many years before this is possible. Particular attention should be paid to panels that occur comparatively rarely in the construction: a damaged non-standard panel at the time of construction would have potentially held up construction rates and a substitute panel would have been needed urgently – additives may have been used to speed availability of a substitute, and some of these affect durability.

With respect to the detailed condition of the panels the following will need to be determined:

(a) Whether panels are loadbearing or non-loadbearing, and hence differ in the thickness of the concrete, thus affecting their ability to accept fixings for the overcladding
(b) Whether the panels can withstand any or all of the potential fixing methods for overcladding, and whether in turn their fixings can take the extra load of the overcladding
(c) Chloride content
(d) Rusting of reinforcement and spalling
(e) The extent of carbonation
(f) The accuracy of the existing building, in order to determine the extent of adjustability required in fixings and claddings. Alignment of panels and windows to determine if claddings are required in non-standard sizes
(g) Quality of the concrete and dry pack in the joints
(h) Presence of and condition of the ties between inner and outer leaves of sandwich panels
(i) Position and size of any cracks, and whether movement has stopped

The surfaces of the concrete should be examined particularly closely at exposed parapets and salient corners, or at junctions between different cladding materials, for these places are where the effects of movements are most apparent. Movements have proved to be rarely due to foundations – thermal and moisture movements will predominate. Inconsistencies in the surface finish, cracks, spalling, staining, looseness and misalignment should be particularly noted.

Rusty streaks caused by iron-bearing aggregates should not be mistaken for corrosion of reinforcement or fixings, since the latter is usually accompanied by cracking.

Where fixings are accessible, a check should be made to see that none is missing or insecure. BRE have found concrete panels which could be moved under hand pressure. Where fixings are not generally accessible, it may be possible to inspect one or two samples at a particular point, eg a parapet coping which can be lifted. If corrosion of such sample fixings is evident, a general inspection will be advisable.

There will be a need to check that any levelling nuts have been backed off and that dry pack is adequate.

If access to the majority of the external walls is not possible, then it will be necessary to allow large contingencies within the contract sum until the building is scaffolded as part of the rehabilitation contract, and access becomes possible. Some overcladding contracts have included a further thorough inspection at this stage.

Although the original specifications may be available, it is most unwise to assume that all was built as intended.

Who inspects?
The inspection should be carried out by competent professionals, ie those with experience of the conditions which might be encountered and the ability to make accurate diagnoses in all respects, for example to be able to distinguish for certain between water penetration, plumbing leaks and condensation stains. It is unlikely that all the necessary expertise will be found in one individual.

Inspecting occupied buildings
It will normally be necessary to gain access to one or more dwellings within the block in order to ascertain the extent of any deterioration of the cladding. A full inspection cannot usually be carried out in occupied dwellings, so that access to a number of unoccupied dwellings with the possibility of some opening-up is highly desirable. It should be noted that access through windows is not always possible, though opening lights may provide useful access for limited local external examination of walls as part of the preliminary inspection. With purpose-made equipment that can be arranged to clamp to the walls at reveals, it may be possible to take samples by drilling the external wall; generally, however, sampling by drilling or coring can be done only by using some form of rigid platform and rarely from an unanchored cradle. A cover meter, the sensor head of which is usually light in weight, may be used with an extension arm via window openings. Wherever possible, the depth of cover found to reinforcement should be compared with the depth of carbonation to obtain an estimate of the future risk of corrosion to reinforcement, and on which to base decisions on the use of applied films intended to reduce further access of carbon dioxide. If carbonation depth is greater than or equal to cover depth, then there is no point in trying to exclude carbon dioxide. (Note also the risk of introducing a

vapour barrier in the wrong place if such films are used.)

• • • • • • •

It is at this point in the process of consideration of potential solutions that a decision in principle needs to be taken on whether overcladding is a viable option for the building. To inform that decision the effects that overcladding may have on the structure need to be taken into account.

Potential effects of overcladding on the structure

Assessment of potential adverse effects

The potential side-effects of overcladding should be examined. Inadvertent vapour barriers in the wrong place, giving rise to possible condensation risk, have been mentioned already, but there will be other side-effects. Damage may also be done to the panels while obtaining fixing points for overcladding, and possible damage to the overcladding may occur due to continued spalling or to loss of exposed aggregate or surface finish after completion of the overcladding.

Role of overcladding in prevention of further deterioration

A full examination of carbonation and other influences on the life of reinforced concrete panels is given in other BRE publications[6,7], to which reference should be made.

A 30-year residual life would be a reasonable expectation for moderately carbonated concrete with at least 20 mm cover to the reinforcement. On the other hand, if the concrete contains significant amounts of chlorides, the residual life will be shorter than 30 years.

The question needs to be addressed whether, if overcladding includes insulation, the warmer, and drier, environment of the concrete will adversely affect the rate of deterioration and, if so, whether this is to an unacceptable degree.

The rate of carbonation in dry concrete will be higher than that in wet concrete (because the latter is less permeable to carbon dioxide). Also, the rate will increase because of the higher temperature. This higher rate of carbonation clearly increases the risk of reinforcement corrosion; but the corrosion will only occur significantly in the presence of moisture, and this should be excluded by the overcladding. On balance, therefore, the corrosion risk should be reduced by overcladding, provided that the design minimises condensation within the concrete and genuinely excludes driving rain. However, if chlorides are present in the concrete, corrosion will continue in the protected carbonated concrete, so that overcladding in this situation cannot be relied upon to reduce deterioration.

In spite of taking all reasonable precautions to ensure longevity in the base structure, it may still be prudent to choose an overcladding system which allows access for inspection and monitoring. This would be done by removing single panels or sections of the overcladding at points on the facades where surveys have indicated some risks to the structure, or where fixings for overcladding may become stressed. It should be noted that certain overcladding techniques do not facilitate inspection, so that this requirement will limit the options available. It may be possible in some systems to allow for access from the inside. The frequency of inspections will need to be based on engineering judgement, and in this respect *BRE Digest* 217[8] would suggest intervals not exceeding every 3 years.

Necessary repairs prior to overcladding

Defects do not appear to be system-dependent, that is to say a wide range of defects can and does occur on all kinds of large panel systems (see Appendix A).

Before any overcladding is begun, all spalled concrete should be cut out and repaired[9]; there is certainly no advantage to be gained by painting the area with a bituminous paint system, since it forms a vapour barrier in the middle of the cladding system. It is not desirable to leave any spalled areas unrepaired on the assumption that the overcladding will safely retain spalling which is already in progress.

BRE Digests 263, 264 and 265 deal with the mechanisms of corrosion, diagnosis and assessment, and repair of reinforced concrete[9,10].

If overcladding is to be fixed into the outer leaf of sandwich panels, and if the ties between inner and outer leaves are deficient or, in part, absent (non-destructive testing methods are available which give some information), then it may be cost-effective to insert a complete set of new ties rather than to attempt piecemeal renewal. Care should however be taken not to use stiff ties which do not allow differential movement: their use may have the consequence of inadvertent cracking of the outer leaf and possible effects on overcladding fixings.

The bolt heads of any remedial treatment will need protection unless inherently corrosion-resistant materials are used, eg suitable stainless steels.

With overcladding systems of the rain-screen kind, joints in the original external concrete panel wall should be made airtight before any overcladding work is begun, unless the proposed solution automatically includes an airtight barrier in itself.

This would involve:

(a) the removal of the baffle and gunning fresh sealant into the backs of all joints, or as far as can be reached into the back of horizontal joints, making sure that the verticals and horizontals interconnect, or Amd 1

(b) sticking a new (could be self-adhesive) strip over the fronts of all vertical and horizontal joints, or

(c) injecting an expanding polyurethane foam into the joint to seal it.

How to choose the best kind of overcladding

Preliminary consideration of costs

It is assumed that the option of simple repair of the external wall has been ruled out, though it may be worth noting in passing that misguided attempts at repair are common following misunderstanding of the principles, eg of the design of two-stage open-drained joints. There is some indication, for example, that two-stage joints have sometimes been sealed on the outer face without renewing the air seal at the rear, thus leading to further rain penetration.

Before any decision on overcladding is taken, the following will need to be determined:

(a) The intended remaining life of the building (this is commonly taken to be not less than 30 years if extensive and expensive remedial work such as overcladding is to be done)
(b) The actual condition of the cladding and the consequent cost of structural repair to the cladding to achieve the remaining design life when overclad, ie whether the proposed measures can slow down the rate of deterioration sufficiently to enable (a) to be met
(c) The acceptable rate of return on the investment
(d) Whether the total cost of overcladding plus the outstanding debt exceeds the residual value of the building

On the other hand, overcladding will be less than the cost of completely new construction including land purchase: if it is a question of overcladding making the difference between usable and unusable dwellings, the decision may become one merely of when sufficient funds become available.

Questions to be considered

When considering particular overcladding options, several questions need to be addressed:

(a) What is the expected life of the structure if nothing is done?
(b) What is the expected life of the structure if only ad-hoc repairs are done as and when needed?
(c) Will the proposed overcladding system deal adequately with identified deficiencies?
(d) If a particular solution for the overcladding seems likely to be useful in principle, what are the practical problems in applying it?
(e) If the practical problems in applying it can be overcome, what practical problems might arise in service:
    i with the cladding itself
    ii with the structure, now that its environment is to be changed?
(f) If those practical problems also can be overcome, what performance, taking account of exposure, should be sought from the overcladding
(g) What are the consequences of those performance needs for the choice of materials for the overcladding?
(h) Are the proposals suitable for the type of building (eg high rise needs an 'engineered solution')?
(i) Upon what principles is the design based? How much experience of the system is there? If innovative, are tests needed? How does it measure up to BS 8200[11]?
(j) When all the above are solved, how does the expected life of the overcladding and structure, plus the maintenance of both, plus the overall cost-effectiveness of both, compare with the social needs for housing?
(k) What past experience of overcladding is there to take into account?
(l) In the absence of in-house expertise, who can be consulted about the design and likely performance?

Most of the overcladding systems, even those originating in the UK, are relatively expensive. Cheaper alternatives which provide an acceptable solution to the identified deficiencies should be exhaustively investigated before the decision is taken to overclad.

It should go without saying that the more complicated the elevations, windows, access balconies, pipes, etc, the greater the physical difficulties of fitting the overcladding and of making it weatherproof. This is why, for example, the side or end elevations of blocks appear in the case studies rather more frequently than the fronts and backs.

Balconies are so troublesome to overclad that they are probably best dealt with by full enclosure or elimination.

Generally speaking, non-prefabricated overcladding is probably more suitable for the more complicated shapes, but attention must be paid to the provision of movement joints.

Change in detailing between adjoining properties under different ownership

Many authorities have reported some difficulty in detailing constructional solutions between walls and roofs where properties are in different ownership, either in persuading the private owners to join the general refurbishing scheme (Figure 11) or in designing a satisfactory junction between dwellings where they will not (Figure 12).

Costs-in-use

As well as considering the capital cost of the overcladding, or of any other part of the building for that matter, the client should have regard to its costs-in-

Figure 11 Bison terrace at Hartlepool where all properties but one have the same owner

Many authorities have reported difficulties either in persuading private owners to join overcladding schemes or in detailing satisfactory constructional solutions where they refuse

***Figure 12** Detailing between adjoining properties with different owners*

use, in other words, total cost and performance. This involves thinking about the likely replacement rate for the item being considered, and how this relates to the remaining life of the building. In addition to the expected life, regard should be had to the expected cleaning, inspection and maintenance costs over the same period. In addition, the effect of different cladding types on heat loss or gain, and on energy use, should be considered on a comparative basis for the choice of solutions being considered.

A difficulty may arise owing to the absence of published cost and performance data on any particular cladding system, and it is recommended that as much information as possible is sought from manufacturers before specifications are drawn up.

The type of information sought should include the earliest date when replacement might be expected to be necessary, or the converse, the length of time before which replacement is extremely unlikely, together with frequency of maintenance and the skills required for this purpose. It may also be important to consider the extent to which replacement, when it is necessary, will have a disruptive effect on the building, and whether or not materials will match up after weathering.

Clearly, information will have to be sought on the sealants, joints and fixings as well as the insulation and panels, so that any particular overcladding system can be costed on a comparative basis with others.

As experience is gained by local authorities in the use of any particular cladding system, it will help them and colleagues in other authorities in future decisions to record the actual running costs once the rehabilitated building is in use, and to organise such recording in a way which can be related to procurement decisions on future schemes.

Technical advice and assessment

We have found it very difficult to identify the sources of knowledge on overcladding currently available to the industry, and there are many apparent gaps in that knowledge. Some of the larger manufacturers and materials suppliers have undisputed knowledge about their materials and their likely performance in cladding. However, they do seem to be very short of practical experience of overcladding, and rely heavily on experience from abroad, mainly Germany. Some systems seem to be deficient in technical back-up or are simply developments or adaptations of existing cladding systems.

Considering the potential size of the overcladding market, and the possible adverse effect on the structure which an inappropriate overcladding may have, more research is undoubtedly needed. To date we have found few UK consultants with any degree of involvement with overcladding.

There is a limited number of contracting firms with experience of installing overcladding, particularly of the rain-screen kind, and enquiries should be made of the source of expertise within the firm.

Some organisations other than housing authorities may well have considered or indeed completed overcladding projects, for example local health authorities (eg Figure 13). Their experience may be relevant.

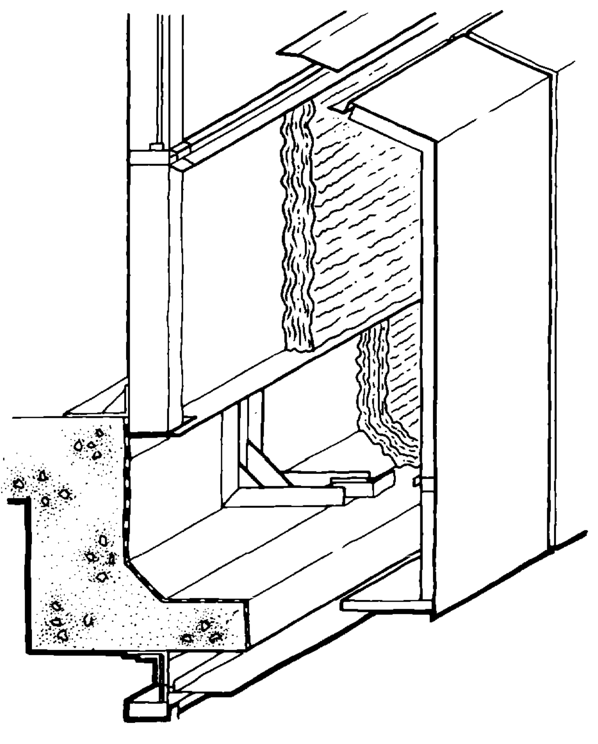


Figure 13 Overcladding in Health Service building (redrawn from Bickerdike Allen Partners' original)

There is a shortage of practical experience of overcladding in the UK and much of the overcladding knowledge and overcladding systems rely heavily on practices from abroad. Some organisations other than housing authorities have completed overcladding projects, for example local health authorities, and their experience may be relevant

Some developers have become involved in the housing renovation market, and recent reports suggest that they have renovated some system-built blocks, although BRE does not have any specific information on these.

Performance specifications

Whilst the use of a performance specification may be a reasonable way of finding out what is available, since it is very difficult to test overcladding systems realistically, the performance specification should not become part of the contract documentation. In the event of disputes arising, they will be almost impossible to resolve.

A case in point arises with the use of rain-screen cladding. A pressure box test of the BS 5368[12] kind, even with overpressure, will not give a useful indication of the raintightness of a rain-screen system. Only a test with droplets carried in an air stream will do so, but not necessarily to a standard which will give reproducible results.

Contract documentation should therefore be based on an explicit offer by a manufacturer and his designer for a specific design. This design, or a prototype, should be tested in advance.

Quality assurance

Quality assurance (QA) has applied for many years to a limited number of the very many products used in the construction industry. The BSI Kitemark scheme provided a third-party assurance that products complied with the relevant British Standard; Agrément Certificates dealt with products where there was no British Standard; some products such as ready-to-use concrete were covered by trade schemes. Recently, concern with the quality of British products led government to sponsor the adoption of QA by firms in general, and BS 5750[13] has been accepted as the master document which encapsulates the principles of QA. BS 5750 concerns itself with management of a firm, and it is now agreed that QA will operate best where a firm conforms not only to BS 5750, but also applies Kitemarking or some other certification to any specific products. With the introduction of BS 5750 as a general management systems document, the scope for QA in construction, and particularly in overcladding, seems to be considerable.

There are a few aspects of overcladding that are already subject to QA. They include coated metals, various kinds of insulation, concrete repair materials and renders, and anchors for fixing overcladding to structures. Agrément Certificates are available for competing products in most of these categories[14].

Aspects of overcladding which are not covered at all by QA at present include the basic ones of design, execution, and the performance of the system as a whole, rather than simply the durability of the finish.

Design of the system will obviously depend on the condition of the existing building: the potential contractors may be given a performance specification, and survey, design and execution could well be within one tenderer's organisation. Expertise gained from previous experience of overcladding should weigh heavily in selecting a firm to do the work, and this crucial need for experience is perhaps borne out by the relatively small number of firms who are prepared to tender for such work.

In a new area such as overcladding this creates problems for the development of adequate QA – how can fresh firms be evaluated as the work load increases? One can only suggest that the overall expertise and organisation of the firms with no previous experience of overcladding should be very carefully considered by independent and experienced consultants.

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From this point in this report it is now assumed that a decision in principle has been taken that overcladding is a viable option, and what remains is to determine the specific requirements and characteristics of the design.

Performance requirements of overcladding systems and how they may be realised

This section includes consideration of some of the main performance requirements for overcladding systems of various kinds, including renders and insulation covered with sheet and board materials, both with and without cavities. It also includes some consideration of open-jointed overcladding of the kind known as rain-screen.

Codes and Standards

The most relevant standard is BS 8200:1985[11], 'Code of practice for the design of non-loadbearing vertical enclosures of buildings'. This standard includes a check-list for design, and there is a more-or-less comprehensive discussion of performance requirements and design and production criteria, much of which is applicable to overcladding.

The list of contents is as follows:

Section one *General*
Introduction, Scope, Definition

Section two *Performance criteria*
General, Size and weight, Appearance, Strength – structural strength and stability, Strength – impact, Strength – explosive forces, Strength – fixings, Fire, Air permeability, Permeability to water vapour, Moisture content, Water absorption, Water penetration, Capillarity, Moisture movement, Effect of frost, Effect of weathering, Atmospheric pollution and chemical attack, Effect of biological attack, Thermal properties, Protection against solar radiation, Effect of changes in temperature, Effect of sunlight, Sound transmission, Junctions, Durability and design life, Safety and security

Section three *Design*
Design method, Choice of enclosure, Windows, Thermal moisture and structural movement, Control of water, Jointing and sealing including glazing, Control of heat, Condensation, Control of sound, Attachment, Access for maintenance

Section four *Production of components*
Tolerances on manufactured components, Handling points, Marking and packing

Section five *Site procedure*
Delivery and handling, Storage of prefabricated components, Erection sequence, Setting out, Fixings, Joints, Glazing, Temporary supports, Protection of work, Cleaning and adjusting

Section six *Inspection and maintenance*
Periodic inspection, Maintenance, Repair and replacement, Documentation

Appendices
Bibliography, Climate, Locality, Activity criteria, Noise criteria, Side effects of activities, Methods of test for impact resistance of opaque wall components, Design decisions

Other documents

Building Research Establishment
The *BRE Digests* most relevant to overcladding are:

119	The assessment of wind loads
217	Wall cladding defects and their diagnosis
223	Wall cladding: designing to minimise defects due to inaccuracies and movements
263	The durability of steel in concrete: Part 1. Mechanism of protection and corrosion
264	The durability of steel in concrete: Part 2. Diagnosis and assessment of corrosion-cracked concrete
265	The durability of steel in concrete: Part 3. The repair of reinforced concrete
227	Estimation of thermal and moisture movements and stresses: Part 1
228	Estimation of thermal and moisture movements and stresses: Part 2
229	Estimation of thermal and moisture movements and stresses: Part 3

BRE Information Paper IP6/81[7] will also be found to be useful.

Agrément
A considerable number of certificates from the British Board of Agrément relate to materials and techniques used in overcladding, and the current lists should be consulted. At the time of writing, certificates are available for complete overcladding systems of only the render type.

Strength and stability

Wind loads
The ability of the building as a whole to withstand wind loads will have been accounted for in the original structural design. The addition of overcladding, provided it does not substantially alter the external shape of the building, will not significantly alter the design wind loads, but these wind loads will now

be applied in part to the external skin of the overcladding. How this is done is still a matter for discussion between specialists, but the BRE view is that design external wind pressures should be determined using the provisions of the BSI Code of Practice for wind loading, CP 3:Chapter 5:Part 2[15]. Depending on the porosity of the overcladding, part of the external pressure may leak through to act directly on the building surface while the remainder will be transmitted through the fixings to the building (Figure 14). The distribution of the fixing loads will also depend on the volume of any void between the overcladding and the building, and on the position of cavity barriers in this void.

In assessing the wind loads the overcladding can be considered to be one of two categories:

1 Installations with a void or cavity between the overcladding and the building – usually panels fixed to the battens or a grid of cladding rails attached to the building

2 Installations with no void between the overcladding and the building – usually insulating panels bonded and/or mechanically fixed directly to the building surface, with an impermeable outer skin

Overcladding systems with void

There are three principal loading cases for overcladding systems with a void:

(a) Overcladding impermeable, voids vented to a known location

In this case the pressure in the void will equilibrate to the pressure at the void vent. If the void is vented to the inside of the building (unlikely), it will equilibrate to the internal pressure of the building, and the load on the overcladding will be the difference between the external applied wind pressure and the internal void pressure (equivalent to all the wind load previously taken directly by the building) and will be transmitted to the building through its fixings. If the void is vented to the outside of the building, then the void will equilibrate to the external wind pressure at the vent, so it is therefore important to know the location of these vents. Cavity barriers conveniently divide the void into manageable sections. Positioning vents in areas of high local suction, as defined in CP 3: Chapter V:Part 2[15], will result in the tendency for

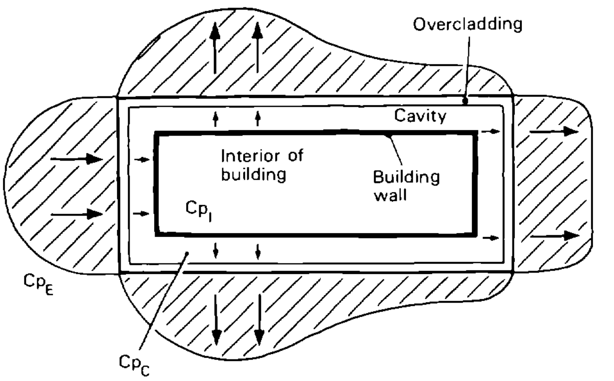


Figure 14 Wind conditions on overcladding

The design wind loads, which will have been accounted for in the original structural design, will now be applied in part to the external skin of the overcladding. Part of this pressure may leak through the overcladding (depending on its porosity) to act directly on the building surface, while the remainder will be transmitted through the fixings to the building

panels to be pressed against the building, reducing fixing loads; care should be taken to avoid excessive deflection at the centre of each panel and to ensure that the existing building structure is able to resist the high local loads when the void area is bigger than the local coefficient area on the previously unclad building.

(b) Overcladding moderately permeable, void large

In this case the pressure in the void will equilibrate to the average of the external pressure over the area of the overcladding, and the load on the overcladding will again be the difference between the external applied wind pressure and the internal void pressure. The smaller the area between cavity barriers, the smaller the cladding loads will be. Cladding loads are minimised when cavity barriers are placed to separate large changes in external pressure, ie at building corners (Figure 15). It is advised that the cladding loads should never be taken as less than one-third of the external pressure.

(c) Overcladding very permeable, void small

In this case the pressure in the void cannot equilibrate and there will be a significant flow through the void from regions of higher external pressure to regions of

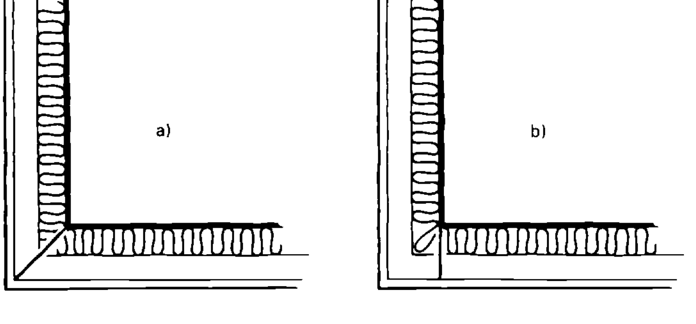


Figure 15 Closing cavities at a corner

When overcladding is moderately permeable the wind pressure cladding loads can be minimised by dividing the internal void area (the smaller the area the smaller the loads) by cavity barriers. Placing these at the building corners also separates large changes in external wind pressures lower external pressure. This sets up a gradient of pressure in the void, where the void pressure is always closer to the local external pressure than in case (b), relieving the overcladding loads further. (This mechanism also occurs with slating and tiling to BS 5534[16], and with loose-laid roof insulation and paving slabs as described in *BRE Digest* 295[17].) Again, it is advised that the cladding loads should never be taken as less than one-third of the external pressure.

Overcladding systems without void
Overcladding systems without a void are invariably nominally impermeable to resist rain penetration. The response of these systems depends on the permeability of the building surface onto which they are fixed.

(a) When the building surface is impermeable and the cladding/building joint is sealed, any deflection of the cladding will be resisted by the formation of a partial vacuum in the joint. (This is the mechanism that prevents failure of low tensile strength built-up bitumen-felt and lightweight asphalt roof coverings in regions of high uplift.)

(b) When the building surface is permeable, the vacuum mechanism cannot be relied on to restrain the cladding, which must be retained entirely by the adhesive bond and mechanical fixings. Most brick surfaces are quite permeable unless they have been treated with a penetrating sealant. Large panel systems may be impermeable in the middle of the panels, but permeable at the joints, unless the steps previously described are taken to make them airtight.

In many cases, the degree of permeability of the building surface is indeterminate and it is safest to assume that the overcladding must transmit the full wind loads through any adhesive bond and mechanical fixings. Bond and fixing strengths may be determined by testing small sections or, alternatively, by applying a proof suction load to the prototype panel using a test rig such as that described in *BRE Information Paper* IP19/84[18].

A further factor to consider will be local deformation of the surface of the overcladding under wind loads, which may alter the geometry of the joint. Certain kinds of overcladding joints, eg unfilled joints in rainscreen systems, are more tolerant of changes in joint geometry than are face-sealed systems, for example. BS 8200 suggests a limit depending on the material, in the range 1/90 to 1/500 span for deflections in opaque infill panels in secondary framing. It will be possible to calculate the effects on joints of differential movements on adjacent panels, and those responsible for the final detailed design should be asked for the necessary calculations.

Fatigue
Continual flexing of panels and fluctuating wind conditions can lead to fatigue and consequent cracking, particularly of sheet metals. There could also be loss of bond between the insulation and its substrate in composite sheets. This potential problem should be raised with suppliers, and a satisfactory assurance obtained. It is suggested that prototypes be subjected to a simulation test using a suitable suction device[18], and BRE have suggested the following regime:

No of cycles	Percentage of design load	
1	90	Applied 5 times
960	40	
60	60	
240	50	
5	80	
14	70	
1	100	

Fluctuations in external surface temperatures can lead to fatigue of material at the interface in metal-skinned sandwich or laminated panels used for cladding external walls. This has been known to cause local delamination which has adversely affected both appearance and durability. BRE tests have shown that it is possible to examine the risks of delamination[19].

Dead loads
The dead weight of overcladding systems will vary according to the design and the materials used, but even the apparently unsubstantial systems can be[20] as much as 50 kg/m^2.

Impacts
Although practical experience indicates that accidental impact damage to the cladding of high-rise buildings is infrequent, the possibility of vandalism must be foreseen on the lower storeys, and also in low-rise buildings: the major source of damage otherwise seems likely to be from access cradles.

The stability and integrity of the whole wall under impact is normally assessed by two types of impact test, 'soft body' and 'hard body'. The former measures the ability to withstand a heavy blow from a large impactor, and examines the possibility that parts of the wall could fall and cause injury to people. Although damage is permitted to occur under test, no part of the cladding should become dislodged. In tall buildings such impacts are most likely to occur from access cradles (Figure 16) and firemen's ladders externally.

Table 4 of BS 8200 gives impact energies of 500 Nm up to 1.5 metres above access, and 350 Nm above that height where access is required for cleaning. There is no requirement for soft body impacts above 1.5 metres if access is not required (Figure 17).

A 'hard body' (steel ball) impact of 10 Nm is also required for the whole surface of the overcladding, with the same criterion that nothing should fall off the building. In practice it is usual for overcladding specifications to call for two different solutions, one for the ground floor (or floor at which access is available) and one above that, with respect to the impact test requirements.

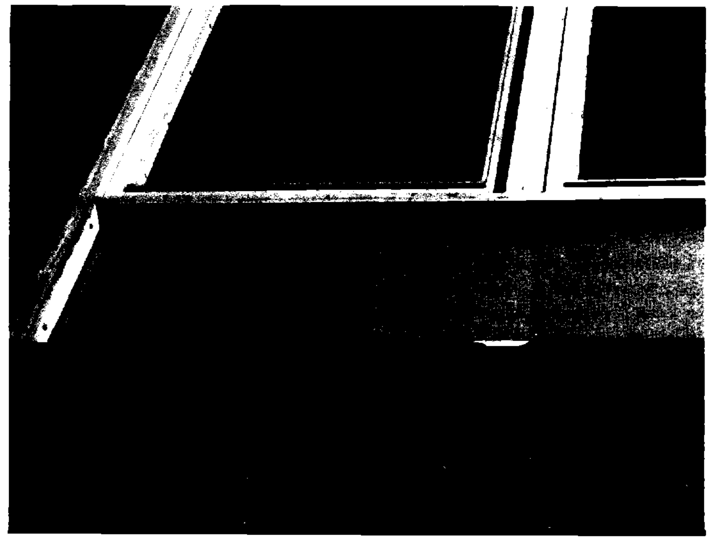
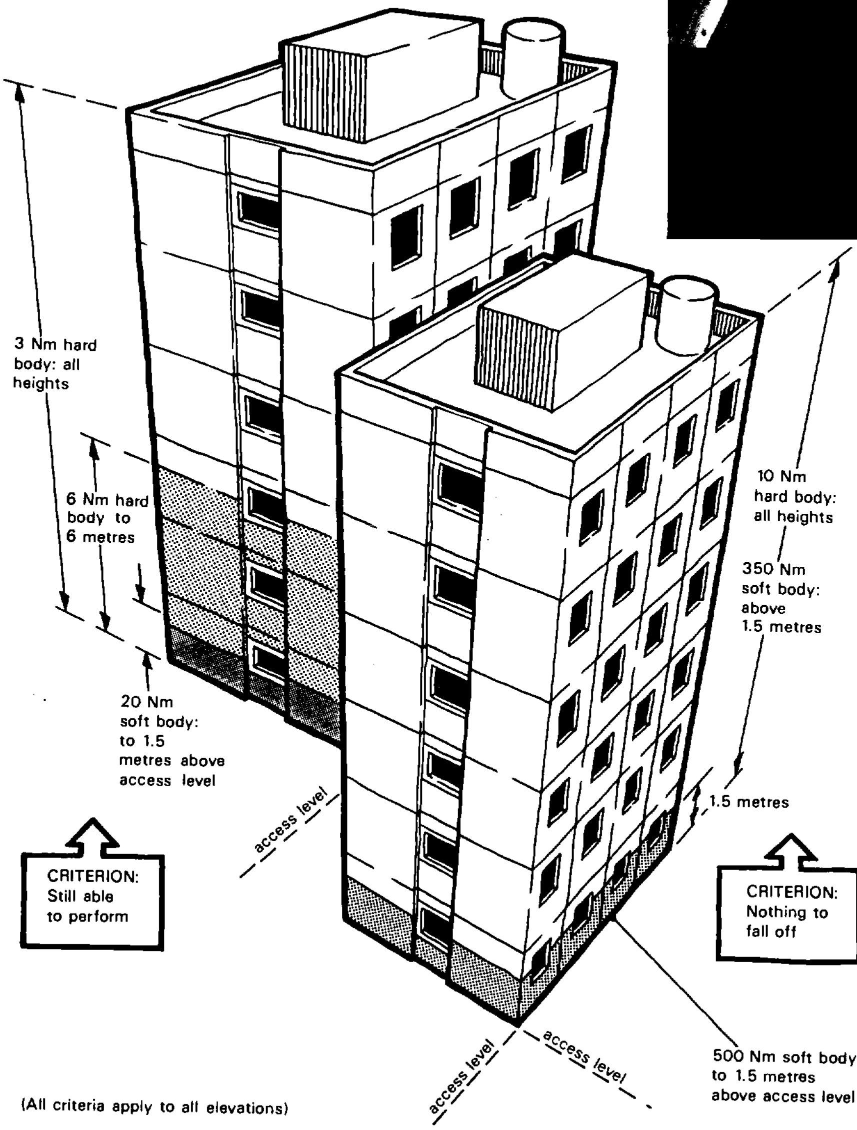


Figure 16 Impact damage from a cradle



Experience indicates that accidental impact damage to overcladding is infrequent, but wilful damage and graffiti are likely on low storeys adjacent to public rights of way. However in tall buildings, impact damage is more likely to be caused from access equipment

Figure 17 *Impact performance criteria*

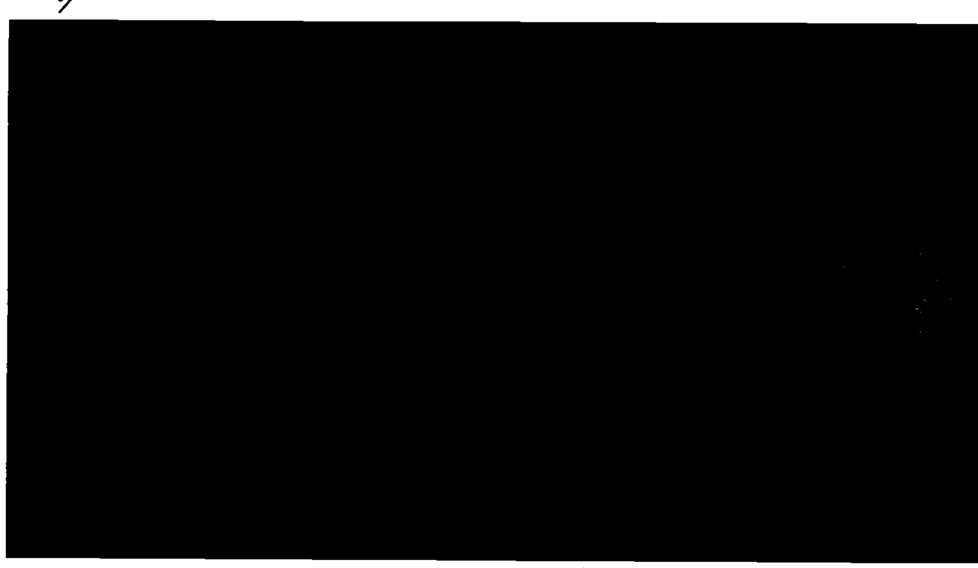


Figure 18 *Vandalised sheet cladding below public access*

The same two impact tests, though at different energy levels, are used to determine whether or not the overcladding will perform its functions after attack – a smaller soft body and a further hard body (a steel ball).

A small soft body impact of 120 Nm is used up to 1.5 metres height only to simulate impact damage, eg from footballs.

A hard body impact of 6 Nm is used up to heights of 6 metres above pedestrian access level, and 3 Nm above that height. The overcladding should still be able to perform its function.

The level of impacts on overcladding at which damage becomes visually unacceptable is far less than that at which the overcladding ceases in other respects to perform acceptably. Although tests are specified, judgement will need to be used on whether the level of performance achieved is acceptable. In particular, the building owner or his agent must judge whether any damage, eg a dent under test, which does not impair technical performance, would be visually acceptable.

It should be noted that some lightweight claddings which have been used in the past will not pass the hard-body impact test[21] and in practice will suffer damage where poor social conditions exist in the estates. It may, for example, seem unreasonable to demand impact resistance to the impact of cross-bow bolts or axes (Figure 18).

Type and condition of base structure

There are over 30 different systems of large panel dwellings, and the range of structures which may need to be overclad is wide, ranging from exposed-aggregate loadbearing concrete sandwich panels in which the outer leaf may be relatively thin, to timber-framed infill non-loadbearing panels, and conventional brick cladding. The range of finishes which might be encountered include self-finished ribbed concrete, exposed aggregate, mosaic tiles, tile hanging and timber boarding. Each particular example will have its own limitations on what can be supported and where, and it is therefore not possible to give universally applicable rules.

In some buildings the outer leaf of the sandwich panel is removed prior to overcladding. It should be remembered also that not all buildings are conveniently shaped – projecting balconies, irregular plans and other obstacles to straightforward application of the cladding are common. (See also Appendix A.)

If the original cladding is non-loadbearing, lightweight, or in poor condition, it will usually be necessary to insert a full grillage of mullions and sometimes transomes to transmit live and dead loads from the overcladding back to the loadbearing (and sound) structure.

Weathertightness

Driving rain

Rain-water leakage through the joints of large concrete panels seems to have been a major factor in prompting the consideration of overcladding. (It is often also the case that repair or refurbishment of the original design to restore raintightness has been tried and has failed, or has been rejected because of other benefits of overcladding.)

It is customary in the UK to predict the amount of rain-water driven onto the faces of a building by means of computed values given in reference 22. Although this is a broad guide to the overall rain-water load, it does not enable accurate assessments to be made of the short-term actual water load on individual joints in the building, since this is a product of the building's own size and shape and surface irregularities and gust distribution during particular rain-storms. BRE observations[23] show that rain-water can be driven upwards in a fast-flowing air stream to impinge on surfaces which are sheltered from above.

Run-off and disposal

Depending on the porosity of any wall, and the existing degree of its saturation, rain-water will be absorbed until the wall becomes saturated and run-off begins. But, it does not follow that all the water runs down in contact with the facade. BRE observations[24] show that even on smooth unbroken surfaces, water flow is not cumulative. Much bounces or splashes off, to be carried away in the air stream and, depending on the geometry of the surface, usually falls as a curtain of large drops some 300 – 600 mm away from the facade.

Overcladding a relatively absorbent LPS building with a relatively unabsorbent skin is certain therefore to change the run-off characteristics of the buildings, so that, for example, an entrance which did not need a canopy before may need one afterwards. Winds tend to drive run-off sideways across the facades of buildings, and in consequence the water load on vertical joints is not necessarily any lower than that on horizontal joints (Figure 19(a)). Vertical ribbing of the surface will to some extent divert sideways flow (Figure 19(b)), but this cannot be quantified.

Water flows will therefore be concentrated at vertical ribs, where the run-off rate can be many times the average. Because of this, where there is a choice, it is preferable not to specify vertical joints in re-entrant corners (Figure 19(c)) unless there are nearby vertical ribs to deflect sideways flow downwards.

Horizontal projections at regular intervals over the height of the building will also help to throw water clear of the facade, and will in consequence reduce water load on horizontal joints (Figure 19(d)).

Water load on joints

Rain-water drops carried in the air stream will enter

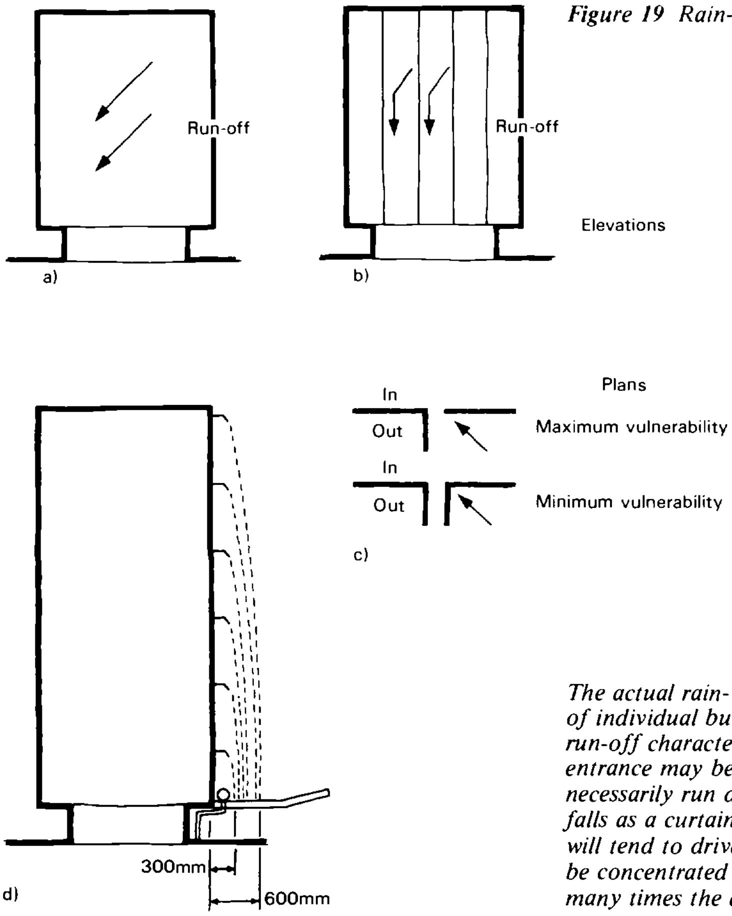


Figure 19 Rain-water run-off

The actual rain-water load on a building is a product of individual buildings. Overcladding may change the run-off characteristics so that a new canopy over an entrance may be needed. The water does not necessarily run down in contact with the facade, much falls as a curtain some 300 to 600 mm away. The wind will tend to drive run-off sideways. Water flows may be concentrated at vertical ribs, increasing run-off to many times the average

the front of vertical joints in direct proportion to the open area of the joint. However, since most flows will be at an angle to the surface of the building (Figure 20), it follows that the depth of the joint, together with the topography of the sides, will directly influence the amount of water reaching the back. This is why, in concrete-panel open-drained joints, if the air seal remains intact, most of the water never even reaches the baffle. The greater the depth of the joint faces, therefore, the lower the water load on the interior of the joint. When considering any open-joint design for overcladding systems therefore, select those with returned edges (Figure 19(c)), other things being equal. Sharp angles are better than rounded for encouraging water to flow down rather than across, but a minimum radius of 2 mm should normally be required as very sharp angles encourage thinning of applied finishes, with reduced durability.

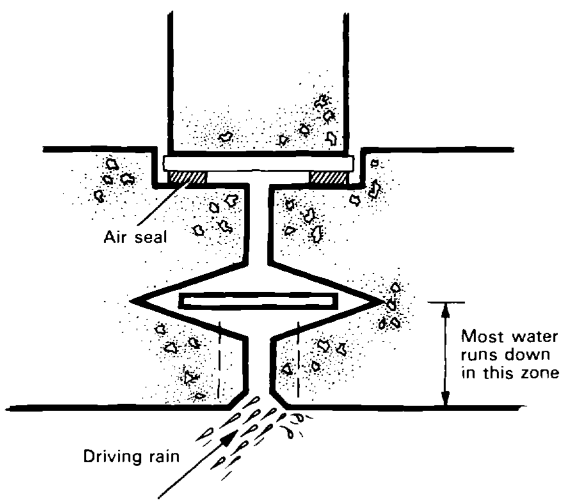


Figure 20 *Provided the air seal remains intact in concrete panel open-drained joints, most of the rain-water never reaches the baffle. Also, the deeper the joint faces, the lower the water load on the interior of the joint. Open joints in overcladding should have returned edges*

Rain-screen overcladding

There is much to be said in favour of the rain-screen cavity-wall principle for overcladding LPS buildings. This principle deals with rain penetration in two separate stages. The first stage is for an air-permeable screen to catch the droplets and to direct run-off. Then, provided there is no, or virtually no, air pressure difference between the two sides of the rain-screen, there is no energy available to drive the droplets across the cavity (Figure 21), and the inner wall remains dry. The second, and crucial, stage is therefore the positioning of a complete air seal at the back of the cavity, which remains dry. CIRIA are preparing a design guide which is due to be published in 1987[25].

The design of a satisfactory rain-screen enclosure is not easy, since it is normally crucial to obtain very high control of accuracy in assembly and particularly over joint widths. Once correctly designed and installed however, there is less worry over the accom-

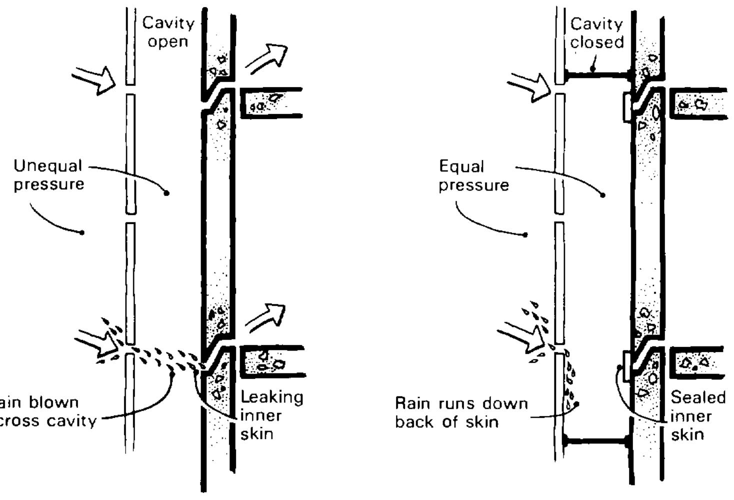


Figure 21 Rain-screen principle

A rain-screen is an open-jointed screen spaced away from an inner wall. There must be a complete air seal at the back of this cavity. The rain-screen catches the droplets, and because the cavity is open there is virtually no energy available to drive the droplets across it

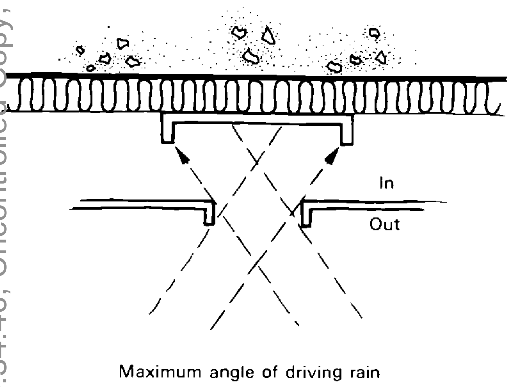


Figure 22 Vertical catchment tray

Rain-screen cladding must be correctly designed and installed but has several advantages in service. Joint widths need accurate control and it is prudent to install catchment trays behind all joints

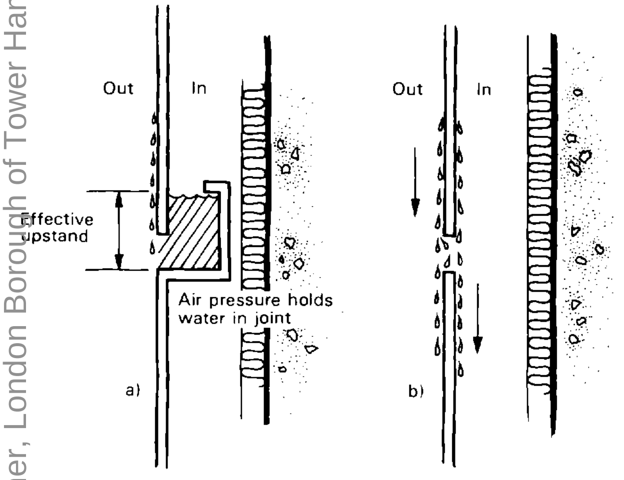


Figure 23 Alternative horizontal joints

Overlapped joints in rain-screen cladding should be large enough not to fill with water. Water can and will run down the back of some designs, wetting the fixings, the panel damping or the underlying insulation

modation of movements and durability of jointing products than would be the case with single-stage or face-sealed joints.

The width of joints must be accurately controlled to tight tolerances, especially where catchment trays are dispensed with. It is for this reason that catchment trays are more often than not included at the rear of both vertical and horizontal joints. The widths of these trays are directly related to the width of the joints (Figure 22), and BRE measurements[26] give a basis for determining the dimensions of trays. It may be possible to combine the tray with the vertical members of the support system. Lapped horizontal joints will need to be provided with sufficient upstand such that they are not likely to fill with water (Figure 23(a)). It is also important that vertical joints do not fill with water, especially at the foot of tall buildings which have continuous vertical joints, since there is a risk that it will overflow inwards instead of outwards, as a result of blocking the ventilation slots.

It is also important to appreciate that water can and will run down the back of some designs of rain-screen panels and any stiffening or damping applied to the back of the panel will get wet. This will also affect fixings on the back of the panel (Figure 23(b)) and, depending on the design, the underlying insulation.

With rain-screen-type claddings it will not be possible entirely to prevent the odd splash of rain-water crossing the cavity or escaping the catchment tray, though in principle the aim is to keep the crucial air seals dry. It will be advisable therefore to arrange for any applied insulation to be water resistant or covered by a breather membrane, and these droplets can then evaporate safely away over a period of time. This is also beneficial where condensation is caused by clear-night-sky radiation on metal claddings.

Since wind action on a rain-screen-clad building will produce both positive and negative pressures acting at opposing extremes of cavities (Figure 24), it is necessary to restrict the size of such cavities near to exter-

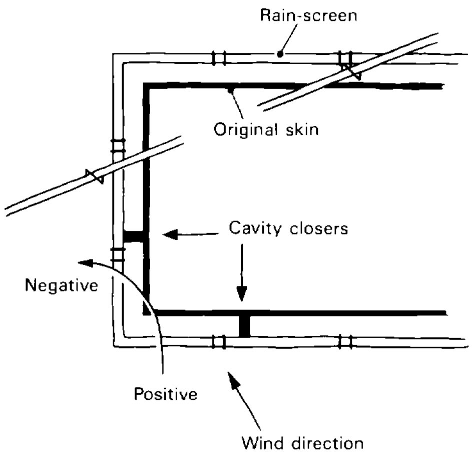


Figure 24 Restricting the extent of cavities

Wind action on a rain-screen-clad building will produce both negative and positive pressures acting sometimes at opposing extremes of cavities. It is necessary to restrict the size of such cavities near to external corners

nal corners. No absolute limit can be given from experimental evidence, but it has been customary to specify a figure of around 1.5 metres. It was noted above that from the point of view of minimising wind loads it is better to close the cavity at the corner. It is a good idea too to limit the extent of cavities within plane facades, and BS 8200 suggests a maximum value of 5 metres. (BRE has some indication that this is too great a value – within reason the smaller the better.)

Face-sealed overcladding
If the chosen insulation is not water resistant, and if there are other reasons why a rain-screen is not feasible, then a face-sealed system of cladding may be necessary, and the jointing products used in them, eg sealants and gaskets, will be subject to movements, etc, which will need to be accommodated. There are exacting raintightness requirements for such joints; they need to be virtually perfect. Rain-water will be drawn in by capillary action if any gap is less than a millimetre or so, and any gap above that will have water pumped through it by differential air pressure.

It may become necessary to provide cavity trays and weep pipes within cladding of this kind to allow rain-water penetrating the facade to escape without percolating to the interior of the building.

Thermal insulation

The Building Regulations[27] currently set a maximum *U*-value for external walls of 0.6 W/m^2K. Although there is no requirement to achieve this value in rehabilitation work, there are good reasons for aiming to achieve at least equivalent performance. Firstly, poor thermal insulation can lead to serious condensation problems and care should be taken to avoid even localised areas of wall with high *U*-values. For this reason, the Scottish Building Standards[28] (Part J) specify that no part of a wall, roof or floor should have a *U*-value in excess of 1.2. Secondly, the overall level of thermal insulation has an important effect on the type of heating system which can be used satisfactorily. Some constructions will preclude the use of individual gas-fired appliances and leave electric heating as the only option with a low capital cost. In such cases it is important that the level of thermal insulation be such that the tenant can afford to heat the dwelling to a reasonable standard, including bedrooms in flats. Electric storage systems have also been found to be best suited to well insulated dwellings which tend to cool down slowly and thereby assist the storage capability of the storage radiators themselves. Electric heating will, therefore, demand high levels of insulation, and cost-effective analysis may show that levels in excess of those required by the Building Regulations are both economic and feasible in some cases[29]. In practical terms, the regulation *U*-value of 0.6 can be achieved in most LPS dwellings by the addition of 25 to 50 mm of insulation.

Thermal improvement can be undertaken by either internal or external insulation. The cost of internal insulation is independent of the cost of overcladding: external insulation on the other hand is economically attractive if overcladding is being undertaken and consequently should always be considered as part of any overcladding process. In most cases of overcladding, the thermal insulation will be fixed to the outside of the original concrete panels. This is one of the easiest ways of reducing cold bridges at cross walls and floors (Figure 8).

In certain circumstances it may be considered that the panels need to be inspected from the outside during the lifetime of the cladding. In this case overcladding and insulation should be easily removable and replaceable.

External insulation implies that the structure itself will be warmer and that the risk of interstitial condensation within the walling structure is reduced.

In developing an overcladding system, consideration must be given to assessing the risk and effect of interstitial condensation. In this respect it is useful to divide external insulation systems into four categories:

1. Permeable insulation with permeable finish
2. Permeable insulation with impermeable finish
3. Impermeable insulation with permeable finish
4. Impermeable insulation with impermeable finish

With permeable insulation and permeable finish, the principle to be adopted to control interstitial condensation is that the construction should allow any water vapour to migrate to the outside of the building. It is important to ensure that where permeable finishes are installed, subsequent maintenance does not involve any operation which is likely to make the outer skin impermeable.

Where the insulation is permeable and the cladding is impermeable, eg Figure 25, there is a need to provide a ventilated cavity immediately behind the outer cladding. British Standard BS 8200 recommends a minimum cavity width of 10 mm. However, experience indicates that this is unlikely to be sufficient in systems where there is a risk of the cavity being blocked (Figure 26). Ventilation openings should be provided preferably positioned at not less than storey-height intervals. Particular care should be taken to ventilate behind large metal sheets, and there is a case for limiting their size to not more than two storeys. Particular attention should also be paid to ensuring that cavities between cavity barriers are ventilated. On no account should an impermeable finish with an unventilated cavity be specified. (See section on fire barriers.)

Figure 25 Permeable insulation behind impermeable cladding

Where the insulation is permeable and the cladding is impermeable there is a need to provide a ventilated cavity immediately behind the outer cladding

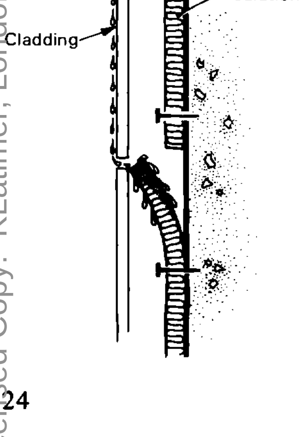


Figure 26 Displacement of insulation, or other causes, may block narrow cavities. Ventilation openings should be provided, preferably at not less than storey-high intervals. Particular care should be taken to ventilate behind large metal sheets and between cavity barriers

Particular problems may arise when impermeable insulants are used irrespective of whether the cladding is permeable or not. In order to assess the risk of harmful condensation it is recommended that a calculation as outlined in BS 5250[30] is undertaken. Even with an impermeable insulant the cavity behind any impermeable finish should be ventilated.

With some internal insulation systems the incorporation of a vapour control layer is sometimes recommended. This report is concerned with the cladding systems and only external thermal insulation systems are discussed. In these types of system there is no need to incorporate a vapour check layer and the guidance outlined above, if followed, should be adequate to prevent serious difficulties. It is important, however, that no vapour barrier, or similar sealing, is applied to the outer face of the LPS panels. Any air sealing should be confined to the existing joints.

Noise

It is assumed that there will be no additional requirement for sound insulation over and above what the building already provides. Most proposed overcladding solutions will give virtually no increased benefit in reduced sound transmission because of their low mass.

However, unwanted noise from the overcladding itself may be a possibility, and some attempt should be made to assess the risk before construction whenever possible. It should be pointed out that noise is often heard, but rarely complained about.

Drumming and whistling

Hail and heavy rain will drum on relatively thin sheet materials, especially of metal, and some damping may be necessary. In at least one case it has proved to be a nuisance to occupants. This phenomenon occurs also with sheet metal roofs – but in the case of overcladding, the existing concrete panels will provide some sound insulation protection to occupants. Roofs have also been known to hum for long periods at low frequencies, but the risk of this in cladding is unknown. Provided some damping is included, or alternatively deep profiling of the panels which gives sufficient stiffness, the risk of disturbance to occupants is probably low.

Whistling or moaning of wind in ventilation slots is also a possibility, though this has not been reported to occur in the applications studied. It is almost impossible to identify either risk or necessary precautions at the design stage, although testing a prototype in a wind tunnel may be useful.

'Stick – slip'
When relatively large, thin panels are subjected to solar heating they will expand rapidly. If these panels are fixed by means of cleats such that the movements will take place over metal to metal surfaces, such expansion can result in the type of intermittent movement known as 'stick – slip'. Stresses at a fixing build up until there is a sudden slippage, accompanied by a loud report. Where this risk is identified the fixing should incorporate a coated surface (eg of plastics). Where this does occur it is known to be a great nuisance, and it is virtually impossible to trace the areas that give trouble.

'Tin-canning' or 'oil-canning'
Another phenomenon which might possibly occur with relatively thin metal sheets, especially those having returned edges, is known as 'tin-canning' or 'oil-canning'. This is where the centre of a panel expands or contracts more rapidly than the perimeter and a loud report results. Damping the back of the panel will reduce this possibility, as also will stiffening, eg by ribs or by profiling the surface. There is no known easy way of assessing the risk, other than by careful examination of prototypes.

Fire

The performance of overcladding in fire is difficult to predict, since many of the usual criteria (eg the fire resistance test in BS 476:Part 8[31] do not apply. It should be said however, that the probability of fire in the overcladding or affecting the overcladding is low. There is generally no risk when non-combustible materials are used for insulation or overcladding except where the existing structure of the building being overclad poses a risk.

The risks depend mainly on combustibility of materials used in insulation or overcladding, and hence spread of fire in the overcladding itself. There is an obvious risk of spread on the outer surface, which is already limited in high-rise dwellings under the Building Regulations, but a small risk also exists for fire propagation within any cavity containing combustible insulation, for example with polyisocyanurate foam or polystyrene (Figure 27).

Combustible insulation and no cavity
Experience of real fires is limited, but laboratory tests on multi-storey rigs have been carried out[32] to assess the fire performance of systems incorporating combustible insulants fixed directly to the masonry wall and to compare these with that of timber cladding, at present acceptable on low-rise buildings. From the tests it is possible to make the following general points:

- Untreated timber overcladding should be restricted to low-rise buildings.

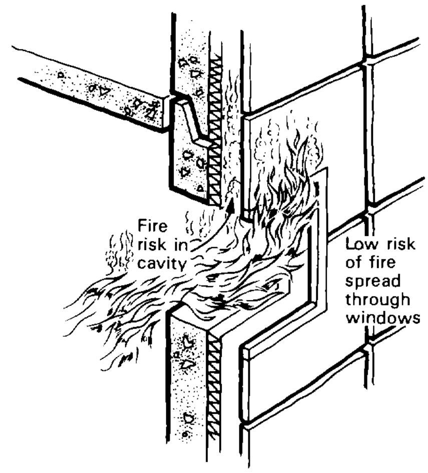


Figure 27 Performance in fire

The probability of fire in or affecting the overcladding is low. The risks depend mainly on combustibility of materials used in insulation or overcladding. Fire spread on the outer surface is already limited in high-rise dwellings under the Building Regulations, but a small risk also exists for fire propagation within any cavity containing combustible insulation

- 25 mm of metal-reinforced cementitious render provides effective protection to combustible insulation. The reinforcement should be independently supported.

- Glass-fibre-reinforced thin renders perform reasonably well over non-combustible insulation, but offer little protection to combustible insulants.

  Polymeric insulants protected only by unreinforced thin resin coatings should not be used where there is any risk of direct flame attack.

There will be some risk in fire of parts of the overcladding becoming detached and falling to the ground, particularly where plastics fixings play a significant role. Metal fixings are less likely to lose their integrity in fire. At the time of writing, further BRE tests are in progress, and they will be reported in due course; until further evidence is available, at least a proportion of metal fixings should be included.

Overcladding systems of this type do not appear to cause an exposure risk to adjoining buildings, and there is little risk of fire which is affecting overcladding entering the building through window openings. Provision of cavity barriers is nevertheless recommended (see section on cavity barriers below) to avoid extensive damage to the insulation.

A fuller report on the tests will be published in due course.

Combustible insulation and ventilated cavity
There is a need to ventilate the cavity of some overcladding systems (see the earlier section on thermal insulation).

Recent tests have indicated that a risk of vertical flame spread may be associated with certain metal overcladding systems which incorporate combustible insulation, fixed adjacent to a ventilated cavity behind the metal cladding. Further tests are being carried out and advice will be issued on modifications which may be required to these systems; meanwhile designers of such systems for high-rise blocks are urged to seek advice from BRE (Mr J Southern).

Boundaries
The Building Regulations criterion of Class 0 surface spread of flame must be observed for buildings at the site boundary.

Cavity barriers
Where combustible insulation is exposed within a ventilated cavity, horizontal cavity barriers are recommended in all buildings above three storeys in height, at least at every other storey, to fill the cavity completely. (In rain-screen designs, cavity closure will be needed in any case to limit the size of cavity for weathertightness reasons.) Where there is no cavity as such, but where combustible materials are used for insulation purposes, it is advisable to interrupt the sheets with a cavity barrier as proposed above, particularly where the insulation is thermoplastic (eg polystyrene) (Figure 28). Cavity barriers are not required for systems where there is no cavity as such and non-combustible materials are used for insulation purposes.

Lightning protection
Overcladding will upset the existing arrangements for lightning protection, especially where metal suspension systems and/or sheet metal claddings are proposed. Guidance can be obtained from BS 6651:1985, 'Code of practice for the protection of structures against lightning'[33]. In existing buildings, only those already with lightning conductors will generally need conductors after overcladding.

The existing conductors can be covered with overcladding systems which are composed of incombustible elements. One problem with this approach is that the continuity of the conductor is not easily checked visually after the overcladding has been applied.

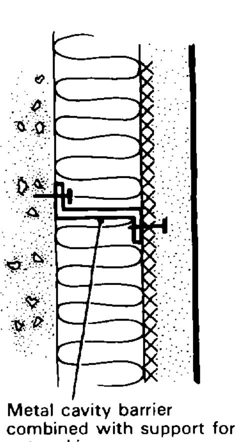


Figure 28 Where there is no cavity as such, but where combustible insulation materials are used, it is advisable to interrupt the sheets with a cavity barrier

New conductors over the cladding have to be firmly fixed, and should preferably be of aluminium rather than copper, as the latter tends to stain the surface and accelerate the corrosion of other metal components. Large areas of metal in systems may become charged, either by forming part of the conductor path, or from contact with the conductor. Neither of these situations will cause problems if the cladding is electrically bonded to the conductor. The most important areas to connect are at the top and bottom of the building, and effort should be made to bond the cladding and the conductors electrically at these levels. Render stop-beads wired to metal lathing, and metal flashings fixed with metal fastenings, should also be bonded to the conductors. Electrical contact to thin metals and meshes can be improved by increasing the area of contact with clamp plates or welded connectors.

The specification of lightning protection should be left to experts.

Durability

Tolerance of movement
All buildings move to a greater or lesser extent in service. Large panel buildings are no exception, and this movement needs to be taken into account when designing overcladding. The original uncovered concrete panels, if they were light coloured, would have been expected to move approximately 3 mm total range per 3 metres of panel height or width. If they were dark coloured, the movements would have been slightly greater, of the order of 4 mm.

When concrete panels are insulated and overclad, movements will be significantly reduced, and it will be possible to estimate the expected range of movements given the method of overcladding proposed. Depending on the method of fixing the original concrete panels, the reduced movements on two adjacent panels could, however, still both occur at the common joint, and for overcladding design purposes this should be assumed to occur (Figure 29).

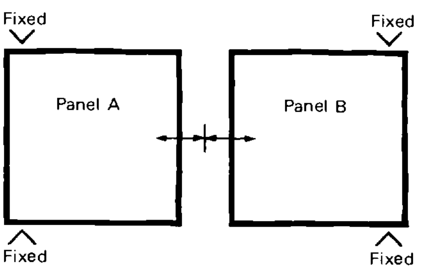


Figure 29 Movement of original panels at a common joint

Even though insulation and overcladding will significantly reduce the amount of movement expected in the original concrete panels, movement could occur on two panels at a common joint. It should be assumed that this will happen and allowance should be made in the overcladding design

Fire spread with overcladding on multi-storey buildings

A risk of increased vertical fire spread has been identified during the laboratory testing of overcladding systems incorporating combustible insulants. Sheeted systems usually have designed or fortuitous cavities behind the cladding. Where the cladding is sheet aluminium, laboratory tests have shown that a fire within the cavity can melt the aluminium and burn through to the surface several storeys above the fire. These emergent flames could re-enter the block via windows.

Fires of such severity are rare. Multi-storey blocks have been clad for 10 years with systems which have a potential for fire spread within cavities but no fires leading to excessive vertical spread have been reported. However, it is advised that both existing and proposed overcladding systems should be examined to determine if modifications are required as a precaution against fire spread.

Local authorities will wish to consider the application of building regulations to cladding systems. However, the Department's minimum recommendations for existing and proposed sheeted overcladding systems are as follows.

Completed sheet overcladding systems Add 1

(a) *Aluminium, combustible insulant*
Fit fire barriers every two storeys.

(b) *Steel or non-combustible sheet, combustible insulant*
Fit fire barriers if a suitable opportunity arises.

Proposed sheet overcladding systems
Specify either non-combustible insulants or fire barriers every two storeys.

Proposed non-sheeted systems
With other types of external cladding, fire spread is likely to be very small. However, where a non-sheeted system is proposed, recommendations to reduce fire spread are as follows.

(a) *Rendered metal lathing, thermoplastic insulant*
Specify sufficient metal fasteners to stabilise the cladding, and fire barriers every two storeys.

(b) *Rendered metal lathing, thermosetting insulant*
Specify sufficient metal fixings to stabilise the cladding.

(c) *Glass-fabric-reinforced thin renders, thermoplastic insulant*
Specify fire barriers,which also support the cladding,every storey.

Although movement in the concrete panels will be reduced, there will be movements in the overcladding which need to be taken into account.

Required life

Thirty years is the normal expectation for the residual life of rehabilitated dwellings as a whole. BS 8200 requires all panels and secondary framing to have a durability equal to the life of the building. In practice not all parts of the system can be expected to achieve that figure, even for rehabilitated housing, but especial care must be taken to ensure adequate life for any components which are difficult to inspect and critical to safety. In practice, similar items will fail at different times, and durability of the separate parts of buildings and the consequent need for replacement therefore needs to be considered. Although it will not be possible to assess with any degree of certainty the likely durability of parts of an overcladding system, some effort should be made to define an expected residual life for the dwellings and the expected life for the whole of, or for any particular part of, the overcladding, given appropriate maintenance or replacement, and to attempt some kind of a match between the two. Lack of real data on service lives actually achieved precludes more than approximate calculations.

Agents of degradation

Whether any particular agent of degradation will affect the life of overcladding depends for the most part on what materials are used, and in what combination, and where the building is situated. For example, whilst stainless steel fixings would be satisfactory for aluminium cladding for most circumstances in most rural and urban locations, their use together in a marine climate demands care. There is therefore no real prospect of building up a satisfactory performance specification unless these kinds of conditional factors are taken into account.

Pollution

Marine conditions have been noted above as being particularly aggressive, and these special circumstances should be assessed separately. However, as a brief guide, it is unwise to use anodised or mill finish aluminium in a marine atmosphere. If used at all it should be coated. Type 316 stainless steel is very durable, but with types 302 and 304 stainless steels in marine conditions care is required in design to prevent crevice corrosion. But whatever the location, it is as well to be aware of local industrial pollution sources. The lee side of a building is the most susceptible, and there should be as few ledges as possible to harbour dust and run-off ponds.

Temperature

Extremes of temperature affect materials used in overcladding panels when stresses due to expansion are restricted by, for example, fixings. When the panels are free to move, any materials contained within joints are subject to stress. There may also be an effect directly on exposed jointing or edging components and materials.

Overcladding systems are usually of low mass, and placed on the outside of thermal insulation, and hence will respond comparatively rapidly to solar radiation. The maximum and minimum temperatures reached will also be slightly more extreme than those reached with high-mass claddings.

Two main points need to be remembered during the design process: surface temperatures can be substantially higher (and lower) than air temperatures, and surface temperatures (for any given orientation) will depend on colour. The darker the colour, the higher the temperature. The rule therefore for maximum durability, other things being equal, is the lighter the colour the longer the life. This should not be taken to extremes, however, since the glare from a light-coloured surface, especially on a tall building, on a sunny day can be disabling and a nuisance, and lighter colours may also suffer more from soiling. Also in some circumstances, specular (mirror-like) surfaces can pose a hazard to traffic by reflecting the sun. A suitable compromise would be reflectances in the range 40 – 65% (approximate Munsell values 7 – 8.5)[34]. Surface temperatures of up to 72°C have been measured by BRE on sandwich or steel panels, and they could go up to 80°C. However, *BRE Digest* 228[35] indicates the values to be taken for calculation of movements as typically −25° to +60°C (range of 85°C) for lighter-coloured low-mass materials tight to thermal insulation, and −25° to +50°C (range 75°C) for similar freestanding panels.

The reflectance value of the surface of a high-rise building may significantly affect the amount of daylight reaching adjoining buildings.

Changes of colour

This phenomenon may prove impossible to control in advance by performance specification, and needs to be assessed in conjunction with suppliers. Ultra-violet radiation is a factor, for example, in the degradation of plastics, which may give rise to colour changes, and these have been noted in BRE site inspections of overcladding. Colour changes have been especially marked in the case of some glass-reinforced polyester (grp) examples. Specialist advice should be sought.

Corrosion

The long-term performance of metallic components will be dictated to a large extent by their resistance to corrosion. Bimetallic corrosion of metals should be guarded against, both in fixings, and between fixings and claddings if the latter are of metal. Contact between two metals does not necessarily cause corrosion, but the wrong combination of metals under particular conditions (including the presence of moisture) will accelerate the corrosion of the less noble. Guidance is available in reference 36.

Metals should be selected for their compatibility with other materials as well as with other metals, and for their inherent resistance to corrosion. From a corrosion point of view, metals perform best in a clean, dry environment. Whilst it is never possible in overcladding to achieve these ideal conditions, the design of overcladding should be such as to prevent, as far as possible, the lodgement of dirt, dust and moisture on the surface. This, in general, means the avoidance of horizontal or near-horizontal surfaces. Whilst it is not possible to avoid surfaces getting both wet and dirty, designs should be free-draining to reduce time of wetness. Ideally, overcladding should be washed regularly (say at least every six months). Since this is unlikely to be achieved in practice, the design should make maximum use of the rain to wash the surface.

Metallic cladding materials

Ferrous materials are in themselves insufficiently durable for use externally, and require additional corrosion protection. This additional protection can either be in the form of a metallic coating, eg zinc, or an organic coating, eg PVC, or a combination of both (a duplex coating). The life of ferrous metals is directly related to their protective coatings.

The most common metallic coating is zinc, although other hot-dipped coatings, eg of aluminium zinc alloys, and aluminium, are available.

The life of zinc coatings is proportional to the thickness of the zinc and the environment to which it is exposed (see *BRE Digest* 305[37]). The thickness of the zinc coating required to give protection depends upon many factors, but generally overcladding sheeting is formed from pregalvanised sheet; this method of manufacture generally restricts the total zinc coating weight to not less than 275 g/m^2 including both sides. This thickness is unlikely to provide adequate protection on its own, and further protection in the form of an organic coating, eg epoxy, will be required.

One type of ferrous metal which can be used without additional protection is a weathering steel, eg Cor Ten. These steels have a low rate of corrosion, and can weather to an attractive colour. However, there is a major drawback as the run-off from such material is rust coloured and will cause staining to adjacent materials.

Aluminium is a suitable material for overcladding, as it has a low rate of corrosion, but it must be expected that its appearance will deteriorate with time. As the white corrosion product forms, the surface will become rough, and will entrap dirt and become unsightly. Pollutants and contaminants will also be collected, and there will be a risk of accelerated corrosion.

The surface of aluminium can be protected by anodising. These anodic coatings can be coloured. Anodising produces a layer of oxide on the surface of the aluminium which in practical terms delays the onset of corrosion. The corrosion product of aluminium is white; hence, if dark-coloured anodic coatings are employed, when deterioration occurs it is readily seen.

Aluminium sheeting precoated with organic coatings is now available: the visually acceptable life of such material is essentially the life of its organic coating for which, for the better-quality finishes, in excess of 30 years is claimed by the manufacturers, but it depends on type of coating, environment, thickness and bond. In aggressive environments it will be necessary to consider repainting to restore appearance.

Whilst steel and aluminium are likely to be the metals most commonly used for overcladding, other metals, such as austenitic stainless steels, may also be used.

Most metallic cladding systems, as well as some non-metallic systems, are likely to be supported on a metallic frame. These frames are likely to be plain carbon steel, aluminium alloy, or stainless steel – the material being selected as much for its strength or its light weight as for its corrosion resistance.

The degree of corrosion resistance necessary for the supporting frame will vary with the conditions expected to occur behind the external skin. Plain carbon steel frames will require some protection, and the most common protective coatings will be hot-dipped galvanising and organic coatings, or both. The required thickness of the zinc will be determined by the size, chemical composition and method of manufacture of the component members of the frame as well as by the required life. Depending upon the service conditions, aluminium may require protection, eg plastics coatings, as well as suitable alloy selection. Copper-bearing aluminium alloys should be rigorously avoided. The frame and the cladding must be compatible or isolated from each other. Similar precautions may be required between the frame and the original building.

The conditions under which overcladding is required to perform become more onerous with increasing height. Great care will be needed to ensure that the cladding is sufficiently weathertight not to promote its own corrosion: it would be prudent, particularly at high levels, to assume that there will be some moisture ingress, and to design to avoid water entrapment. Allow for drainage, and ensure that the frame material is adequately corrosion resistant or corrosion protected.

The presence of thermal insulation behind the cladding could also complicate the situation as moisture could collect in some materials and be retained as it were within a poultice in contact with the frame. Whilst it may seem that the major risk is from rain penetration, one should not rule out the possibility of condensation increasing the risk of corrosion, both to the frame as well as to the internal face of the metal cladding.

For metallic reinforcement in rendered overcladdings, it may be prudent to use stainless steel mesh for high rise and for marine areas, but for the majority of exposures, galvanised will be sufficient.

Fixings

The selection of fixings poses many problems. Selection is based on factors such as ease of installation, compatibility with other materials in the cladding system, and inherent corrosion resistance. The choice involved in any one fixing must be a compromise.

Fixings must be manufactured from corrosion-resistant materials or have a corrosion-protective coating applied which is adequate to withstand the service conditions. Fixings manufactured from materials with a low rate of corrosion will nevertheless have a finite life. Take, for example, aluminium pop rivets. Whilst aluminium has a low rate of corrosion, there is evidence of the corrosion of such rivets over time, resulting in, for example, loss of roofing sheets and large-scale replacement of rivets before renewal of roofing sheets.

The most exposed conditions are likely to be on high-rise blocks where any loss of fixing will almost certainly result in loss of cladding under adverse weather conditions.

Durability of fixings into concrete must be assessed carefully. The risk of corrosion is greatest with chloride-bearing concretes: in these concretes, in the presence of moisture, even 18-8 stainless steels are subject to crevice corrosion. Type 316 stainless steels should be specified.

Particular care should be taken in the specification of self-tapping screws. Self-tapping screws are generally manufactured from carbon steel in order to achieve the desired mechanical properties. Corrosion protection has to be applied without dulling the cutting edge. This is normally provided by a thin zinc or cadmium coating. Unfortunately the life of such a coating can normally be measured in months rather than years when exposed externally. Whilst in dry conditions these fixings may perform adequately, in damp conditions their durability is suspect. The outer part can be protected, given an adequate standard of workmanship, with an O-ring and plastics cup, but the back is vulnerable, and hence long-term durability could be threatened. Repeated loading under wind action may cause partial unscrewing. Self-tapping screws should not be considered as a permanent fixing, therefore, where regular inspection would be difficult and the consequences of failure might be serious.

Maintenance

Cleaning

Few surfaces are truly self-cleaning under the action of rain-water, since streams of run-off will preferentially follow certain routes rather than others. Early in the specification process, therefore, it will be necessary to consider whether uneven dirt adherence can be tolerated (Figure 30) or whether periodic cleaning will be necessary, and whether or not it is likely to be carried out – one imported aluminium system requires washing down several times a year (Figure 31). Some of the heavily textured rendered surfaces will tend to dirty unevenly, and may be prone to algal growth.

Few surfaces are truly self-cleaning under the action of rain-water as streams of run-off will have preferential routes. Periodic cleaning may be necessary but this may not be carried out. Corrugated sheets self-clean much better if the corrugations run vertically rather than horizontally

Figure 30

Figure 31

Trapezoidal profiled or sinusoidal corrugated sheet for example will self-clean much better if the corrugations run vertically than if they run horizontally. Anodised or mill-finish aluminium needs to be washed periodically in any case, to preserve its integrity. In practical terms this will usually exclude it from the range of options, though it has performed well in exposed items in case study 14.

Replacement of damage
Ease of repair is likely to be critical near to the ground or at access levels at any height in the building, and it should be possible to take out and replace individual panels, for example, without removing and replacing a whole run. Special one-off replacement panels with unique surface profiles can be very costly to supply – one authority keeps a set of formers for just such a reason.

Some means of access by operatives to the cladding will be necessary for the replacement of damage, indeed the action of access in itself will increase the risk of damage. There may therefore be a case for the installation of a permanently available access system as an integral part of the overcladding, and preferably some means of anchoring suspended cradles against sideways movements on buildings more than 30 metres high.

Buildability

Buildability in this context includes assessing the ease with which work can be carried out in possibly exposed conditions at high levels, and the likelihood therefore of the installation being carried out properly.

Weather interference
The extent to which overcladding work is likely to be delayed or interfered with by bad weather will depend on the method of access and type of construction, but the risks of hold-ups should be given some consideration.

Table 2 Work time lost on low- and medium-rise buildings owing to bad weather

	Hour's lost per day*	
	January	**July**
Heathrow		
Worst in 5 years	4.5	1.5
Average	3.4	0.9
Best in 5 years	2.1	0.2
Glasgow		
Worst in 5 years	6.2	1.8
Average	5.0	1.2
Best in 5 years	3.6	0.6

*Predicted average lost time in hours per day between 07.00 and 17.00 h GMT, assuming work stops when mean hourly wind speed exceeds 12 m/s, there is snow, sleet or hail falling, or the 'state-of-ground' is icy or snowy.

Work on low- and medium-rise buildings
For most work on low- and medium-rise LPS buildings using prefabricated overcladding panels of no more than one storey in height, it will normally be most efficient to work from access scaffolding, with the materials lifted onto the scaffolding platforms in advance: there will be safety risks associated with handling the panels in strong, gusty winds, and due to slipperiness when there is ice or snow on ladders and scaffold boards. Assuming work stops under these conditions, an idea of likely lost time is given in Table 2.

Work on high-rise buildings
For work on high-rise buildings, or where prefabricated overcladding panels larger than one storey in height are used, it will normally be more practicable to lift the overcladding into position by crane at the time of fixing. For this, a more onerous wind-speed limitation will apply, considering the difficulties of safely handling and positioning large, lightweight panels. Restricted visibility due to fog will also prevent safe operation of cranes, and slipperiness criteria (as above) will also apply. Assuming work stops under these conditions, an idea of likely lost time is given in Table 3.

There is also the possibility that certain types of operation, such as joint sealing, may not be practicable when the weather is wet or cold, and that a further source of delay may be experienced. For further information refer to Keeble and Prior[38].

The message is that installing many types of overcladding involves highly weather-sensitive operations, and due account must be taken of this in planning and costing such work. Overcladding high-rise buildings is likely to be especially vulnerable to weather delays.

Table 3 Work time lost on high-rise buildings owing to bad weather

	Hours lost per day*	
	January	**July**
Heathrow		
Worst in 5 years	7.0	4.4
Average	6.0	3.4
Best in 5 years	5.0	2.5
Glasgow		
Worst in 5 years	8.4	5.5
Average	7.4	4.4
Best in 5 years	6.3	3.4

*Predicted average lost time in hours per day between 07.00 and 1700 h GMT, assuming work stops when mean hourly wind speed exceeds 10 m/s, visibility is less than 30 m, there is snow, sleet or hail falling, or the 'state-of-ground' is icy or snowy.

Note that the above data are based on wind speed at the standard height of 10 m; for high buildings even more interference may be expected.

The necessary skills
No matter which system of overcladding is used it must be capable of correct installation if its performance is to be guaranteed. Many of the metal sheet systems are highly sophisticated designs using combinations of different materials and skills which are highly sensitive to error of fabrication and installation. The missing gasket separating different metals, or the wrong type of fixing, may easily negate months of careful investigation and design work. These systems may need specialist skills not normally associated with construction, those of general engineering and metal working being more appropriate.

Even the old building skills like rendering and bricklaying need careful specification, high levels of skill and supervision. Pre-contract training, both for workmen and supervisors, may be necessary; 'leaving it to the site' is not acceptable. Every detail of the work should be considered and clear instructions prepared. Many of the proprietary systems need specialist knowledge and experienced workmen to apply them. Involvement by the specialist at the design stage may be prudent. 'Mock-ups' of the system and 'trial runs' may well reveal problems of installation — trying to solve an unexpected problem under the pressures of contract completion dates and the unpleasant conditions experienced on every site is highly inefficient.

Adjustability
Where the outer leaf of sandwich panels is removed, the inner leaf has been found to be extremely uneven and provision to accommodate very high dimensional variations has had to be made in the overcladding system. Other problems occur in variations in the widths of profiled metal sheets — fixing these to line becomes more of an art than engineering. Original window positions are also variable. One way of dealing with this is to incorporate oversize window linings in the overcladding (which can be aligned) allowing the actual windows to 'float' within the lining. Where gaps or overwide joints are used to accommodate inaccuracies in sheet overcladding, they should be carefully positioned where they are not too obvious.

Fixing devices should have sufficient adjustability built in to cope with all but the grossest of assembly deviations of the existing facades. Deviations are often considerably greater than expected. The buildings should be measured if at all possible, but if not, then a total longitudinal adjustment range of 75 mm will be needed to take account of deviations within one storey, and probably as much as 50 mm more will be needed to take account of deviations over the height of the building (Figure 32).

Time of year
The likely time of year when installations will take place, and hence the moisture and temperature conditions of both original structure and overcladding, should be taken into account in the design. By way of illustration, the sizes of overcladding panels will be at a maximum in high summer, and clearances will need to be set accordingly so that tolerances on joints, for

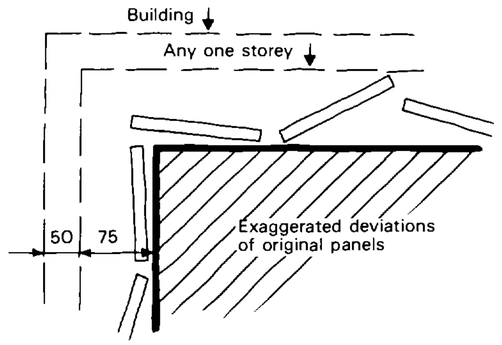


Figure 32 Deviations in original panel assembly

The original building will have been constructed with very high dimensional variation; deviations are often considerably greater than expected. Before the overcladding is designed the building should be measured, as special provisions may be required

example, are not exceeded when the panels are at their smallest in winter. Similarly, fixing grillages should be interrupted at every 2 or 3 storeys, for example, to allow for expansion and contraction.

The long-term durability of renders applied in the winter months can be affected by rain or frost occurring during application.

Where materials guarantees are required by the specifier, careful reading of the conditions could well reveal precise requirements for the application of those materials. Mastics, adhesives, paints, and concrete repair systems are often very sensitive to temperature, moisture, dust or dirt. It has been suggested that conditions are so precise for some materials that they can only be used on a few days each year.

There seems to be a tendency for larger and larger sheets of cladding to be specified, and in this connection it should be remembered that as sheet size increases, total movements will form an increased proportion of controlled joint widths (equally important with open-drained, mastic or gasketted joints). The maxim is, the smaller the panel, other things being equal, the less critical are the movements and hence their effects on the joints.

Safety

It is sometimes thought that overcladding can provide some protection to pedestrians from falling concrete or aggregates, and some systems are being installed especially to do this (Figure 33). In some, a mesh is secured over the original cladding prior to overcladding. Whilst this practice may help in some circumstances, it must be remembered that any case of dislodgement becomes a potential source of failure in the overcladding, giving rise to possible detachment of insulation and surface material, and hence to leakage of the envelope.

The original structure must therefore be repaired to the full 30-year standard before overcladding, irrespective of the kind of solution proposed.

Habitability

Overcladding can normally be carried out without decanting residents, although at considerable inconvenience to them if, as is normally the case, renewal of windows is also undertaken. This is usually very desirable, as the windows need to be considered integrally with the overcladding itself. Otherwise the nuisances are noise and dust (eg from drilling). See Appendix D.

Experience has shown that tenants need to be properly informed about the nature of the work, and its likely effects. Liaison between tenant, contractor and the local authority is beneficial to all parties before and during the contract. A sensitive approach by the contractor can do much to ease tenants' worries, and it has been possible to organise work schedules to suit their needs, even where illness or infirmity are involved.

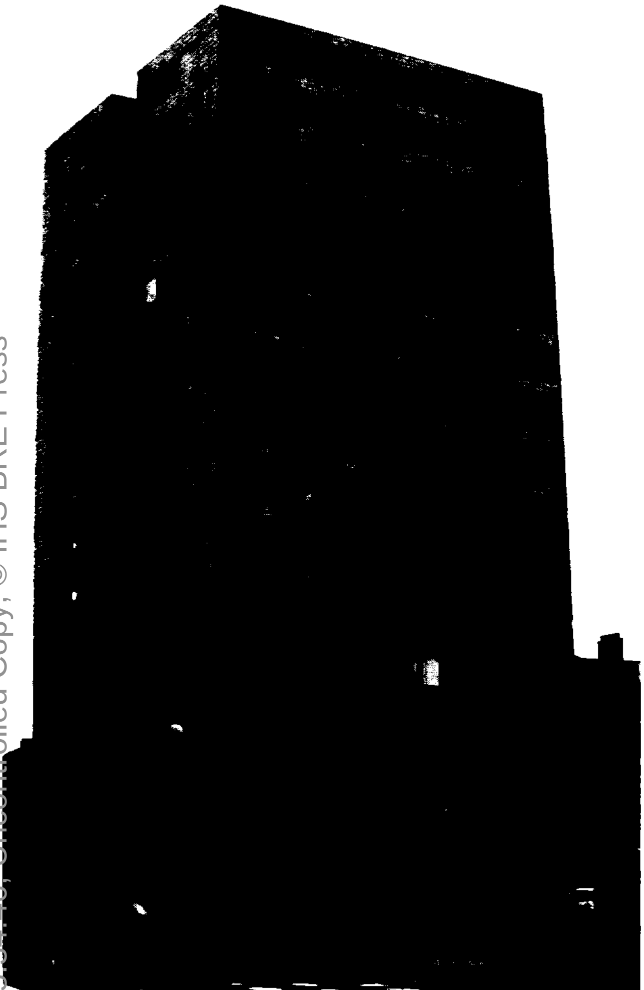


Figure 33 *Some overcladding systems are being installed especially to protect pedestrians from falling concrete or aggregates. However, the original structure must be repaired to the full 30-year standard before overcladding*

Component parts of overcladding

The full overcladding usually consists of six basic components:

1 Thermal insulation applied either direct to the old concrete panels or held off with a battening system of some kind
2 Fixing for insulation
3 The outer skin or weatherproof layer
4 The suspension and fixing system for the outer layer
5 Windows
6 The weatherproof joint(s) for the outer layer

Each component has many options, and the permutations therefore are legion. This report can only deal with generic solutions found to have been used in examples inspected.

Note: Appendix C provides notes on the major physical characteristics of common materials, and draws attention to any inherent deficiencies in their performance.

Thermal insulation

Insulating renders
Insulating renders can combine a measure of insulation with a more or less acceptable rendered finish. Such renders, incorporating lightweight aggregates such as polystyrene or expanded minerals (perlite) in a cement-based mix in thicknesses of 25 to 75 mm and without reinforcement, have had some application in low-rise housing in the UK since 1978 and in high-rise since 1983, with mixed results. The main problem has been delamination either of the protective coat or within the lightweight render itself. One system has been used successfully for over 5 years, whereas other systems have been withdrawn from the market following serious failures. They are not normally recommended for overcladding directly onto LPS dwellings, even low-rise ones, unless great care is taken in their specification and completion, since there is no completely satisfactory way of avoiding cracking over the joints and the consequent risk of detachment.

Only by supporting the render on a reinforced mesh and bridging the joints with a slip layer supported from the body of the panels, can such renders find application to LPS dwellings.

The lightweight renders do not perform well under impact tests, and should not be used in areas accessible to vandals.

Boards
Boards of insulating materials of various kinds are available. Examples are expanded and extruded polystyrene, polyurethane, polyisocyanurate, foamed glass, phenolic foam, or mineral fibres. They are available in various thicknesses, and some are supplied with permeable but water-resistant coatings. All, however, will normally require an outer skin. There is no difficulty in achieving any particular *U*-value found to be economic. For a full discussion of alternatives see Pezzey[29].

The board may be fixed directly to the old concrete panels. If of sufficient strength, it can be held off from the wall by timber or metal battens or cleats, or wedged between them. There is no particular advantage in having a cavity between the panel and the insulation and certainly not in ventilating it, since insulation value will be lost.

Quilts
Quilts of mineral fibre can be fastened directly to the concrete panels. Some materials are better than others from particular points of view, eg waterproofness for rain-screen. All require an outer skin.

Cold bridges
In all cases, the insulation should cover all vertical surfaces as consistently as possible to avoid cold bridges. The suspension system for the board or quilt materials in the external cladding in most cases needs to be taken back to the panels, at least at intervals, and there will therefore be some loss of insulation where the uninsulated cleats act as fins. Insulation should be cut and fitted as tightly as possible round these points (Figure 34).

If new windows are to be fitted, it may be necessary to consider making them smaller than the originals in order to accommodate thermal insulation at reveals.

Outer skins

Lath and render
Lath and cement/sand render is a possibility for low- and high-rise systems where the total surface can be

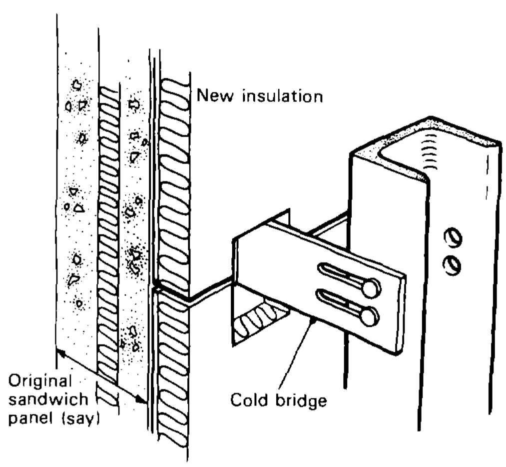


Figure 34 Insulation should be cut and fitted as tightly as possible around metal supports to avoid cold bridges

Amd 2 restricted in size and any necessary movement joints incorporated. The lathing can be supported on battens or by direct fixing through the insulation using special pins driven into holes drilled in the walling. The render may also be reinforced with, for example, glass fibre rovings. Generally speaking the reinforced renders perform better than the unreinforced.

Movement joints will need to be provided. Unmodified cement renders need movement joints at centres not exceeding 5 metres both vertically and horizontally, and positioned at the points of greatest stress, eg vertical joints between window openings (Figure 35).

For modified cement renders or proprietary renders, there will be specific requirements given by the manufacturer.

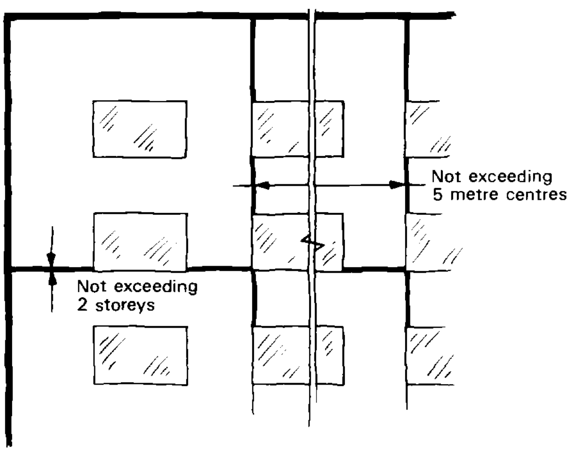


Figure 35 *Unmodified cement renders need movement joints both vertically and horizontally at the points of greatest stress*

Thin plastics-based render finishes

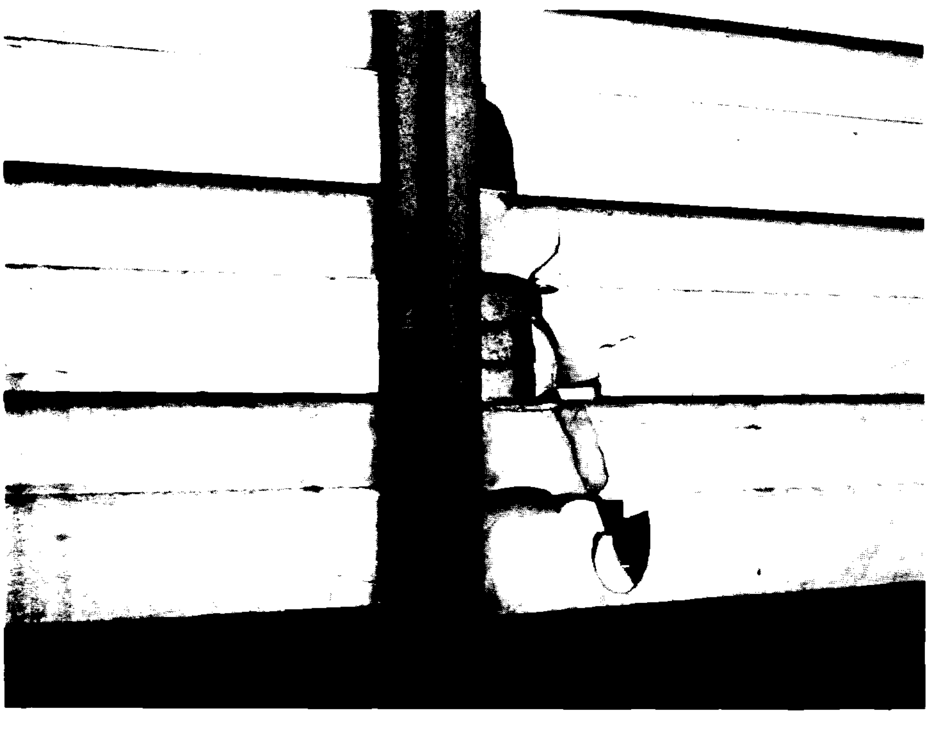
In some systems, plastics-based renders with or without cement binder, usually reinforced with glass fibre in some form, are applied directly over the insulation. Not all thin crusts will pass the impact tests especially if they are on the less dense substrates and even when reinforced, and especially where they are finished with polymer-bound coatings. Suppliers should be asked for impact test results. With this reservation, there is no reason to believe that these finishes cannot meet a 30-year life, though considerations of appearance could require some redecoration within this period.

Sidings

Other finishing techniques which may be considered for low-rise systems include battens and sidings of, for example, wood, metal or uPVC. Sidings are not recommended at low level as they will not in general meet the vandal-resistance criteria for impact (Figure 36), or other abuse, eg prising off or even unscrewing accessible parts of the fixing system. Sidings of uPVC are also prone to colour changes or 'bloom' – both have been observed in BRE studies. Wood battens will need to be treated against rot.

Tile hanging

Tile or slate hanging is another possibility for low-rise systems, but not at ground-floor or access levels because of poor impact resistance. It would not be advisable to specify tile hanging over three storeys high, because of possible dislodgement by wind conditions, unless special arrangements were to be made for fixing and clipping. Mathematical tiles are more robust, and they may be available with integral shaped thermal insulation boards, but again evidence would be needed of the security and longevity of attachment arrangements.



Material used for low-rise overcladding systems should meet the vandal-resistance criteria for impact or other abuses

Figure 36 *Impact damage to uPVC sidings*

The main advantage of traditional solutions of the kind described so far is that, in general, the techniques involved are well understood by the industry. This is not necessarily the case with the sheet or board finishes which are appropriate to high-rise situations.

Brickwork

Brickwork as the outer skin finds application mainly in low-rise blocks, although it has been used in multistorey blocks where the structure can be adapted to carry the extra loads and the brickwork carried on shelf angles, for example, at each floor level. Since the concrete structure has already undergone most of its shrinkage, the need for movement joints at each floor level is less exacting than with new-build: only thermal movements will be significant. The choice of brick is governed by similar conditions to those of new-build.

Any brick skin will need to be tied back to the original panels, for example by resin-bonded anchors at the same centres as ties, as if one was designing new brickwork at that identical exposure.

Sheet metals

Sheets are usually of galvanised steel or aluminium (Figure 37). Galvanised steel is available with polyester coatings, silicone polyester coatings and vinyl coatings. Aluminium is available with polyester coatings, PVF2 and modified alkyd coated sheets.

Profiled steel and aluminium sheets are not usable below 1.5 metres height above access level, since, in their commonly available thicknesses, they will not meet the impact damage level. Steel greater than 0.8 mm would be satisfactory above 1.5 metres, but aluminium would need to be thicker. The manufacturers should be asked for test results.

Where long lengths of steel sheet are to be used, the manufacturer should specifically be asked whether any curvature due to the 'roll memory' has been taken into account.

Steel or aluminium sheets can be pressed into panels with returned edges (Figure 38), or shallow drawn deformations can be pressed in the centres of the panels (Figure 39), or they can be used as corrugated sheet. Although sheets are available in lengths of up to 20 metres, care will be needed to provide for thermal movements in the lengthways dimension of the sheet; movements are automatically compensated for in the width direction, because of the inherent flexibility given by the corrugations.

Provided the sheets are protected to a standard not less than that given in the appropriate Agrément certificate, and there are no abnormal pollutants, a basic life of approximately 30 years ought to be expected, though not necessarily without maintenance. Protection of steel is by galvanising and powder-coated paint systems, or by stoved or vitreous enamels. Aluminium protected by powder-coated paint systems is repaintable if deterioration ensues.

Sheet metals coated before forming should not have sharp arrises or sharp radius bends. The quality of the cover on the back of panels or sheets should be no less consistent than that of the front, especially for those components to be used in a rain-screen design where the backs will be wet for long periods. It is not possible, however, to maintain the same cover on cut edges, which are likely to show deterioration earlier than the rest of the sheet. Machine shear cut edges are less vulnerable than sawn edges, so the latter should be protected by a joint overlap wherever possible.

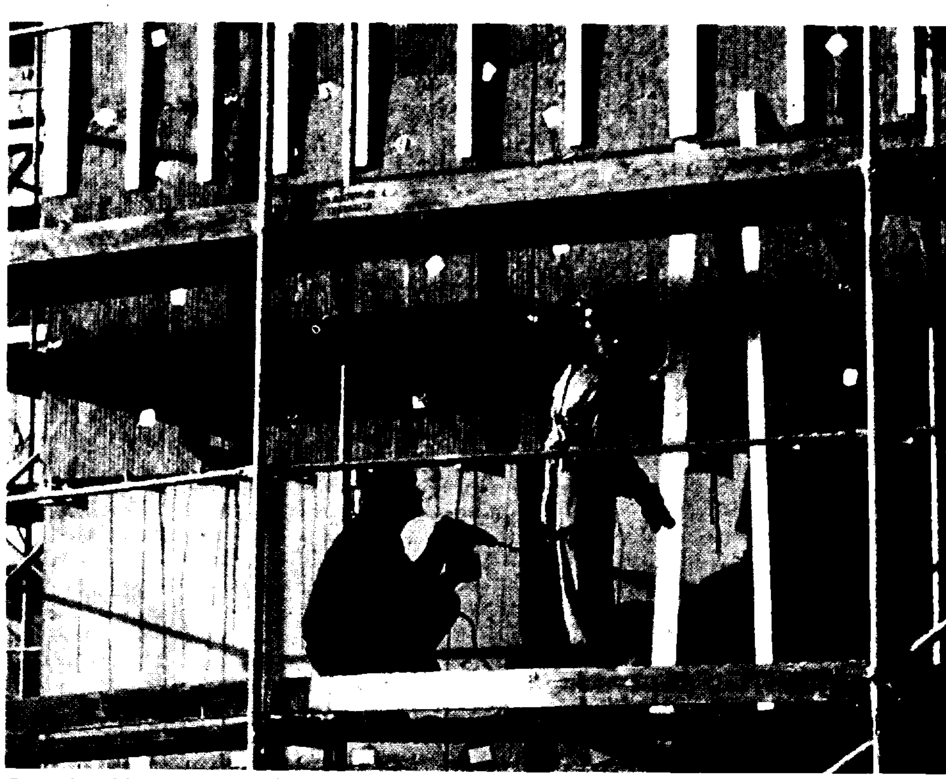


Figure 37 *Sheet metals will need a secondary support system*

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Figure 38

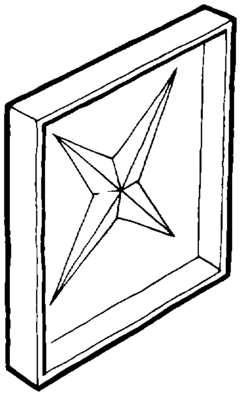


Figure 39

*Steel or aluminium sheets can be stiffened with returned edges **(Figure 38)** or with shallow-drawn deformations of the centres of the panels **(Figure 39)**, or used as corrugated sheet*

Vitreous enamelled steel is always coated after forming. Although it offers an extremely durable surface, the panels are prone to chipping around fixings, which therefore need to be carefully designed and installed.

Some aluminium or steel sheets are supplied already bonded to thermal insulation, eg expanded polystyrene, polyurethane or polyisocyanurate, and are designed to be fixed with a cavity. The cladding is relatively easy to install, but careful detailing is needed to avoid cold bridges at returns. The metals should be protected to the same standards as unbonded sheets.

Boards

Boards are available in fibre-reinforced cement or calcium silicate, or with resin binders. Some boards have smooth polymer finishes.

Fibre-reinforced predecorated cement-based boards consist of compressed and autoclaved sheets of Portland cement reinforced with natural and synthetic fibres and fillers, with surface coatings permanently fused or bonded to the base sheet.

These boards find application in virtually all situations for rain-screen cladding with carefully controlled joints, and with a ventilated air space behind. Alternatively they are used in sealed weather-skin cladding with all joints between panels filled and pointed with a non-oil-based mastic.

For low-rise buildings, planking in horizontal overlapping strips has been used.

Boards can be obtained with the following properties:

Dimensions:	4 and 7.5 mm thickness with aggregate finish typically 6.5 mm; overall size 3070 and 2520 × 1240 raw edges.
Weight:	4 mm, 7.4 kg/m²; 7.5 mm, 13.1 kg/m²; with aggregate finish, 20 kg/m² depending on type.
Appearance:	Flat boards have a distortion-free surface in a wide range of colours. Surface-textured boards have a lightly dimpled, sculptured surface. The structure, size and colour of aggregate-finished boards is controlled by the quarried stone.
Working characteristics:	Cutting and drilling of panels is normally done before delivery, although some fitting on site may be necessary in some instances. No special equipment is needed for limited cutting. Planking can be cut by scoring.
Maintenance:	Redecoration could well be required. Rain alone will not wash surfaces clean. Periodic washing with a mild detergent may be necessary. Stains can be treated with hot high-pressure water.

Fixing methods:	Panels or planking can be nailed or screwed, with suitable nails or screws, to treated timber battens fixed to the structure. Adhesives should be used only to provide auxiliary support. Panels can also be pop riveted back to a supporting framework of (usually) aluminium members fixed by brackets or clamps to the face of the building.
Jointing:	Joints against continuous bearers are usually backed by flexible purpose-made neoprene strips, and horizontal joints without continuous bearers are usually flashed with aluminium chair-section flashings. Sealed joints should be made by a specialist firm using non-oil-based material.
Site storage and protection:	All materials must be stored flat on pallets under cover, and protected from the weather and other trades. Any moisture penetrating between stored boards will cause permanent surface staining. Protective paper or plastics sheet between decorative faces should not be removed until after fixing.

Panels of grp

Glass-fibre-reinforced polyester (grp) is a composite material consisting of a thermosetting resin reinforced with glass fibre. On its own the resin is brittle, but the inclusion of a glass fibre produces a tough high-tensile-strength material of low weight.

Panels of grp are produced by building up layers of liquid resin and glass fibre mats or fabric, and then compacting the whole with a roller. Alternatively, the material can be built up by simultaneously spraying the resin and the fibres. The resin reacts with added catalyst, generating heat and causing the resin to set hard.

The above description characterises a process which can produce panels with a wide variety of properties. A major difficulty of assessing this material for use in overcladding is that seemingly similar panels can have widely varying properties, depending on the resin type, glass content, compaction efficiency and curing conditions. Quality control after the panels are made is very difficult, and the best assurance for a designer is to choose manufacturers who have experience of similar work and can show examples of it.

Glass-fibre-reinforced polyester panels can be produced to a wide variety of sizes, shapes and surface finishes. Provided the surface gel coat is well cured and well bonded, there is no reason why a 30-year life should not be expected, although there could be colour changes. Panels of grp are only recommended for rain-screen designs if care is taken to obtain a satisfactory surface finish on the inside of the panel which will withstand intermittent wetting.

Composites

Sheets or boards are available in which the thermal insulation is integrally bonded to the outer protective layer. These are sometimes known as sandwich panels, although they may not be a true sandwich with a soft core skinned on both sides.

Metal-skinned composite panels used in cladding in the past have not always proved to be wholly satisfactory because there has been local delamination, affecting both appearance and performance.

In any event, with metal-skinned sheeting, it is arguably better to separate the insulation from the protective sheet by a cavity, and this fact would militate against its use as overcladding for LPS dwellings.

Windows

Windows are normally replaced at the same time as overcladding is installed, and should be considered integrally with the overcladding. It may be possible to fix the windows into a sheet cladding system, or at least to the suspension system, instead of to the original concrete panels, and consideration will need to be given to compatibility of materials. The new windows may also be fixed before the old ones are removed, reducing inconvenience to occupants.

Otherwise, there is no restriction on materials, since high-performance designs can be obtained in all the common materials.

There are some theoretical advantages in fixing windows to inner leaves which are insulated on their outside. Since this leaf will be in a more stable environment (and warmer), the stresses on the window will be reduced compared with windows fixed into the overcladding. There is less need to worry about weatherproofing and thermally insulating the joint edges, though a thermal break in the window frame itself, where appropriate to the material, would still be advantageous in reducing both heat loss and condensation risk. On the other hand, if the windows are fixed to the original panels, there may be sizeable differential movements between panels and overcladding which will tend to fracture joints. Robust weathering details are essential. Fixing to the overcladding will need some means of masking the gap at reveals, leaf or sills with a flexible material (Figure 40(a)).

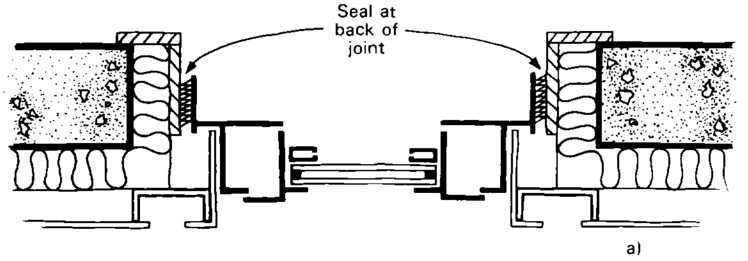
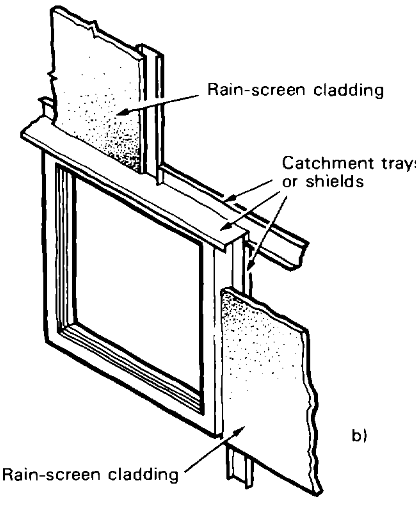


Figure 40 One method of installing windows in rain-screen



It is always better in principle to seal windows at the back of the window-to-wall joint (a), and to have some kind of mechanical joint, overlap (b) or bead at the front in order to create, effectively, a two-stage joint

Joints

Window-to-wall joints

It is always better in principle to seal windows at the back of the window-to-wall joint, and to have some kind of mechanical joint, overlap, or bead at the front, in order to create, effectively, a two-stage joint. This applies whether or not the joints in the surrounding overcladding are one- or two-stage (Figure 40(b)) whichever leaf contains the window.

Two-stage joints

For rain-screen claddings, it is important that the original concrete panels do not allow air to pass through them. Therefore any new applied insulation should either be sufficient to provide an air seal over previous open-drained joints, or a separate air seal should be added to the outermost part of the original concrete panel over each old joint, as described earlier. If no catchment trays are provided behind the overcladding joints, for satisfactory performance it is essential that the new overcladding joint widths be closely controlled. Experimental evidence shows that with open vertical joints of 2.5 mm ± 1 mm, and horizontal joints of 25 mm ± 4 mm, very little water will cross a 25 mm cavity. Accuracy of this order, however, over the whole building is not very practical, and it is therefore arguably better to provide catchment channels. Figure 41 gives the necessary sizes, which depend on the joint widths chosen[26]. Although there is only limited experimental evidence, it is considered that these dimensions ought to give satisfactory performance in exposed situations.

It is of course possible in principle to form channels by overlaps on the edge profiles of adjacent panels, both vertically and horizontally, and the panels will therefore not be symmetrical (Figure 42). Lapped panels are more difficult to install than unlapped panels and are also more difficult to disengage when replacement is needed. With horizontal channels it is crucial that the joint does not fill with water[39].

The cavity of 25 mm was that used under controlled test conditions, and it will need to be wider to accommodate all the deviations of construction — within reason, the wider the better.

Proposals have been seen for hybrid jointing systems, part sealed and part open. In general these mixtures should be avoided, though it may be necessary to employ both techniques round windows.

One-stage joints (Figures 43 and 44)
Sealed joints should be designed, as far as possible, to lap rather than butt. This gives protection to the gasket or sealant from solar radiation, and some protection from driving rain should the seal fail prema-

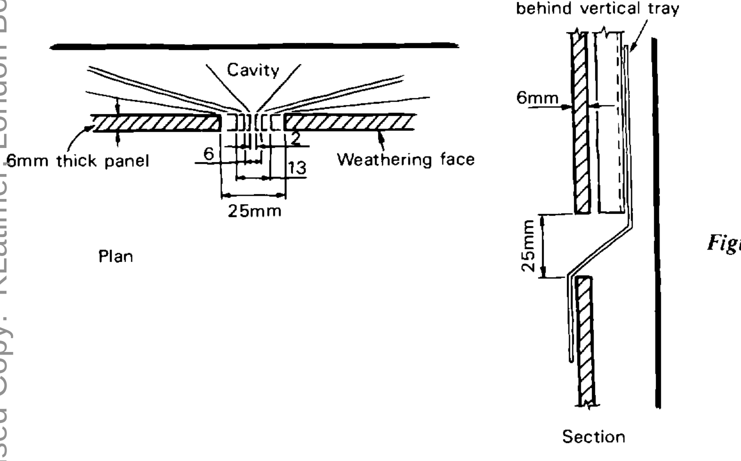


Figure 41 Experiments show that joint widths in rain-screen overcladding must be closely controlled so that open vertical joints of 2.5 ± 1 mm and horizontal joints of 25 ± 4 mm are achieved if water is not to cross a cavity of 25 mm. As this level of accuracy is unlikely in practice, it is better to provide catchment trays sized to suit the joint widths chosen

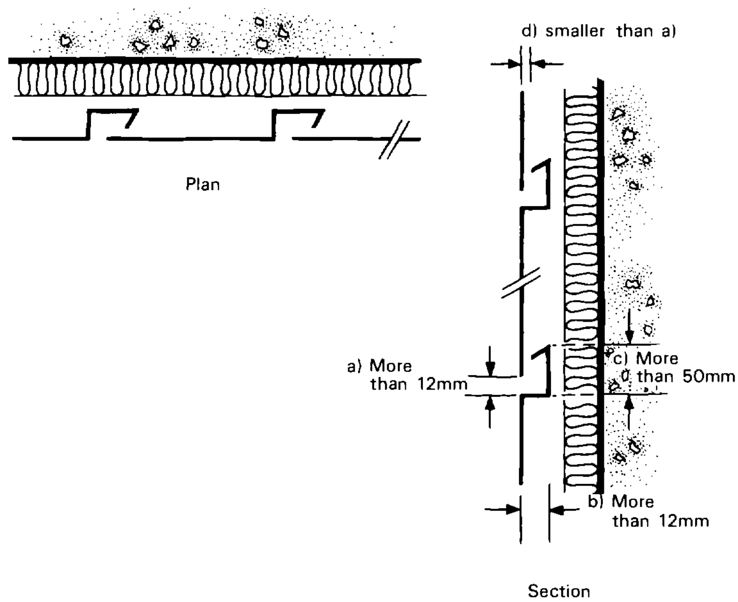


Figure 42 *Forming lapped joints in a rain-screen*

Catchment trays may be formed on panels as edge profiles, but lapped panels are more difficult to install and to replace. Care is needed in sizing the horizontal and vertical channel to prevent it filling with water

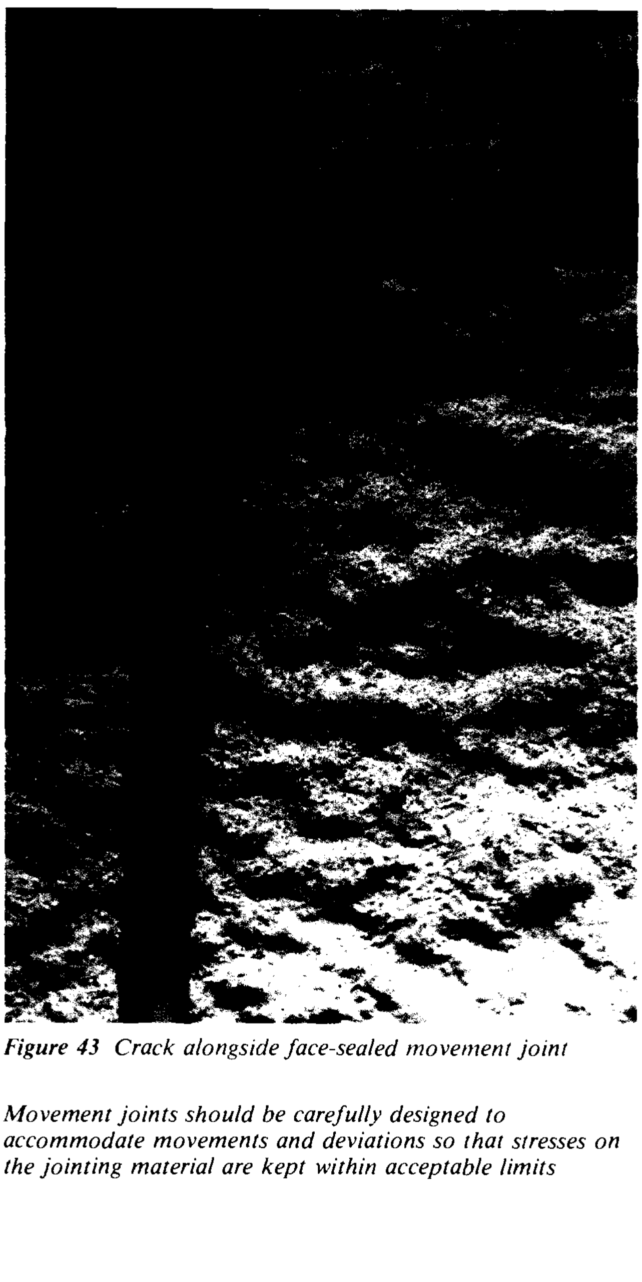


Figure 43 *Crack alongside face-sealed movement joint*

Movement joints should be carefully designed to accommodate movements and deviations so that stresses on the jointing material are kept within acceptable limits

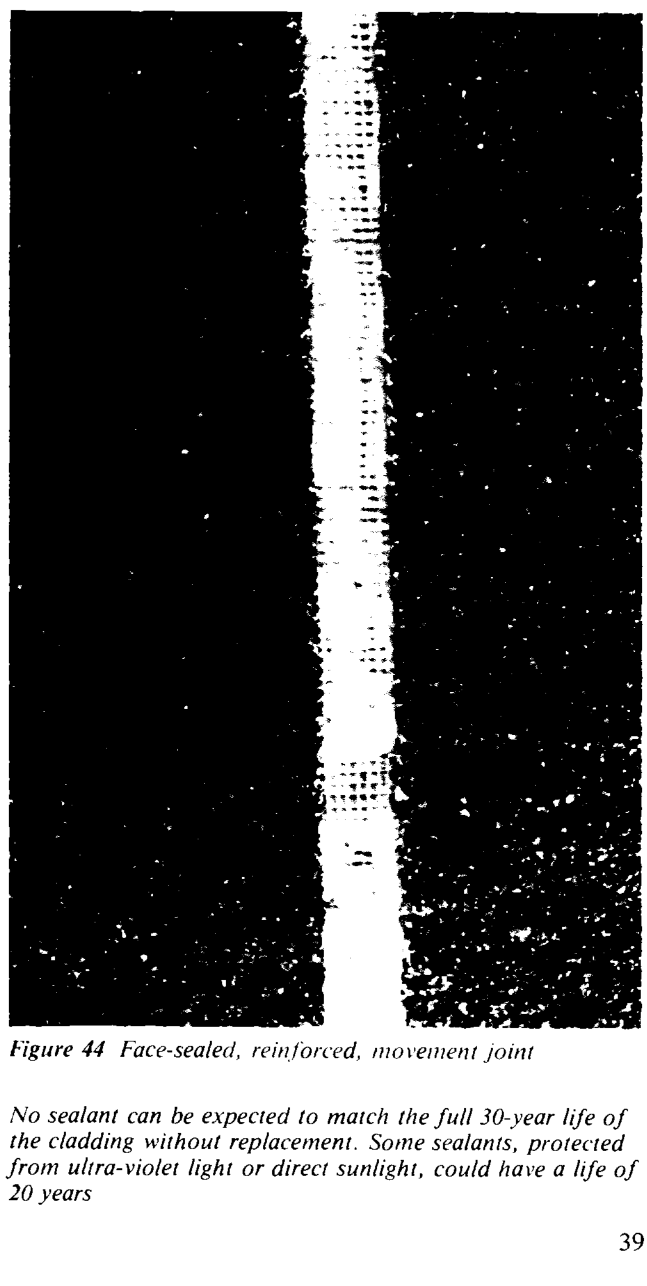


Figure 44 *Face-sealed, reinforced, movement joint*

No sealant can be expected to match the full 30-year life of the cladding without replacement. Some sealants, protected from ultra-violet light or direct sunlight, could have a life of 20 years turely through, say, ageing. Against this, replacement of the seal will not be so easy if the joint is lapped.

In any event the joints should be carefully designed to accommodate movements and deviations[40,41] so that stresses on the jointing product, mastic or gasket, are kept within acceptable limits.

Where rendered metal lathing is used as overcladding, movement joints at 5 metre intervals horizontally and 2-storey height vertically are required. Joints should preferably be located across the shortest opaque length of walling through both surface and lathing.

No sealant can be expected to match the full 30-year life of the cladding without replacement[42]. Choice of sealant together with its renewal dates will therefore need to be made against a knowledge of the remaining design life of the dwellings.

Provided protection can be afforded from ultra-violet or direct sunlight, eg by cover mould or shape of the profile, lives of up to 20 years can be expected from 1 or 2 part polysulphides or polyurethanes and 1 part silicones. The elastic sealants such as the polyurethane and silicones will be found to perform best with the relatively lightweight sheet materials of high thermal conductivity such as are usually used in overcladding, though compatibility should be checked before specifying.

The range of materials and profiles for gaskets is very wide, and it is not practicable to give guidance in this report.

Ends and edges

It is most important that satisfactory designs are prepared in advance for crossover and tee-joints, and especially where vertical and horizontal are not in the same plane, to check for continuity. It is also advisable to have standby designs available for the extremes of variability which might be encountered in assembly (Figure 45).

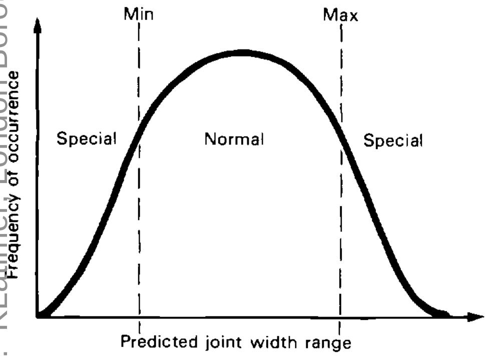


Figure 45 *Standby joint designs should be available to cope with extremes which might be encountered in assembly*

Fixings

Adhesives

Thick adhesives such as polymer emulsion modified cementitious mixes can be used to stick insulation boards such as expanded polystyrene to concrete panels. These adhesives are sometimes supplemented with large-headed plastics or metal pins locked in place by hammering into drilled holes in the concrete

Thin adhesives, which depend on surface contact, will not be suitable for use on exposed aggregate panels, or on those with ribbed surfaces.

Adhesives, however advanced the formulation, must not be relied on to fix the suspension system for the outer skin of the overcladding.

Pins

Metal or plastics pins hammered into predrilled holes at appropriate centres probably form the main method of fixing for lightweight expanded plastics boards finished with thick render on lath. Provided the original concrete is sound, pull-out strengths well in excess of dead and live load requirements are available[43]. Pin material should be chosen to be compatible with the materials fixed, and in this respect it may be useful to specify a closer spacing of a lower-strength pin if it gives better thermal insulation performance (ie does not form as serious a cold bridge through the insulation). Stainless steel, nylon and polypropylene fixing pins are obtainable, so durability should not be a problem, except in fire. Nylon and polypropylene fixings melt in fire, and it is therefore recommended that at least one fixing per square metre of every kind of overcladding should be of metal[32].

Bolts

Suspension systems for rails carrying the sheeted overcladding systems may well warrant heavier expansion-bolt-type fixings, provided the concrete is good enough to accept them. Even in good concrete, care must be taken that the concrete is not fractured on tightening. Indeed, the condition of the concrete may well preclude such a solution.

Shot firing

Shot firing of hardened steel pins into precast reinforced concrete panels should be avoided. The fixings may be insufficiently durable because the firing destroys the protective plating on the pin, though hammered pins may find a place for fixing battens in low-rise sheltered situations where consequences of possible early failure may be more acceptable.

Screws

Most sheet or board systems not formed into panels will need to be fixed through the sheet. Self-tapping screws into metal should be avoided, for reasons discussed earlier, but corrosion-resistant wood screws are an acceptable fixing into timber battens. Pin and cam fixings (Figure 46) giving easy removal for inspection and repair/replacement have much to be said for them, although they should be supplemented with

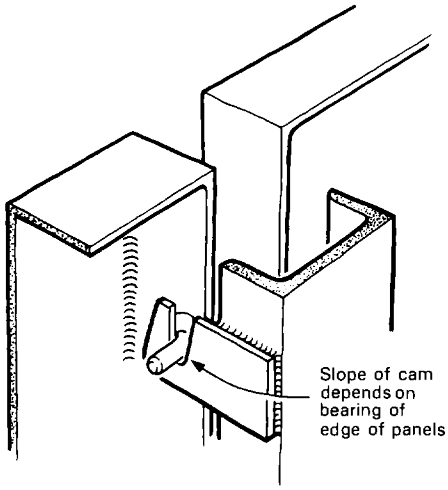


Figure 46 *Pin and cam fixings give easy removal of panels for inspection or repair*

at least one bolted fixing per panel, or an alternative means of positive location to supplement gravity should be used. Certain of the thicker board systems can be part drilled from the back to receive secret fixings concealed within the board thicknesses, and total security, as with all kinds of fixings in the last resort, depends on frequency and the tensile characteristics of the board materials. BRE does not at present have any information on their performance and durability.

Pop rivets
Large pop rivets are used in some systems, usually for fixing thin flat panels to metal bearers, often through a gasket material. With care in the choice of metals for rivet and bearers (and panel if of metal) satisfactory performance ought to be expected, although consideration should be given to the effect on durability of any dissimilar metals which may remain in the rivet. The rivet heads can be concealed by plastics plugs matching the panel colour.

Tolerances

The original LPS building can have inaccuracies of the order of ±55 mm over a typical elevation, and even more over the height of the building, and it will rarely be practicable to design a fixing such that it can be adjusted to take out errors of this magnitude. Nevertheless, as much adjustability as possible and not less than ±30 mm should be sought, consistent with adequate strength, and the more practical designs are usually based on the twin slotted angles (Figure 47). Some common pitfalls are described by Bonshor[44].

Errors in panel alignment, other things being equal, may be more apparent against the rather precise and 'clinical' appearance of overcladding compared with the more crude original.

It should be remembered that errors in overcladding alignment will be less apparent the wider the joint (Figure 48), though, for filled joints, there will be a penalty in using more material.

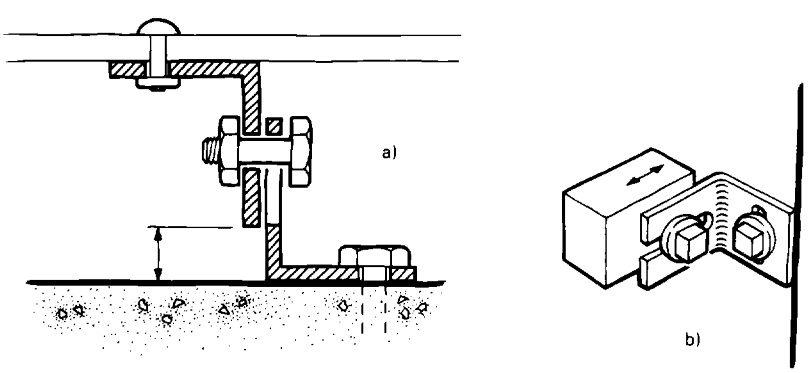


Figure 47 *Fixings for overcladding support rails will need to tolerate very large inaccuracies in the original building. The more practical designs are usually based on the twin-slotted angles*

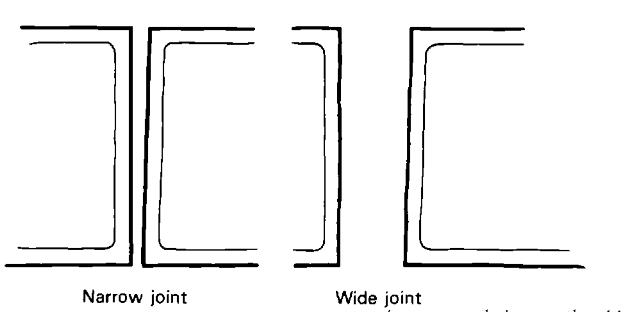


Figure 48 *Errors in alignment of relatively precise overcladding panels may be more apparent against the more crude original; inaccuracies are less noticeable the wider the joint*

Experience of installations

In the United Kingdom

Within the UK it is Scotland, and specifically the city of Glasgow, which has the most experience of overcladding. Indeed the city council has now adopted partial overcladding of its high-rise housing as a matter of long-term policy, and has completed work on about 30 blocks including 22 LPS blocks over 16 storeys.

There follows a list of sites where overcladding has been adopted, is being considered, or has been rejected.

Overcladding adopted

Birmingham Some overcladding of non-LPS — further details not sought.

Camden Numerous 8- and 10-storey non-LPS buildings have been partially overclad with profiled composite steel sheets — see case study 23.

Now considering overcladding two estates of 8-storey non-LPS blocks which have inadequately restrained brick panels and extensive spalling of the brickwork, both on exposed elevations and under walkways. Proposed to use render on lath over mineral wool insulation.

Final design stage has been reached on plans to overclad three 21-storey non-LPS blocks to stabilise the brickwork. It is proposed to import the aluminium panels including an elaborate guide-rail system for access cradles. Cost of the scheme, including high-performance aluminium windows, is said to be about £300/m^2.

About 6 years ago, four non-LPS tower blocks were overclad with aluminium panels (see case study 15).

East Kilbride See case study 13.

Edinburgh 12-storey block with expanded polystyrene sheets coated with glass-reinforced gypsum render pinned to existing panels, then site-applied polyester finish.

Gateshead A two-and-a-half-year project to overclad six tower blocks of non-LPS has just been completed. The hybrid system of aluminium sheets and brick cladding is a final attempt to rectify defects said to have been found in the original buildings. This is the subject of litigation. BRE has some information about the schemes, but since they were design and build, the copyright belongs to the contractor, and there are difficulties over publication.

A further small contract has just finished to insulate and render, externally, projecting bays of 3-storey maisonettes.

Greenock See case studies 8 and 9.

Greenwich Overcladding of non-LPS using external insulation and render; no further information is available.

Glasgow 30 blocks have been overclad, mostly end elevations, including six 32-storey non-LPS blocks in 1976 – 78 (see case studies 2, 3, 10 and 11).

Hartlepool 2-storey Bison terraces clad in brick and 4-storey Bison terraces using rendered metal lathing over insulation.

Hounslow Three tower blocks have been overclad (see case study 22).

Hull Are about to start overcladding YDG houses.

Islington Some medium-rise non-LPS dwellings have been overclad with foamglass. No further information is available.

Motherwell See case study 12.

Newham Three 22-storey blocks have been overclad with Petrarch sheet cladding.

The authority have a continuous inspection programme for all their high-rise blocks and are assessing concrete repair and overcladding systems.

Sandwell A tower block has been overclad with external insulation, with a sprayed coating, and brickwork to ground-floor level (see case study 6).

3-storey Bison flats have been externally insulated and rendered (see case study 5).

Smiths system semi-detached houses have just been overclad with external insulation and Stenni panels (see case study 4).

Surrey Heath Render and insulation on Orlit houses. No further information was sought.

Tower Hamlets Final design complete and tenders received to overclad a Wates LPS tower block in aluminium sheet (see case study 24).

Westminster One 19-storey tower block in in-situ reinforced concrete and brick is just complete (see case study 1).

Warwick Overcladding of Wimpey 'no-fines' semi-detached houses has just been completed using brickwork and rendered aerated concrete blocks (see case study 16).

Waveney Have non-LPS houses overclad with Coloroc. No further information sought.

Currently being considered

Bristol Some trials are planned to overclad non-LPS.

Luton Information is being gathered and inspection of sites is being carried out in preparation for a scheme to overclad brick blocks. No decision has yet been reached.

Sheffield Considering overcladding high-rise Reema blocks, but may not go ahead for lack of funds. Blocks may be demolished (see case study 19).

Small-scale trials have been started on low-rise blocks.

4-storey non-LPS maisonettes have recently been partially overclad with render on laths.

Waltham Forest Deciding now what to do with their LPS. No further information is available.

Wrekin BRE's Advisory Service and BRECSU have been consulted on proposals for the cladding of a non-LPS block 10 storeys high.

Authorities rejecting overcladding

Hillingdon Four high-rise Bison blocks have been reclad in brickwork, following removal of the outer leaf of the sandwich panels.

Milton Keynes Reema houses in sound condition, but difficult to heat because insulation standards were thought to be low. Internally insulated by dry-lining, and external joints raked out and remade.

New Forest Reema houses insulated internally at a cost of about 20% of the cost of overcladding, and this includes payments to tenants for disruption. Houses are said to be in sound condition.

Salford Are against overcladding.

Walsall Have examined the case for overcladding LPS dwellings, but decided on this occasion not to proceed. No further information sought.

Rugby Did not proceed with overcladding on Bison Wallframe dwellings because the design did not show sufficient cost benefits, and the authority had little confidence in the proposed system.

Abroad

Description

Whilst there are several UK firms with experience of the design, manufacture and installation of various systems of thermal insulation and a suitable weather-tight skin for low-rise construction, there is not the same depth of expertise in high rise, particularly of the rain-screen type of overcladding.

Although research on rain-screens was carried out in the UK by BRE in the 1970s[26], a much more substantial experience exists in Norway, Canada, Switzerland and Germany. Swiss and German firms have in consequence much more experience of actual installations in all kinds of buildings, including blocks of flats, and in consequence UK firms have gone to them for assistance. Similarly, few consultants in the UK are experienced in the design of overcladding systems.

Some tall blocks have been overclad in Denmark[45,46] and in Sweden, for the most part with mineral wool with a rendered finish (J R Britten, private communication), although some have been done with prefabricated panels.

In Denmark, systems employing external insulation are preferred to those employing internal insulation. The Danish National Building Research Institute warns that there is a need to carry out further investigations of the durability of non-traditional designs.

Brookes[47] gives further information on the design and performance of foreign systems.

Assessment

BRE does not have any first-hand knowledge of the performance of systems abroad, although some consultants in the UK have made studies of particular aspects, for example Gill and Anderson[25]. Experience is mainly from Canada, West Germany and Switzerland where it is reported that overcladding both of the rendered and of the rain-screen type has performed satisfactorily. However, these countries habitually specify to high standards which are relatively uncommon in the UK, and unmodified imported systems may be found to be expensive. Modification for cost-cutting usually carries implications for performance.

There is considerable experience abroad of the performance of insulating renders and ordinary or modified renders over insulating materials. In Switzerland, for example, there has been more than 20 years' experience of systems using resin-modified renders over expanded polystyrene, and more than 7 years' experience with systems employing glass fibre insulation[48].

Whilst the majority of installations have given few problems, there have been some failures. In particular, because of cracking of the render attributed to movement of the insulation, it has been recommended that fixings for insulation should not consist solely of pins, but should also include adhesion, either over the whole area, or in strips over the whole width of the insulation, in order to minimise this movement. There have also been problems associated with condensation forming behind the insulating layer.

It has been pointed out that refinishing the thin resin-modified renders with extra material following deterioration may effectively create a vapour barrier in the wrong place, ie on the cold side of the insulation, thereby promoting the occurrence of interstitial condensation. The Swiss have some experience, also, of thicker, conventional, renders over insulation, which are more permeable, where the risk of creating interstitial condensation following recoating is less than with the thin renders.

This Swiss experience points to the need for a study of the future risk of interstitial condensation before refinishing thin resin-modified renders.

Conclusions

1 Few LPS dwellings in Britain have been overclad, though some other building types may provide relevant experience.

2 Overcladding is one of a range of several options currently being considered for the refurbishment of LPS dwellings. There is a vast range in the costs of the various overcladding systems which are being investigated at present, from £40/m^2 to £300/m^2. Apart from some obvious differences in performance required from low and high rise, most of the requirements are similar. It can only be concluded that, in most of the examples seen, the required finished appearance of the building has played at least as significant a role in the decision on system and material, as has cost and performance.

3 Overcladding is not a panacea for all the ills of system building. On its own it will not reinstate the structural integrity of a building nor prevent further decay where inherent problems are to be found with the manufacture or assembly of the original components. Unless suitably designed and installed, it will almost certainly make it more difficult to identify any continuing deterioration. The decision to overclad must therefore be taken only after exhaustive consideration of the condition of the building; not all buildings will be found suitable for overcladding, and where it is unsuitable it may not increase the expected life of the building as much as might be expected.

4 Following the work on which this report is based, BRE is concerned about the widespread lack of knowledge and understanding available to the industry and its clients. However, BRE found a new awareness among consultants, manufacturers and clients, of the need to improve standards.

5 Reinforced concrete of the quality found in many LPS buildings must be recognised as a limited-life material. Provision must be made to monitor the performance of the buildings over time.

6 Some overcladding systems need frequent maintenance, and may need substantial repairs to achieve their advertised lives. Replacement of purpose-made parts may be expensive. Provision must be made to monitor the performance of all overcladding systems over time.

7 Overcladding, when coupled with other measures of housing management, can provide a transformation for run-down estates.

Acknowledgements

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Appendix A Known defects in large panel system dwellings by system

Claddings, weatherproof joints and defects in the principal large panel systems

System	Description of cladding	Type of joint*	Type of defect**
Anglian Houses	Large precast concrete panels on gable walls and parts of main elevations; lightweight timber-framed infill panels on main elevations	1 2 4	G
Balency	Concrete wall panels; cast-in windows; various external finishes	2 4	No information
Belfry	Houses — concrete panels with timber infill panels. Flats — concrete panels; exposed aggregate finish; cast-in windows	2 4 6	No information
Bison	Concrete panels; exposed aggregate, mosaic or patterned finishes. On low-rise, brick facings	1 4 6	A B C D E F G
Bryant	Concrete spandrel panels; mosaic, tile-hung, sprayed or trowelled finishes	2 4 5	No information
Camus	Concrete panels; exposed aggregate, square tiling or mosaic finishes; cast-in windows and doors	2 3	A B C D E G
Carlton	Concrete gable end panels; timber infill panels on main elevation	4	No information
Cebus	Non-loadbearing facade panels; various external finishes	1 2 6	A C E
Conclad (Reema)	Concrete panels; exposed aggregate or fair-faced finishes	1 4	No information
Cosmos	Concrete panels with ground beams; timber frames; plastic cladding	1 4 6	No information
Fram Russell	Concrete panels; exposed aggregate, mosaic or tiled finishes; cast-in windows and doors	1 2 3 4 7	No information
Gerrard 'Incon'	Concrete panels; mosaic, exposed aggregate, tile-hung finishes; ground floor — brick	4	No information
GLE	Concrete panels; brick, exposed aggregate, clay, tile-hung or weatherboard finishes	1 4	No information
Gregory	Concrete gable end and slab walls between storeys; brick cladding; timber infill panels elsewhere	4 5	No information
Housing Development Construction	Concrete panels alternating with timber infill panels	1 3 4	No information
Jesperson 12M	Concrete gable end walls; timber-framed or concrete infill panels to front and rear; various external finishes	1 4	No information
Laing/BRS 'battery cast'	Concrete panels; various external finishes; cast-in windows	1 2	No information
Larson & Nielson (TWA)	Concrete panels; various external finishes; cast-in windows and doors	1 3 6	A B C D E G
Lecaplan	Concrete panels on end walls and on ground-floor storey of main elevations; exposed aggregate finish; timber-framed curtain walling elsewhere	1 2 3 4 6	No information
Sir Lindsay Parkinson (HSSB)	Brick-faced concrete cavity wall units; some treated concrete; timber boarding	4 7	C D
MFC (Moss & Sons)	Concrete panels; exposed aggregate, brick or painted finish on ground floor; tile hung, predecorated aluminium weatherboard or timber boarding elsewhere	2 4	No information

(continued)

System	Description of cladding	Type of joint*	Type of defect**
Modus	Concrete panels with various finishes, brick or tile; timber infill secondary units; cedar boarding	1 4	No information
PAC	Concrete panels; exposed aggregate finishes; curtain walling; mosaics	1	A B G
Reema	Concrete panels; variety of finishes; cast-in windows	1 2 4	C D E
SB2	Concrete panels; exposed aggregate, tiles or mosaic finishes		No information
Skarne (Crudens)	Non-loadbearing concrete panels; timber-framed curtain wall panels; brick cladding	1 4	A B C D E G
Shepherd Spacemaker	Concrete panels; exposed aggregate, patterned concrete, brick, tile hung. On low rise, timber	1 4	No information
Sundh	Non-loadbearing concrete panels; various external finishes; cast-in windows and doors	2	No information
Tracoba	Non-loadbearing concrete panels; various external finishes; cast-in picture windows and doors. On low rise, timber infill panels	3 4 6	No information
Wates	Glazed joinery units; concrete panels; storey-height window units; tiled and brick facings	1 2 4 7	A B C D E F
XW (Selleck Nicholls Williams)	Brick; re-formed stone; timber infill panels; concrete with exposed aggregate; tile hung; weatherboarding	1 2 4	No information
YDG (Yorkshire Dev Group) Mk1	Concrete panels; exposed aggregate finish; timber infill panels	1 4	A B C D E F G

*Type of joint:

1 Open-drained joint, vertical and horizontal
2 Face-sealed with mastic
3 Face-sealed with gasket
4 'Traditional' joints, eg bricks, timber infill
5 Sealed with cover strip/capping piece
6 Open-drained joint, horizontal only
7 Grouted with mortar

**Defects quoted by Reeves[2]:

A Rain penetration — through panel joints
B Rain penetration — around openings
C Fabrication errors
D Carbonation and calcium chloride presence
E Physical damage and distortion of cladding panels
F Inaccuracies in panel assembly
G Defective thermal insulation, ventilation and condensation

Appendix B Case studies of applications of overcladding

The case studies described are not limited to large panel system buildings. All costs quoted are those at the time of installation of the overcladding.

List of case studies

1	Parsons House, Edgware	Aluminium pressed panels over mineral wool
2	Pollockshaws, Glasgow	Fibre-reinforced cement sheets over expanded polystyrene sheets
3	Woodside, Maryhill, Glasgow	Melamine plastics laminate sheets over expanded polystyrene sheets
4	Dunkirk Avenue, West Bromwich	Glass-reinforced polyester panels over expanded polystyrene board
5	West Smethwick Estate, West Bromwich	(a) Render over mineral wool, or (b) Polymer paint system
6	Churchill House, Sandwell	Reinforced polymer render system over mineral board
7	Machrihanish, Kintyre	Dashed cement render on expanded metal over expanded polystyrene board
8	Peat Road, Greenock	Reinforced polymer render system over polystyrene board
9	Bow Farm, Greenock	(a) Polystyrene beads in render, or (b) Polymer paint
10	Royston Hill, Glasgow	Troughed aluminium sheet over expanded polystyrene board
11	Red Road, Glasgow	Troughed steel sheet over expanded polystyrene board
12	Allan Tower, Motherwell	Troughed aluminium sheet over mineral wool board
13	High Common Road, East Kilbride	Troughed aluminium sheet: no insulation
14	Ivybridge, Isleworth	Flat asbestos cement over mineral wool
15	Snowman House, Camden	Dimpled aluminium panels: no insulation
16	Compton Close, Leamington Spa	(a) Render, or (b) Tile hanging, or (c) Brick with mineral wool cavity filling
17	Canynge House, Bristol	Grp panels over mineral board
18	Caldwell Road, Oxhey	(a) uPVC shiplap over expanded polystyrene board, or (b) Render over expanded polystyrene board
19	Chapeltown, Sheffield	Not specified
20	Park Hill, Sheffield	Brick slips over expanded polystyrene board bonded to polymer concrete
21	Coldharbour Lane, Hayes	Brick over expanded polystyrene board
22	Norman Crescent, Hounslow	Elastomer-based paint system
23	Cromer Street, Camden	Steel sheet: composite insulation
24	Bacton Tower, Bethnal Green	Aluminium sheet over mineral wool
25	Northway Estate, Tewkesbury	Reinforced polymer render system over expanded polystyrene board
26	Oxgangs, Edinburgh	Reinforced polymer render system over expanded polystyrene sheet

Parsons House, 124 Hall Place, Edgware Road, London W2

Owner Westminster City Council

System 19-storey concrete frame with brick panel infill

Defects before overcladding Rain penetration, draughts, expensive heating, rotten windows, spalling concrete, inadequately restrained brickwork panels and roof upstands

Overcladding
Thermal insulation 80 mm mineral wool blanket externally; no breather paper; plastics pin fixing

Cladding All-aluminium horizontally ribbed panels, with anti-drumming compound, clipped at six points to support spigots in aluminium alloy rails. Panels separately removable (Figures 49 and 50).

Figure 49

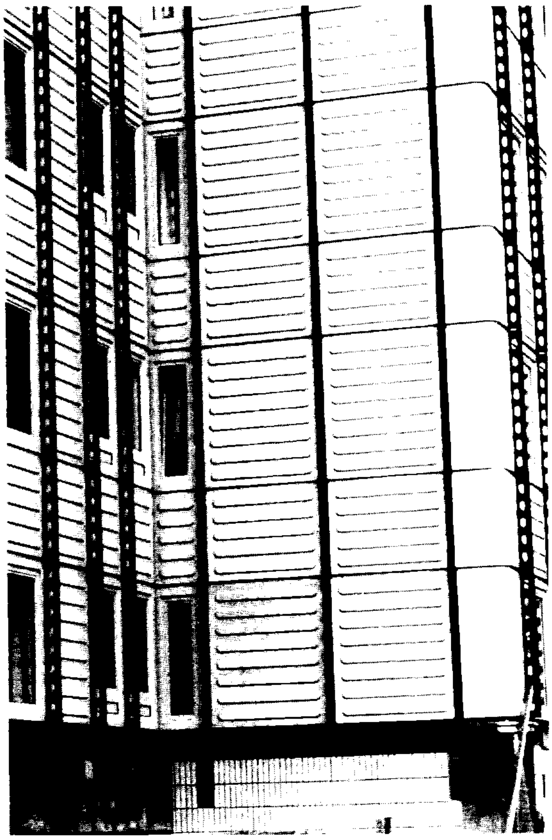


Figure 50

It is a true rain-screen solution, with a labyrinth vertical joint associated with the vertical cladding rail. The cladding rail doubles as a cradle guide (Figures 51, 52 and 53).

Windows Aluminium-faced wooden double-glazed tilt and turn

Date of installation 1985 – 86

Designer Peter Bell and Partners

Consultants Bickerdike Allen Partners
Michael Barclay Partnership

Contractor Willett Ltd

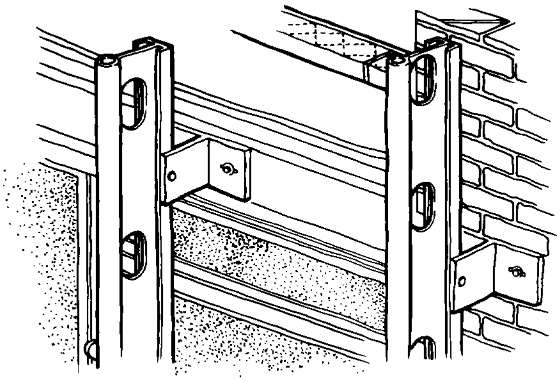


Figure 51 (Redrawn from Peter Bell's original)

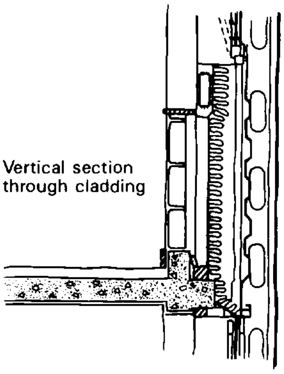


Figure 52 (Redrawn from Peter Bell's original)

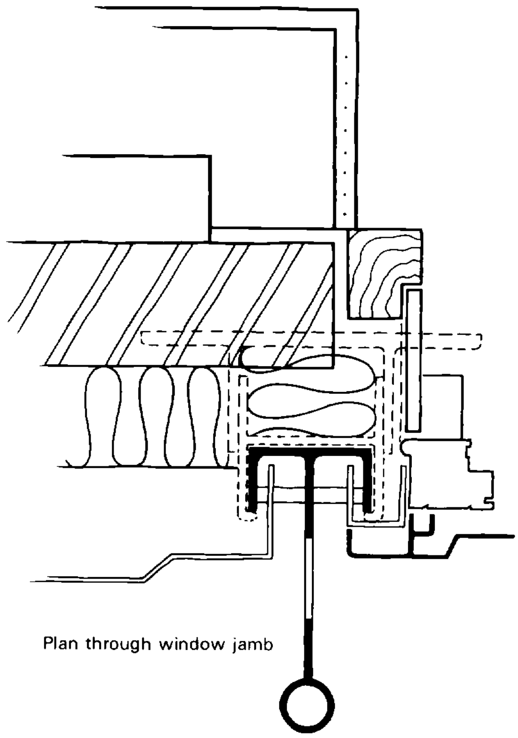


Figure 53 (Redrawn from Peter Bell's original)

Specialist cladding Hans Schmidlin (UK) Ltd

Approximate cost £220/m^2

Comment on design

It is too early to assess the actual performance of the installation, but the following comments can be made. The vertical joints run effectively for the whole height of the building, and there is a risk that they will fill with water in heavy rain-storms, so that, locally, some rain penetration through the joints may occur, though a continuous cavity closing tray at each floor will minimise this. As the insulation has no breather paper, it will be at risk of surface wetting.

The ribs to the panels are horizontal, and are inherently less self-cleaning than vertical ribs — indeed they were already beginning to mark when the building was inspected by BRE (Figure 31).

The horizontal joint has a good overlap and should work well.

Each panel is separately removable, held by spring clips and a slot and pin device. The panels were specially deep drawn, and the owner will need to carry a stock of spares into the future. The windows were installed into the overcladding before the old ones were removed, giving little disturbance to occupants.

BRE measurements on a sample of the colour-coated rail showed wide variations in coating thickness, as might be expected on such large and complex sections. Since the colour-coating is nominally satisfactory for isolation purposes, no separate washers were used to isolate the aluminium from the stainless steel fixing bolts. However, when the bolts are tightened, there is a risk of breaking the surface coating so allowing bimetallic action, although there is minimal interaction between these metals. This risk is thought to be tolerable within the service conditions. No isolating membrane was used between the backs of the colour-coated rails and the original RIW-coated concrete floor slab edge, but as this area will normally remain dry, there is little risk of interaction.

Case study 2

Pollockshaws, Glasgow

Owner Glasgow City Council

System 16- and 20-storey Bison/Harley Haddow large concrete panel finished in exposed aggregate

Date built 1970

Exposure rating Severe

Defects before overcladding There had been problems with rain penetration and condensation, particularly on the gables. It was also necessary to hide panel repairs undertaken following panel slippage.

Overcladding
Thermal insulation 25 mm expanded polystyrene sheets held with plastics pins

Cladding Vertical aluminium rails at 1 metre centres with lighter auxiliary rails in between, to which fibre-reinforced Eternit Granitex panels are pop riveted. Cavity between insulation and cladding skin. Vertical joints sealed with flat gaskets placed against the aluminium rails, and horizontal joints with a chair section. Some exposed aggregate and some smooth-finish panels.

The cavity at the rear of the panels is ventilated and drained.

The return ends of the gables are closed by vertical timber battens. Window surrounds fabricated out of sheet aluminium, pop riveted, and flashed to the Eternit panels (Figure 54).

Date of installation 1985

Designer Glasgow City Council

Consultants Eternit

Contractor Miller Construction Northern

Specialist cladding Eternit

Approximate cost £128/m^2

Assessment
Solution seems to have virtually cured the rain penetration and condensation. Slight evidence of water staining at one window which could have been caused by either drainage or condensation. Corrosion of pop rivets is a possibility, and this would then raise long-term durability problems. However, recent examination by Eternit SA of a scheme carried out in Belgium in 1966 is reported to show 'No sign of deterioration or loss of efficiency'.

The risk of damage in fire is currently being assessed.

Graffiti have now appeared at the upper levels.

Figure 54

Case study 3

Woodside, Maryhill, Glasgow

Owner Glasgow District Council

System 20-storey Bison/Harley Haddow flats and maisonettes

Date built 1970

Exposure rating Severe

Defects before overcladding Spalling concrete. A concrete panel had fallen off one block.

Overcladding
Thermal insulation 25 mm polystyrene pinned to concrete panels

Cladding Eternit Ventisol Resoplan (melamine-surfaced plastics laminate) sheets pop riveted to aluminium rails. Horizontal joints have an aluminium chair section flashing. Neoprene seals, although not normally installed in this system, were used at panel junctions vertically. Cavity between the cladding and insulation is ventilated. (Figures 55 to 59)

Reproduced by permission of Eternit Tac Limited ***Figure 55***

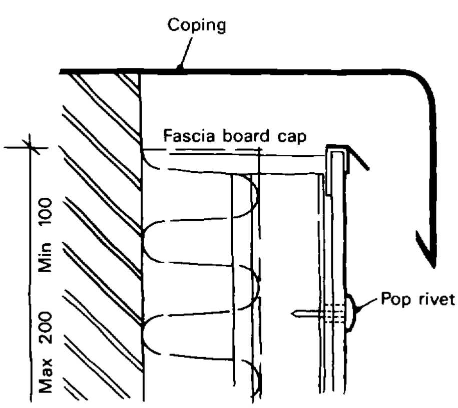


Figure 56 ***(Redrawn from Eternit Tac Limited's original)***

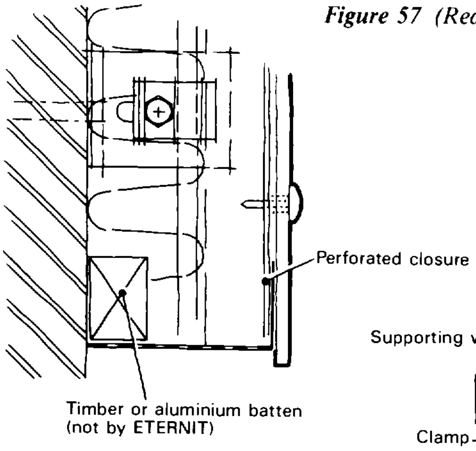


Figure 57 (Redrawn from Eternit Tac Limited's original)

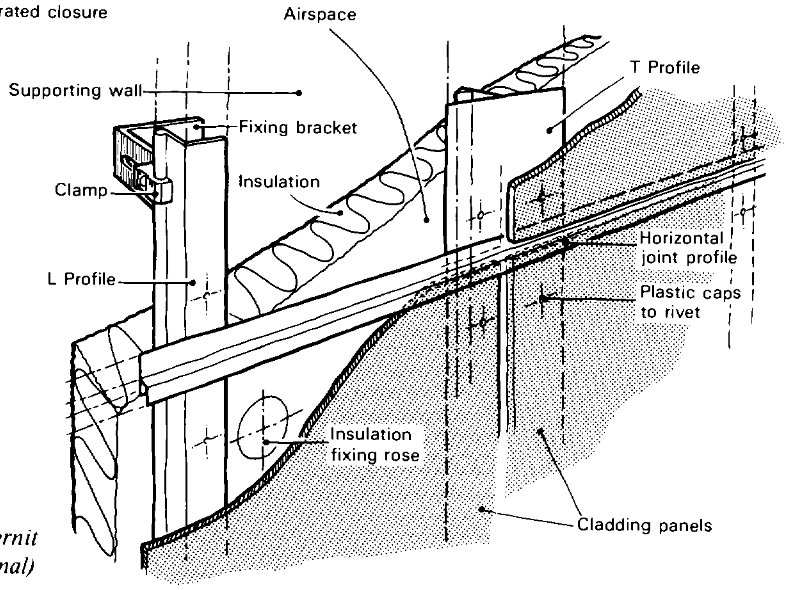


Figure 58 (Redrawn from Eternit Tac Limited's original)

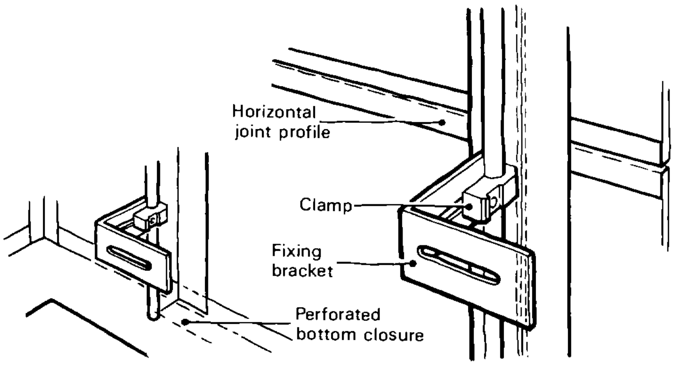


Figure 59 (Redrawn from Eternit Tac Limited's original)

Windows Not included

Date of installation 1985

Designer Glasgow District Council

Consultants Eternit

Contractor Miller Construction Northern Ltd

Specialist cladding Eternit

Approximate cost £128/m²

Assessment

The system appears to be working reasonably well, though there has been a little rain penetration. The reason for this is not known. The coping (not of Eternit design) at the top of the overcladding (see Figure 56) is vulnerable to water travelling up the face of the building. There is no surface staining, and the panels are consistent in appearance. The life of the fasteners (rivets and screws) may well be less than 30 years, although a scheme examined recently was performing well — see case study 2. The seals at panel junctions will probably be satisfactory for the projected life of the cladding.

Graffiti have appeared at upper levels.

Case study 4

Dunkirk Avenue, Greets Green, West Bromwich, West Midlands

Owner Sandwell District Council

System 2-storey Smiths system houses

Exposure rating Sheltered

Defects before overcladding Difficult to heat. Thermal movement of concrete panels creating cracking where jointed, with cracks through brick slips. Corrosion of reinforcing steel in slabs causing spalling of concrete. Figure 60 shows original state.

Figure 60

Overcladding

Thermal insulation Polystyrene insulation board laid between softwood battens

Cladding Glass-reinforced polyester panels screwed to battens, which in turn are bolted back to the concrete panels. The overcladding panels have an applied aggregate surface finish, in contrasting colours on different storeys (Figure 61). Joints are filled with polysulphide mastic (Figure 62).

Date of installation 1984

Specialist cladding Stenni

Approximate cost £7.5 thousand to £8.5 thousand per dwelling, including replacement uPVC windows

Assessment

The performance of the cladding so far is in accordance with requirements, and there is no apparent reason why it should not continue to perform thus. The owner is pleased with the appearance.


Figure 61

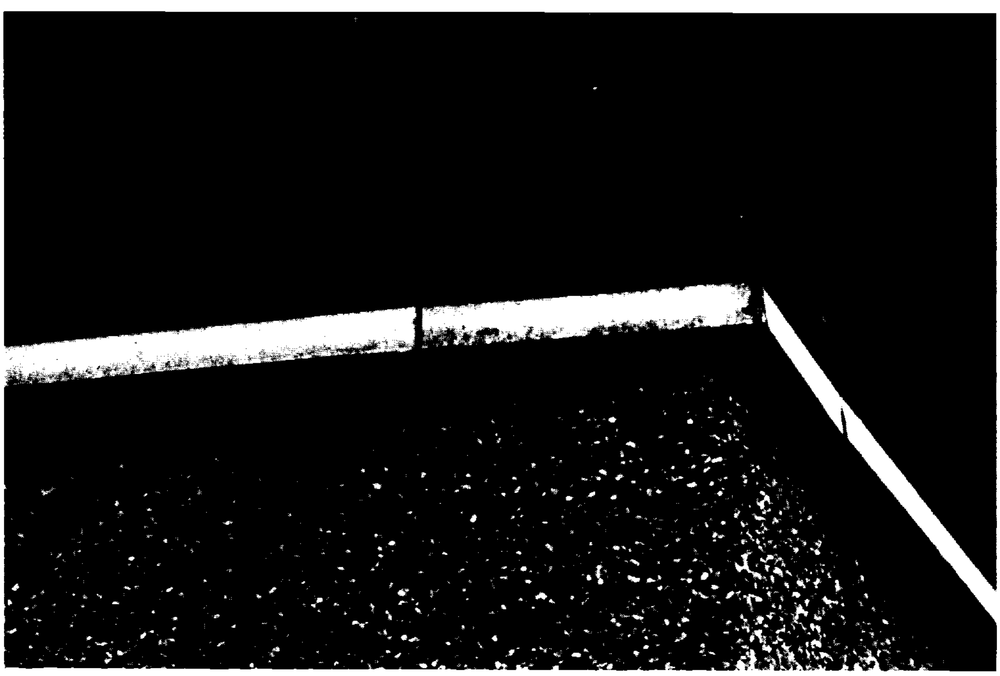


Figure 62

Case study 5

Raleigh Court, West Smethwick Estate, West Bromwich, West Midlands

Owner Sandwell District Council

System 3-storey Bison concrete panel flats

Date built Early 1960s

Defects before overcladding High-density estate, with drab appearance, condensation, difficult to heat

Overcladding
Thermal insulation One block only has Rockwool slab

Cladding The insulated block has a rendered finish in sand/cement. For the remainder the cladding consists only of a thick protective paint coating.

Windows Not included

Date of installation 1981

Assessment
The rendered finish has weathered badly, and the light-coloured surface coating is showing signs of general staining, especially on the gable walls. More severe staining has occurred beneath window openings (Figure 63). Cracking of the render around window openings is evident and some repairs have been attempted. More recently, some further blocks on the estate have been refurbished, and a decorative/protective masonry paint has been used to good effect (Figure 64).

Both the rendered and the painted blocks will need repainting at regular intervals to maintain their appearance.

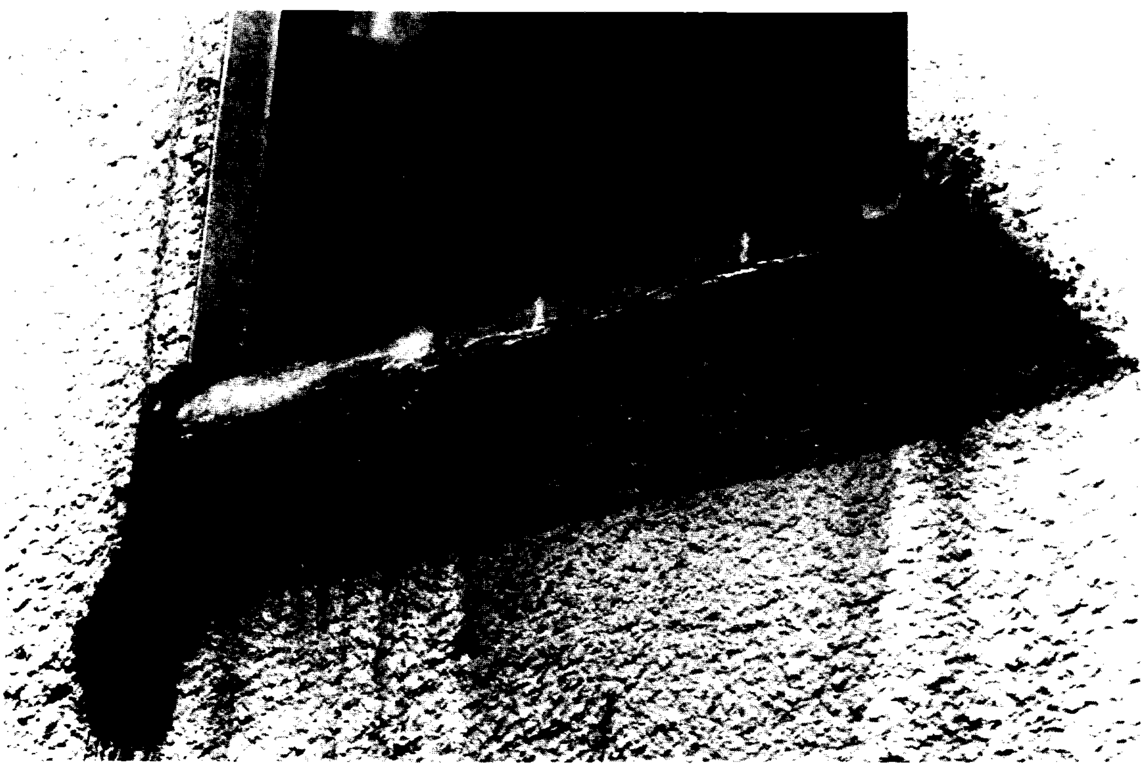


Figure 63

Figure 64

Case study 6

Churchill House, Plane Tree Road, Sandwell, West Midlands

Owner Sandwell District Council

System Tracoba 21-storey concrete panel

Date built Early 1960s

Exposure rating Moderate

Defects before overcladding Rain penetration, condensation, expensive heating, spalling mosaic, concrete cracking, and insecure panels

Overcladding
Thermal insulation 30 mm mineral fibre board, fixed with stainless steel pins

Cladding Two base coats and two finish coats, sprayed glass-reinforced plastics emulsion. Movement joints are inserted every other storey, and at regular intervals along the facade. Weep pipes to all window heads. Ground floor brick clad. (Figures 65 and 69.)

Figure 65

Figure 66

Windows Not included

Date of installation Jan – Nov 1981

Designer Gunac Ltd

Contractor Gunac Ltd

Specialist cladding Gunac Ltd

Approximate cost £60/m^2 (includes repairs to concrete panels)

Assessment

Prior to overcladding, all the defective mosaic and concrete was removed, and exposed reinforcement treated with rust inhibitor. Proprietary sprayed concrete was used to repair all defective areas of the surface.

The Rockwool panels were treated with an emulsion before the glass-fibre-reinforced emulsion was added. Following completion, tenant reaction is favourable, and the building is said to be much warmer.

The proprietary surface coating has shown some signs of distress (Figure 66). Groups of bubbles beneath the surface are visible in one area (Figure 67) with occasional large isolated bubbles elsewhere. There are areas of undulating surface, with some horizontal folding, and indications of vertical sliding (Figure 68). In spite of this, the performance of the finish with regard to other aspects of performance was said to be unaffected at this early stage. Cutting out the affected areas is not considered desirable on appearance grounds, though small areas have been tried. The situation is being monitored by the local authority.

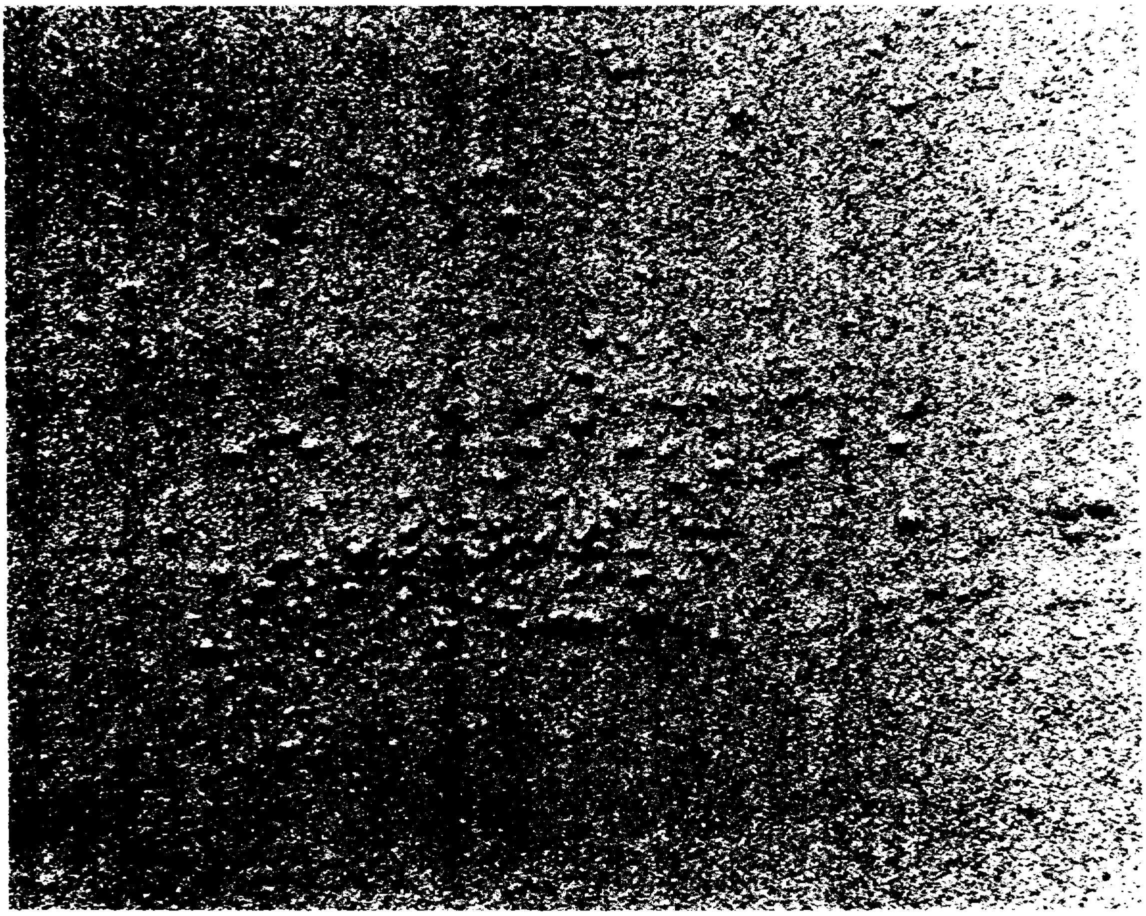


Figure 67

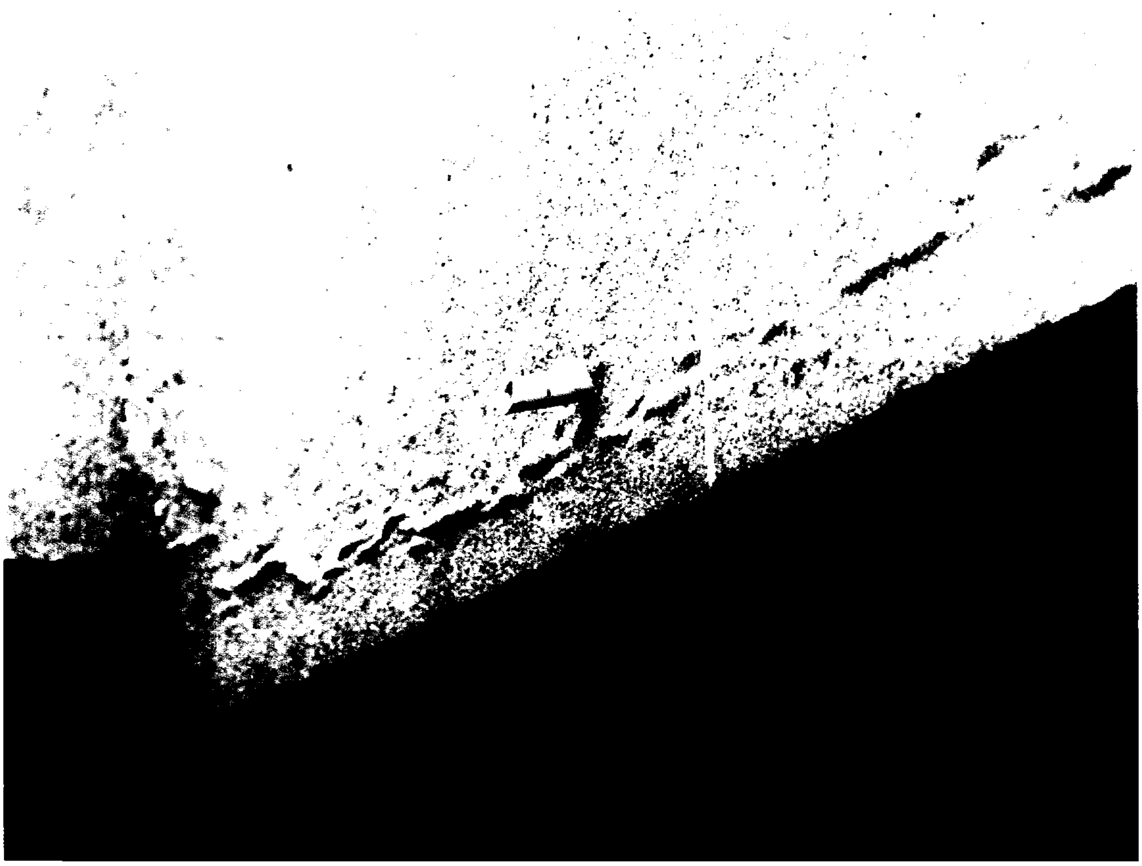


Figure 68

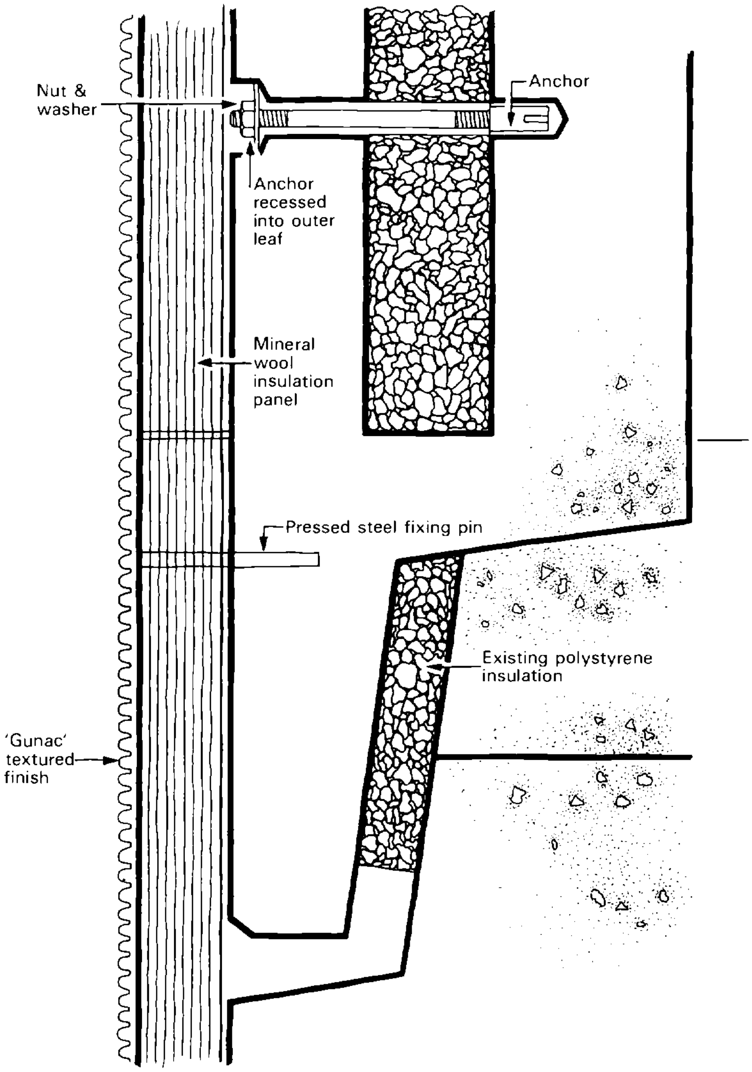


Figure 69 *(Redrawn from Gunac's original)*

Case study 7

Machrihanish, Kintyre, Scotland

Owner Property Services Agency

System Bison 2-storey concrete panel

Date built 1964

Exposure rating Very severe

Defects before overcladding Rain penetration, difficult to heat

Overcladding
Thermal insulation 50 mm expanded polystyrene board, precoated

Cladding Two-coat render with dry dash on stainless steel lath. Fixed through the insulation with stainless steel and polypropylene pins (Figure 70).

Windows Replaced

Date of installation 1985

Designer Property Services Agency

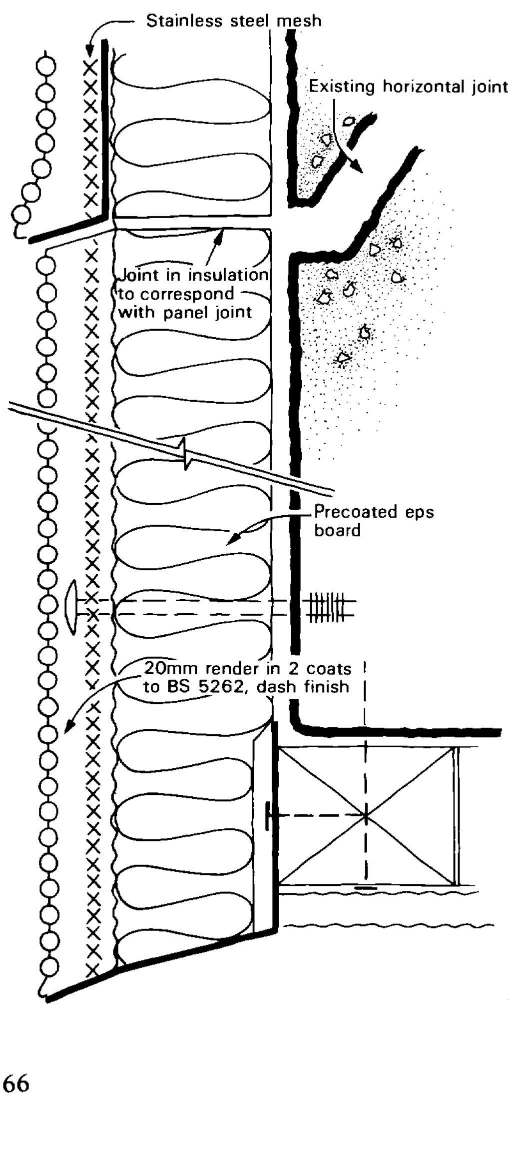


Figure 70

Consultants Scott Bennett

Contractor Eglinton Stone Group

Assessment

Render on stainless steel lath over insulation has proved successful for 6 years elsewhere in the climate of the west of Scotland. Although the site is classed as especially severe for wind-driven rain, the system, provided it is well executed, should behave well in the long term.

Sealants will need replacing after about 15 years. There is some possibility of condensation at low level because of cold bridging where the underbuilding was not insulated, but this is being modified in later phases. Figure 71 shows cold bridging at a corner of an external wall.

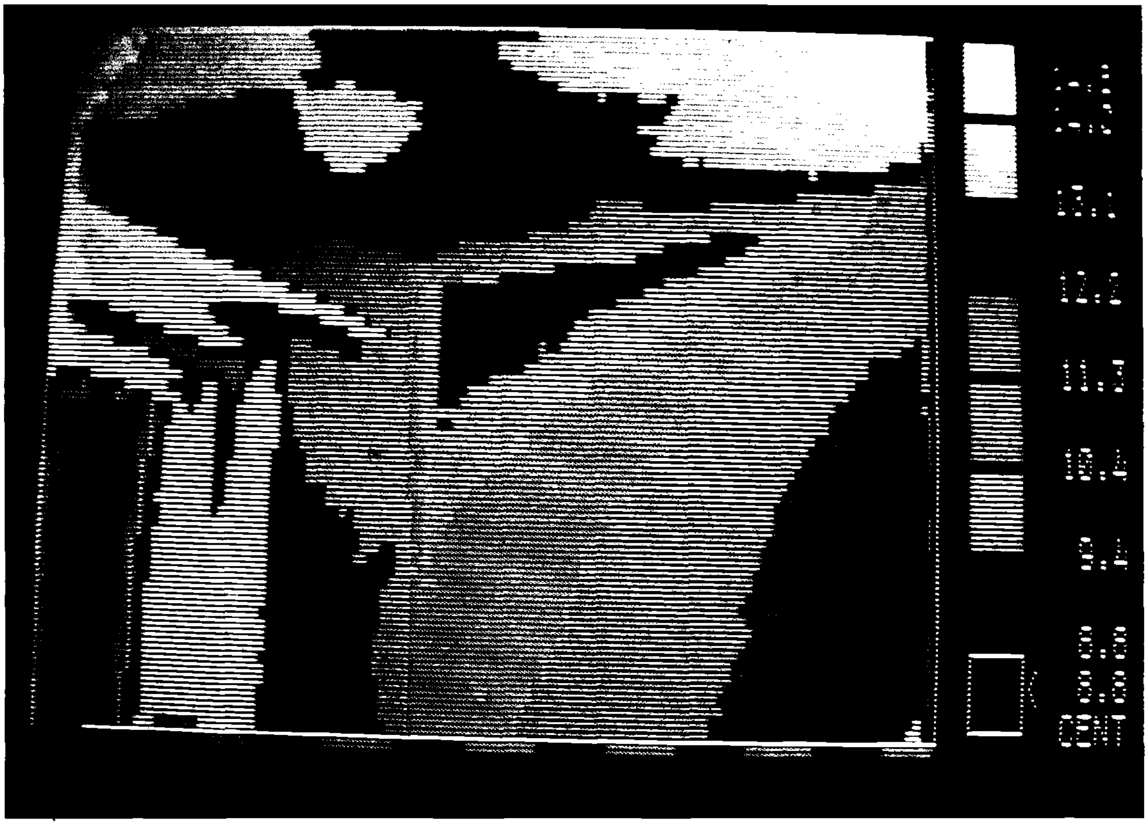


Figure 71 *Cold bridge shown by thermal camera*

Case study 8

Peat Road, Greenock

Owner Inverclyde District Council

System 4- and 5-storey cavity brick with concrete floors

Exposure rating Severe

Defects before overcladding Rain penetration, render detaching from concrete and brickwork, and difficult to heat. Cold bridges at the exposed concrete floor slab.

Overcladding
Thermal insulation Adhesive-fixed polystyrene boards

Cladding Thin glass-fibre-reinforced polymer-modified cementitious render, with trowelled polymer-bound surface finish (Figure 72).

Windows Not included

Date of installation 1979

Designer Inverclyde District Council

Contractor Eglinton Stone

Figure 72

Assessment

The treatment has been effective in curing the rain penetration and reducing condensation, but the appearance of the blocks was poor.

The surface coating has discoloured with mould growths, particularly on the north and east elevations. Some blistering of the surface coating has occurred and, in areas alongside the windows, some of the coating has washed off. Fine cracks and some impact damage were noted.

Case study 9

Bow Farm, Greenock

Owner Inverclyde District Council

System 10-storey concrete frame with brick infill

Date built Early 1960s

Exposure rating Very severe

Defects before overcladding Rain penetration and condensation, poor appearance (Figure 73)

Overcladding
Thermal insulation Some blocks have 'Swissrend', a polystyrene bead aggregate in a 20 mm thick cement-based render. Other blocks have 30 mm Rockwool pinned to the brickwork and rendered over.

Cladding 'Swissrend' as above on expanded metal lathing, with a top coat of thin polymer-bound render. Other blocks have 'Permarock' polymer-based coating.

Windows Not included

Date of installation 1983 – 84

Figure 73

Assessment
The flats are on a very exposed hill overlooking the Clyde Estuary, and have given problems since they were built. Various remedial measures were attempted, including a coat of bitumen-based material which eventually failed.

The first attempts at the remedial overcladding were applied in extremely poor weather conditions, and subsequently there have been delamination failures, with sheets of the material approximately 20 mm thick becoming detached (Figure 74). Most of the problems have been on the south and west elevations of the first block clad, but there have been less severe problems in other areas. Repairs have been attempted, which appear to have been reasonably successful, with the original faults largely cured.

Later blocks are currently being overclad with 'Permarock' over Rockwool.

Figure 74

Case study 10

Royston Hill, Glasgow

Owner Glasgow District Council

System 24-storey Reema flats

Defects before overcladding Rain penetration and condensation

Overcladding
Thermal insulation 25 mm thick polystyrene board

Cladding Timber battens carrying colour-coated aluminium sheets. A combination of vertical and horizontal ribbing (Figure 75). Panels fixed back through a neoprene gasket.

Windows Some secondary glazing

Date of installation 1984

Designer Glasgow District Council

Consultants Allscott

Contractor Allscott Contracts Limited

Approximate cost £130/m^2

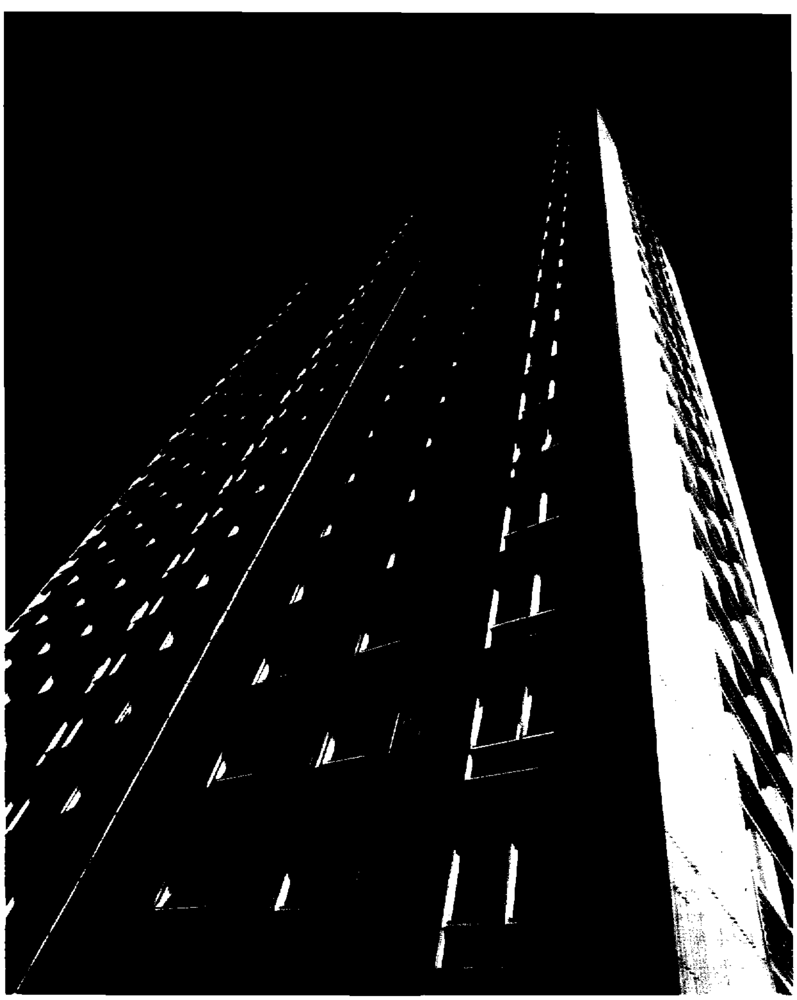


Figure 75

Assessment

It was not clear whether or not the problems of rain penetration had been entirely eliminated at the time of the BRE visit. The problem seems to centre on the open drying areas, since the overcladding had not been returned round the edges of these. The condensation problem had been virtually eliminated. Externally, differential staining was evident from water run-off and bird droppings. Some gaskets filling spaces between horizontal and vertical ribs of the cladding had been displaced. The cladding has, since installation, been damaged by a suspended platform used during a programme of resealing windows (Figure 16).

Case study 11

Red Road, Glasgow

Owner Glasgow District Council

System 32-storey steel-frame flats with asbestos cement on timber-frame panels

Date built 1967 – 68

Exposure rating Severe

Defects before overcladding Rain penetration, lack of thermal insulation. Figure 76 shows early remedial measures which were unsuccessful.

Overcladding
Thermal insulation 19 mm polystyrene boards to three of six blocks

Cladding Galvanised, troughed, plastisol-coated steel sheets screwed to original panels with stainless steel screws through 19 mm synthetic rubber strips; in later blocks through 19 mm expanded polystyrene boards (Figure 77).

Windows Not included

Date of installation 1975 – 78

Designer Glasgow District Council

Contractor Allscott Contracts Limited

Approximate cost £30/m^2

Figure 76

Figure 77

Assessment
The first few blocks to be overclad had no extra thermal insulation. Rain penetration appears to have been cured. Steel sheeting shows minor signs of staining near the lower edges of sheets and slight rusting where surface coating is damaged, and is expected to need recoating at about 15-year intervals. There are no rusting problems at the fixings. There are no cavity barriers in the cavity.

Removal of panels confirmed that sealants were still in good order.

Many stains were found on inspection, including differential dirtying, bird droppings, paint splashes and sealant extrusion. They are not obtrusive on casual inspection from the ground. Noticeable fading and colour variation of surface coating has produced a striped appearance on some blocks.

Case study 12

Allan Tower, Motherwell

Owner Motherwell District Council

System Crudens concrete-frame 20-storey reinforced concrete flats with rendered brickwork infill panels

Date built 1970

Exposure rating Severe

Defects before overcladding Rendering becoming detached and falling

Overcladding
Thermal insulation 30 mm Rockwool boards

Cladding Aluminium rails bolted to the concrete with 18-8 stainless steel bolts, and carrying a skin of profiled aluminium sheets (Figure 78). Sheet joints are sealed with silicone rubber, and the laps are pop riveted with aluminium alloy rivets.

Windows Some replacement — not included in price

Date of installation 1985 – 86

Designer Allscott

Consultants Case Design Associates, Edinburgh

Contractor Allscott Contracts Limited

Approximate cost £130/m^2

Assessment
This installation is externally similar to case study 10, but the earlier experience has enabled an aesthetically neater solution. There are no problems apparent to date. Great care was taken by the consultants to avoid corrosion, by isolation.

Some difficulties arose with alignment of panels due to window opening variations in the original building.

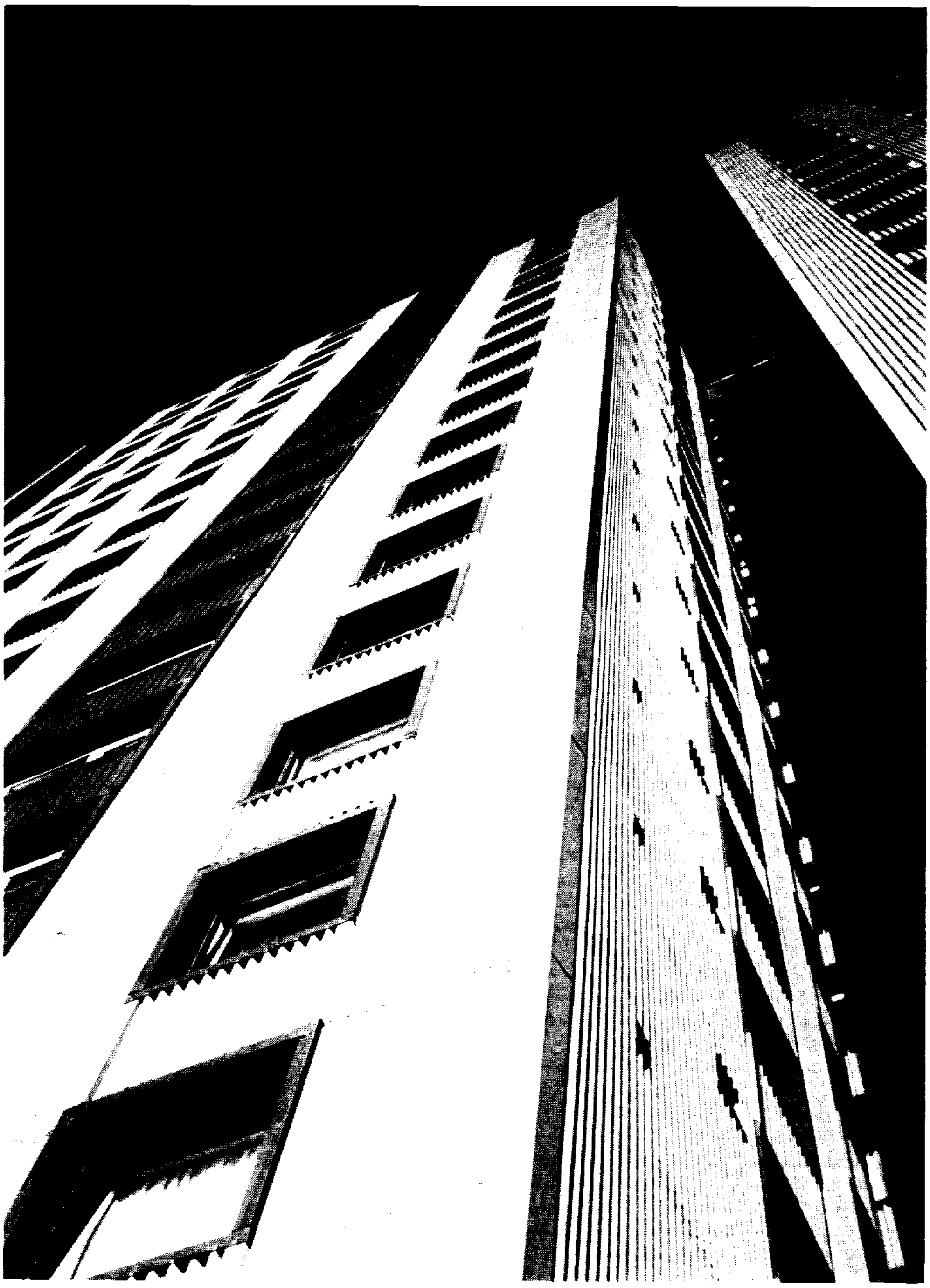


Figure 78

High Common Road, East Kilbride

Owner East Kilbride Development Corporation

System 20-storey Reema LPS flats

Date built About 1970

Defects before overcladding Rain penetration, particularly on south-west gables. Large variation in original joint widths, with some panels displaced relative to each other. Some corners chipped off, probably during assembly.

Overcladding
Thermal insulation None

Cladding Horizontal stainless steel rails supporting profiled sheet aluminium, carried out on the south-west-facing gable ends only (Figure 79).

Windows uPVC

Date of installation 1985

Designer Ove Arup

Approximate cost £170/m^2 (excluding windows and their associated details)

Assessment
The cladding has uniform appearance, with no sign of any defects, and the rain penetration appears to have been cured.

No insulation was included in the design although it would have been a simple installation.

Figure 79

Case study 14

Ivybridge, Summerwood Road, Isleworth

Owner London Borough of Hounslow

System In-situ reinforced concrete frame

Date built 1971

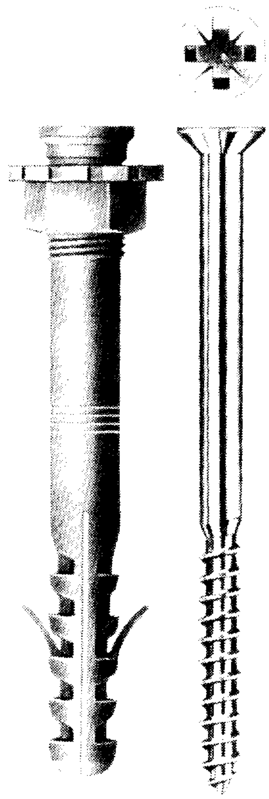
Exposure rating Moderate

Defects before overcladding Building started in the 1960s but the contract was later determined with work in varying stages of construction. The site stood incomplete for several years until 1970/71 when Alan Crocker of Mathews, Ryan and Partners in consultation with James Nudd developed jointly a remedial scheme. They realised that the thermal insulation and weatherproof properties of the external walls built to the original design would be deficient, and the overcladding was instituted immediately as a means of overcoming these faults.

Overcladding
Thermal insulation 25 mm mineral wool blanket glued to in-situ concrete wall, with 25 mm minimum residual cavity

Cladding Eternit asbestos cement sheets screwed to asbestos cement vertical battens (Figure 80). The battens are held off the wall by Fischer plugs (Figure 81).

Figure 80



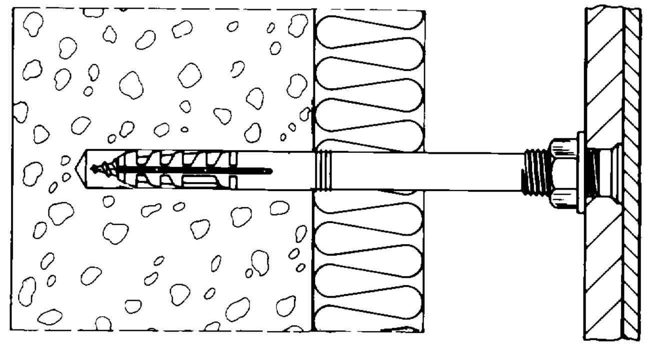


Figure 81 (Reproduced by permission of Artur Fischer (UK) Limited)

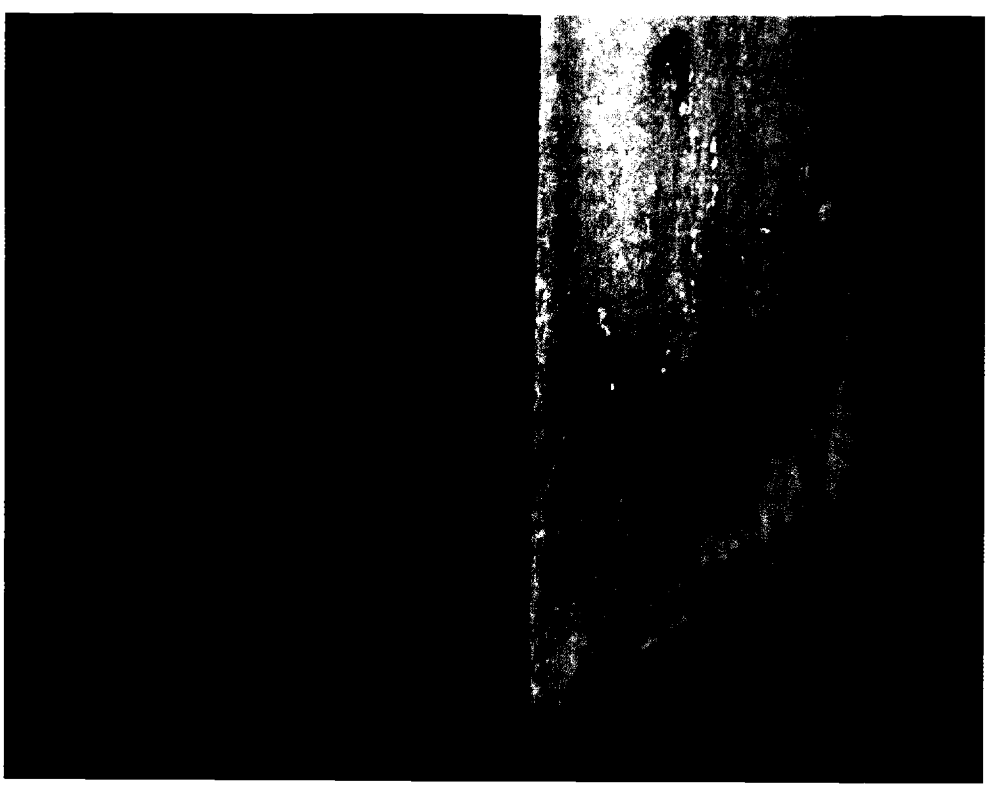


Figure 82

These three blocks were some of the first in the UK to be overclad. Most of the overcladding is of straightforward construction, with vertical joints in the boards made against wide asbestos cement battens (Figure 82) screwed tight up to synthetic rubber gaskets. The horizontal joints are flashed with chair section aluminium alloy sections.

In order to overcome gross inaccuracies in the original walls, the residual cavity varies from 25 mm to 125 mm.

Windows Stained softwood with aluminium sills and heads integrated into the design of the overcladding

Date of installation 1974

Designer Mathews, Ryan and Partners, succeeded by Alan Crocker and Partners

Consultants James Nudd

Contractor Mowlem

Specialist cladding Whittakers

Specialist fixings Fischer (UK) Ltd

Assessment
There has been no evidence of rain penetration into the dwellings.

The aluminium sections used in sills and flashings are mill finish (Figure 83). In spite of absolutely no maintenance during the 12 years since installation, they were in remarkably good condition when inspected by BRE. The asbestos cement panels are very slightly rain-marked in places, for example at sill ends and under flashings, but also are in good condition. There have been no breakages.

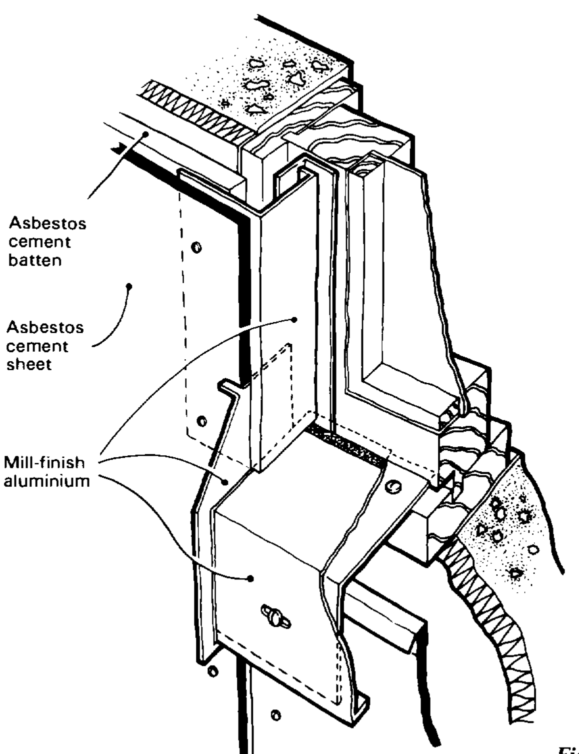


Figure 83 (Redrawn from Alan Crocker's original)

As an experiment, at the time of construction, the horizontal flashings were omitted from the overcladding on the tank rooms on one of the blocks (Figure 84). This has, in effect, made the design at this location a true open-jointed rain-screen similar to the original Norwegian pattern. One panel removed during the BRE inspection showed a little rain-marking on the back of the panel, both in front of the battens and also in between the battens (Figure 85). This is to be expected in such an exposed location. There was, however, no evidence of rain-water staining at the foot of the cladding, showing that rain penetrating the joints must have evaporated harmlessly. The mineral wool insulation had discoloured and was very dusty, and the adhesive had apparently failed. The insulation was being held in place by virtue of its tight fit, but there is a risk of it falling forward across the cavity. It was obviously still effective as an insulant.

The plastics-coated fixing screws were in good condition.

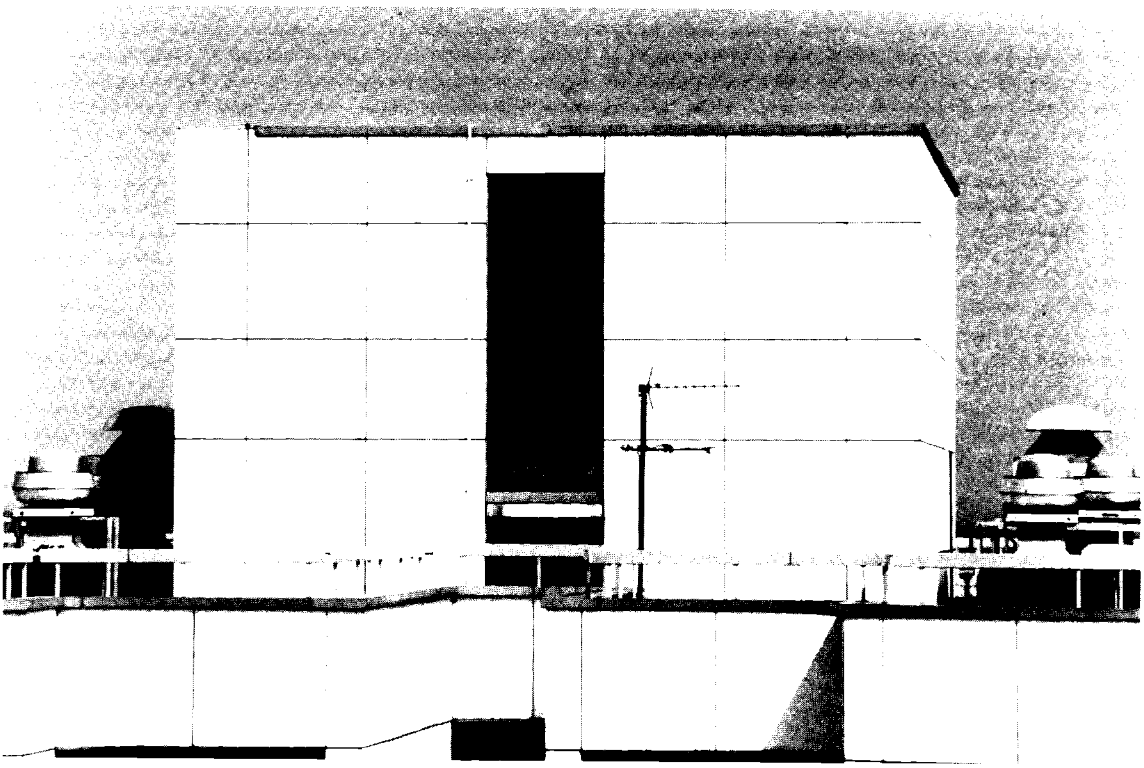


Figure 84

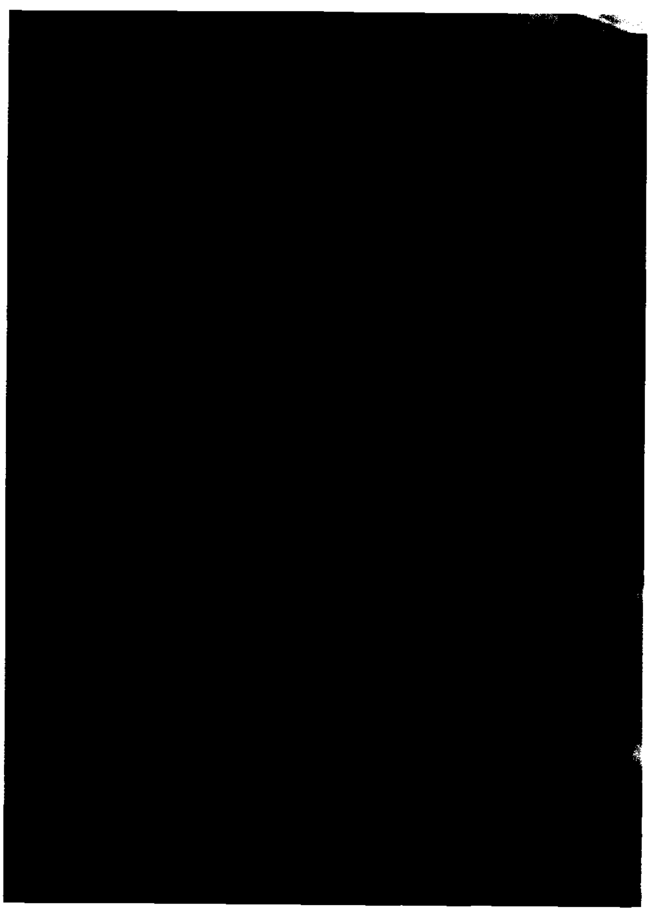


Figure 85

Case study 15

Snowman House, Abbey Road, Paddington Green, London

Owner London Borough of Camden

System Laing concrete frame and precast concrete cladding panels

Date built Mid-1970s

Defects before overcladding Falling mosaic

Overcladding
Thermal insulation None added

Cladding Specially formed dimpled aluminium panels fixed to aluminium frame, and bolted back to concrete panels (Figure 86). System designed to catch any further mosaic which might fall.

Windows Not included

Date of installation 1982

Designer Bickerdike Allen Partners

Contractor Laing

Specialist cladding Essex Aluminium

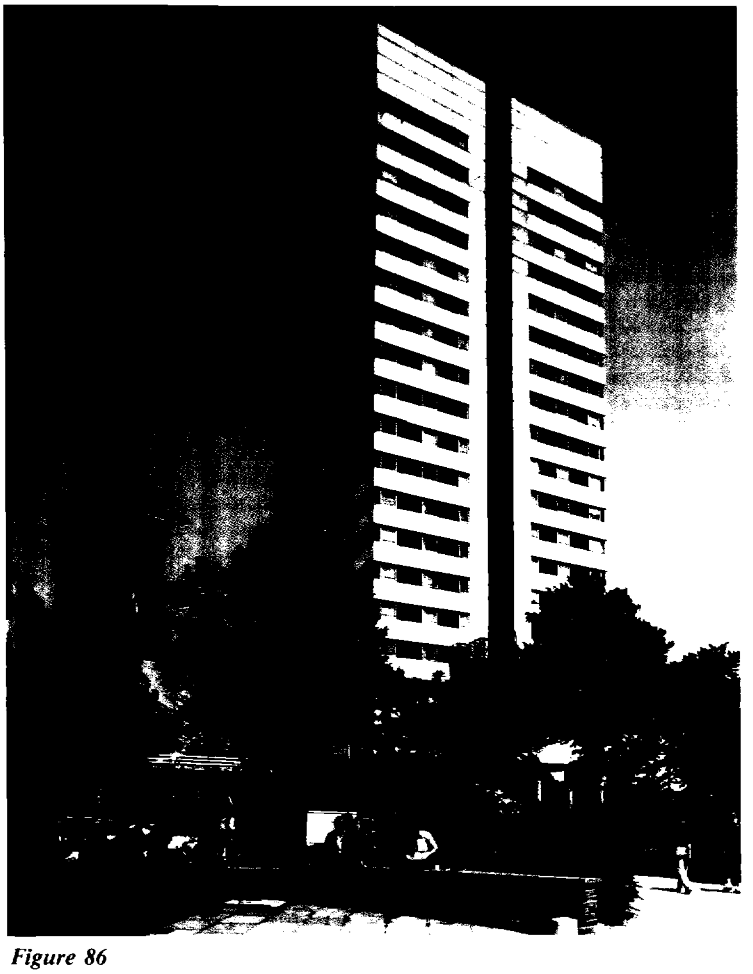


Figure 86

Assessment
The cladding has successfully contained the falling mosaic.

The buildings now show weather staining, and the overcladding has been damaged in some places within reach of public access (Figure 18). Cappings have been removed; some distortion at seams has occurred; some gaskets are protruding from joints (Figure 87). Noise from rain drumming on the panels has been reported.

The unique profile has made repair and replacement of damaged panels costly, and a special set of formers is kept by the owner. Sufficient resources to maintain the cladding have not been provided — even the routine washing has not been achieved.

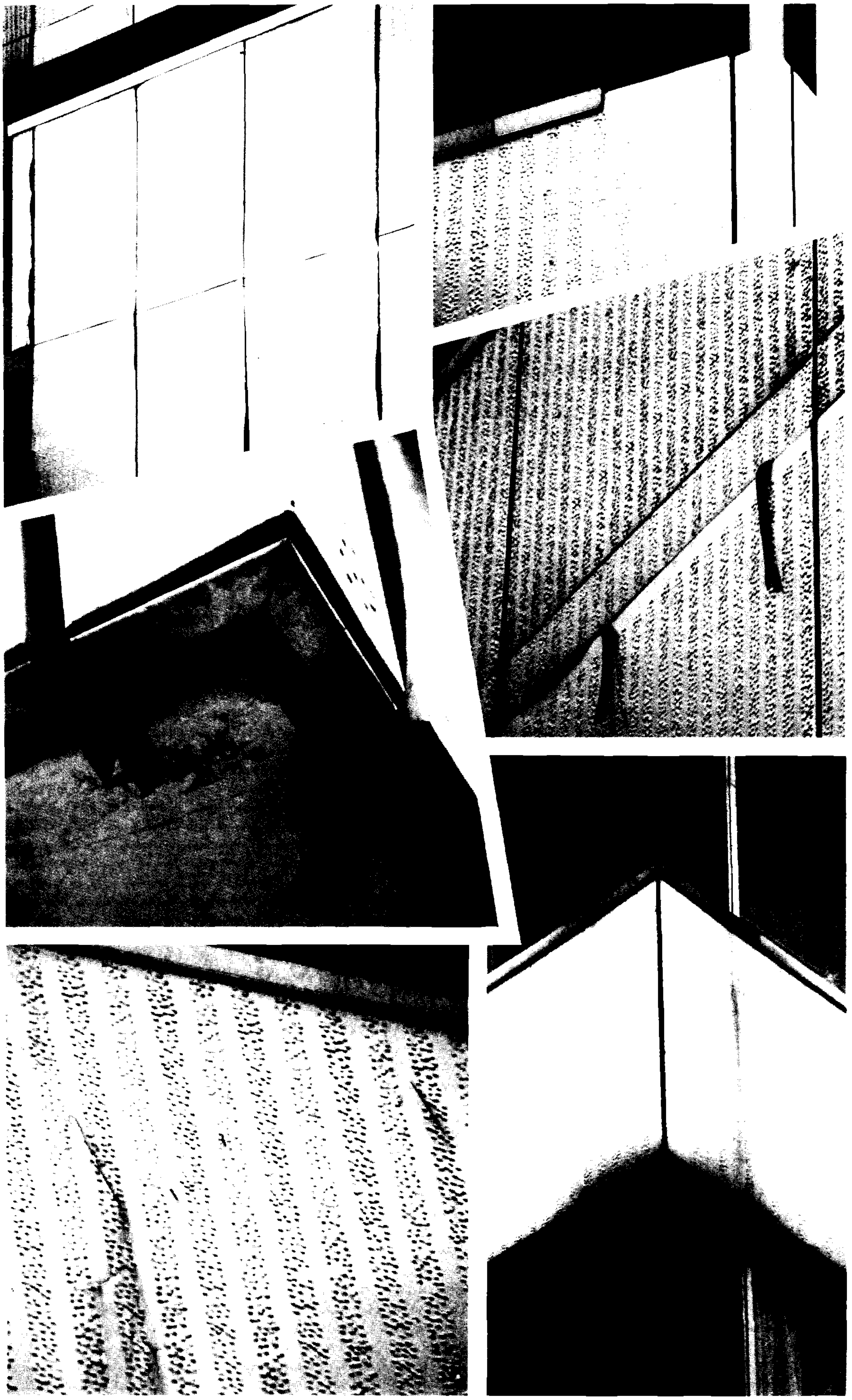


Figure 87

Case study 16

Compton Close, Buckley Road, Leamington Spa

Owner Warwick District Council

System Wimpey 'no-fines' semi-detached and terraced housing

Date built 1954 onwards

Exposure rating Sheltered

Defects before overcladding Condensation, attributed to lack of thermal insulation and no central heating

Overcladding trials
During 1983 and 1984, one pair of dwellings was overclad with 50 mm polystyrene thermal insulation board pushed in between softwood battens fixed to the no-fines wall. The ground-floor walls were finished with sand-cement render on 'Twill-lath', while the first-floor walls were finished in tile hanging. A subsequent trial used mathematical tiling in lieu of the rendering (Figure 88).

Neither scheme was deemed to be entirely satisfactory: the sand-cement rendering cracked, and the general appearance of the mathematical tiling was unacceptable (Figures 89 and 90).

Final proposal
The final solution is to use a new outer leaf of brick or block (Figure 91) carried on extended foundations (Figure 92). The external wall includes 50 mm 'Dritherm' filled cavities. There is a small amount of masonry paint finish to the block walls which will need redecorating at regular intervals. This finish was used for aesthetic reasons.

There are problems with detailing where houses have been sold (Figure 93).

Figure 88

Figure 89

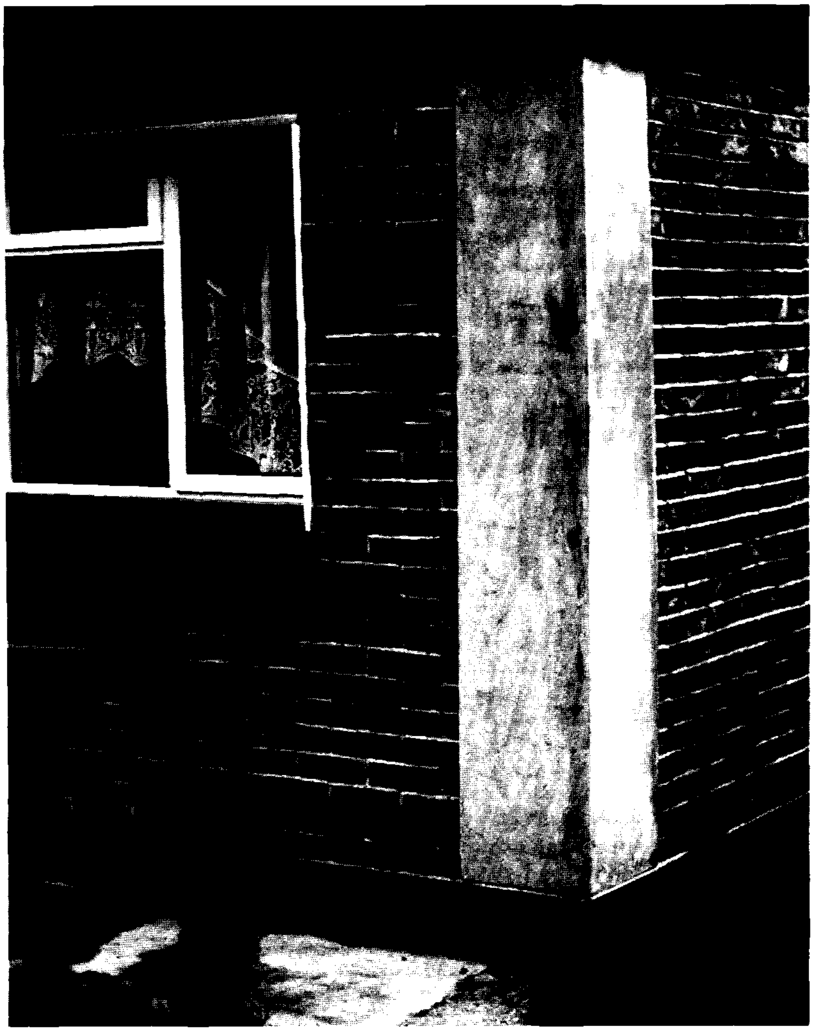


Figure 90

Figure 91

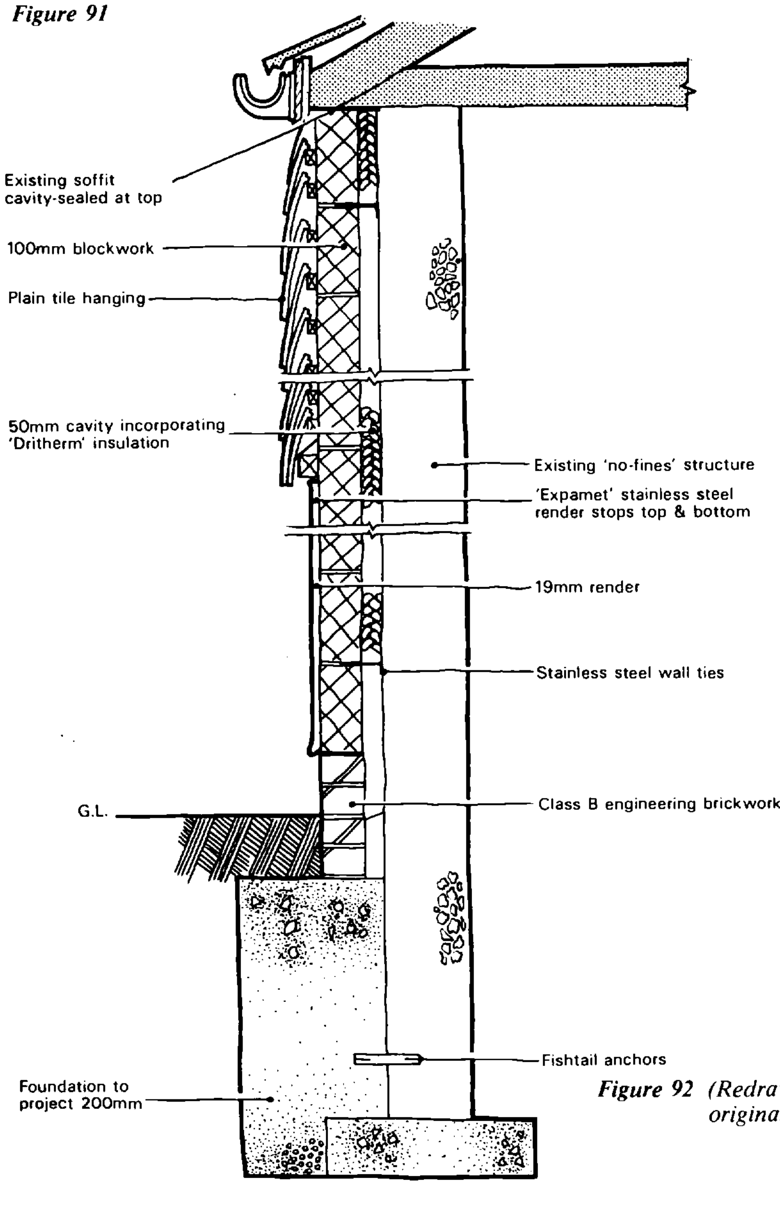


Figure 92 (Redrawn from Warwick District Council's original)

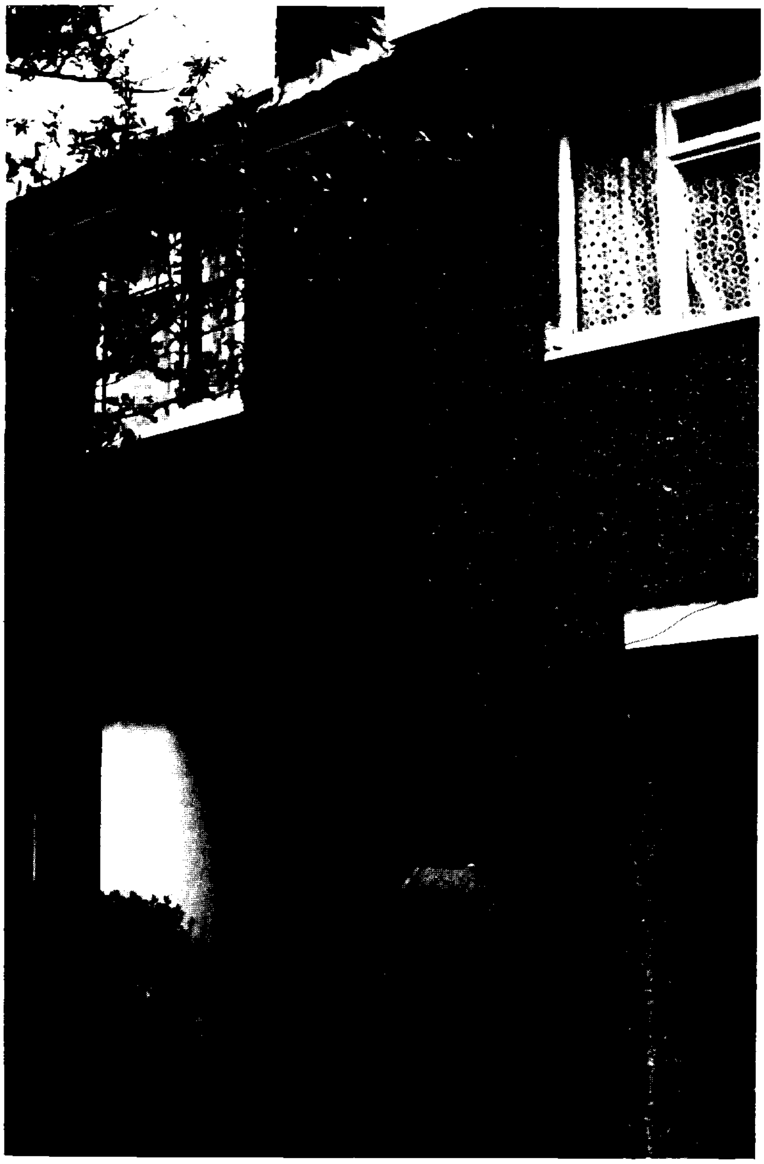


Figure 93

Case study 17

Canynge House, Redcliffe, Bristol

Owner City of Bristol District Council

System In-situ concrete frame with rendered hollow clay pot walling

Date built 1953

Defects before overcladding Rain penetration, condensation, and difficult to heat. Previous attempts at repair were ineffective.

Overcladding trials
Thermal insulation Coolag thermal insulation held in place by softwood battens fixed by means of special screws into the hollow clay pots.

Cladding Stenni panels screwed to battens with stainless steel screws at 150 mm centres. All joints are bedded in mastic strips over the battens. The joints are filled with mastic, and finished with pieces of aggregate to blend with the surface (Figures 94 and 95).

Date of installation 1986

Designer City of Bristol

Specialist cladding Stenni

Assessment
The installation is just complete and no information on actual performance is yet available. There are no indications that performance will be other than to requirements.

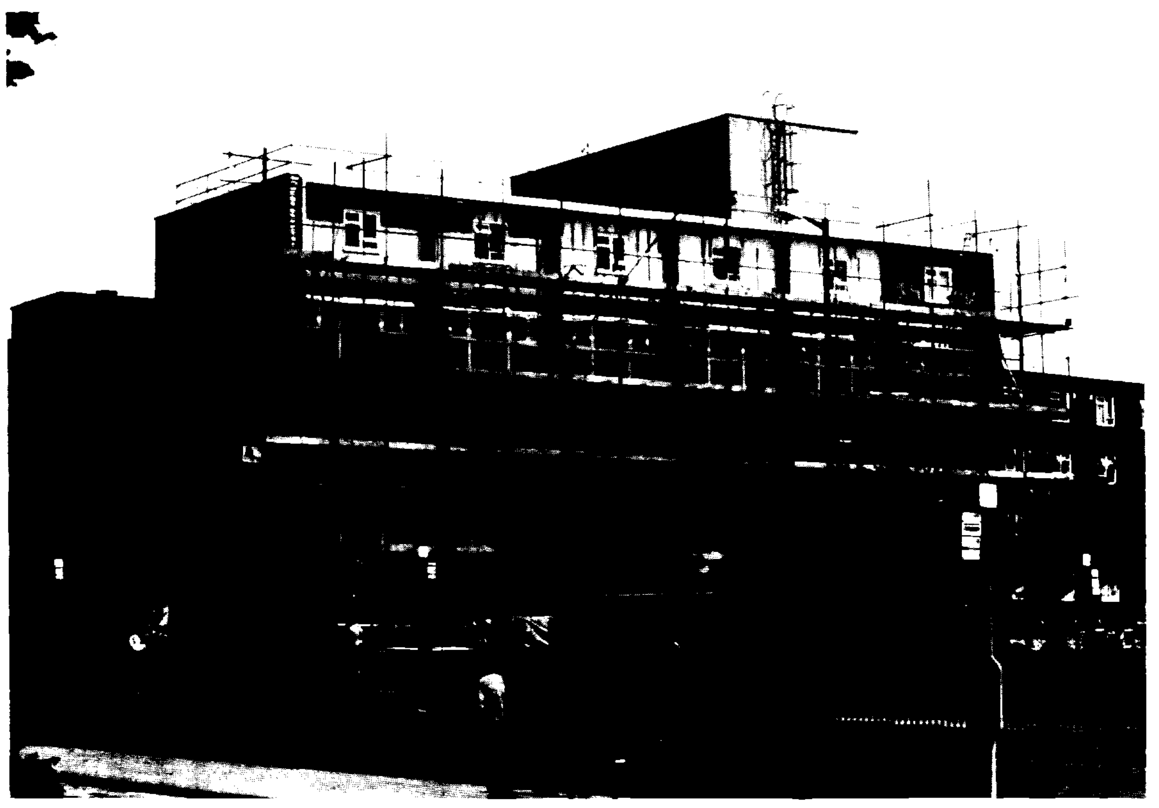


Figure 94

Figure 95

Case study 18

Caldwell Road, Oxhey, Herts

Owner Three Rivers District Council

System BISF steel-framed system houses

Exposure rating Sheltered

Defects before overcladding Difficult to heat

Overcladding
Thermal insulation First floor: 50 mm polystyrene boards fixed between 50 mm square timber battens. Ground floor: 40 mm polystyrene insulation glued over the original render (Figure 96).

Cladding First floor: Marley uPVC shiplap. Gables, where necessary, and all ground floor: 2-coat render, reinforced with mesh, and dash finish (Figure 97).

Windows Anodised aluminium

Date of installation 1984 onwards

Designer Welling and Partners

Contractor Durkan Bros

Specialist cladding Eglinton Stone

Figure 96

Assessment
The insulation appears to have been successful, and so far there have been no weather-tightness problems. There have, however, been colour-fastness problems with the brown-coloured shiplap used on the first dwellings. The white shiplap used later on appears to have fared better.

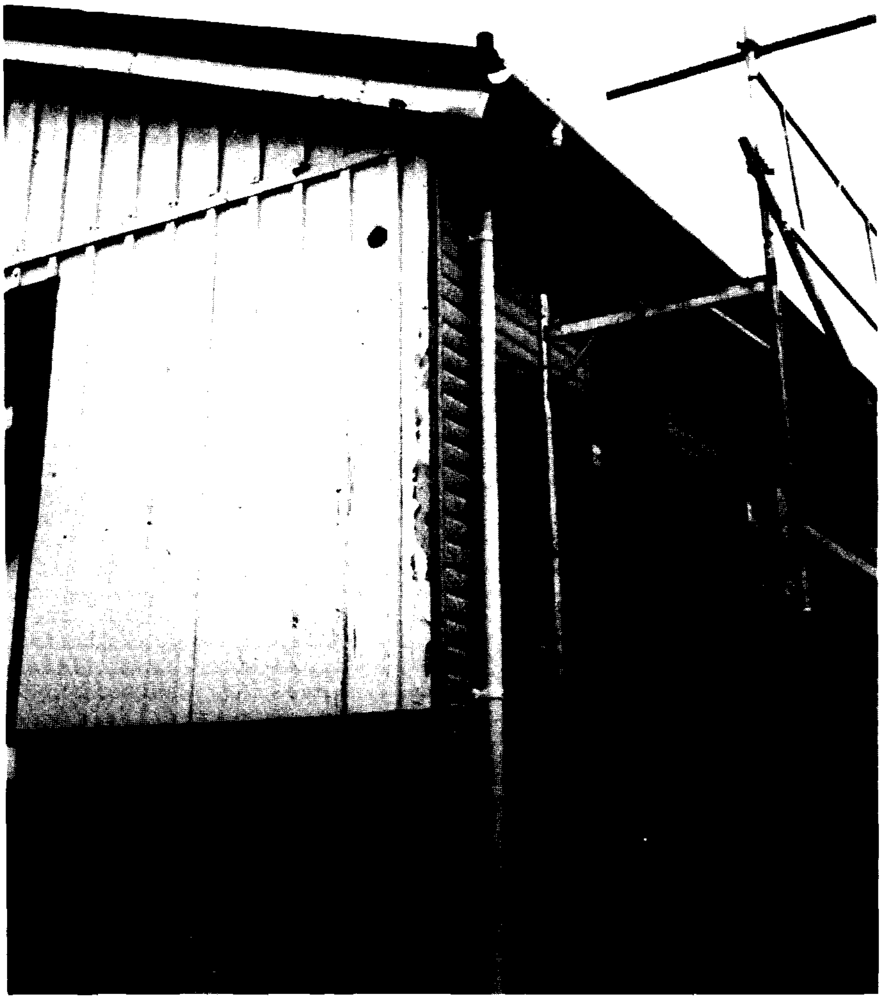


Figure 97

Case study 19

Greenhead Gardens, Chapeltown, Sheffield

Owner Sheffield City Council

System Three 12-storey tower blocks built in the Reema system (Figure 98)

Date built 1965

Defects before overcladding Structural strengthening, repairs to concrete, defective heating, old wiring, presence of asbestos, deteriorating windows, insufficient thermal insulation (Figure 99).

Feasibility study for overcladding
The feasibility study included examination of a range of options, including minimum repairs and refurbishment, up to a full refurbishment, including overcladding.

The original concrete cladding gave evidence of a number of problems, including cracking and spalling around window and door openings, spalling concrete around balustrades, including exposed reinforcement, broken corners of panels, and hair cracks on the external face of wall panels.

Repair without the additional protection of the overcladding would not give sufficient assurance of long-term durability, and exposed concrete would probably need re-treatment at 10- to 15-year intervals.

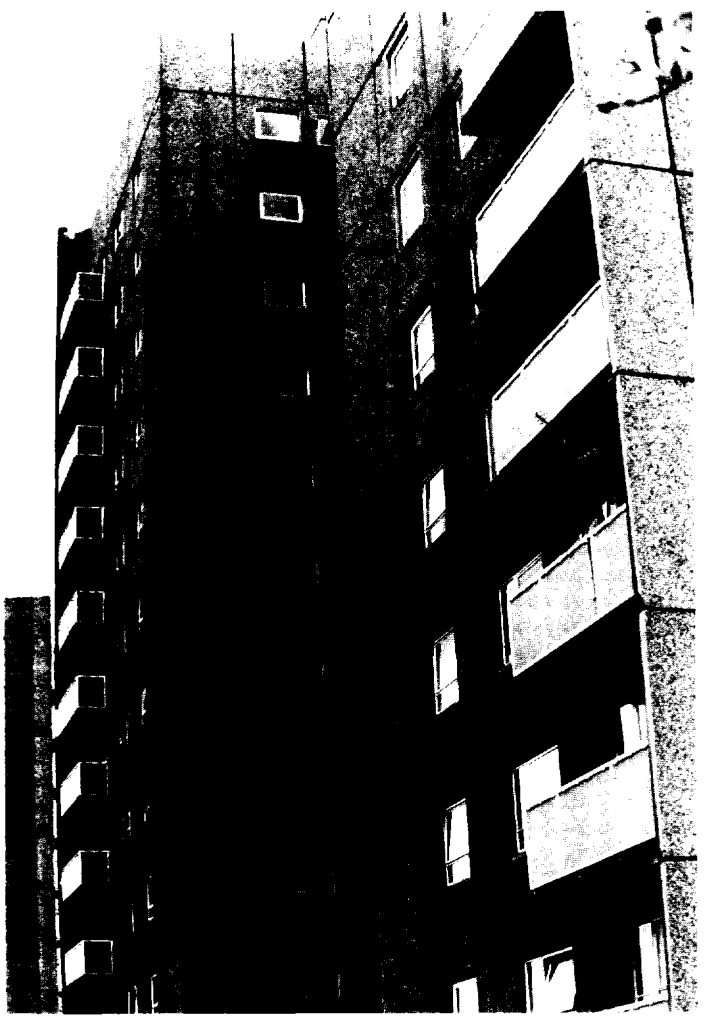


Figure 98

Among the advantages of overcladding identified in this case were the opportunity to provide additional thermal insulation on the outside of the building, making the most of the proposed new electrical heating system, and a reduction of the risk of interstitial condensation. It was also concluded that the appearance of the blocks could be greatly improved. Among the disadvantages identified were the fact that some of the balconies would need to be removed to enable the overcladding to be fitted.

It was concluded that overcladding with additional thermal insulation and a sheet outer covering was the preferred technical solution. However, when considered with the essential extensive structural strengthening required, full refurbishment became financially prohibitive. The City Council resolved therefore to rehouse the tenants with a view to eventual demolition.

Figure 99

Park Hill, Duke Street, Sheffield

Owner Sheffield City Council

System Reinforced concrete frame with brick infill

Date built 1960 onwards

Defects before overcladding Spalling concrete, cold bridging and mould growth along positions of concrete frame in unheated bedrooms. (The district heating system is said to be inadequate.)

Overcladding trials

Thermal insulation The following measures are still being monitored. 50 mm blown mineral wool insulation on the walkway soffit, covered with plain non-asbestos insulating board on softwood battens screwed to the concrete.

Overcladding the parapet around the roof edge beams with custom-made sheet aluminium cladding over Styrofoam thermal insulation (Figures 100 to 102). It is possible that an alternative thermal insulation would be injected later.

Overcladding the brick infill panels with 'Plasmor Thermostyle' fixed directly to the wall with stainless steel screws and bolts (Figures 100 to 102). The composite panel is faced with brick slips bonded with polymer-modified fibre-reinforced concrete to the tongued and grooved thermal insulations.

Date of installation Trial being evaluated

Designer Sheffield City Council

Specialist cladding Plasmor

Approximate cost £40/m^2

Comment

The proposal to overclad the parapet with aluminium alloy sheets should give the required performance. BRE has no first-hand knowledge of the performance of the brick-slip-faced panels: adhesion of the brick slips will be of crucial importance for durability.

Figure 100

Figure 101

Figure 102

Glenister House, Fitzgerald House, and Wellings, Avondale Drive, Coldharbour Lane, Hayes

Owner London Borough of Hillingdon

System 3- and 4-storey blocks, 13- and 14-storey blocks; Bison wall-frame system

Date built 1966 onwards

General condition of Bison dwellings owned by Hillingdon A report to the owners on the condition of Bison dwellings on six estates identified problems of cladding failures, condensation and water penetration; the 3- and 4-storey blocks also had structural deficiencies.

The options considered include:

For the high-rise blocks
1 Essential repairs and limited improvement
2 Full refurbishment of existing buildings

For the low-rise blocks
3 Demolish and rebuild on existing foundations
4 Demolition and full redevelopment to a new brief
5 Demolish only

It was concluded at an early stage that if all the defects in the high-rise blocks were to be remedied, overcladding provided the best prospects for success. The decision was taken to demolish the low-rise blocks.

Overcladding options — high rise
Possible options considered for overcladding included:
1 A lightweight skin around the structure, which would contain debris
2 Removal of the concrete cladding and construction of a lightweight skin
3 Removal of the concrete cladding and replacement with concrete panels
4 Removal of the concrete cladding and replacement with brickwork

Option 4 was chosen.

Overcladding
Thermal insulation 50 mm Styrofoam

Cladding Half-brick skin carried on stainless steel shelf angles bolted through the inner leaf of original concrete panels at about 250 mm above floor level to avoid the horizontal joint between panels (Figures 103 to 105). Cavity varies in order to accommodate wide deviations in accuracy of the original panels. The blocks were completely vacated during the contract, each one for 12 months. Whilst the blocks were empty, internal refurbishment was also carried out including re-asphalting of the roof, rewiring, new heating, new kitchen fittings, access security system, redecoration, etc.

Windows Double-glazed polyester-coated aluminium

Date of installation There are three identical 13-storey blocks at Avondale Drive; overcladding of Glenister House was completed in 1983, of Fitzgerald House in 1984, and of Wellings in 1985. Overcladding of a fourth block (14 storey), Rabbs Mill House, Chiltern View Road, Uxbridge, was completed in 1983.

Designer Department of Building Design and Construction, London Borough of Hillingdon

Assessment
The work has only just been completed. Some minor cracking of brickwork has occurred at the ends of lintels (Figure 106) though the reason for this is not known, and also where movement joints have not been carried through (Figure 107).

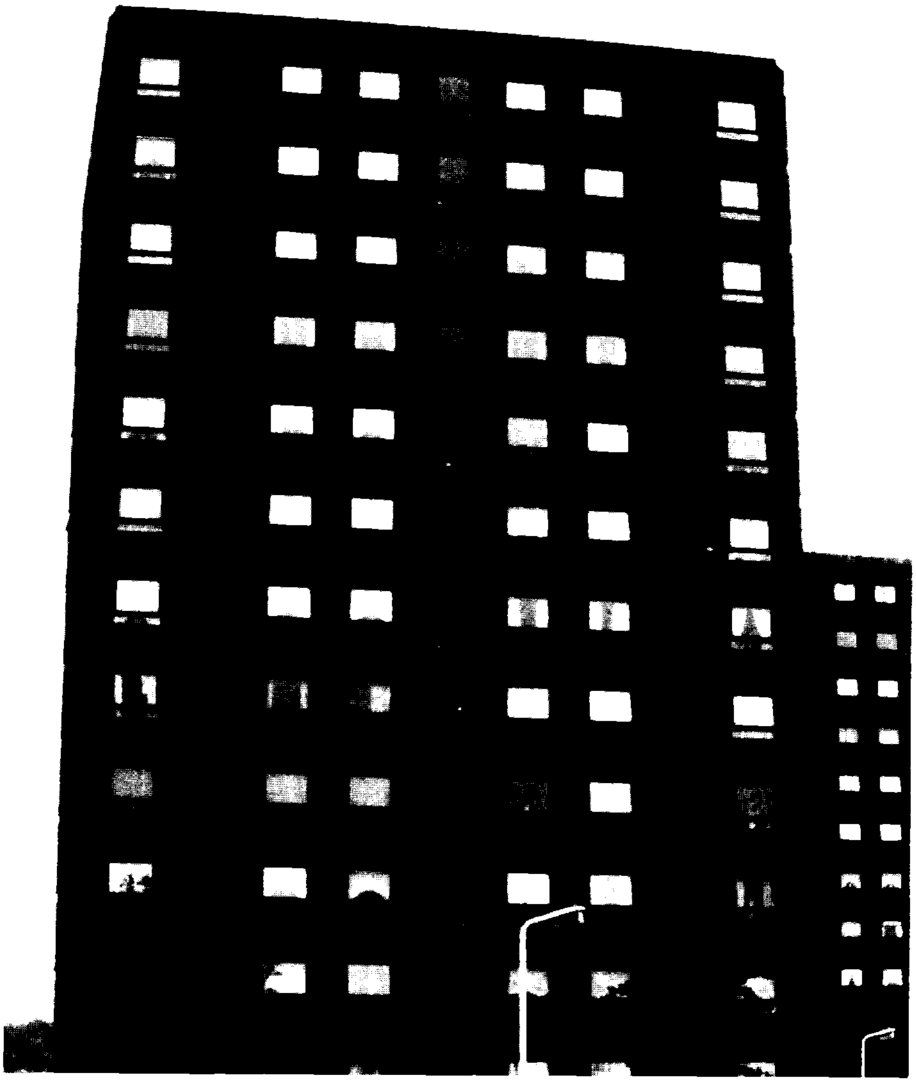


Figure 103

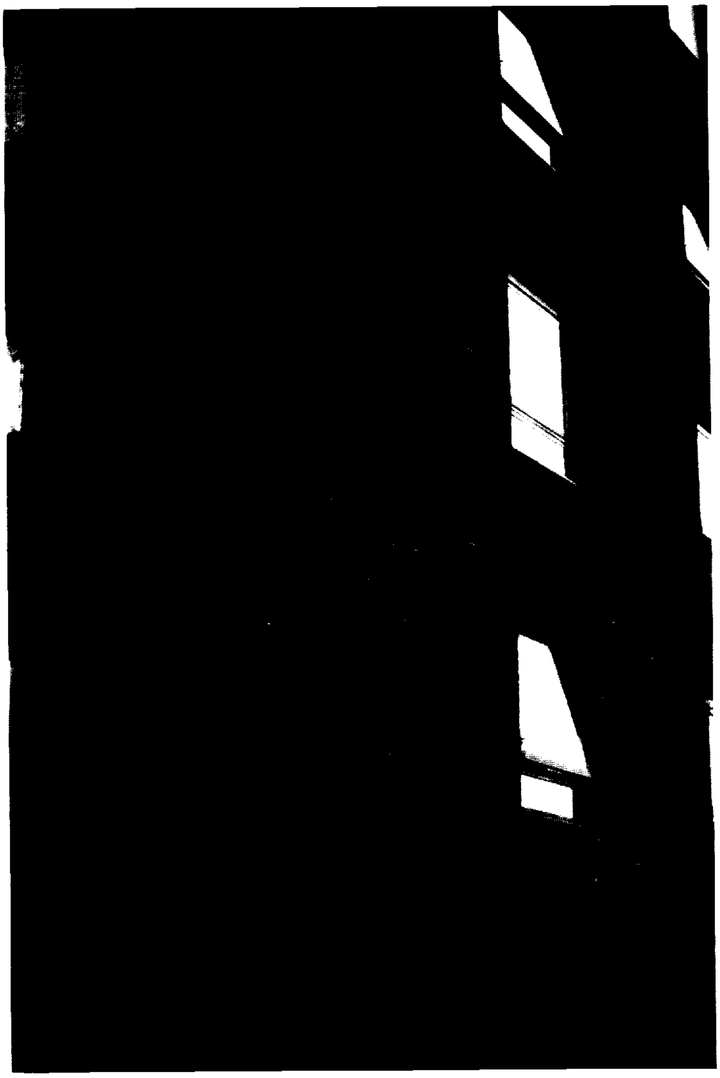


Figure 104

Figure 105

Figure 106

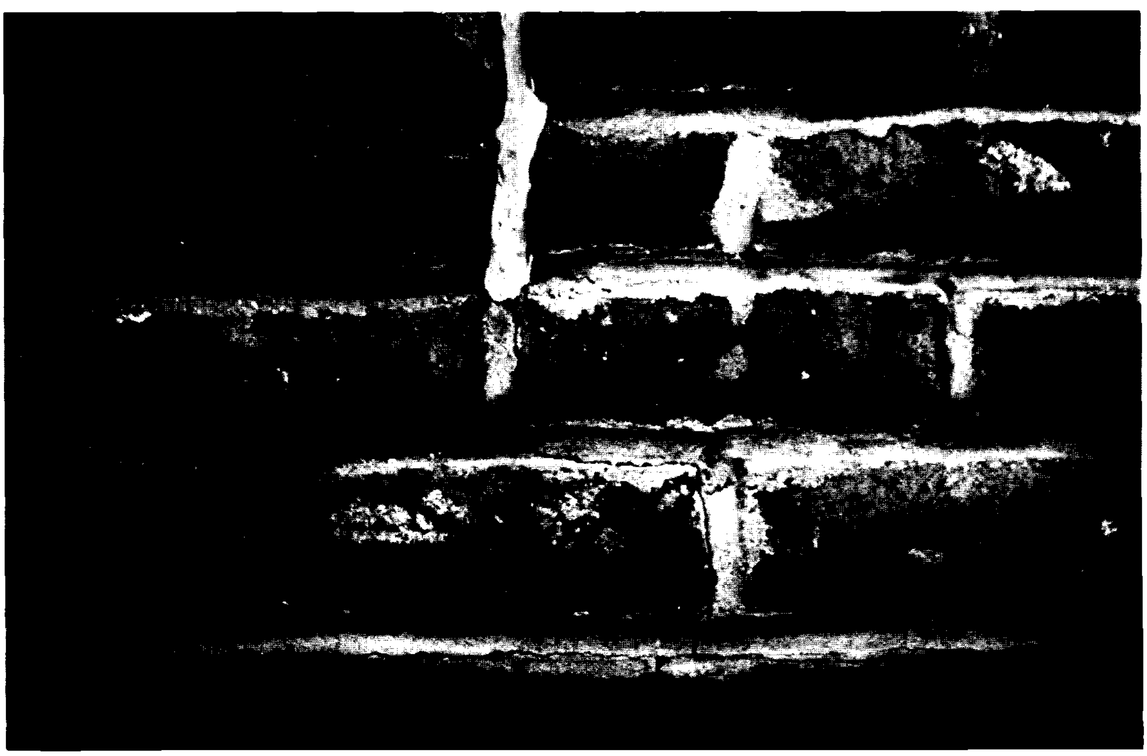


Figure 107

Case study 22

Norman Crescent, Redwood Estate, Hounslow

Owner London Borough of Hounslow

System Bison system maisonettes and flats

Date built Late 1960s

Exposure rating Moderate

Defects before overcladding Leaking baffle joints, carbonation, drab appearance (Figure 108).

Overcladding
Thermal insulation Small amount of extra insulation on inside of gable walls

Cladding Decadex. This is a water-based elastomer coating with optional co-polymer fibre reinforcement (Figure 109).

The system required structural strengthening, and this was accomplished by steel angles bolted through the structure. It proved difficult to disguise the repairs. The original open-drained joints had leaked, and various patching repairs had not proved successful. It was therefore decided to convert the joints into a face-sealed system, and overcoat the whole of the concrete with a durable finish which would keep the concrete dry and reduce the future rate of carbonation.

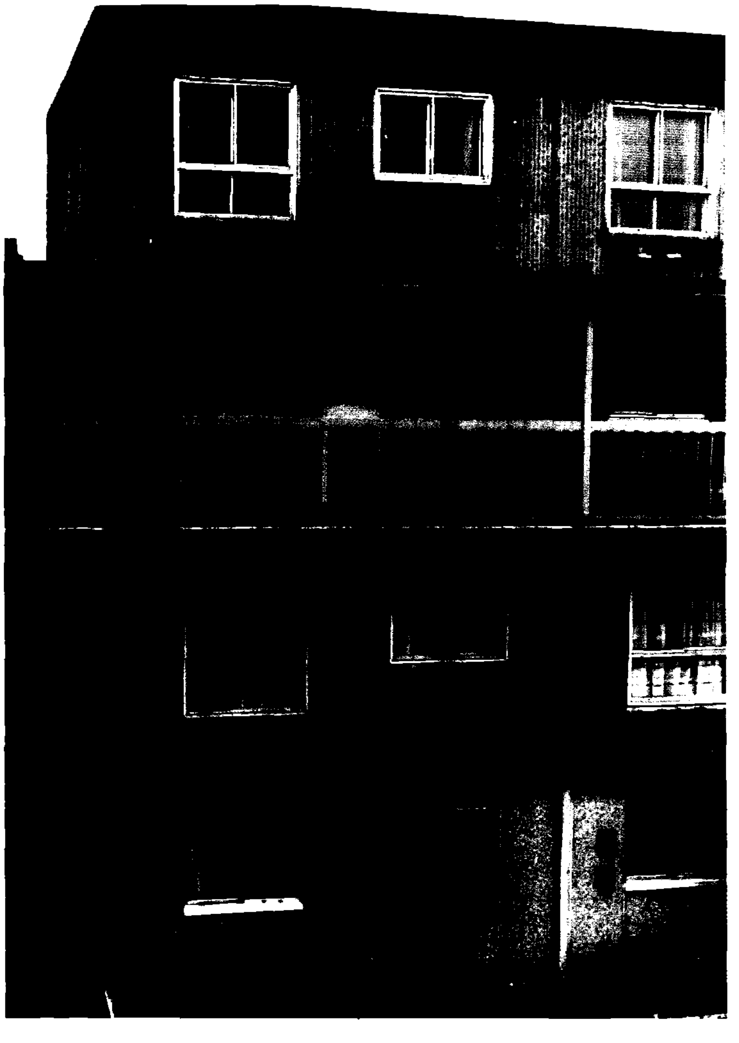


Figure 108

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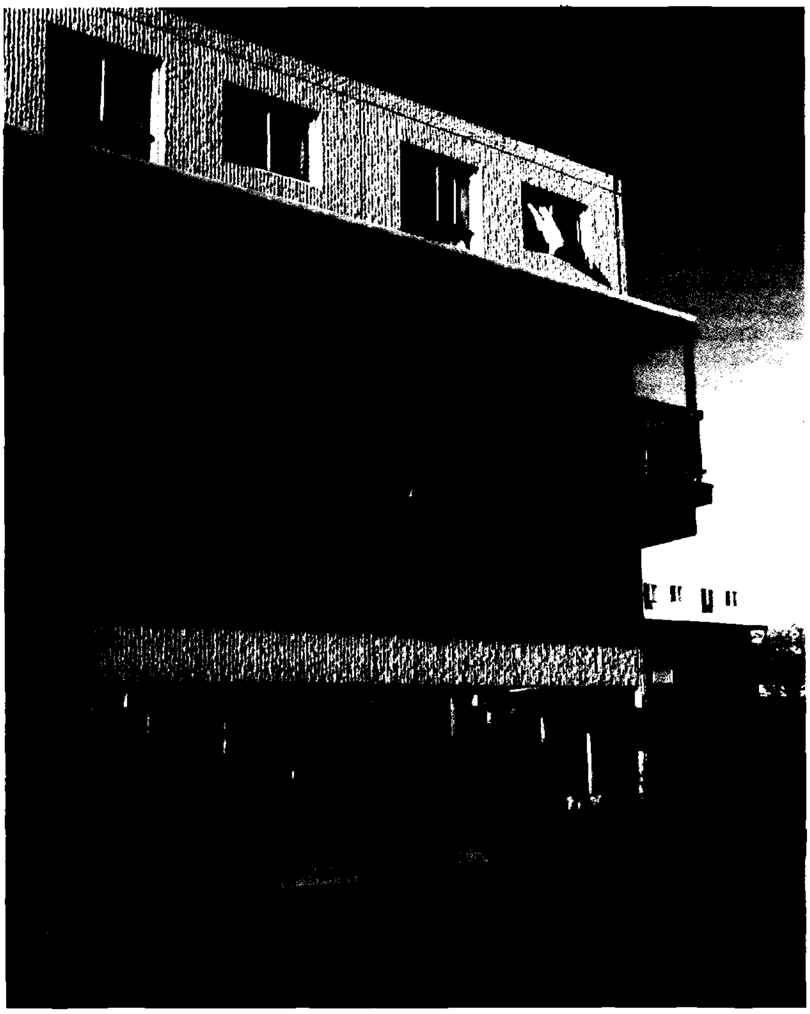

Figure 109

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Windows Anglian aluminium with secondary glazing

These dwellings are in the flight path for London (Heathrow) Airport, and were originally double glazed for that reason. The windows had deteriorated, and required extensive overhaul. After the work had begun, it was realised that the extra cost of replacement rather than repair would amount only to £45 per dwelling, and a replacement programme for windows was then implemented.

Date of installation 1984 – 86

Designer NBA Building Performance Services Ltd

Quantity Surveyors Dearle and Henderson

Contractor Laing Management Contracts

Approximate cost £8/m^2

Assessment
The finish is vapour permeable, and is expected to perform according to requirements. The joints were cleaned and resealed with a silicone mastic, which will probably need renewal within the 30-year period. The first blocks were sealed after applying the Decadex, but the later blocks were sealed before.

All the work was undertaken with the occupants still in residence.

Case study 23

Cromer Street, Kings Cross, London

Owner London Borough of Camden

System Concrete-cased steel frame, with brickwork flank walls and precast concrete panels forming the cladding and permanent shuttering to the gables

Built About 1946 – 48

Defects before overcladding One of the precast panels fell. On inspection, many were found to be loose. Corrosion of the handling reinforcement was general.

When the more dangerous precast concrete panels were removed, it was found that the in-situ concrete was badly honeycombed. It was therefore decided to remove all the cladding panels and reclad. Rendering was rejected for aesthetic reasons.

Overcladding
Thermal insulation Composite panels carrying 30 mm thermal insulation

Cladding The original concrete panels were removed. Composite panels of sheet steel with plastisol coating were then carried on stainless steel framework bolted back to the concrete with resin-bonded anchors. The panels were fixed to the frame with self-tapping screws, and there is a 50 mm cavity between the cladding and the concrete wall. (Figures 110 and 111.)

Windows Not included

Approximate cost £30/m^2

Figure 110

Assessment
Some difficulty was experienced in designing a suitable detail at window openings (Figure 112). Erecting the profiled sheets to line was not easy, since the window openings varied between storeys. The composite panels had wide variations in widths, and matching the profiles across a joint was difficult. Later work using non-insulated panels has proved easier in this respect.

The former GLC would not allow the system to be used in buildings above 10 storeys. Instead, in these cases, mineral wool insulation was fixed directly to the walls, and an uninsulated steel sheet fixed over a 50 mm cavity.

The plastisol panels are said to have a period to first maintenance of 20 years.

Figure 111

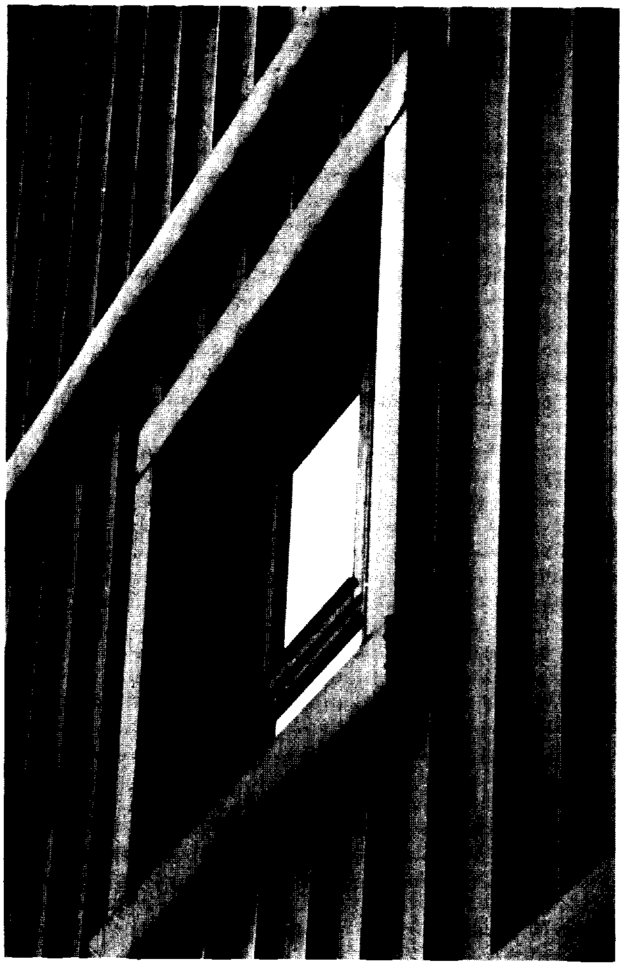

Figure 112

Case study 24

Bacton Tower, Roman Road, Bethnal Green

Owner London Borough of Tower Hamlets

System 14-storey flats built in the Wates system

Date built 1960

Exposure rating Moderate

Defects before overcladding Ceramic tile cladding falling, and many tiles were crazing (Figure 113). Corrosion of reinforcement in concrete caused by lack of cover. Some of the reinforced concrete panels were touching each other, and hence were spalling under the influence of thermal movements. Some panels misaligned. Calcium chloride levels were such as to give rise to concern about future durability.

Options considered
The building is immediately beside public pavements (Figure 114), and there was an overriding need to prevent any further falls of structure or finishes from the building. Several options were put to the authority by the consultants:
1 Unreinforced resin render
2 Mesh-reinforced resin render (to act like a bandage round the building)
3 Demolish
4 A balcony at first-floor level to catch the debris
5 Overcladding

Overcladding was the preferred option, for the following reasons:
1 Loss of accommodation could not be afforded
2 Tenants could remain *in situ* during operations
3 The building could be thermally insulated
4 The concrete panels would be kept dry, reducing the rate of corrosion following carbonation
5 A building on a prime site would 'look new'
6 Overcladding would catch the debris
7 Demolishing the building would release land for only two or three houses

Overcladding proposals at the final design stage
Thermal insulation 50 mm Rockwool thermal insulation covered with aluminium mesh and bolted back to the concrete panels.

Cladding 50 mm cavity. Purpose-made profiled aluminium panels with polyester powder coating (Synthapulvin), hung off stainless steel rails bolted back to the concrete panels with 'Hilti' stainless steel bolts. The panels are secured with a 'top hat' section at joints after these have been sealed with a gasket.

Designer Watts & Partners, Chartered Building Surveyors, Construction Consultants

Fabricator/Supplier Witneybridge Limited

Approximate cost £1.4 million

Assessment
The design work was started in 1983. Approximately 13 material manufacturers were interviewed by the designers but they were not confident that the manufacturers seen possessed the necessary experience. The designers prepared a performance specification and found it difficult to find published information on the properties of overcladding solutions. In addition to defining the performance criteria, the performance specification called for a design solution to be submitted as part of the tender. This was to be based on the schematic drawings and elevations prepared by the designer.

Sheet aluminium cladding was chosen because it was felt that it would perform well, would not need much maintenance and would not be vulnerable to tenant abuse with this application since there is no possibility of access to the overcladding from balconies. In addition, the performance specification required that joints within the system should be free from sealants, thus avoiding periodic maintenance of this detail. Experience has shown that even minimal maintenance is not carried out.

No UK manufacturer could meet the tolerances required by the designer and none was prepared at that time to supply a complete package of overcladding and replacement windows. The required standard for components and materials was set by specifying a design life of 60 years. However, paint manufacturers would only offer a 20- to 30-year life to 'first maintenance'. Furthermore, the coated surface is required by the potential suppliers to be washed down at 3-monthly intervals using a mild detergent and warm water. No special provision such as cradle guides has been made for this since the local authority said there was no chance of meeting such a requirement. There must therefore be doubts regarding the coated finish meeting the desired life.

Inspection of the concrete panels where it is known that high chloride levels had been used has been recommended on a 3- or 4-year cycle. Provision has been made within the design to dismantle panels easily to allow inspection and sampling to take place.

The design work is complete at the time of writing and suppliers and contractors have been identified.

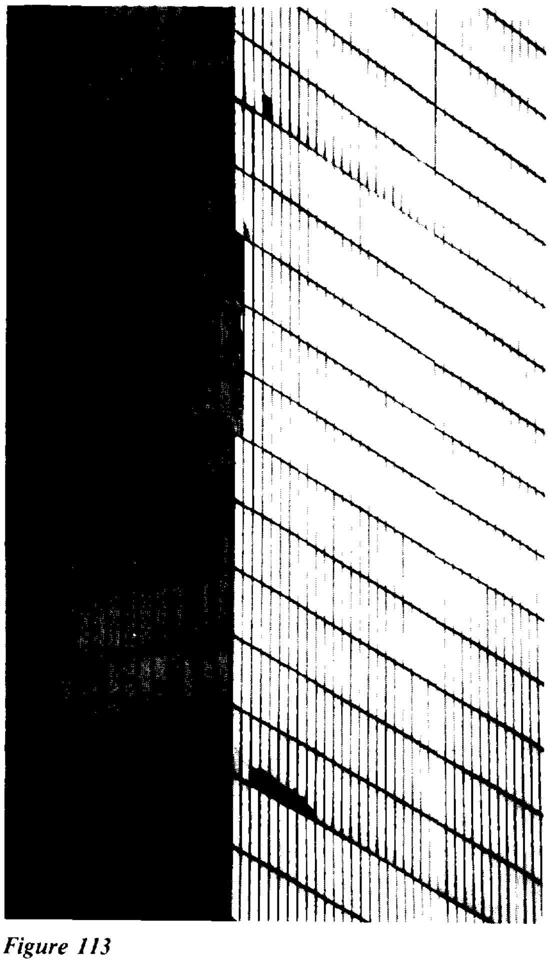

Figure 113

Figure 114

Case study 25

Northway Estate, Tewkesbury, Gloucestershire

Owner Tewkesbury District Council

System 2-storey Woolaway system houses

Exposure rating Sheltered

Defects before overcladding Excessive condensation and high heating costs

Overcladding
Thermal insulation 50 mm extruded polystyrene boards, adhesive-fixed with additional mechanical fixings

Cladding Glass-fibre-reinforced cement render and roller-applied polymer-bound final coat (Figure 115).

Windows Blacknell weatherstripped

Date of installation Winter 1981 – 82

Contractor Pattison Insulations Ltd

Specialist cladding Cape Insulation

Approximate cost £33/m^2

Assessment
The overcladding appears to have contributed towards solving the condensation problem, and the houses are more economical to heat.

Widespread cracking of the surface coating began almost immediately after completion, typically from window corners, ie the points of greatest stress. Cracks up to 0.8 mm width. There was also some lack of bond between the polystyrene boards and the original wall surface.

The failure is more one of appearance than performance, since the overcladding does not appear to have leaked. Repairs have not masked the cracks.

It should be noted that the particular proprietary system used here is no longer marketed, although similar systems are available.

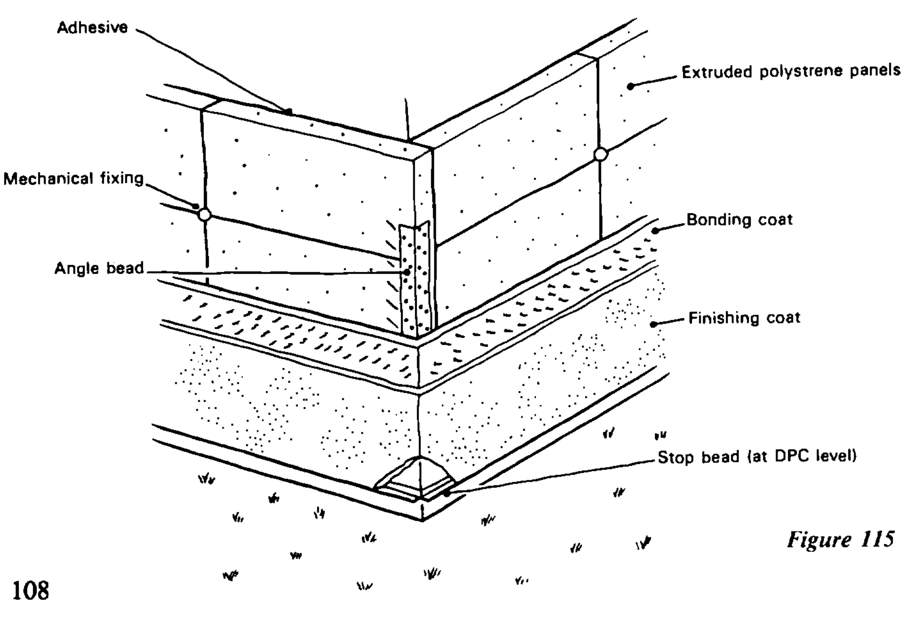

Figure 115

Case study 26

Oxgangs, Edinburgh

Owner Edinburgh District Council

System Precast concrete panel. System not established at time of writing

Date built 1975

Exposure rating Moderate

Defects before overcladding Rain penetration

Overcladding
Thermal insulation Incorporated with cladding

Cladding Expanded polystyrene sheets coated with glass-reinforced gypsum render, pinned to existing panels, then site-applied polymer finish with scrim over joints.

Date of installation 1984

Designer Gunac

Contractor Gunac

Approximate cost £70/m^2

Figure 116

Assessment
In the absence of cavity barriers, the expanded polystyrene sheets could contribute to fire spread in the cladding. Site-applied finish is non-uniform in appearance and now showing adhesion failure (Figure 116). This is likely to continue. It is understood that the company is no longer offering this solution, and is now offering foamed glass or Rockwool insulation with a different external finish.

Appendix C Description and commentary on materials

Material	**Glass-fibre-reinforced, aqueous-polymer-based, proprietary renderings**
Application	Subject to any fire requirements (which may apply particularly to flammable insulating substrates): any conditions
Description	Specialised rendering systems used as finishing to expanded plastics or mineral fibre external insulation slabs. Typically, the renders are based on aqueous acrylic polymers. The render base coats may require the addition of Portland cement; glass-fibre mesh is incorporated in this base coat. Finish coats are available in a number of colours and textures.
Forms in which used in overcladding	Site-applied render, as part of a proprietary insulating overcladding system.
Fixings	The render coats rely solely on adhesion for fixing. The associated insulation layers will normally be fixed by some combination of polymer-based render adhesives and mechanical fixings.
Maintenance and durability	Subject to regular inspection, and repair whenever damage is found which could allow water ingress, German experience suggests a life in excess of 20 years. Dirtying of light-coloured finishes will occur during this period. Recoating is possible but is preferably avoided as it will reduce the vapour permeability of the surface, and could increase the risk of interstitial condensation in the insulation. If recoating has to be considered, a check should be made on this risk.

Material	**uPVC**
Application	Subject to fire requirements: all situations in principle; but in practice, because it is normally used in the form of shiplap 'boarding', it is not recommended for use above three storeys unless special consideration is given to fixing.
Description	Unplasticised polyvinyl chloride with added fillers and colours. (uPVC may normally contain a small proportion of added plasticiser, to aid fabrication.) In common with all plastics, the material has a high coefficient of thermal expansion. Light colours preferred for external use.
Forms in which used in overcladding	Extruded single-wall or cavity-multiwall sections simulating timber weatherboarding, in a range of sizes. Associated uPVC or aluminium fixing accessories are available.
Fixings	Normally fixed with aluminium nails to vertical timber battens, using associated accessories. If battens are pre-treated with copper chrome arsenate preservatives, aluminium fixings and nails must be avoided; stainless steel must be used. In fixing, care has to be taken to allow for the thermal expansion of the material: the proper fixing accessories assist in this.
Maintenance and durability	The life expectation for the material is in excess of 20 years, though some loss of surface gloss will occur during this period, and periodic cleaning will be required to remove dirt accumulation and maintain a reasonable appearance. Overpainting is possible with conventional gloss paints.

Material	**Cellular uPVC**
Application	Subject to any fire requirements: all situations in principle; but in practice, because it is usually used in the form of shiplap 'boarding', it is not recommended above three storeys unless special consideration is given to fixings.
Description	Unplasticised polyvinyl chloride with added fillers and colours, in the form of extruded sections. The sections have a cellular core and a smooth, dense exterior surface. A range of colours is available; certain (dark) colours must not be used externally. In common with all plastics, the material has a high coefficient of thermal expansion.
Forms in which used in overcladding	Mainly used in the form of shiplap 'boarding'. Other sections are, however, available and can be used as necessary corner and other trims in the cladding process. In many respects the material can be used simply as a replacement for painted timber cladding.
Fixings	Conventional fixings, such as would be used for timber, are used, ie nails, screws, etc, of adequate corrosion resistance. The manufacturer's recommendations should be followed carefully to ensure sufficient account is taken of thermal expansion.
Maintenance and durability	The life expectation for the material is in excess of 20 years given periodic cleaning to remove dirt accumulation. Some loss of surface gloss will occur within this period. Overpainting is possible with conventional gloss paints.

Material	**Fibre-reinforced cement sheets**
Application	All situations, depending on form, though planks (eg shiplap) are not recommended above three storeys unless special consideration is given to fixing arrangements.
Description	Cement or calcium silicate/filler mixes reinforced with natural or artificial fibres. Fibres are usually of mineral origin, but sometimes organic fibres, eg plastics, are used. The surface of the sheets may be coated with colour finishes and/or mineral granules.
Forms in which used in overcladding	Sheets and planks. Planks may be rebated to provide 'shiplap' form.
Fixings	No difficult compatibility problems exist, so that a wide range of corrosion-resistant screws, rivets, bolts or concealed fixings may be used.
Maintenance and durability	For a non-asbestos substitute for ordinary corrugated asbestos-cement sheet, the British Board of Agrément have said its life 'will equate to that of asbestos-cement used in similar circumstances'. Like asbestos-cement, the matrix will carbonate and embrittle over time. Some fibre reinforcement materials may also weaken. For a coloured surface sheet material, the manufacturers claim a life of over 40 years, based on accelerated testing.

Material	**Aluminium alloy**
Application	All situations, depending on form used, but not recommended at ground level, or where access is possible, because of the risk of impact damage.
Description	Sheets are available either mill-finished, anodised, or colour-coated with paint or plastisol coating. A range of colours and textures is available. Colours of some anodised panels can vary between batches.
Forms in which used in overcladding	Flat, troughed or corrugated sheets. Curved sheets are available. Can also be readily formed into special shapes of panels.
Fixings	Care must be taken to avoid electrolytic corrosion by correct choice of metal for fixings, or by careful isolation of fixings from sheets, eg by the use of plastic washers. Suitable aluminium alloy or stainless steel pop rivets or screws are frequently used.
Maintenance and durability	The mill-finish aluminium alloy is not usually recommended unless regularly washed, as corrosion quickly develops and may produce a rough, dirt-collecting surface in polluted atmospheres. Anodised finishes can maintain a better appearance but likewise demand regular washing and are unsuitable for polluted atmospheres. For a polyvinyl fluoride-coated sheet, the British Board of Agrément quote a life in excess of 30 years but say that 'maintenance painting to restore appearance should be envisaged after 20 years'. For a polyester-coated material, life to first maintenance painting is said to be 10 to 15 years, depending on degree of pollution.

Material	**Coated steel sheet**
Application	All situations, depending on form, but not recommended at ground level or where access is possible because of risk of impact damage.
Description	Mild or high-tensile steel sheets which may or may not be coated with zinc prior to the application of paint or plastisol coating. A range of colours and textures is available.
Forms in which used in overcladding	Used as flat, troughed or corrugated sheets which may be disposed either horizontally or vertically with simple sealed overlaps. Curved sheets are available.
Fixings	Care must be taken to avoid electrolytic corrosion by proper choice of fixings. Alternatively, fixings can be isolated by washers from the metal sheets. Typical fixings are screws (into wood) or pop rivets. Suppliers may be able to provide specialised fixings, designed to avoid damaging the coating.
Maintenance and durability	Depending on the level of pollution, the life expectation is 10 to 20 years before first maintenance. First maintenance involves repainting with an approved coating system. Subject to this maintenance, the material should give good service for in excess of 25 years. Intermediate inspections are advised to check for any local peeling of the coating, which may require early treatment if more expensive maintenance is to be avoided later.

Material	**Glass-fibre-reinforced polyester resin**
Application	Subject to fire requirements, all situations.
Description	Thermosetting polyester resin with added fillers and/or colours, and possibly fire-retardants, reinforced by random glass-fibre mat or glass-fibre mesh. The surface coat of the panels should be free from reinforcement, but may contain embedded aggregate for the sake of appearance. Wide range of colours available. In common with all plastics, the material has a high coefficient of thermal expansion.
Forms in which used in overcladding	Available as flat or profiled sheets, or as purpose-designed moulded panels as part of an overcladding 'system' of panels and supports. Special shapes are relatively easily produced.
Fixings	The design of the fixings has to accommodate the high thermal expansion. No particular incompatibility problems exist, however, so that a wide range of corrosion-resistant fixings can be used.
Maintenance and durability	Some loss of surface gloss occurs on weathering, but this should not be progressive. Dark colours may show a light 'bloom'. Life in excess of 30 years is quoted by the British Board of Agrément for one material.

Material	**Plastics laminates**
Application	All situations, subject to any fire requirements.
Description	These materials are essentially outdoor versions of the familiar plastics laminates used internally for many years. The core of the materials is usually of phenol-bonded paper, and the surface is of melamine resin. A range of colours is available.
Forms in which used in overcladding	Flat sheets, up to 10 mm thick.
Fixings	No difficult incompatibility problems exist so that a wide range of corrosion-resistant fixings should be suitable — though advice should be taken from the sheet manufacturer. Allowance should be made for thermal expansion.
Maintenance and durability	One manufacturer quotes a life in excess of 30 years.

Material	**Render on stainless steel lathing**
Application	All situations.
Description	Usually but not necessarily applied over insulation. Insulation pinned to wall by proprietary fastenings. Stainless steel mesh then fixed through to background. Render then applied to mesh in accordance with the recommendations in *British Standard* BS 5262:1976 'Code of practice for external rendered finishes'.
Forms in which used in overcladding	Dry- or wet-dash finish. Smooth with paint finish.
Fixings	Plastics or steel with appropriate washers. Directly to wall or via battens.
Maintenance and durability	Up to lifetime of building for dry and wet dash with little or no maintenance if properly applied. Ten years if paint finish, when recoating will be required.

Appendix D Recommendations to reduce noise and disturbance to occupants during overcladding operations

The following is based on information supplied to BRE by Bickerdike Allen Partners.

1 Diamond drills, though relatively fast and quiet, are not acceptable because of the large amount of water which finds its way into cavities in the building. Percussion drills are to be preferred. During tests it was found that:

(a) Lubricating water emerged quickly into flats.
(b) A fairly rigid platform is needed for diamond drills.
(c) Percussion drills usually need more holes, say three attempts in any one area, in order to obtain the required depth of bore (because of reinforcement encountered). Needs a new drill to cut through reinforcement.
(d) Some dust was generated; where flats are wall-papered this should not cause problems.

2 Percussion drilling will cause severe noise disturbance over the whole of the building (Figure 117).

(a) In the absence of anything better, it was proposed to relate the results of noise tests to the criterion for noise from adjacent building sites *British Standard* BS 5228 'Code of practice for noise control on construction and demolition sites'. It seems that while percussion drills are in operation, most flats in a typical LPS block will suffer noise above the recommendations of BS 5228. Many will suffer noise such that telephone conversations will be difficult, and a good number such that ordinary conversation will be difficult.
(b) Noise levels for most people will be so bad that the practice of having as many drills working around the building as possible should be considered, in order to reduce the time of exposure to a minimum.

3 This noise disturbance will be minimised by:

(a) Drilling to set daily periods (eg 08.30 to 12.30 Monday to Friday with Saturday in reserve in case of weather hold-ups).
(b) As many drills as possible (see above).
(c) Advance notice should be given, eg by posters in lobbies, and the programme kept to.
(d) Employ a resident liaison officer.
(e) Provide houses, or flats in other buildings, equipped as retreats, ie rest rooms, sitting rooms with telephones and/or kitchen facilities.
(f) Some tenants may need to be temporarily rehoused, ie the infirm, families with babies, shift workers, etc.

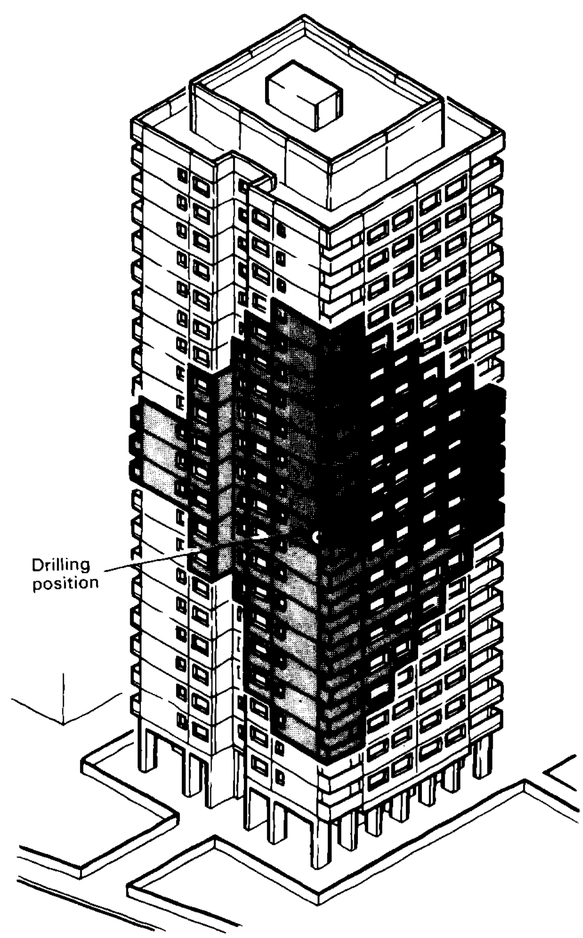

Figure 117 Drilling position on tenth floor: noise contour based on BS 5228 criterion (redrawn from Bickerdike Allen Partners' original)

Overcladding external walls of large panel system dwellings

H W Harrison, J H Hunt and J Thomson

ERRATA

Page 11	In item (a), the word 'renewal' should be 'removal'.
Page 34	In the second line, the word 'Tile' should be 'The'.
Page 2	Figure 1. Note that vulnerable cladding as shown in (b) and (c) is not suitable in public access areas.

ADDENDUM

Pages 25 – 26 give advice on the performance of overcladding in fire and refer to further tests on fire spread. On 9 December 1986 the Department of the Environment issued the following further advice:

Fire spread with overcladding on multi-storey buildings

A risk of increased vertical fire spread has been identified during the laboratory testing of overcladding systems incorporating combustible insulants. Sheeted systems usually have designed or fortuitous cavities behind the cladding. Where the cladding is sheet aluminium, laboratory tests have shown that a fire within the cavity can melt the aluminium and burn through to the surface several storeys above the fire. These emergent flames could re-enter the block via windows.

Fires of such severity are rare. Multi-storey blocks have been clad for 10 years with systems which have a potential for fire spread within cavities but no fires leading to excessive vertical spread have been reported. However, it is advised that both existing and proposed overcladding systems should be examined to determine if modifications are required as a precaution against fire spread.

Local authorities will wish to consider the application of building regulations to cladding systems. However, the Department's minimum recommendations for existing and proposed sheeted overcladding systems are as follows.

Completed sheet overcladding systems

(a) *Aluminium, combustible insulant*
Fit fire barriers every two storeys.

(b) *Steel or non-combustible sheet, combustible insulant*
Fit fire barriers if a suitable opportunity arises.

Proposed sheet overcladding systems
Specify either non-combustible insulants or fire barriers every two storeys.

Proposed non-sheeted systems
With other types of external cladding, fire spread is likely to be very small. However, where a non-sheeted system is proposed, recommendations to reduce fire spread are as follows.

(a) *Rendered metal lathing, thermoplastic insulant*
Specify sufficient metal fasteners to stabilise the cladding, and fire barriers every two storeys.

(b) *Rendered metal lathing, thermosetting insulant*
Specify sufficient metal fixings to stabilise the cladding.

(c) *Glass-fabric-reinforced thin renders, thermoplastic insulant*
Specify fire barriers,which also support the cladding,every storey.