THE ARUP JOURNAL

APRIL 1979

THE ARUP JOURNAL

Vol. 14 No. 1 April 1979
Published by
Ove Arup Partnership
13 Fitzroy Street, London, W1P 6BQ

Editor: Peter Hoggett
Art Editor: Desmond Wyeth FSIAD
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St. John's College

Sir Thomas White Building

DESIGNED BY ARUP ASSOCIATES

Philip Dowson

'A world within a world', in the words of the President of St. John's, or 'a room of one's own', in those of the Principal of Somerville, sum up the aims behind the design of an undergraduate room.

St. John's new building in Oxford, which was completed last year, combines in many respects a developing set of ideas that can be traced from our first university commission in 1957 for a graduate building for Somerville College. These ideas were developed in a design for some flats for Bracknell New Town, and through later buildings for Corpus Christi and Trinity Hall Colleges in Cambridge, and for a further scheme for Somerville.

In the case of St. John's, we had to inject a large new development into one of our historic precincts, and whilst it had to fulfil today's needs, it had to do so within a very sensitive historic context. It is a modern building, but intends to reflect the mood of Oxford, the character of its surroundings, and to settle into the established pattern of this medieval city.

Diverse relationships

Common to all these buildings, however, is a wish to create rooms with a sense of location and of generosity, a sense of enclosure and release. A wish to develop a relationship between the small scale and the large, and between the manmade and the natural via the intermediate spaces created between the interior and the exterior areas within these schemes. We aimed to exploit the richness and unity that can at once be derived from the diverse use of repetitive elements, and the various strands that can be woven within strict disciplines, which can help to identify the 'part' within the 'whole', and so help to create a sense of belonging.

St. John's was the subject of a limited competition, held in 1966, between ACP, Howell Killick and Partridge, William Whitfield, and ourselves. The brief originally included, on a larger site, a lecture theatre, a science library, a swimming pool, married Fellows' flats, a special dining room for the governing body, a restaurant for the undergraduates, and parking for 170 cars. Both sides of Museum Road were included within the site.

The design for this first scheme was worked up and presented in 1969. At this point there was a new President, and a developing recognition that the initial brief was no longer wholly relevant. There was a need for a review. Rather than tinker with the existing proposals, we suggested that the College should reassess its needs in the light of the work that had been done. In the meantime, we would also go away, lick our wounds, and, in response to their review, rethink the problem from scratch. We gave each other six months. The present, more modest design, was the outcome. The new buildings have 156 sets and bed-sitting rooms. This effectively doubled the existing accommodation within the college precincts.

The design of the rooms themselves includes a wide range of size, shape and character. The organization of the plan into 'staircase-service-links' and pavilions provides for adaptability within the latter to accommodate Fellows' flats. All new development is now to the south of Museum Road, and so within the natural college precinct.

The combination of the scale of this scheme and the complexity of its brief, with the extreme vulnerability of its site, presented the most difficult architectural problem we have ever had to undertake.

Fig. 1
Model of the winning scheme – subsequently abandoned

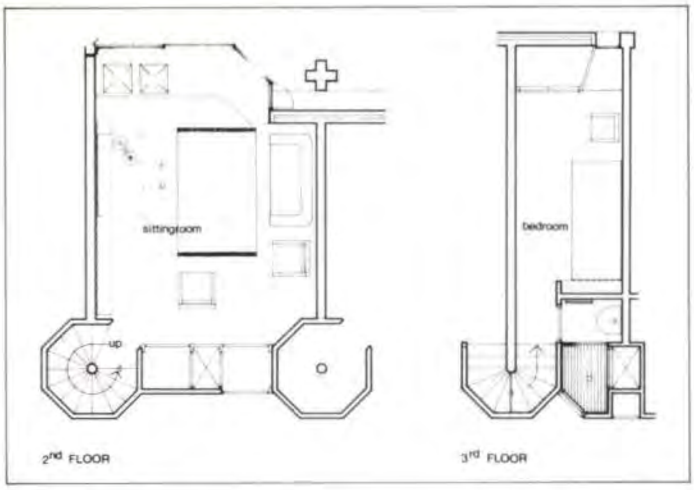


Fig. 2a above
Typical layout of 'set' with bedrooms on intermediate floor

Fig. 2b
Model of 'set' stair to bedroom

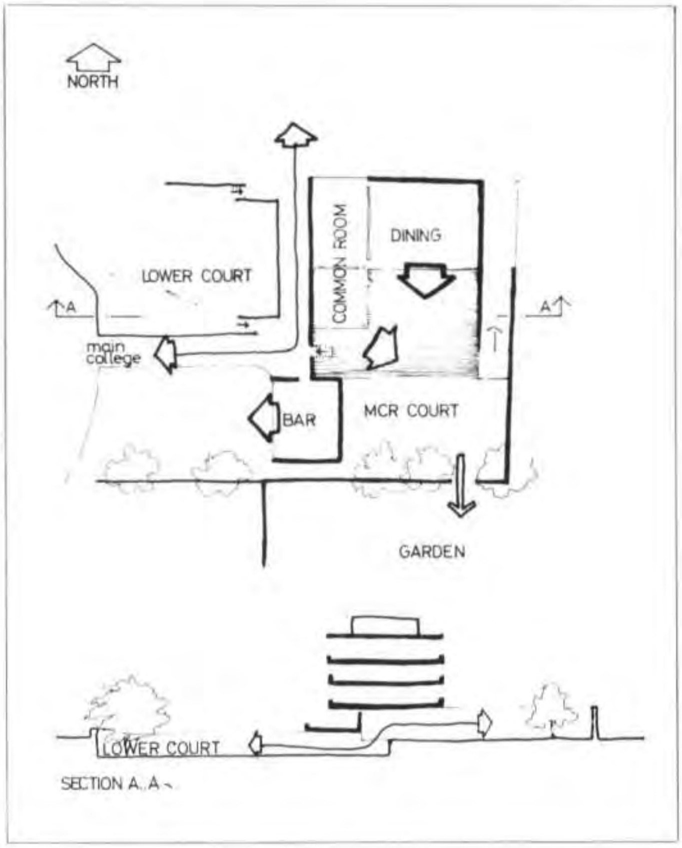


Fig. 3 right
First scheme: general section and site plan

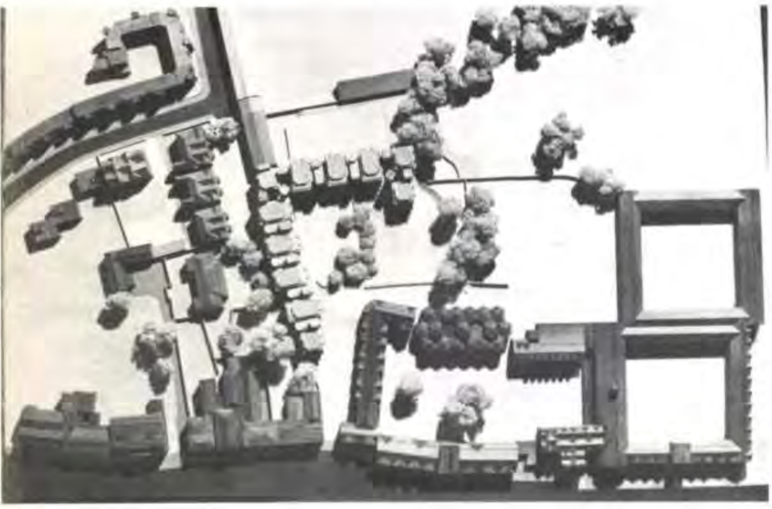


Fig. 4
Final scheme: model of development shown within the context of existing buildings

Fig. 5
Aerial view of site

Fig. 6a left
Façade to 'sets'

Fig. 6b
Façade to bedsitting rooms

Four faces

There are four faces to the design of St. John's. The first is glimpsed from St. Giles', and forms a part of the urban scene. The second appears above the walls of St. John's great 18th century garden, and is seen between groups of large trees, as well as from a distance across its open lawns. The third is the elevation to the new quadrangle itself, and finally, there is the new entrance and porter's lodge off the Lamb and Flag Passage, and this façade also forms the outer wall of the College. There is in a sense also the fifth face – the roofscape and silhouette, which had to respect the skyline of Oxford. In this case, the organization of the plan naturally creates a strongly differentiated set of forms at roof level, which aim to be compatible with their collegiate and domestic neighbours.

Fig. 7
The urban 'face,' as glimpsed from St. Giles

Fig. 8
As seen from St. John's great garden; note that the lowered quadrangle reduces the apparent height

Fig. 9 above
'Face' to the new quadrangle

Fig. 10 left
The outer 'face' and outer wall to the college, next to the new entrance

Fig. 12 right
The silhouette – the fifth 'face'

Fig. 11 below
View from President's garden with new screen wall and summer house

Adjacent to the site, to the north, is a small lane, which is typical of Oxford, and opposite there is a row of five-storey, semi-detached Victorian houses, which have been rehabilitated for College use, and which match the massing of the new pavilions. The building, together with new high garden walls and landscaping, was of a large enough scale to create its own environment; however the varied character of the site's perimeter required a solution within which there was a sufficient diversity to enable it to be grafted in to the existing tight-knit medieval pattern.

Fig. 13
Entry to colonnade

Fig. 15 below
Precast 'H' frame

Fig. 14 left
Stone and wood: typical detail

Material

Oxford was built largely of Headington stone, which gave the old city its uniquely beautiful colour. Many of the older buildings have now been refaced with Clipshan because the quarry ran out, and the weathering properties of Headington were sadly less durable than those of the stones which are now replacing it. We wanted as close a match to the original stone as possible. Clipshan is too yellow, and Portland too white, and neither have the subtle warmth of Headington. A quarry near Paris provided the nearest that we could find. It had been used on Chichester Cathedral, and had many of the qualities of Caen stone. Surprisingly, in spite of transport, the costs were more favourable than for an equivalent English stone, largely due to highly mechanized quarrying techniques.

The precast concrete 'H' and half 'H' frames were tooled and used a Baladon aggregate similar to our previous college buildings. The attic storey and roof was clad in lead. The problem of weathering was very carefully considered in the design, particularly in view of a proposed lifespan of 400 years.

Scale

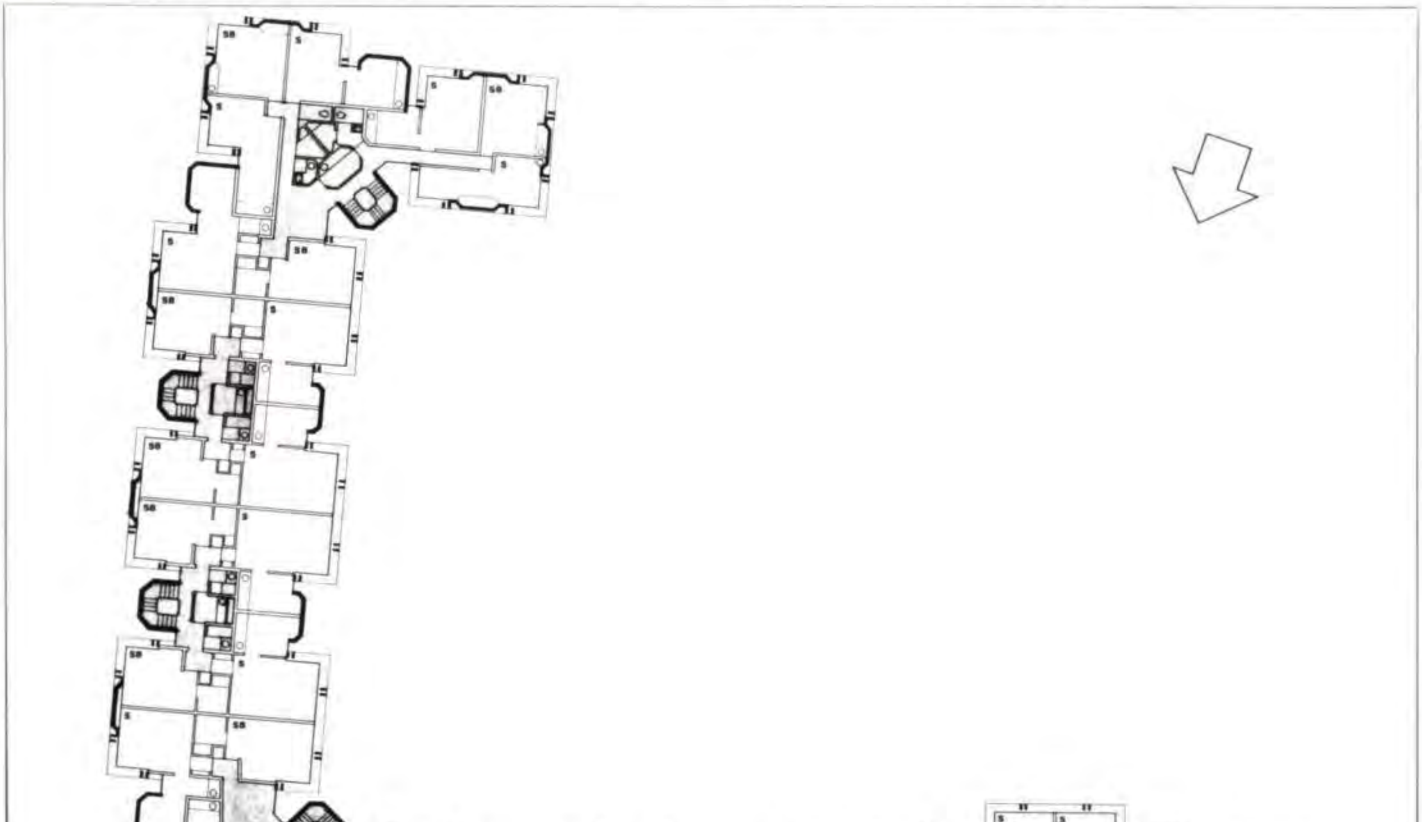
As well as four faces, there are four scales to St. John's. The major one is the organization of the plan into 'pavilions' and link towers. This arrangement allows flexibility in section as well as in plan. Thus in section the terminal block is six feet lower than the porter's lodge and the angle between the two wings is adjusted to suit the site.

In this way, almost one storey in height is lost, and, as seen from over the old wall, is of comparable height to the Canterbury quadrangle which faces the main garden. End and corner pavilions are square, cheating the eye to believe that the others, which are larger, are the same size. This visual deceit makes the building look smaller than in fact it is.

Fig. 16 below
Site plan with ground floor

Fig. 17 above
New quadrangle with lowered garden, whose wall provides a visual base for the old building

Fig. 18
First floor plan. 'Sets' are planned on the south and west and bedsitting rooms on the east and north



Second scale

The second scale is the structural one. The precast 'H' frames define the enclosed spaces within the pavilions.

Third scale

The third is the element of the cladding itself. The stone shields are detailed within the main frames, and the metal sections of the large sliding aluminium windows become the equivalent of moldings.

Fourth scale

The fourth scale is formed by all that which fits within the framed enclosures, and is constructed largely of wood. This is the domestic, and the smallest scale, and is designed to be distinct and separate, but also a smaller restatement of the same essential idea. This is the scale at which the building is handled, touched and used.

There is, in this way, a system by which the various elements of the building are not only related, but are also visibly interdependent. Starting from the smallest scale, and working up to the largest.

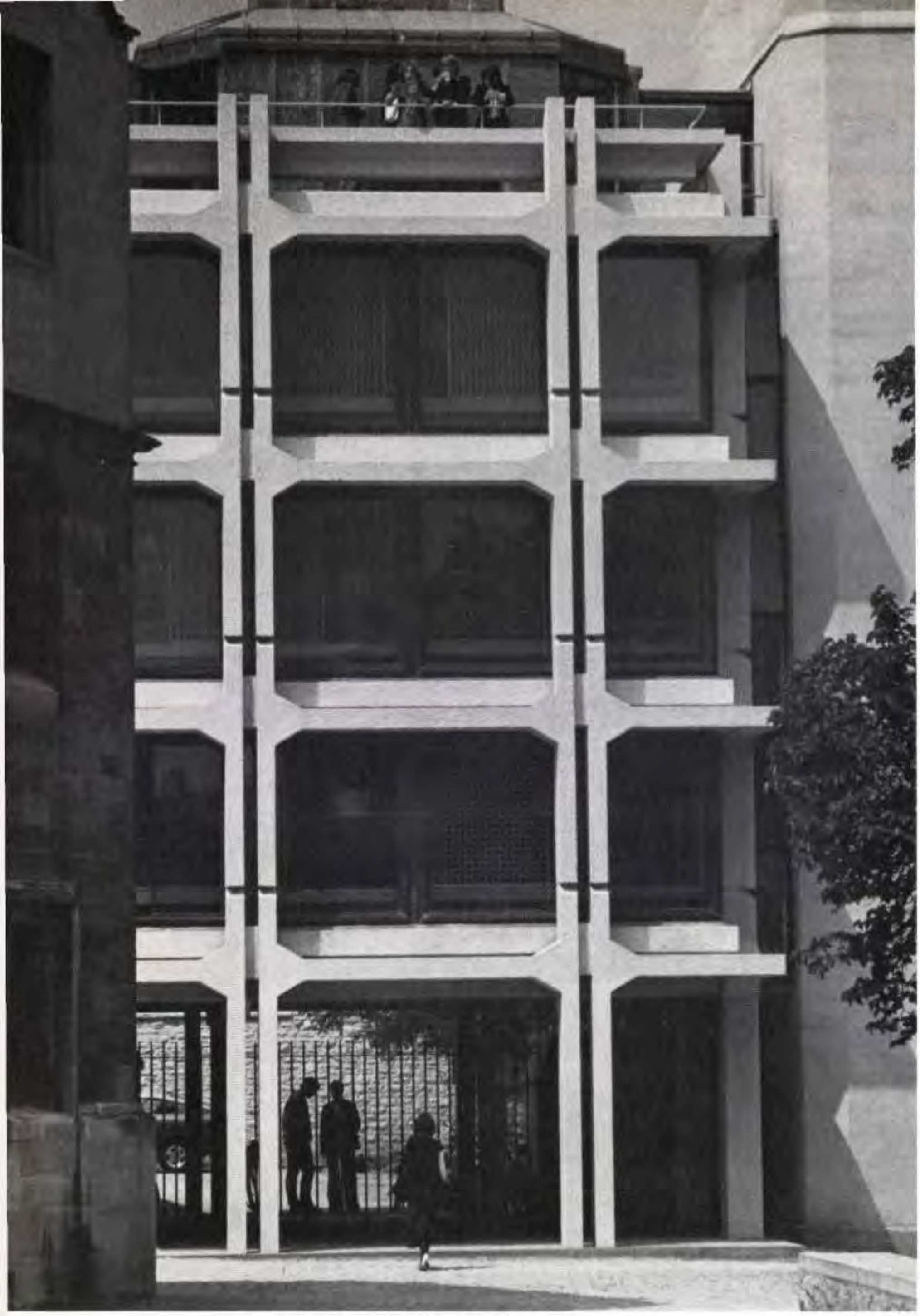


Fig. 19 top left
The new college entrance from the Lamb & Flag Passage as seen from the new quadrangle

Fig. 20 above
New squash courts with 'sets' over, viewed from the Robert Graves Room

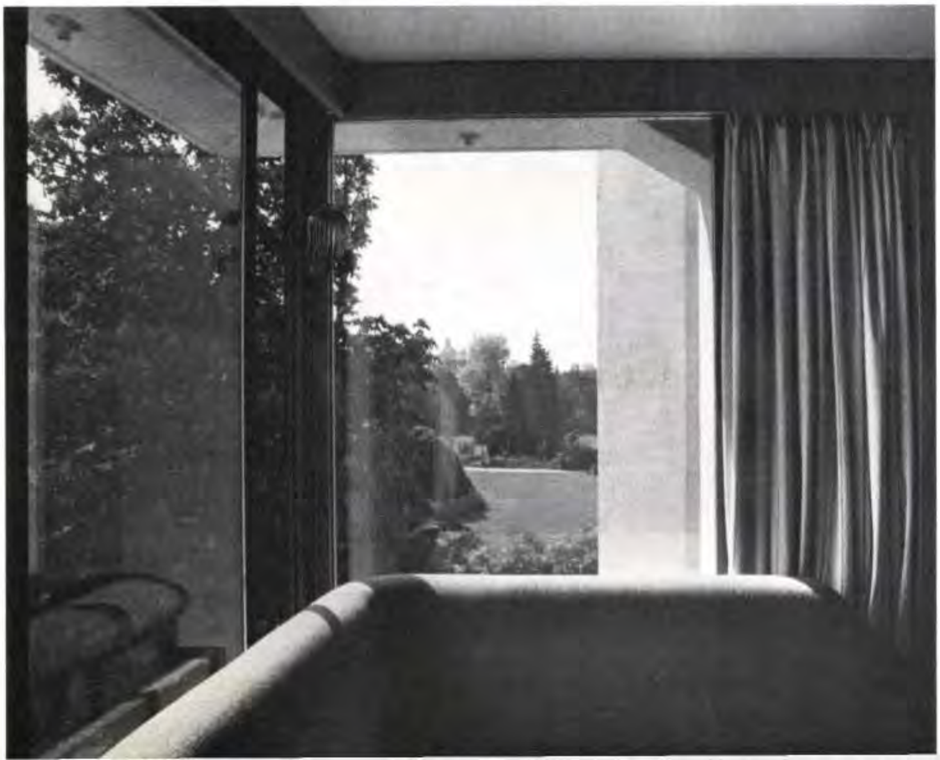
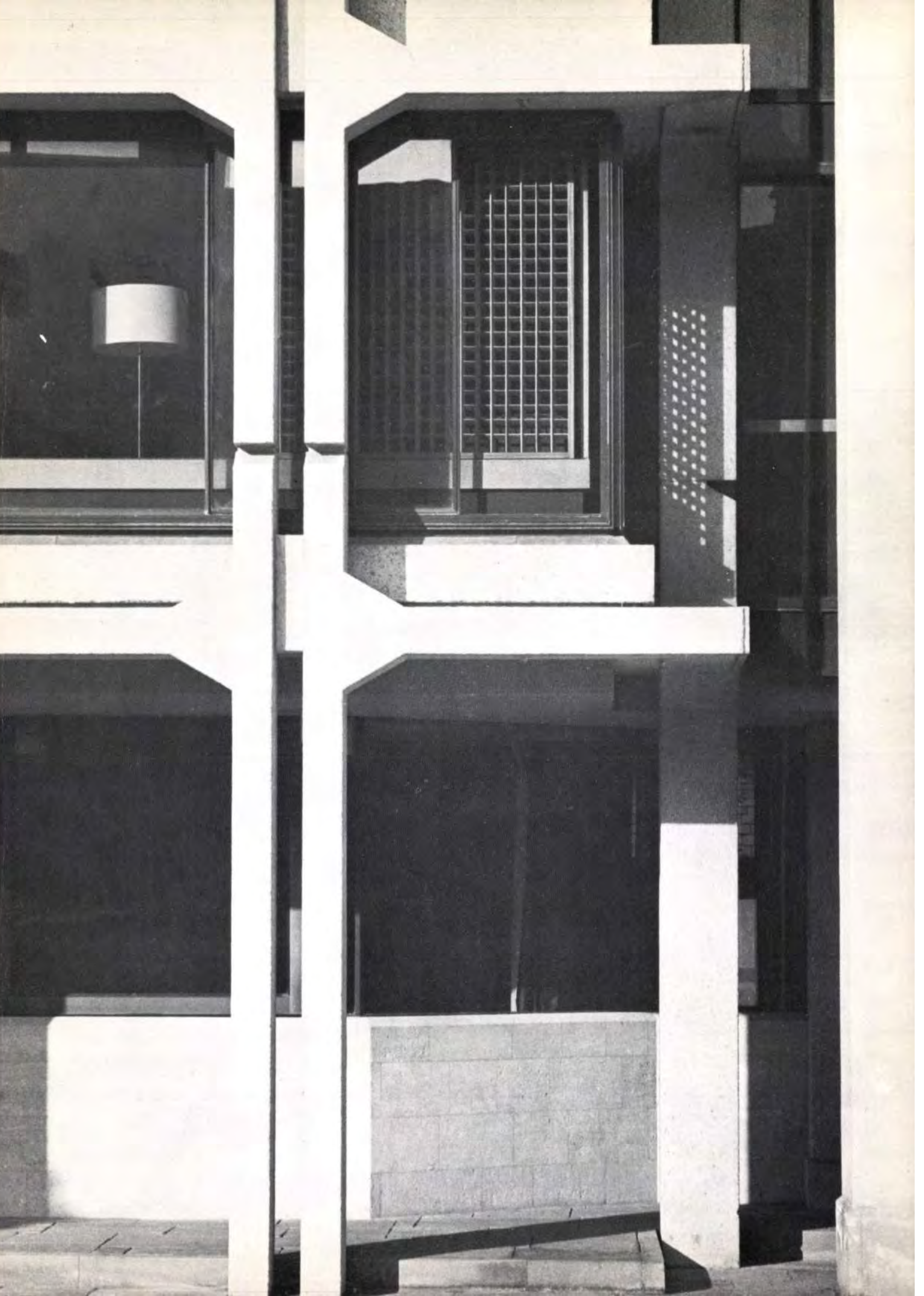


Fig. 21
A garden building – typical outlook

Fig. 22 right
The elements from which the building is made



Circulation

All staircases, ground floor common rooms and bars, have direct access from a single colonnade. This colonnade faces towards the old college buildings, so that it is not only visibly part of the circulation system of the college, but also helps to tie and identify the new buildings with the old. It links the porter's lodge at one end to the east quadrangle and the new squash court buildings and 'sets' at the other, with access to St. John's main garden. In the design of this most important aspect of the buildings we wanted particularly to invite curiosity and search. Only by walking through the buildings and experiencing them did we wish them slowly to be fully revealed and then naturally used. This, of course, is very much within the tradition of the pattern of Oxford colleges, and bearing in mind the size of the new buildings, one which we wished to exploit.

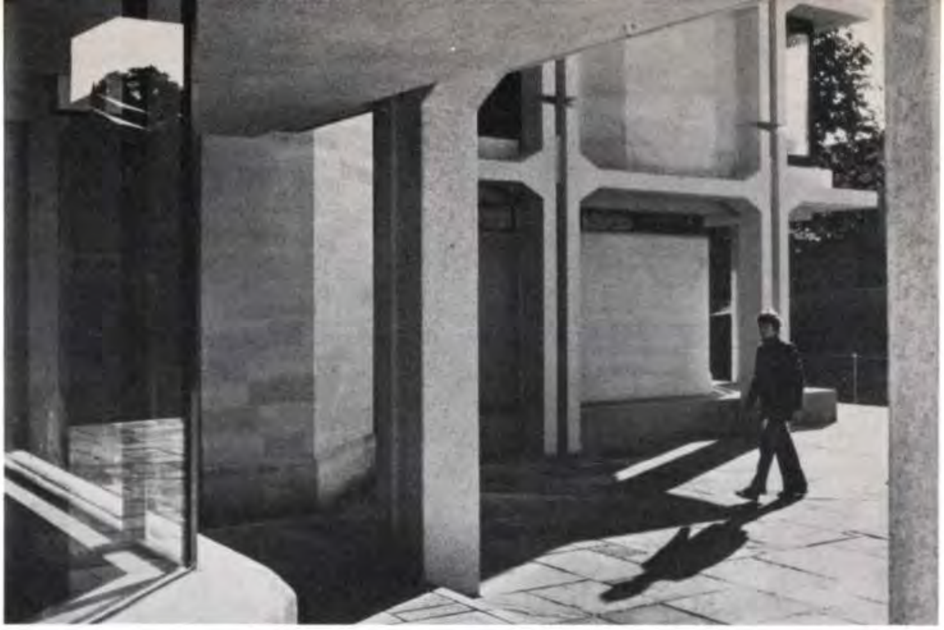


Fig. 23 above
South west paved court and end pavilion

Fig. 24 left
Main colonnade from which all staircases and commonrooms have access

Figs. 25 and 26
The design of the circulation within the Oxford tradition intends to stimulate curiosity and invite search

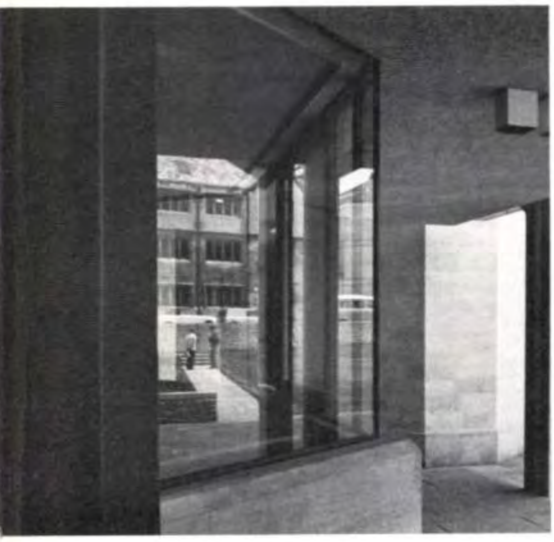
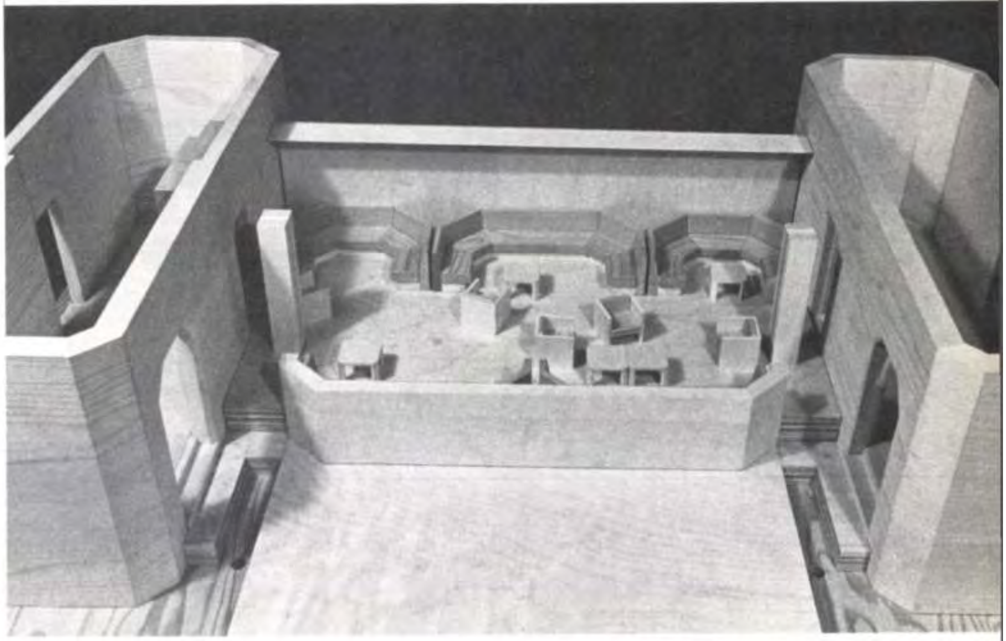


Fig. 28
Reflections of old and new



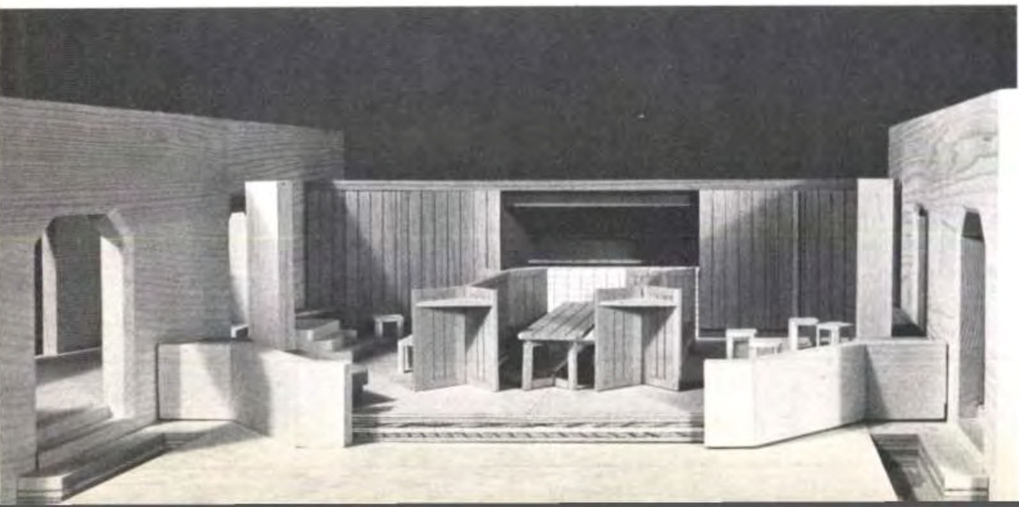


Fig. 27 top
The main college bar faces south onto the quadrangle

Fig. 29 above
Upper (soft) bar (cill to colonnade is above eye level) with view over gardens

Fig. 30 left
Model of main (hard) bar

Fig. 31
'The world within a world'

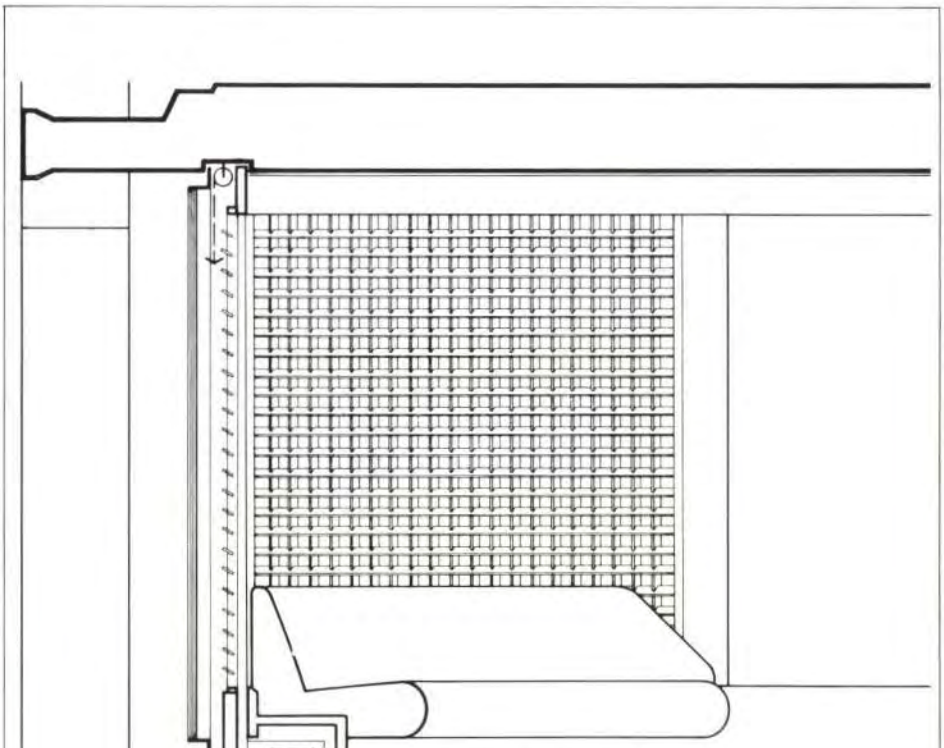


Fig. 33
Section showing relationships between structure, glazing, screens and interior furnishings

Fig. 32
Model of a 'set' unit

The Room

Within the minimum of space, the multiple functions of a student bed-sitting room or set is a problem of opposites. It's a place of work and sleep, a retreat, and a place to entertain, a personal place, yet an identifiable part of a larger community. In some respects it follows directly the aims of the 'minimum living unit' that Wells Coates worked on in the '30s and '40s. Within this limited area, however, the intention is to provide for these various functions and reconcile the conflicting needs to create above all somewhere with a sense of generosity. A place with a strong relationship to its site, and to the architecture of which it is a part.

The sets are split into rooms which open out to the gardens, and the bedrooms are enclosed within the stone towers. There is a change of level between these, to accommodate the stepping of the pavilions down the site. The rooms, in both the sets and the bed-sitting rooms, each have large sliding windows, opening so that in fine weather the whole room can become a balcony.

Timber sliding screens, and holland blinds replace curtains in the sets only, which are on the south and west elevations. The screens double up as sunbreakers, room dividers, grids on which to hang posters and so on, as well as providing visual privacy from adjacent sets. On the east and north elevations, window areas are much smaller, and curtained. In these cases the towers themselves provide for visual privacy between adjacent rooms.

The natural randomness of the positions of these screens, is a very important element in the design of the quadrangle elevations. It provides vitality and movement at the scale of use – the fourth scale.

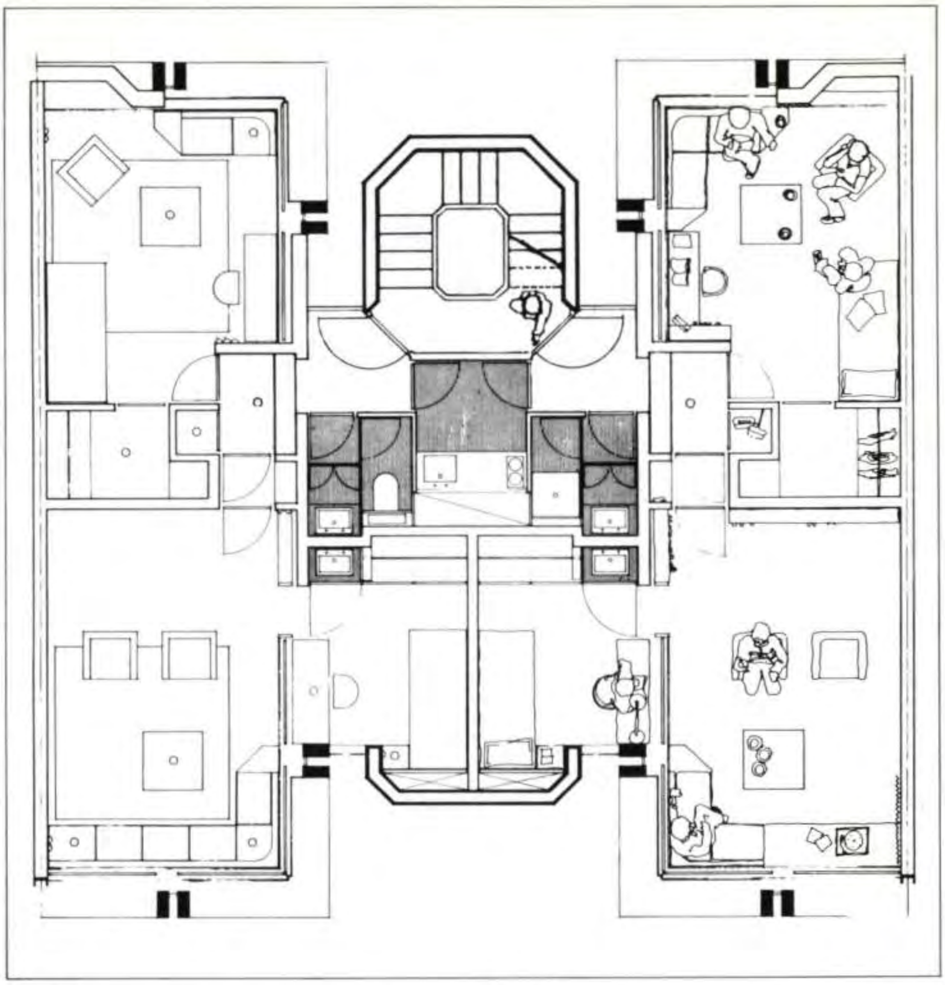
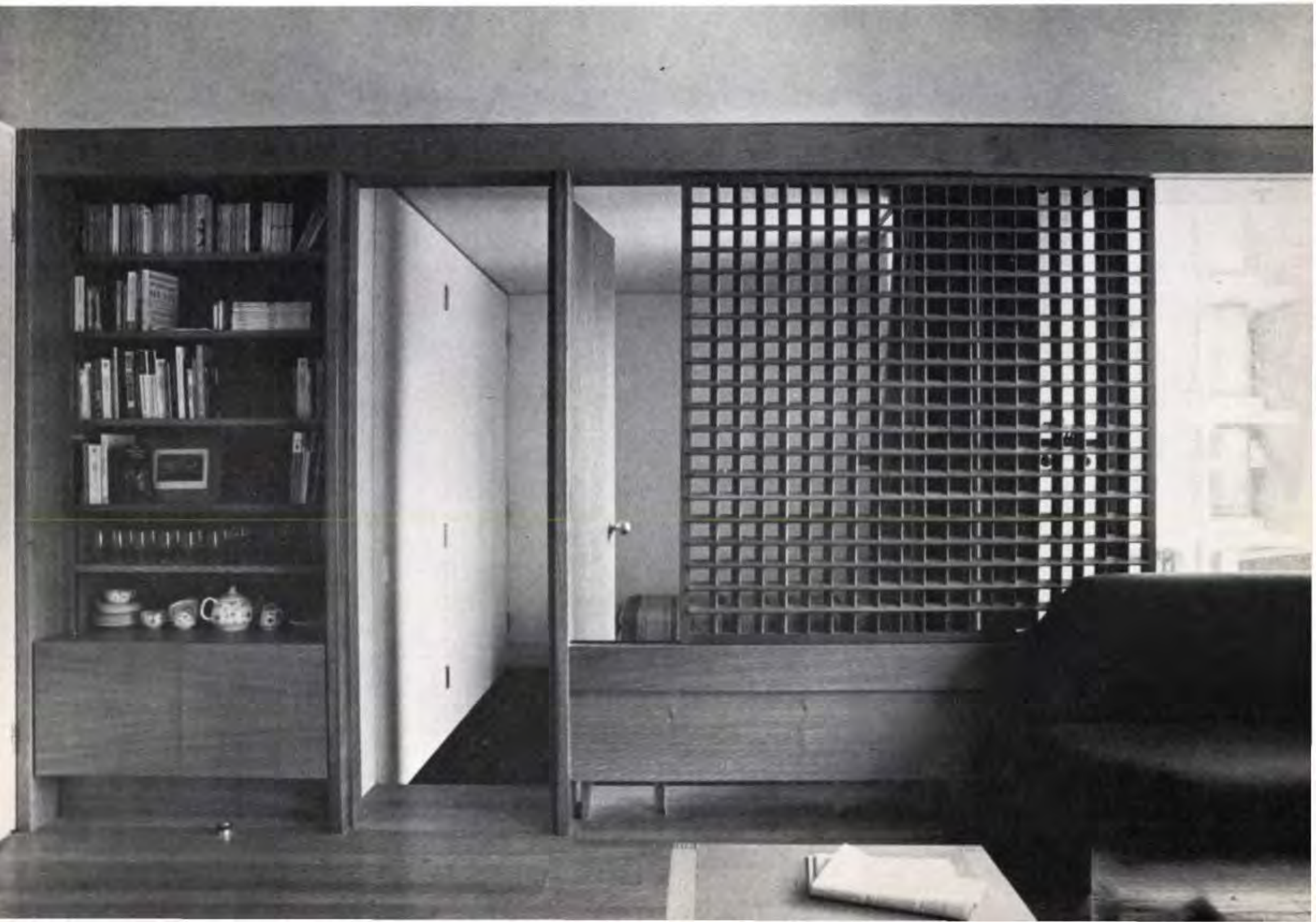


Fig. 34
Plan of typical bay, showing 'sets' and bedsitting rooms with shared services

Fig. 35
View through to bedroom; note change of level as pavilions step down the site



At night, the play of light against the chamfered stone faces and through the screens and brown blinds is particularly successful, which proved a very happy surprise, not entirely foreseen.

Finally the attic storey with roof terraces on the south and west provides flats for Fellows as well as rooms with an entirely different character. These are 'roof rooms' with lofty spaces between low eaves lines, and with spectacular views over the gardens and over Oxford.

Fig. 36
Stone towers provide privacy between adjacent bay windows

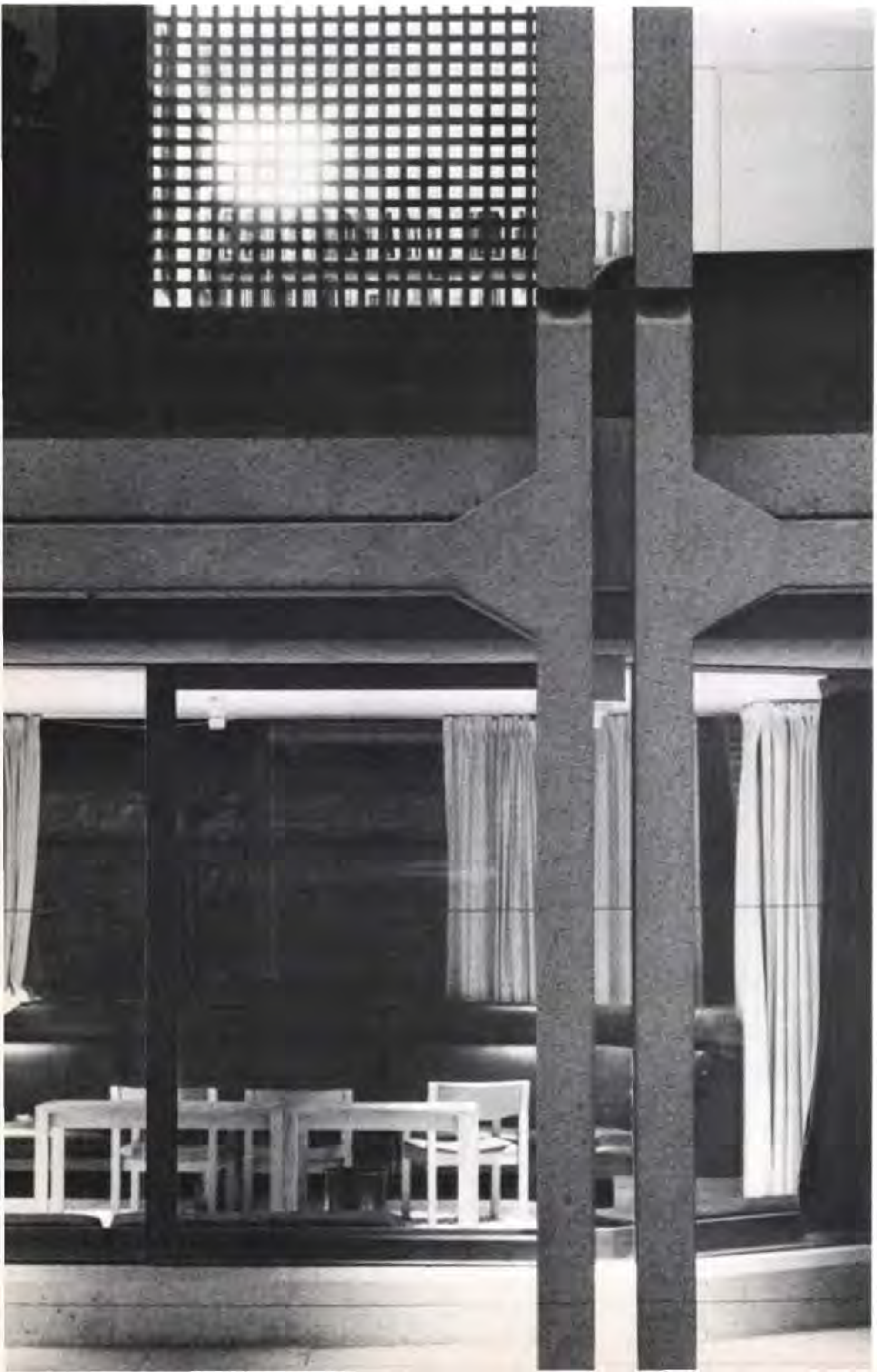


Fig. 37
Night view; lighting behind random screen positions creates a varied and changing spectacle

St. John's is a building that has to work at a number of levels, and which seeks both to draw references from Oxford as well as visual metaphors from the collegiate tradition.

It is probably the end of an era of college extensions of this magnitude, and strangely is within 200 yards or so of that first university commission for Somerville's graduate building designed over 20 years ago. Whilst this article covers in some detail the design of a single building, nevertheless I hope it exposes wider ideas and attitudes that have grown up in the intervening years. There has always been a close relationship between the architecture of our college building and much of our office, laboratory, and industrial work. Each has nourished the other, and St. John's, perhaps more than any of our work so far, reflects this variety of sources – as well as our attitudes, and architectural values, applied in this event to an historic site.

Main contractor: Johnson & Bailey
(Photos: Arup Associates)

Value for money in urban renewal

Peter Dunican

This paper was originally presented at the Public Works Congress, November 1978 under the auspices of The Institution of Structural Engineers.

INTRODUCTION

I propose to discuss this most important subject under two headings; headings directly concerned with two rather disparate aspects of the urban renewal need: firstly, the general problem of our older, worn out, or nearly worn out housing that still exists close to the heart of most towns; the kind of problem which we have been tackling in the last decade through the widespread use of area rehabilitation – General Improvement Areas and, more recently, Housing Action Areas. This is a field in which we have a substantial working experience and on which we can base an assessment about the future. And also where the question of value-for-money is not too elusive; all we have to do is decide the measure of future usefulness and acceptability of rehabilitated dwellings, related to financial expenditure upon them, compared with that of newly built homes. This may not be as difficult as it appears provided we set up the right equations.

The second heading is the very special and particular problem of our inner cities; and this is a complex amalgam of physical and social problems concerned not only with housing, but also with industry, commerce, communications, education, civic and governmental functions – and with the interaction of all these elements. In this field, in contrast with the first, we certainly do not have a decade of experience to help us – at least not of a positive, remedial and creative kind.

However, we are beginning to identify the nature of the problems and their past causes, but we have barely begun to take action; let alone decide what that action should be and how it could be achieved. But we do know without any doubt that the full evaluation and solution of the inner city problem will require new depths of thinking, new heights of determination and a much wider breadth of co-ordinated expertise.

In the inner cities we will be swimming against the natural tide of economic and social trends of the past 30 years which has been to recreate and serve demands that have ceased to exist. We must be successful. We shall have to do our sums much more differently than we do them for the generality of housing rehabilitation within predominantly residential zones. There will be more complex, less tangible criteria to identify in deciding relationships between cost and benefit – in deciding what represents true value-for-money.

HOUSING RENEWAL

We are all aware that there has been a gigantic swing of the pendulum during the last decade away from wholesale clearance towards rehabilitation. The numbers of outworn or ill-equipped homes improved with the aid of Government grants and procedures operating during that period reached its peak in the early '70s. At the same time construction of new housing, both in the public and the private sector, fell dramatically from the numerical targets and achievements of the '60s.

We also know there were several factors that precipitated and subsequently sustained that pendulum swing: economic restraints; a new awareness that sweeping clearance after having dealt with the hard core of slums was in danger of going too far and destroying with the bad much that was good; disenchantment with a lot of the new housing built to replace the slums; realization that much of the remaining older housing was not only a still valuable resource in terms of housing supply, but also made a vital contribution to urban environmental balance and structure. Therefore, we could not afford to go on throwing it away with such brash abandon.

Rehabilitation is here to stay. Clearly this is not a unique view. I believe that the pendulum's swing now needs to be checked and even given a gentle nudge in the other direction. In fact, I believe that we are fast approaching the stage at which the broad-brush area rehabilitation procedures in operation since 1969 will have achieved as much as we can expect of them as the primary means to relieve bad housing conditions while making the best use of our resources to that end.

These methods have been dramatically successful in promoting the very concept of rehabilitation – and to show the importance of its place in the processes of urban renewal. They have demonstrated where rehabilitation can be technically feasible, economically viable, socially desirable and rewarding. But they have also shown us where it is not!

In the future, I believe that if we wish to maintain a fully cost-effective response to the physical, social, economic and conservationist needs that relate to housing, we must move towards a more selective, sensitive and flexible approach to rehabilitation – and provide the procedural and financial support systems that will allow this. At the same time we should seek a more natural balance between rehabilitation and new-build – and establish systems that are flexible enough to allow the two elements to work together in the successful achievement of urban renewal.

In looking for more specific answers for the future, we must be certain to look fully and dispassionately at the situations and problems we now have in clear focus from our past experience. I will now try to help this process.

We have some areas – perhaps mainly in the South of England, and of a type we could label as 'early suburbs' – of fairly varied, moderate density housing, mainly owner-occupied, built in the period say 1870/1920; areas in which most dwellings lacked basic amenities, needed repair, and had an environment that had suffered from the effects of interloping industry, the motor vehicle, and general public neglect.

Because of local housing pressure, the lack of alternatives, the extensive use of grant-aided private improvement of the dwellings, and public improvement of the environment, facilitated by the moderate density, some such areas have been transformed. Clearly, and with only limited, occasional infill, they will remain as areas that provide decent housing standards and encourage on-going private investment – perhaps for yet another 50/60 years. In fact, some of those areas are regarded by both young and old residents as far more desirable and characterful than the brash, new, high density estates, so often less well located for urban amenities, education and employment. And financial expenditure in those areas, even if it had been at the same level as for new housing, would have been very good value-for-money; at anything less than these costs it has been a bargain!

But unfortunately there are not many areas where success has been so absolute. There are others, perhaps physically similar, and also declared as General Improvement Areas – with similar types of action intended or initiated – but where the downhill trend has barely been disturbed, let alone reversed. And in those areas both public and private investment in the small numbers of dwellings improved will not have been well made.

Perhaps the local housing supply/demand situation was different. Perhaps more homes were owned by people with inadequate funds to pay their part of the costs. Perhaps the local authority was less than effective in dealing with environmental sores.

On the other hand, overall success and value-for-money might have been achieved by more public funding of rehabilitation; or by a more ready facility to clear the worst properties and infill with new housing designed to knit sympathetically with the old. The first option was impossible because of the relative inflexibility of the grant system, or lack of incentive for landlords; the second, perhaps because of restraints on acquisition, unrealistic planning demands, 'yardstick' inflexibility, or for private developers, the relatively greater attractions and fewer problems of building on green-field sites.

Very high density areas

Yet another type of housing area comes to mind – and this is one that predominates in, but is not exclusive to, the North and Midlands; the very high density areas of two-up/two-down, narrow fronted cottages – the product of the later stages of the Industrial Revolution, and in which the housing is often still side by side with heavy industry. Some of these were declared as General Improvement Areas, but more recently, and although often predominantly owner-occupied, they are a target for the Housing Action Area system.

With this type of area we need to look closely at some of the physical characteristics of both the dwellings and their environment – in order to set the scene for an assessment of rehabilitation value-for-money. I believe we will conclude that some such housing must continue to be upgraded for long-life and must be conserved, even at increased cost, as an important part of regional heritage – and since, in the right circumstances, it may continue to provide useful homes in high demand. But I also believe we will conclude that this will not be socially or cost-effective on the scale we have envisaged or attempted so far.

For the majority of such housing, though by no means all – and this could also apply to many 'early suburb' areas – the achievement of value-for-money will, I believe, result from a more decisive recogniton that rehabilitation, and the financial investment in it, has only a short-term objective; that it is to give immediate relief to intolerable conditions – and is a gap-filling expedient until, within the shortest possible time, new homes are built.

The common, critical physical characteristics of the 'two-up/two-down' dwellings that I referred to are these: first, their size and shape. They are often very narrow fronted – as little as 3 or 4 m – and have an even narrower back extension, containing a scullery and possibly a small extra bedroom above. No bathroom; only an outside WC, often shared. These cottages may have a theoretical capacity of four or five persons, but their total floor area can be as little as two-thirds of that we expect for minimum-sized new dwellings. To provide an inside bathroom and WC – without building expensive, space-consuming and sometimes environmentally disastrous extra back extensions, or providing a very poor internal layout – can reduce the four or five person dwelling to one which, to modern acceptable standards, will only house two or three. Individually, depending on existing occupancy, this may be enough and may be economic. But while recognizing that we now have huge shortages of small dwellings, mass concentrations of them in large areas of identical two-up/two-down cottages is unlikely to be a realistic or socially acceptable solution.

Fig. 1
City of London, 1955
(Photo: Aerofilms)

There are two other spatial features that are important; staircases often so narrow and steep that, for long-term acceptability, they may have to be replaced and lower-than-tolerable ceilings in back extensions. If, in dealing with these, the Building Regulations have to be satisfied, the practical and cost problems can be critical, and the already restricted living space even further reduced.

Features of their construction and repair condition that we have to contend with are these: distortion through settlement, rising damp, perished and deformed roofs, half thickness party walls, no thermal insulation, damp through solid outside walls with perished joints or rendering, infested structural timber, rotted windows – and, of course, the need for new or replacement services.

The problem is not that these defects and deficiences cannot be cured. Obviously they can: it is physically possible. The problem is that, to cure them effectively – and to the extent needed to give the dwellings reasonable life, without an unreasonable on-going maintenance commitment – can cost a lot of money; far more than may be catered for within current grant levels; and leaving a far bigger gap than can be bridged by the present occupier.

In fact, many owner-occupiers of properties in worst condition – and this applies particularly in some Housing Action Areas – are elderly or otherwise of limited means. They may find raising even a small mortgage loan either a practical impossibility or emotionally intolerable. Even if they can bridge the gap, in the existing circumstances of their rundown area, there may be little incentive to do so. Low market-value may make it a poor investment. Equally this can be a deterrent to effective action by a public agency – such as the local authority, or a housing association; the total cost of acquisition and full improvement and repair may far exceed even an upgraded market value. And market value is about the only firm element of the equation we can use to determine the cost/benefit of rehabilitation, and how firm is this?

Another feature of these areas that we can hardly ignore is their environment. Overall density is often extremely high – sometimes twice the figure we would normally tolerate for new low-rise housing. There may be narrow streets, no front gardens, only rudimentary back yards, filled almost to capacity by back extensions. Without at least some clearance there may be no hope of providing even limited car parking, or play areas for young children, or to plant some much needed trees. Invariably, in some part of any given area, there will be a concentrated problem of noise, pollution and congestion from inter-mingled industry. Utility services may be completely outworn. And the environment may have suffered generally from years of blight and of poor street maintenance, the continued presence of derelict, bombed sites, and so on. Therefore, effective long-life rehabilitation and achievement of a reasonable social benefit from the money spent on improving the homes, will inevitably depend on very high public expenditure on the environment.

Larger properties

There is one other general category of property whose physical characteristics are again different, but worthy of note when considering rehabilitation value-for-money. They are the larger, four and five storey properties, often closer to the centre, originally built for the 'gentry', but now usually landlord-owned and multiple-occupied. They may be in smaller concentrations than the other categories, but are a prime target for HAA treatment and for conversion through the public agencies. Because of their location, they can also be a part of the inner city problem. Again, for both practical and conservationist reasons, many must be retained and given long life. But not all of them! And again, even at higher costs than we currently allow, we may not achieve some of the standards we expect of new housing. We have to decide how critical that is.

In these properties, problems and high costs arise particularly in achieving adequate sound insulation and fire separation between flats, or in providing 'means of escape', in utilizing basements with low ceilings and poor daylighting, and in carrying out effective repair of ornate façades and complex roof forms – as well as in putting right the full catalogue of constructional defects common in the smaller properties.

Leaving aside the particular physical and social features of particular types of property, there are two, more general, and unfortunately less tangible factors that we ought to consider in the value-for-money equation.

One of these is the question of the productive use of our construction industry resources. Rehabilitation, by its very nature, is labour-intensive. In current circumstances some may consider this an absolute benefit: but this intensive use of labour is, in fact, of high skills that are in short supply even at this time. Rehabilitation work, in particular, requires those skills. But the work is also low-productive: some claim capital value output per man to be less than half that on new housing construction. This arises because of the complexity of the operations, wide variations of repair even among small groups of apparently identical dwellings, lack of opportunity to 'rationalize' or introduce industrialized methods, difficulty in phasing trade operations and in achieving effective programming and site control of the work.

Certainly, in the case of contractors experienced in rehabilitation, some of these difficulties are reduced, and all the direct costs are presumably reflected in the sometimes startlingly high tender figures. But one is less certain that there are not more general hidden costs or other penalties that we should be considering, at least at a national or regional level.

The other less tangible factor is that of the hidden costs of the administrative and procedural input by the local authority. It remains hidden more often in ignorance and by the absence of hard information than by intent. Some say it is a 50% oncost. Others say it is closer to 100%. We need to know. Otherwise we cannot give the answer about value-for-money. However, equally, we will continue to recognize that on the other side of the scales, the hidden costs of all the procedural and approval hoops we must go through to build new homes is not insubstantial!

I believe that, when we come to an assessment of the more specific problems referred to earlier, and to take full account of the last

Fig. 2
City of London, 1975
(Photo: Aerofilms)

decade's experience, we will recognize that among the results of rehabilitation so far can be found some significant conclusions.

There are many thousands of rehabilitated dwellings on which there has been high expenditure of public and private money – aimed at achieving long-life – but where it is clear that these homes will not provide the quality of accommodation and environment to fulfil our aims.

Equally, there are many thousands of cases in which relatively high expenditure – up to 'eligible limits' – has still not been sufficient to achieve a level of repair and physical soundness that removes the need for excessive on-going maintenance and remedial costs; costs that private individuals will not be able to afford; work that will, therefore, not be done. Again the 'long-life' will not be achieved: and at least some of the money spent will have been wasted. Or, in the case of public agencies, there will be alarm at the level of un-budgeted maintenance costs – we have already seen some 'headline' reports.

Inadequate grant support

On the other hand, there are many other properties, of such inherent quality and desirability as to be potentially capable of very long life – some indeed more than the 60 years we notionally allocate to new homes – but which, because of inadequate grant support and private funds, will not be up-graded to reach that potential. In those cases costs as high, or even higher than those of new dwellings, would have provided good value-for-money.

Apart from the very obvious and essential short-term relief of bad conditions in countless thousands of other homes, often at relatively low cost, there is, of course, a substantial number of dwellings in which the higher expenditure and long-life aims have not been so sadly mis-matched. We got what we expected, and for the targeted costs. Regretfully they may be less numerous than the others.

Also – and we might consider this on the credit side – the problem of unexpected and expensive remedial problems is not exclusive to rehabilitation. There are plenty of other 'headlines' to tell us of the disasters befalling much newer estates!

I believe that, however difficult it is to quantify them, if we consider the balance of those results – and also take account of the hidden factors of 'overheads' and building resources – we will conclude that we should be looking in the quite near future for a new formula of policies, procedures, financial incentives and allocations that allows the following to happen:

(1) A modest return-swing of the pendulum in which replacement by new homes becomes the primary means of dealing with fully outworn stock that we do not wish to conserve for the long term. And this could well require a more elastic yardstick, plus possibly a local loosening of planning and other controls, so that infill replacement can be successfully married with the best of the older stock and environment we wish to conserve.

(2) That, for the relatively small proportion of older properties that are good enough to conserve for long-life, enough money is made available and actually spent to achieve that aim. In individual cases that could well require far higher input of public funds than hitherto. It would certainly require great flexibility, both of funding and procedures, to meet wide variations of physical circumstance and private resource. And it is perhaps relevant here to express the view that, if we achieve in reality the 30 years' future life we have in the past used as a measure of anticipated long-life performance in rehabilitation – then we might just as well assume it will be 60 years. To achieve 30 years must mean that the dwelling is equally as acceptable to the user, and of equally sound structure, as a new one.

(3) That, for the remaining sub-standard older stock, there is a more positive recognition that rehabilitation is only a short-term expedient for which financial expenditure must be kept to the absolute minimum until replacement is possible.

To achieve success in applying this formula will require more careful selection and judgements than have been applied so far within the broad boundaries of 'declared' rehabilitation areas. But this greater care will be needed at both ends of the assessment scale; on the one hand in determining overall trends of supply/demand and developing overall strategies: on the other, in deciding what action and expenditure is appropriate for quite small groups of dwellings and their environment.

In my view, unless these changes of emphasis, policy, and method are introduced fairly quickly, we will look back in only a few years and be startled to discover just how little we have achieved and how much money and other resources we have spent in the process. We will not have had value-for-money.

Except in the inner cities I believe that there is one final and absolute test we could apply, in many areas where enough money has been spent to physically conserve, for long-life, any worthwhile, privately-owned older property – but in which there is now space available for infill with new housing, as part of the renewal process. We will have to answer only one question. Is it a practical and profitable possibility for private developers to build and sell that infill housing? We may not wish them to do so, for any number of reasons: and builders might not wish to do so, for reasons other than profitability. Therefore the question may be hypothetical. That does not matter. If the answer, even to the hypothetical question, is 'no' – this will imply fairly clearly that there is insufficient demand for, and marketability of housing in that area to ensure the confidence and on-going private investment needed to sustain the long-life for which we have initially hoped and paid.

If the answer is 'yes' then we are winning.

THE INNER CITY PROBLEM

The inner city situation is much more complex, intangible and incapable of rational resolution than the relatively simple question of housing renewal. It cannot be subjected to over-simplified tests. In fact it usually begins in quite another place; a place in which rationale and logic do not reign as they should.

But at some stage, sooner rather than later, an inner city programme will be prepared. It will inevitably consist of a long list of miscellaneous ideas suggested by local authority departments at district and county level, central government departments, voluntary bodies and statutory undertakers, police and academics, officials and politicians, gathered in by a net spread deliberately wide to ensure that no area either of direct or indirect involve-

Fig. 3
City of Birmingham, 1946
(Photo: Aerofilms)

Fig. 4
Centre of Birmingham, 1974
(Photo: Aerofilms)

ment, geography or fringe benefit will have been left out of account. This list will have to be reviewed on some sensible and accepted basis to a length that can be accommodated within the available resources.

Now getting value-for-money means spending money where it achieves most good, but most has to be defined. If two mines produce lead and gold you cannot compare their output in tons, without taking into account the price of lead and gold. It is what I would call the apples and pears argument. Where there is no market and no price, there is no common denominator between the criteria. Social economists have tried to find an objective standard, other than price, to measure whether one set of circumstances leaves people better off than some other set of circumstances, but so far very few useful rules have been established or even laid down.

Yet the programmes being proposed for inner cities contain projects of many different kinds and the policies announced in the White Paper envisage breaking into areas of activity in which local authorities have barely trodden in the past. All of these projects have to be weighed one against another if common sense decision-making is to prevail. We cannot afford to neglect democratic communal decision-making.

We could be concerned with problems involving choices between housing and environment and something else perhaps altogether much more important. If I could give an example: a typical inner city authority is now preparing its programme from a collective ideas paper which contains suggestions as diverse as special types of housing for extended families, more social welfare officers, interpreters, a Caribbean cultural centre and the ultimate suggestion that the whole problem is a moral one and therefore requires a moral solution so all the money available should be put into building a temple for a particular religious faith!

No rigorous analysis can be found which will produce a list in priority order, but it seems reasonable to try to provide a guide by setting down the general aims of the inner city policy as we see them.

You have to start with the overall strategy decision between on the one hand improving the area as such and on the other hand doing something for the people who live in it. The former would justify more parks and open spaces, more buildings which would benefit people from the outer areas and more industries which would employ labour from the outer areas or outside the district altogether. The latter would justify more in the way of housing and social welfare. You could of course go for a third overall strategy, often described as planned orderly withdrawal, which would be to suggest that in renewing the inner cities at all we are playing Canute against an irresistible and overwhelming tide of economic forces. Practically speaking this third choice is not open to us since fortunately the decision to have an inner cities programme has already been made, but it is a logical possibility, some will argue for it, and decisions will have to stand up to criticism from those who do.

In one way, however, inner city programmes *will* be fighting against economic trends. The aim of inner city policies is to direct expenditure towards people and areas which would be missed out if a free market were left to allocate it to areas of lowest cost. Building costs are likely to be higher in all the inner city areas than they would be in the rest of the country, so value-for-money is by that much diminished for every inner city building project.

Project grouping

Having decided on the overall strategy in these terms you need to break it down further in terms of the main headings under which projects will be grouped. Headings will be housing, employment creation, transport, health, education, sports and leisure, environmental improvement, personal social services, industrial development. It should be possible to put these headings into priority order or to give them some sort of weighting – so much per cent of the programme to housing, and so much per cent to sports and leisure, and so on. The sort of choice to be exercised here will be between:

(a) going for the old familiar pattern of local authority expenditure, biased towards the inner city but otherwise unchanged with 75% of capital spending going on housing, or

(b) recognizing the claims of the social services some of which bring back no dividends to the general public like day centres for the elderly, while others bring unquantifiable dividends, like youth clubs which it is thought keep youth away from crime, but all of which are being pressed by a large number of thoughful people, or

(c) moving into the comparatively new area of industrial development, where many worthwhile schemes will already have been tackled by an army of people in the private sector who can probably do as well as the small group under an industrial development officer in the Town Hall, where there are arguments for initial subsidies in the form of reduced rents or interest-free loans but difficulties in assessing which projects will really take off once the initial subsidies are withdrawn, but where, at least, there should be some rate of return on the money spent, or

(d) environmental works, 'cosmetic treatment of eyesores' too much of which without anything else to back it up, does smack of the planned orderly withdrawal strategy which we mentioned and ruled out earlier.

Armed with this strategy you have some sort of standard by which to assess projects, not a rigorous mathematical technique but something to go by and one which will produce a slightly different result from the rigorous mathematical technique could such be devised. Any mathematical algorithm that could be envisaged would tend to allocate all expenditure to one category which produced most in terms of units of welfare up to a certain point at which some other category became marginal and then expenditure would be allocated to that second category leaving some categories with nothing. We are likely to produce a list of projects in practice which allocates something to all categories of expenditure. This could be argued for on the grounds that we do not know and do not even have a rough subjective assessment of the marginal contributions to welfare of different categories of expenditure so it is quite rational to play safe and give something to all, even on some random basis. But there is probably also an element of political necessity in this kind of solution.

Money

The next step after determining the strategy is to decide how much money there is to be spent. There will be a specific sum allocated under the Urban Aid grant, but this will be subject to a 25% contribution from the local authority. The contribution is asked for because it is thought that grants normally bring back revenue to the local authority in some form directly or indirectly, like increased rates and increased activity in the area, but in any case it is likely that local authorities will in effect have their 25% contribution returned to them in the form of needs grant under the settlement of the rate support grant in the following year.

The grant may be spent on revenue, recurring projects or on capital. If any grant is spent on the former then there is a commitment in future years which will reduce the amount of new money available in those years. If it is spent on capital works then the revenue consequences in future years have to be assessed. These consequences are more likely to be expenditure than income, and where local authorities are now spending 20% of their recurrent funds on servicing debt they are becoming increasingly anxious to avoid capital works which may generate future expenditure and hence there is a further argument for moving towards the economic development side of urban renewal.

It is unlikely that the Department of the Environment will lay down revenue/capital ratios for expenditure of Urban Aid grant, but they will have to watch how the totals between all authorities work out and they may have to exercise some control in the future. Other financial resources will be available from the Locally Determined Sector allocation which is not a grant but an authorization to raise loans.

Bending of main programmes

Then over and above these and other minor sources of funds it is likely that as much again will be allocated to the inner cities through the process described as the bending of main programmes, the allocation by central and local government of an increased proportion of money available under for instance, education or housing, to inner city areas. Where the local authority does the bending there is no overall increase in the funds available to it. Where the bending is done by central government then the local authority with the inner city problem is that much better off at the expense either of other local authorities or of other categories of government expenditure.

The next step is to look at all the ideas and bids which have been submitted for the inner city programme which has to be drawn up each year by the end of the summer. Certain of the ideas can be ruled out immediately and certain of them will in fact be general policy suggestions which could modify the strategy in the future, and some of them will be general suggestions for projects of a certain kind; more old people's day centres as opposed to a day centre in a particular location. All the rest have to be analyzed.

You do not want to spend too long on the projects which have very little hope of being accepted or in the first instance on those which are certain to be accepted. You need to concentrate on the marginal projects, but you don't know which ones these are going to be so one stage in the process is to make a rough estimate of the cost of all and compare the total with the resources available. You can then rule out a lot of projects and move to the next stage which is to concentrate effort immediately on those left.

When decisions have to be made on the marginals you need to analyze more fully the certain runners because these also will have to be justified in the programme document. This is a two bites at the cherry approach, and one which local authorities are not very well geared to following. There is always great reluctance in local authority to produce rough estimates with the danger than one may be held responsible for them. Rough estimates of cost require rough details of content, and these are often difficult to extract.

Performance indicators

Details of content and performance are important in the whole process. It is being emphasized that every project listed in an inner city programme should have as many performance indicators as possible listed against it. If you argue for additional social workers you must show how many you have at present and how they compare with the national average per 1000 of population, generally and in stress areas. If you want a 'drop in' centre for youths, you must estimate how many are likely to use it and what class of youths over what area you expect it to cater for. Whereas we meet all the difficulties of comparing unlike with unlike which have been described in the paragraphs above, when we try to decide whether a social worker is worth more than a dog catcher, there must nevertheless be some level of dealing with social service referrals per week and some level of performance in terms of dogs caught per week which would positively rule one out against the other.

The National Building Agency has been producing a management model to define the activities which have to be gone through in order to prepare and monitor an Inner City Programme.

It becomes apparent from the model that the time available for the preparation of the first draft of the programme will be exceedingly tight and although we have described above a two-stage process of rough estimates refined later it is possible that yet a third iteration will be required because of the lack of time available to finalize the second stage satisfactorily. After the first draft of the programme has been produced and submitted to the Department of the Environment for consideration, it will be desirable to have another run through the projects, checking their cost estimates and the other measurements of what they are supposed to achieve, before the programme is finalized in January to March immediately before the beginning of the financial year. All this will require a considerable amount of effort particularly by the quantity surveyors and planning teams.

Once you have all these indicators recorded you use them not only to decide which projects are to be included in the programme, you use them to see that you are getting value-for-money in another sense in actual performance as the projects are implemented. Housing for extended families may have been included in the programme on the grounds that there was a demand for at least 100 units. How many of those actually built to date in response to this suggestion, have been taken up? How many dogs have in fact been caught? Whereas it was planned to build flats at £12,000 per unit, how many have in fact worked out at £12,000 plus inflation and how many have cost more than that?

Monitoring of indicators

It is proposed that monitoring of all these indicators should go on as soon as the first year's programme begins to be implemented. A group of officers will meet regularly to review these matters and a systematic report on past projects will be part of the annual assessment of the current situation in the inner city areas which officers will put up to Partnership Committees and other committees responsible when they begin preparing the programme document for the following year, rolling forward their three-year inner city programme for another year.

There are many instances of housing schemes giving grey hairs to architects and quantity surveyors and bringing finance committees to despair with their extra costs while yet housing contented tenants and becoming part of a wider process of successful improvement. It is hoped that there will be a further stage of monitoring not of individual projects but of overall achievement of results produced by all the projects working together. This latter form of monitoring will go back to the strategy decisions and see how far they have been achieved, whether there has in fact been a noticeable improvement in housing or the environment overall regardless of how far individual projects may have succeeded or otherwise. One imaginative suggestion is that this sort of monitoring might be assisted by a series of before and after photographs covering as large an area as possible.

Monitoring will also go a stage further back and look at the change in certain indicators on a higher level of generality, at the kind of things which study teams used to measure malaise in the Inner City – crime, vandalism, poor health, unemployment and low educational standards.

Measurement of achievement

You measure achievement for the purpose of educational standards not in expenditure on new classrooms nor on pupil/teacher ratios but in terms of academic attainment and 'O' and 'A' level passes. These things have to be measured in the long term. The programmes now being prepared will be implemented in 1979/80 and any buildings contained in them will not be completed until 1980/81 or after. The first classrooms built in response to the present policies will not open their doors to pupils for three or four years and the brighter interior behind those doors will not have its effect on 'O' level achievements of those pupils until some years after that.

If there are improvements it will be hard to demonstrate that they would not have taken place anyway through other influences. If there is no improvement it will be possible to argue that things could have been actually worse if our policies had not been implemented. However, difficult as it may be to assess these things they will be the real measure of improvement and it is only through these measures in the distant future that we will know the real value for money achieved by our policies for the Inner City.

Clearly we must have faith. We must have faith in ourselves to deal sensibly with this most complex problem. And I do believe that we can be successful provided we are not too intoxicated by the technological possibilities of this last quarter of this century which appear to ignore the need for balanced human judgement exercised in the best interests of our community.

Arts and Social Sciences Building Trinity College, Dublin

ARCHITECTS:
AHRENDS, BURTON AND KORALEK

Peter Ryalls

During the years 1938 to 1958 the number of students at Trinity College increased slowly from 1500 to 2000. Since that time the student population has more than doubled, and in 1966 the College commissioned a development study of the whole of the site. That development plan determined the pattern of growth for the College and established the design parameters for the new Arts Building. Ideas were then sought from architects, and of the two schemes submitted, that of Paul Koralek, of Ahrends, Burton and Koralek, was considered more sympathetic to the aims of the college, whose stated requirements were 'a design involving one or two interlinked new squares, of elegant proportions, whose style should be consistent with the historical interest and architectural value of the site'.

Emphasis was placed on the desirability of retaining a substantial area of lawn immediately to the south of the old library, and of preserving as many trees as possible. Pedestrian access to Nassau Street, exclusion of traffic noise, and flexibility of accommodation were essential requirements of the building. In addition the architect was urged 'to seek to provide facilities for staff and students which would give the Faculties, Schools and Departments concerned a new sense of identity and community, yet preserve and develop those aspects of the present arrangements that encourage a sense of membership of a college with a rich diversity of activities'.

The site (Fig. 1) lies in the Fellows' Garden, a fine and relatively restricted area of garden on the southern edge of the College. It is surrounded to the north-east by the new library (also designed by ABK and completed in 1967, and to which the new Arts Building bears a strong affinity, being clad in the same light cream Wicklow granite), to the south by Nassau Street and its belt of flanking trees, and to the west by the Provost's House and garden.

The outline brief and the site posed, in the architects' own words 'the problem of concentrating a large amount of accommodation on a restricted site, further restricted by the desire to use the minimum site area without making a high building, and the intention to form a well proportioned new square on the site of the Fellows' Garden, a square comparable in scale to the older squares in College and completing the pattern of these squares, symmetrically about the central axis of the college'.

The trapezoidal shape of the site created the further problem of reconciliation between the rectilinear forms of the buildings and squares of the College, and the oblique angle of the line of Nassau Street on the southern boundary. The apparent mass of the building and its height had to be in harmony with both the old and new libraries facing onto the new Fellows' Square (Fig. 2).

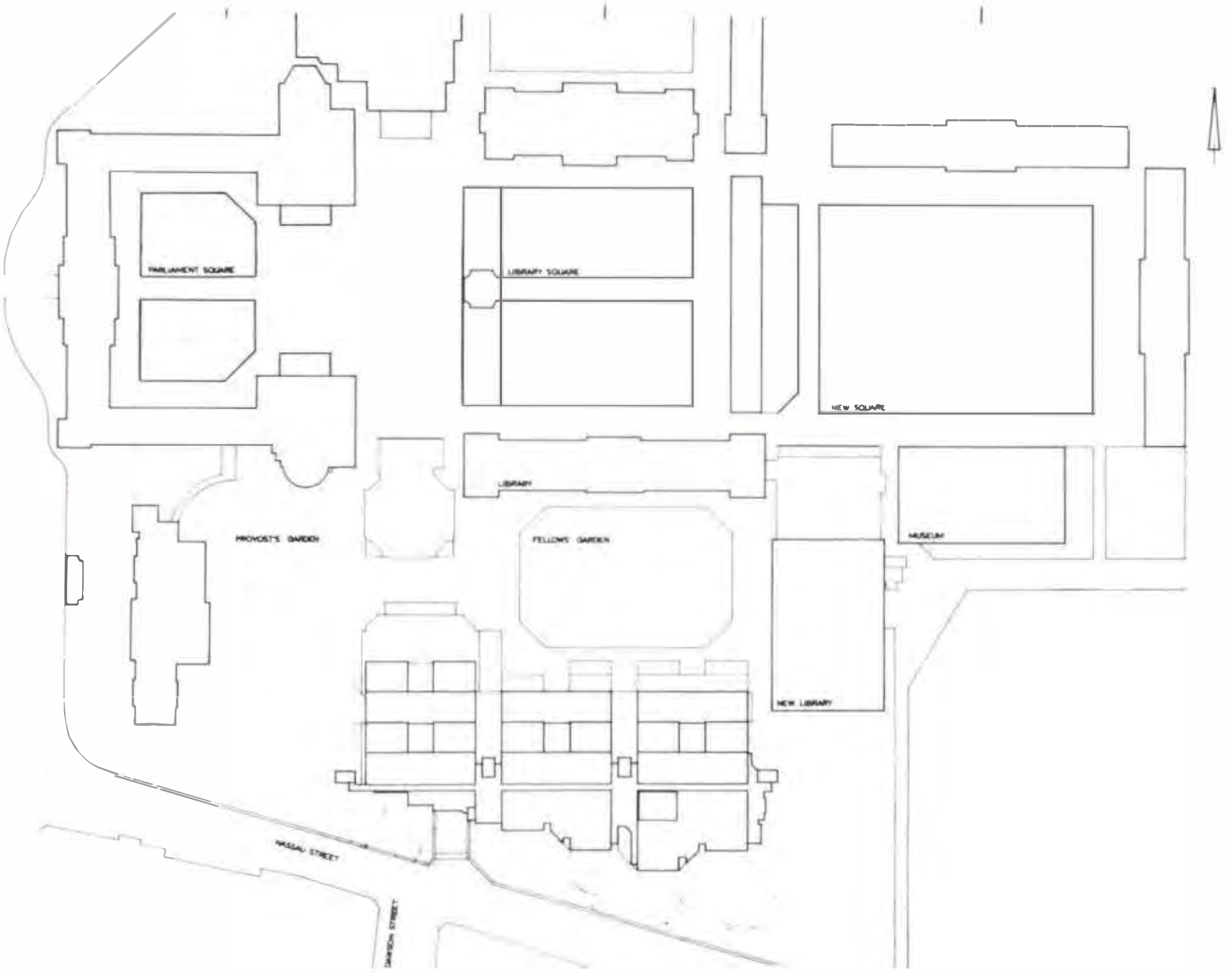


Fig. 1
Site plan (Reproduced by courtesy of the architects)

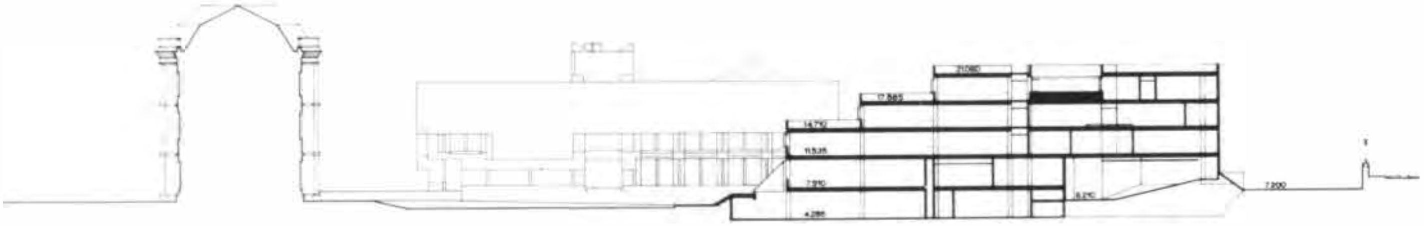


Fig. 2
Section showing relationship of the new building to the old and new libraries (Reproduced by courtesy of the architects)

Fig. 3
Models showing evolution of the design from first planning approval (top) to building as built (bottom) (Photo: Antoine Raffoul)

The building form, for which planning permission was first granted in 1972, is shown at the head of Fig. 3. An appeal and public enquiry concerning the siting of the building in relation to Nassau Street was held and a revised building line moved the building about 14 m to the north, thus reducing the Fellows' Square, and disrupting the relationship of the new building with its existing companions.

Paul Koralek and Patrick Stubbings considered that the building in its revised location was unacceptable and they embarked upon successive strenuous and exhaustive exercises to remould and adapt the fixed volume of the building to a more confined setting. These are shown progressively in Fig. 3. The building originally approved is at the top, the alternatives and modifications progress downwards, arriving at the building as built at the bottom.

Fig. 4
Stepped north façade looking onto the new Fellows' Square (Photo: Antoine Raffoul)

Attempts were made to reduce the apparent height by stepping the north face, in order to open up again the reduced Fellows' Square. The success of this can be seen clearly in Figs. 4, 5 and 6. The roof line was kept down to that of the new library, and the building was squeezed down, the ground floor being now below the level of Fellows' Square; the permissible 'squeezing' being constrained by the high water table. Apparent height has also been reduced by earth banking. 'Remoulding' caused the 400 seat lecture theatre (Fig. 8), which projects clearly at the top of Fig. 3, to be tucked under the general accommodation, to such good effect that its roof (extreme right of Fig. 4) and the upper part of its west flank wall, are barely noticeable behind the bank and shrubbery of Figs. 6 and 7.

When trial pits were dug for the site investigation the inflow of water was such that pit sides collapsed quite quickly. Allowance was therefore made in the Bills for pumping the site, if necessary. Individual pad footings were blinded immediately formation level was reached. The lower ground floor slab was laid on 200 mm of no-fines concrete to avoid impeding ground water flow, and the slab and associated retaining walls were designed as watertight to a level above expected flood levels. During excavation, water flow was found to be far less of a problem than had been feared. Once the local water table had been drawn down, the flow was easily contained, to the relief of all concerned.

The Edmund Burke Theatre

The roof of the Edmund Burke Theatre is generally of reinforced concrete beam and slab construction. Overall height of the theatre had to be kept to the minimum; the roof level had to be kept down to improve the open

Fig. 5
North face: the clear sloping glazing forms the roof to the double-storey library (Photo: Antoine Raffoul)

Fig. 6
West face, with Georgian university buildings in the background
(Photo: Antoine Raffoul)

Fig. 7
West face, showing the flank wall of the 400-seat lecture theatre unobtrusively tucked almost below ground and beneath the glazed accommodation in the middle foreground
(Photo: Antoine Raffoul)

aspect of New Fellows' Garden, and the floor had to be kept up out of the water. The solution adopted was to span reinforced concrete beams from back to front and to support these on a fabricated steel beam, 1.5 m deep spanning 18 m transversely, located directly above the lecturers' dais. The beam supports, in addition, one storey of professors' accommodation. Service ducts passing from front to rear between the concrete beams pierce the steel beam very significantly and necessitated the use of heavy plating and stiffening. The beam was concrete-cased, weighed approximately 20 tonnes and was brought to site in three sections. Stepping of the north face of the building has resulted in the creation of peaceful courtyards (Figs. 9 and 10) around which the rooms of professors and lecturers are clustered.

The building volume, which was displaced by stepping the north face, moved above the lecture theatres on the south face, and the new south side of the building follows the oblique line of Nassau Street, (Fig. 11).

Fig. 8 (below)
Interior of the main lecture theatre
(Photo: Antoine Raffoul)

Fig. 9
One of the enclosed, elevated courtyards (Photo: Antoine Raffoul)

Fig. 10 (below)
A different view (Photo: Antoine Raffoul)

Fig. 11
Model showing the varying arrangement of walls on the south face (Photo: John Donat)

Fig. 12
The south face, faceted, and cream granite clad (Photo: Antoine Raffoul)

Fig. 13 (below)
45° chamfered corners of walls are a strong feature of the building, both externally and internally (Photo: Antoine Raffoul)

Fig. 14
The east face. The sharpness, clarity of line and meticulous detailing shown here are characteristic
(Photo: Antoine Raffoul)

The staggered, cream, granite-clad faces provide both shelter to the occupants from the noise of Nassau Street, and a delight of wandering walls and peeping windows, glimpsed through the curtain of trees to the passer by (Figs. 12, 13 and 14).

Whereas the granite cladding to the new library is 100 mm thick, that of the Arts Building from the same source, due to financial stringency, is only 35 mm. This created problems of detailing, of both stones and supports, particularly where a splay corner stone follows a wall which turns through 45°. In order to make the stone appear continuous around a corner, it was mitred and glued at the factory. Design of suitable supports for such a stone which allows for vertical shortening of a four storey high wall, thermal expansion of the granite on a south aspect, and variation of wall location from the theoretical, produced a fine exercise in tolerances, horizontal, vertical and personal.

Within, use of applied finishes has been kept to a minimum, and the white concrete coffered ceilings and painted block partitions are shown at the entrance to the Douglas Hyde Gallery, (Fig. 15).

Fig. 15
Interior surfaces showing the decorative use of a lignacite wall, and exposed coffered white concrete slab soffit as a ceiling
(Photo: Antoine Raffoul)

Fig. 16
The entrance hall, using air conditioning ducts as sculpture (Photo: Antoine Raffoul)

Fig. 17
The entrance hall, coffered slabs and cruciform columns (Photo: Antoine Raffoul)

Fig. 18
The two-level library and north light glazing (Photo: Antoine Raffoul)

Fig. 19
'Time for reflection' (Photo: Antoine Raffoul)

Fig. 20
Brightly painted air ducts are used as a feature (Photo: Antoine Raffoul)

Exposed services form a feature in the entrance hall, (Figs. 16 and 17) with a painted rainwater pipe running alongside the cruciform-shaped columns.

The coffered floors are 400 mm overall depth, but the carefully detailed rebates 50 mm × 50 mm on the soffit of the rib reduced this. Spans of 11.25 m × 8.55 m indicated a very flexible floor, and precautions were taken to reduce relative deflections during construction by loading two floors with stacked blockwork before permitting block wall construction to commence on the lower floor. This restriction was maintained throughout. Considerable difficulty was experienced in achieving and maintaining the high standard of soffit finish required. Formwork arrises of the rebates deteriorated rapidly; coffers would stubbornly warp, and carefully taped joints would sometimes leak. The results show, however, that the efforts made by all concerned to achieve a high quality 'as struck' finish in white concrete have been successful.

The library (Figs. 18, 19 and 20) is on two levels, and the sloping north-facing, glazed roof provides illumination to both levels. The lower level, to the right of Fig. 18, projects under Fellows' Square. Air supply ducts boldly traverse the coffered ceiling of the upper level, (Fig. 20).

The exhibition hall, (Fig. 21) is of double storey height. Demountable exhibition walls shown at the left of the illustration are clamped to stainless steel wires suspended from the roof and bolted into the floor. Sockets are permanently fixed in floor and ceiling on a grid pattern, and wires may be strung as required to form hanging walls.

Construction began in 1974, and the College moved in and entered upon the first academic year, in October 1978. With accommodation for 3000 students the New Arts Building is humming with activity.

The architects have said that 'the design aims to provide a coherent visual order which is directly related to the functional order of the building and is also an expression of its construction. This approach extends into the interior design and furnishing of the building which is seen as a direct extension of the architecture. The Arts Building is designed in the belief that the quality of the visual environment matters and that it has a part to play in the educational function of the building'.

The building was officially opened on 11 December 1978 by the President of Ireland, Dr Hillery. At that ceremony, at the reception which followed and at the evening party sponsored by the design team, nothing but praise was expressed. Even the press and the students themselves are very pleased with what must be described as a very successful conclusion to 10 years of committed work by all concerned.

Acknowledgments

Architects
Ahrends Burton and Koralek

Quantity surveyors
Patterson Kempster and Shortall

M & E engineers
Varming Mulcahy Reilly Associates

Acoustics consultants
Kenneth Shearer and Associates

Landscaping
Lanning Roper

Main contractor
John Sisk and Son Ltd.

Fig. 21
The double storey exhibition hall, and gallery (Photo: Antoine Raffoul)

The British Library: a computer model for London clay

ARCHITECTS:
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Nick O'Riordan

Introduction

The British Library project has already been described in general terms in the last issue of *The Arup Journal*[1]. The structure, which is to be built on a site in Euston Road adjacent to St. Pancras Station, will consist of up to seven storeys above ground and will have areas of two, three and four basements. The deepest basements will be about 100 m square and require excavation to roughly 24 m below ground level and 4 m into the Woolwich and Reading Beds. At about the same level, the tunnels of the Northern Line and Victoria Line will pass between the areas of deep basement. Further London Transport and British Rail tunnels run just outside the site boundaries at shallow depth.

In this article, the problems associated with the design and analysis of the deep basements are discussed. The size of these basements is such that their design will involve a substantial extrapolation beyond the experience gained from other previous excavations and it is therefore considered that the best computational methods available should be used in the justification of the design. To this end a special finite element model for London Clay has been developed and will be used in the analysis. In order to subject the theory to criticism from across the civil engineering profession, a paper[2] describing this model has been prepared and submitted for publication. This article contains an abbreviated description of the model itself and the methods used to calibrate it.

Design of the retaining walls

In order to limit ground movements, it is proposed to construct the basements by a scheme similar to that used for the New Palace Yard Underground Car Park[3]. Diaphragm walls will be constructed around the site boundaries and these will be supported by floor slabs. Excavation will proceed by mining beneath successive floor slabs. The slabs will be supported by piles and columns placed before excavation is started.

Generally soil-retaining structures can be designed using the standard Rankine or wedge methods. These, however, assume that the limiting active and/or passive states are attained and give no information on the implied strains and movements. To decide whether such approaches are valid in this case it is worthwhile to consider the sequence of events that will occur in the soil/structure system during and after the construction of the deep basements as follows:

The construction of the diaphragm wall will reduce the magnitude of the horizontal stresses in the clay causing inward movement of the surrounding soil. However, as the wall is constructed in short lengths, the effects will be localized and the overall reduction in pressure will probably not be great.

The bored piling operation will result in inward movement of the clay in each pile shaft. These movements will be associated with overall inward movements of the diaphragm wall and surface settlement within the site.

At the start of excavation there will be equal and opposite pressures acting on each face of the diaphragm wall.

As each floor level is excavated, the pressure due to that storey height of soil is removed. This will cause increased horizontal compression in the soil inside the wall below the excavated level and in the floor slabs already constructed, resulting in inward movement of the wall and a decrease in pressure outside the wall.

While the inward movement of the wall will be sufficient to allow an active state to develop in the fill above, the strains within the London Clay itself will not be sufficient to reduce the stresses to the active pressure values.

Inside the excavation, the progressive removal of soil will cause a reduction in the available passive resistance of the material not yet excavated so that, as the horizontal stresses increase, this material will tend to yield passively.

The movements and changes in stress will be determined by the stress/strain characteristics of the different materials. They will also be time-dependent as discussed below.

On completion of the structure, the horizontal pressure on the outside of the wall will be somewhere between the original pressure (the pressure at rest) and a minimum value which is equivalent to the active pressure.

The reduction in horizontal pressure (total stress) in the soil outside the wall and the corresponding horizontal expansion of the clay causes a reduction in the pore water pressure which can become a suction (negative pore water pressure).

This drop in pressure will cause water to flow into the area from other areas where the water pressure is higher. The rate of flow will depend on the permeability of the clay which is primarily determined by the presence of connecting sand lenses and open fissures. The situation where the change in pressure occurs rapidly compared to the rate at which water can flow in is called the 'undrained' condition.

The increase in water pressure after the structure is complete will cause increased compression and shortening in the basement floor slabs and inward movement of the wall.

The floor slabs shorten elastically as the compression in them increases. In addition, long-term shrinkage and creep will allow further inward movement of the wall to take place.

It is apparent from the above description that the deformation of the soil and structure and the stresses induced in them will be highly indeterminate and will depend on the construction sequence and timing and also on the relative stiffnesses of the different materials.

In order to design the diaphragm walls and to predict the likely movements of the tunnels and surrounding buildings, it is necessary to understand not only the deformation behaviour of the structure, but also of the London Clay and of the underlying strata. A number of approximate Young's Moduli for these are available from various back-analyses of deep excavations in London Clay (Cole and Burland[4] and St. John[5]), and these can be used in finite element and other computations. However, these previous back-analyses have assumed linear elastic soil behaviour and, although a fair degree of agreement with field measurements has been obtained, a number of problems have been noted as follows:

It has been difficult to achieve good predictions of both the movements of diaphragm walls and of points outside the excavation from the same analysis.

In order to obtain satisfactory results, the stiffnesses assumed for the London Clay have to be very much greater than those measured in laboratory tests.

It is apparent that the material inside the diaphragm walls will progressively yield passively as the excavation proceeds and to take account of this requires a non-linear model.

While linear elastic theory is reasonably applicable to the undrained condition when the high bulk modulus of water effectively maintains the soil at constant volume, in the drained case, the change in volume of the clay matrix results in a change of stiffness and this introduces a high degree of material non-linearity. Long-term predictions have therefore in the past been restricted to simple calculations of overall consolidation settlement and heave, etc.

Although the above factors are not of overriding importance, it was thought that they must be considered since analysis for the British Library requires an extrapolation beyond the experience gained from other, but significantly smaller, excavations. The non-linear elastic-plastic model of London Clay (called 'Model LC') has therefore been developed to enable these effects to be quantified and their importance assessed.

Non-linear effects observed in London Clay

It is well known that the results of laboratory stiffness tests are difficult to correlate with stiffnesses back-figured from measurements of full scale structures. Typically the ratio E_u/C_u is found in laboratory triaxial tests to be about 100, but in the field to be between 500 and 1000[6]. Marsland[7,8] has claimed that stiffnesses measured in large (865 mm) diameter plate bearing tests are fairly close to the back-figured values. In Fig. 1 the comparison between triaxial, plate test and large scale results is shown, reproduced from St. John[5].

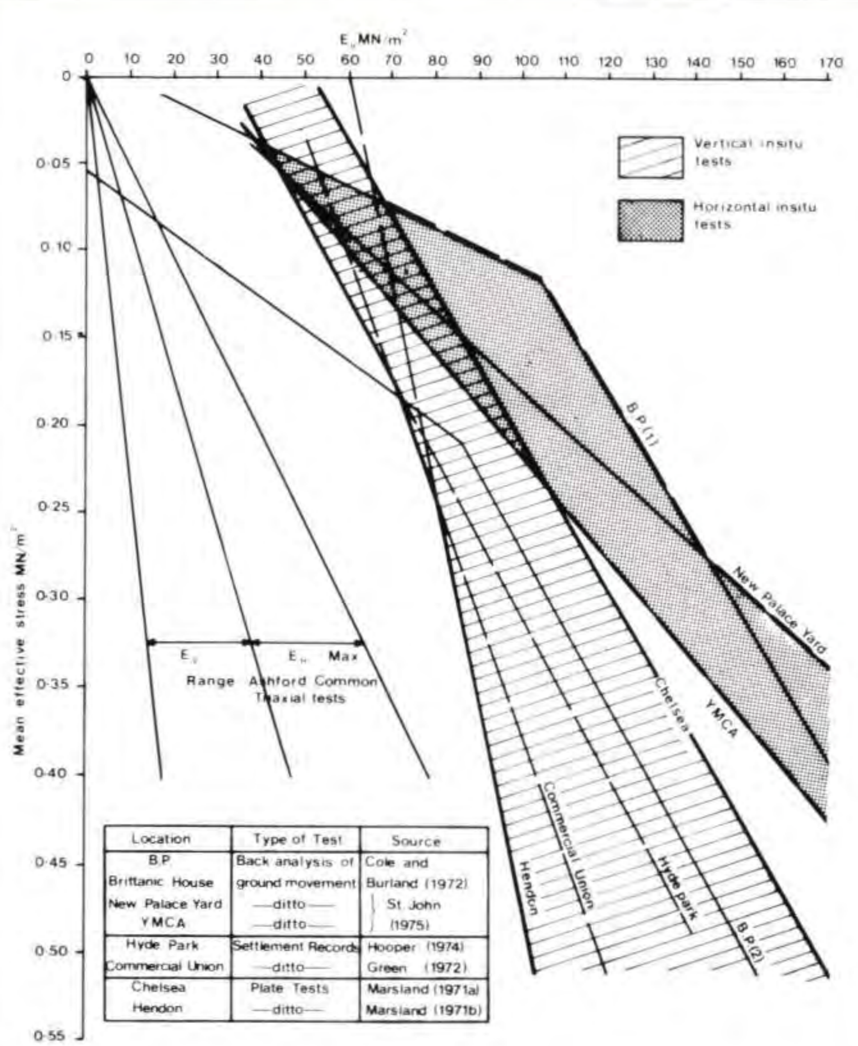
It is commonly stated that the reasons for the much lower stiffnesses measured in the laboratory are sample disturbance (especially the opening of fissures) and bedding of the samples in the test apparatus. However, the results of very careful laboratory work show that remarkably consistent and repeatable results can be obtained. Atkinson[9] prepared triaxial specimens from block samples obtained at the Barbican site. He found that for strains up to about 1% the material behaviour appeared to be anisotropic elastic for a large variety of stress paths. For a given initial stress state, the behaviour was linear up to 1% shear strain.

In contrast to the consistency found by Atkinson, it would be expected that the effects of sample disturbance and bedding would be fairly random. It therefore seems appropriate to investigate other reasons for the consistently low stiffnesses measured in the laboratory.

Many workers, including Lewin[10], Som[11] and Atkinson have reported 'threshold effects' in London Clay and other soils. In some of his oedometer tests, Som held samples at constant stress for many days and then recorded exceptionally high stiffness as the next small increment of strain was applied. Lewin reported a similar high stiffness when the direction of straining was changed. It is therefore useful to compare the magnitudes of strains relating to various loading situations as follows:

The stiffness parameters reported in *laboratory tests* are usually based on a range of shear strain up to about 1%. Atkinson states that his measurements at strains of less than 0.2% are not reliable and therefore quotes Young's Moduli based on tangent moduli at 0.25% strain.

In Fig. 2, the results of 'typical' *plate bearing tests* reported by Marsland are reproduced. An approximate scale for the average shear strains occurring within one diameter beneath the plate has been added to the horizontal axis. At very small strains ($<0.1\%$), the tangent modulus is similar in magnitude to the values found from back-analysis ($Eu/Cu=$



Location	Type of Test	Source
B.P. Brittanic House	Back analysis of ground movement	Cole and Burland (1972)
New Palace Yard	—ditto—	St. John (1975)
YMCA	—ditto—	
Hyde Park	Settlement Records	Hooper (1974)
Commercial Union	—ditto—	Green (1972)
Chelsea	Plate Tests	Marsland (1971a)
Hendon	—ditto—	Marsland (1971b)

Fig. 1
Variation of E (undrained) with mean effective stress; after St. John (1975)

1000). As shear strains increase beyond 0.5%, however, the secant modulus approaches that measured in the laboratory.

The shear strains occurring behind a *retaining wall* are shown in Fig. 3. For a movement of 0.2% of the wall height (an upper bound for retaining walls in firm soil according to Peck[12]), the shear strain in the ground exceeds 0.1% only very locally.

Hence it appears likely that when London Clay is subjected to very small strain increments following a period of rest or a change in the direction of straining, its stiffness is much greater than that at the larger strains normally measured in the laboratory. This change of stiffness as straining proceeds is an important feature of Model LC.

At large strains, beyond about 1% shear strain, London Clay exhibits the characteristics of plastic flow which can be summarized as follows:

The total strain increment is the sum of elastic and plastic strains, and changes of effective stress are related only to the elastic strains.

The relative proportions of the components of a plastic strain increment are dependent on the current stress state and not on the applied stress increment.

The overall magnitude of a plastic strain increment is dependent on both the current stress state and the stress increment.

The principal axes of plastic strain increment are coincident with those of the current stress state and not the applied stress increment.

It has also been demonstrated that the stiffness of most soils increases with the mean effective stress; this feature is included in Model LC.

Description of the model

Model LC relates increments of effective stress to increments of strain, given the current stress state. Attention has been concentrated on plane strain conditions, but, with few restrictions, the model can be used for axi-symmetric work and possibly for plane stress.

Three ranges of strain are considered:

Elastic strains (within the strain 'threshold')

The concept of a higher stiffness at very small strains can conveniently be represented using a 'Kinematic Yield Surface' (KYS) which defines a small zone in strain space such that the higher stiffness applies to an element of soil until its state reaches the KYS. Straining within the KYS is purely elastic, though non-linear (Fig. 4a). As the element is strained further the yield surface moves (hence 'kinematic') and the effective stiffness is reduced (Fig. 4b). If the direction of straining is reversed the higher stiffness again applies (Fig. 4c) until the KYS starts to move again (Fig. 4d). The most appropriate shape for the KYS is not known. A spherical shape has been assumed in strain axes defined by $(\varepsilon_x + \varepsilon_y, \varepsilon_x - \varepsilon_y, \gamma_{xy})$.

It is assumed that the in situ state for London Clay (defined in computations as zero strain) is at the centre of the initial KYS. It is possible that, due to creep effects, the centre of the KYS will move to coincide with a new strain state if that state is maintained for a long period of time. This could model the threshold effects after time lapses, reported by Som.

The work of St. John (Fig. 1) suggests that the ratio of horizontal to vertical stiffness may be similar at very small strains to that found in laboratory tests at larger strains. All the stiffnesses used for the small strain range have been assumed to be proportional to those obtained from laboratory test results (i.e. the stiffnesses during 'intermediate' behaviour).

Intermediate strains (outside the KYS)

The strains during 'intermediate' behaviour represent the range normally measured in laboratory tests. Atkinson[9] reported that London Clay behaved like an anisotropic elastic material in this range of strain, except that strains were not necessarily recoverable. Thus the behaviour has the appearance of elasticity but is to some extent plastic – hence the term 'intermediate'.

The stiffness moduli adopted have been chosen to fit Atkinson's data with the assumption that all intermediate stiffnesses are proportional to $(s + c'\cot\varphi')$ (that is, the mean normal stress in the plane of deformation, with an additional term to take account of cohesion). This assumption ensures that both stiffness and strength are compatible as limiting conditions are reached.

Plastic strains (approaching the limiting shear strength)

It has been found that the curve shown in Fig. 5 can be used as a 'state boundary curve': that is a curve separating attainable stress/strain states from those that cannot be attained. This curve takes the form of the normalized shear stress F plotted against 'total plastic shear strain' γ_p:ie the sum of all incremental plastic shear strains, irrespective of direction. If a flow rule is assumed, it can be shown that this is uniquely related to the plastic volumetric strain v_p. Thus γ_p is a reasonable directionless parameter which with suitable manipulation and choice of origin, can be related to the voids ratio.

A modified form of the Cam-clay flow rule (Schofield and Wroth[13]) has been found to fit Atkinson's data when used in conjunction with the state curve as follows:

$$\frac{\delta v_p}{\delta \gamma_p} = \sin\varphi' \, (F_a - F)$$

where $F = t/(s \sin\varphi' + c'\cos\varphi')$

$$t = \frac{\sigma_1' - \sigma_2'}{2}$$

$$s = \frac{\sigma_1' + \sigma_2'}{2}$$

σ_1' and σ'_2 are the principal effective stresses.

As plastic strain develops the state of an element of soil will progress along the state boundary curve shown in Fig. 5 unless it is unloaded, in which case it will fall below the curve. On reloading it will rejoin the curve at the point where it left it.

Numerical values

The numerical values used in Model LC have been obtained by curve fitting to laboratory and field tests and by back-analysis of instrumented excavations as described below and are as follows:

Elastic range

The kinematic yield surface is a sphere in $(\varepsilon_x + \varepsilon_y, \varepsilon_x - \varepsilon_y, \gamma_{xy})$ space. Its radius $= \varepsilon\alpha = 0.02\%$ (200 microstrain)

The stiffness in this range is 10 times the intermediate stiffness.

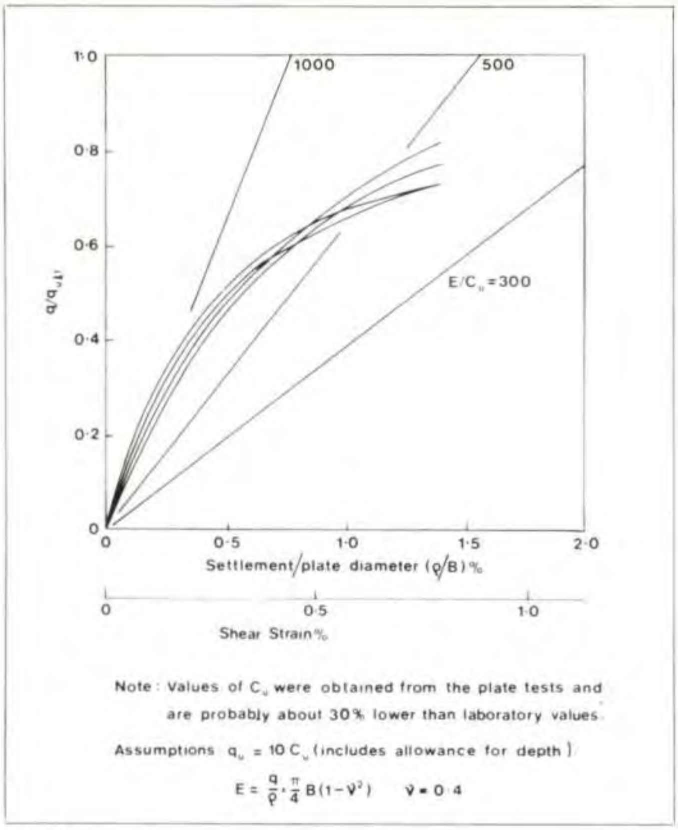


Fig. 2
Results of 865 mm diameter plate-bearing tests on London Clay; after Marsland (1971)

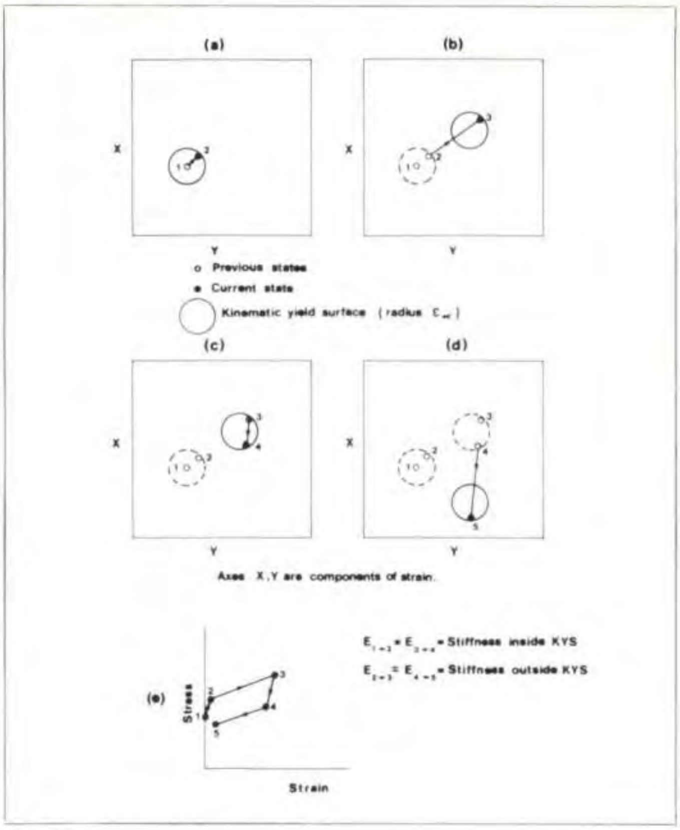


Fig. 4
The kinematic yield surface effect

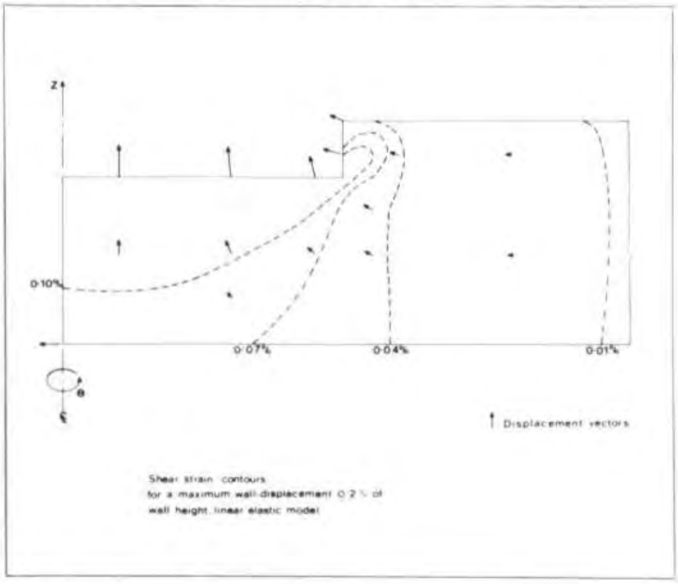


Fig. 3
Strain contours around an excavation

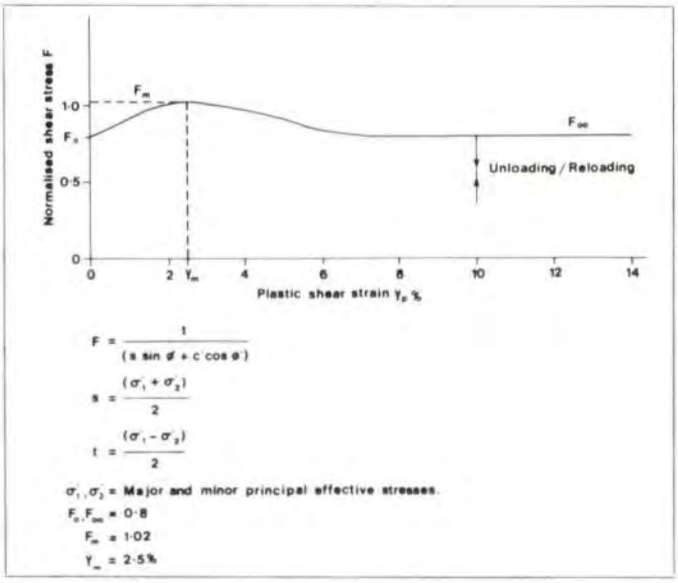


Fig. 5
The state boundary curve

Intermediate range

The parameters of anisotropic elasticity are adopted.

$E'_V = \bar{E}'_V\,(s + c' \cot \varphi') = E'_H / 1.67 = G'_{HV}/0.4$

$\bar{E}'_V = 50$

$\upsilon_{HV} = 0.16, \quad \upsilon_{HH} = 0.2$

$c' = 20$ kN/m²
$\varphi' = 26°$ for British Library London Clay
$c' = 35$ kN/m²
$\varphi' = 22°$ for Atkinson's London Clay

Plastic range

Plastic shear strains (γ_p) are defined by the curve in Fig. 5 (in computations this curve is represented by an exponential equation). There is no plastic straining for states below the curve. Plastic volumetric strains are related to the shear strains by the flow rule stated earlier.

Implementation into the finite element program

The finite element program 'SAFE' developed by Ove Arup and Partners is used for two-dimensional finite element computations under plane stress, plane strain or axisymmetric conditions.

The program is suited to geotechnical problems and to non-linear behaviour in particular. Pore pressures and effective stresses are identified separately, and gravitational loads and initial stresses may be specified. Non-linear problems are dealt with by the 'initial stress' technique, which may be used incrementally or otherwise, and a facility is also available for changing material types in order to simulate excavations or embankments incrementally. The implementation of Model LC in the SAFE system is conveniently described in terms of its incremental behaviour in the elastic/intermediate state and the plastic stage.

Fully drained behaviour can be modelled by holding pore pressure constant. The undrained state, i.e. when there is no macroscopic flow of water relative to the soil skeleton, is more complicated. In this condition there are large changes of pore pressure, and changes in volume are governed by the compressibility of the pore water. The bulk modulus of the water is therefore included in the finite element formulation. This can lead to unreasonable fluctuations in the computed pore pressures but a technique has been developed in the SAFE program to overcome this. The result is a set of computed pore pressures which is smoothly distributed and also conforms to overall equilibrium. Mean volumetric strain in each element is very small but significant volumetric strains may occur locally within each element, particularly in areas of high stress gradient.

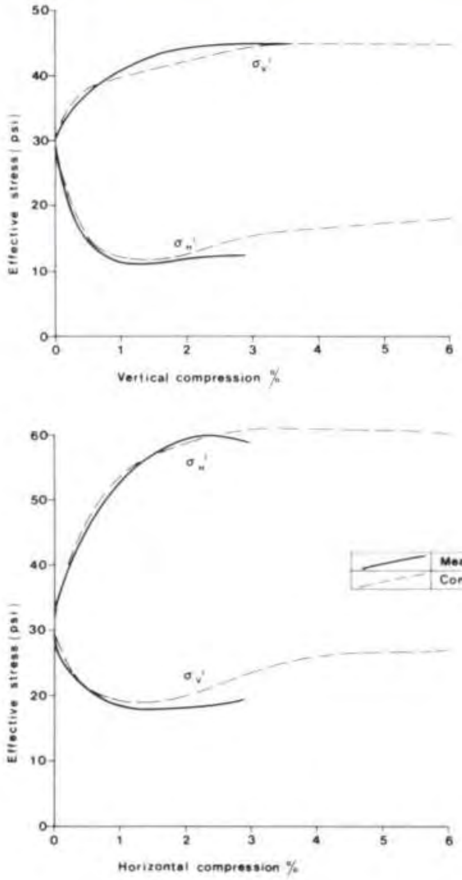
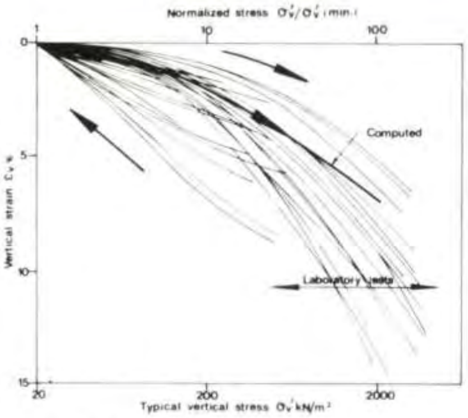
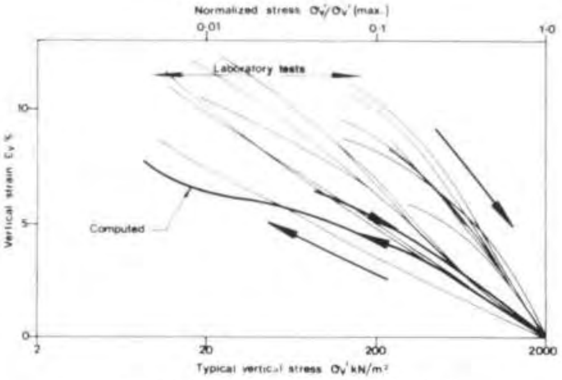


Fig. 6
Plane strain tests



(a) SWELLING FOLLOWED BY CONSOLIDATION.



(b) CONSOLIDATION FOLLOWED BY SWELLING.

Fig. 8
Oedometer tests

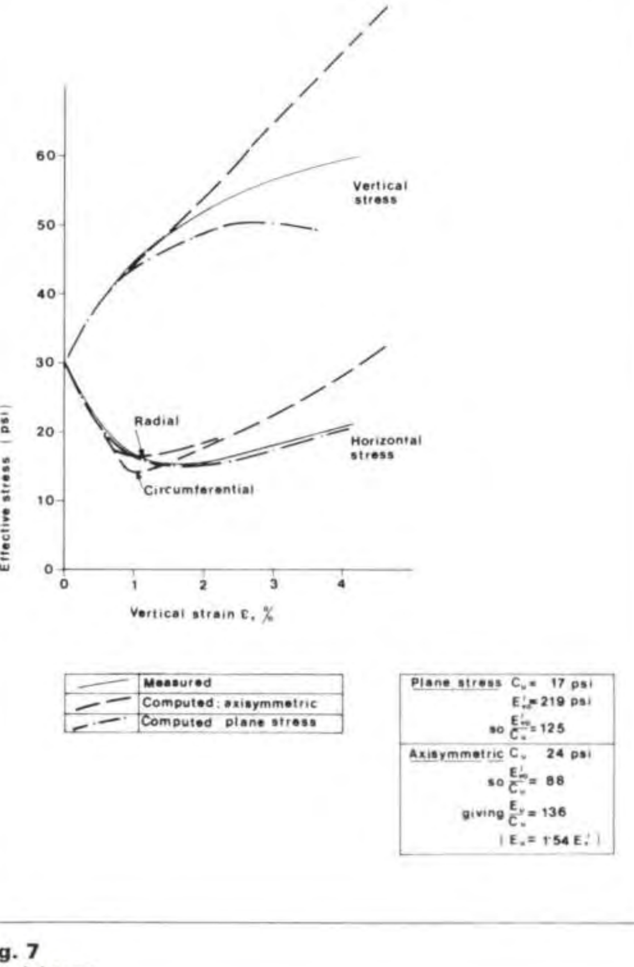


Fig. 7
Triaxial tests

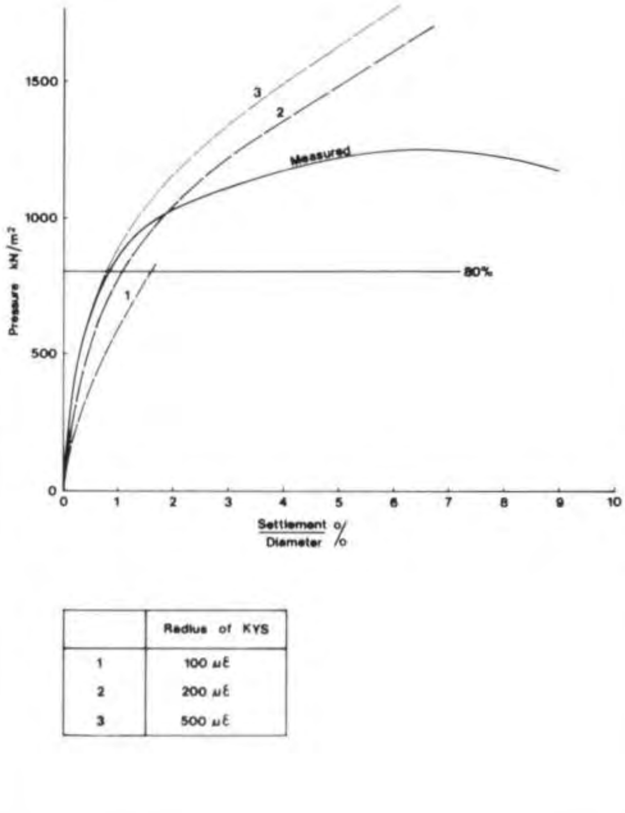


Fig. 9
Plate bearing tests

Comparison with laboratory and field tests

Predictions of the model have been compared with the results of plane strain and triaxial undrained tests carried out by Atkinson. In Fig. 6 the computed predictions for two undrained plane strain tests are compared with Atkinson's results, and a good correlation is achieved in each case.

The triaxial test is much more difficult to model. Two approaches have been tried and the results are shown in Fig. 7. If plane stress is assumed, the results agree fairly well with Atkinson's measurements. The failure stress is lower and occurs at smaller strain than that measured, possibly because there is less restriction in the third principal direction than occurs in the laboratory test. A single finite element was also tested in axisymmetric conditions. Up to about 2% vertical strain the computations agreed well with measurements. However, no failure was predicted and the shear stress increases slowly. This occurs because the model is not designed to cope with situations of significant strain in the circumferential direction.

In Fig. 8 the results of a large number of oedometer tests have been plotted to a normalized scale. The results are taken from the British Library site investigation and predictions from Model LC have been superimposed onto these plots. In studying these results it is necessary to compare the gradients of the curves in the various ranges of stress. On this basis it can be seen that the computed and measured results agree fairly well in the stress range of major interest, 100 to 400 kN/m^2. In general, the stiffness of the model is greater than that of the soil being tested.

The results of the comparison with the plate-bearing tests reported by Marsland are shown in Fig. 9. The measured load/displacement curve is compared with predictions made using three different values for the radius of the kinematic yield surface (ε_α). The computed load/deflection curve is close to that measured at stresses up to about 80% of failure stress. Rather better results could be achieved using a higher value of $\varepsilon_\alpha = 500\ \mu\varepsilon$, rather than 200 $\mu\varepsilon$.

Comparison with measured heave below a deep basement

May[14] published measurements of the heave of a basement built over a deep layer of London Clay. The net unloading after excavation and construction was about 175 kN/m^2. Unfortunately measurements were not started until the end of construction and a complicated extrapolation is therefore needed to estimate the total heave which has taken place. The more recent readings suggest that about 130 mm of heave has occurred in 10 years and that there is no indication that the movement is approaching a limit.

A simple program using Model LC was written to provide a prediction for this problem. The final heave was computed to be 228 mm, assuming that the pore water pressure will eventually return to its original value. However, the predictions are extremely sensitive to the pore water pressure distribution, particularly in the upper layers and this value reduces to 180 mm even if only a small reduction in water pressure is assumed.

It would seem that in this case the model will give a reasonable prediction, although possibly somewhat on the high side. This may be contrasted with the tendency to predict too little deformation in the laboratory tests.

Back-analyses of excavations in London Clay

The excavation for the car park at New Palace Yard has been back-analyzed as part of the calibration procedure for Model LC. Burland and Hancock[3] describe the site, together with the design, construction method and monitoring of the New Palace Yard excavation. Figs. 10 and 11 are reproduced from their paper and show a plan and section of the work. St. John[5] provides further information on the excavation process and its effect on the ground.

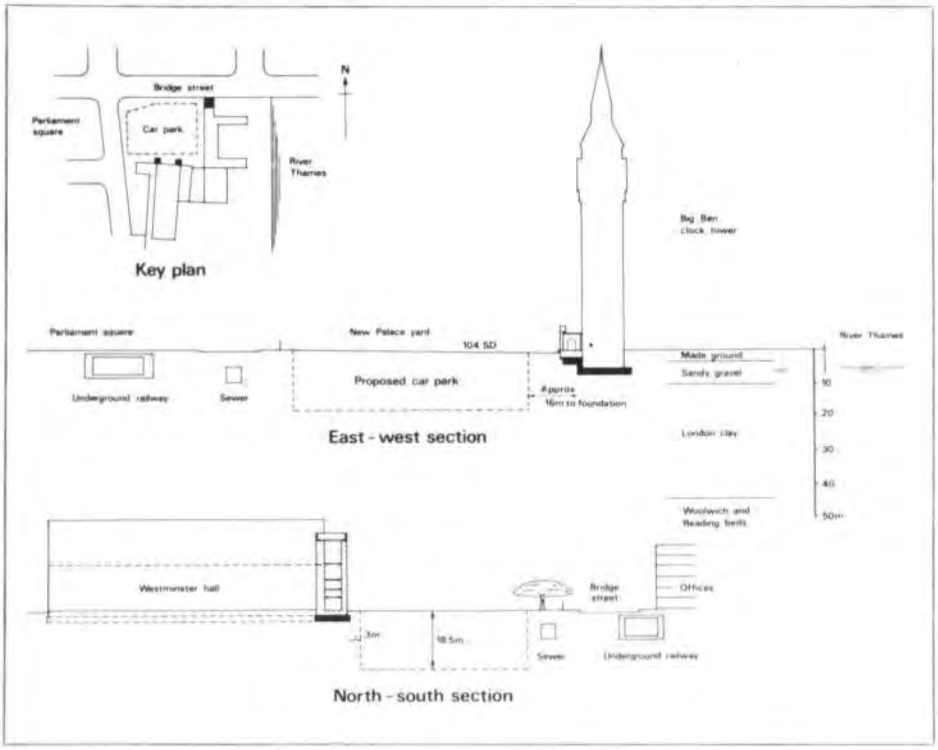
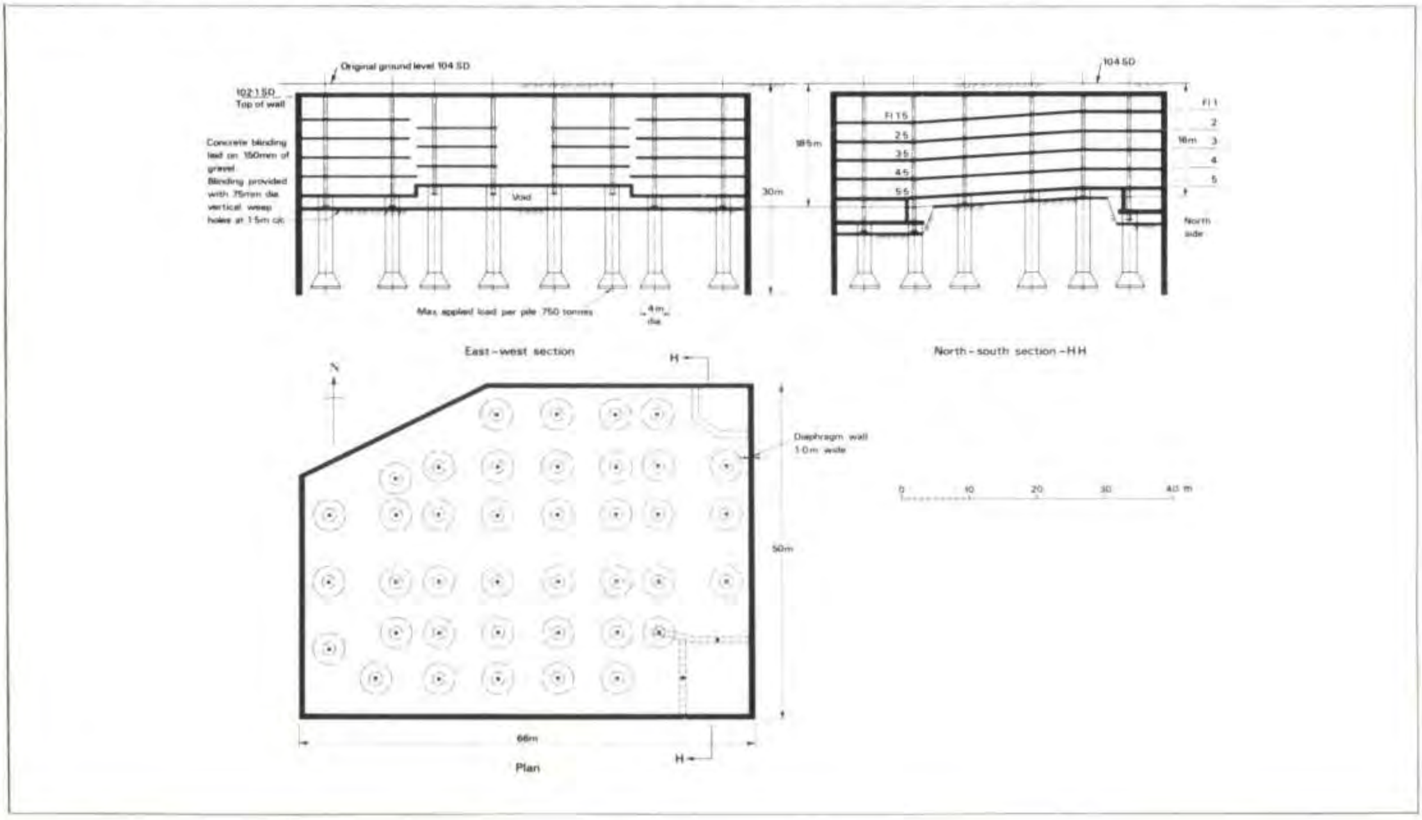


Fig. 10
New Palace Yard: general layout

Fig. 11 (below)
New Palace Yard: plan and sections



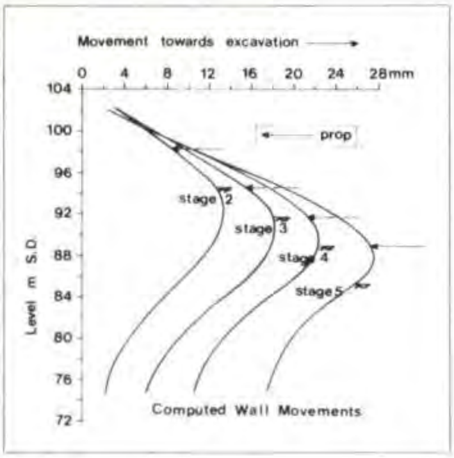


Fig. 12
New Palace Yard:
south wall movements computed

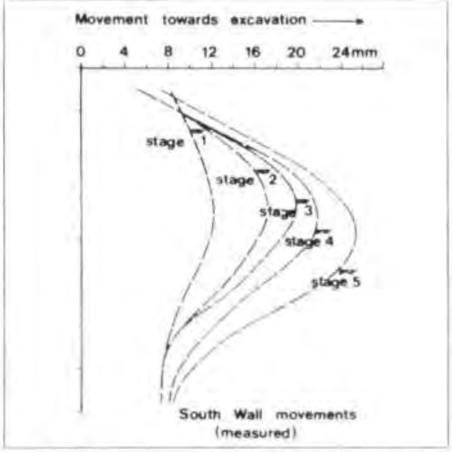


Fig. 13
New Palace Yard:
south wall movements measured

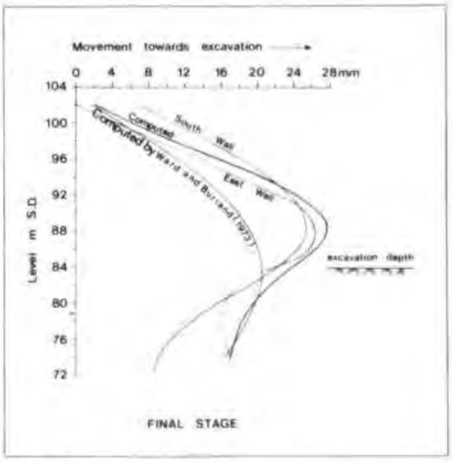


Fig. 14
New Palace Yard:
final movements computed and measured

Figs. 12-15 show the comparisons between the measured and computed values for the deflections of the diaphragm walls and the pore pressures. These results are discussed in detail in Reference 2. The paper also contains a comparison of the site measurements at Neasden Underpass as described by Sills *et al*[15] with the results of back-analyses. While the New Palace Yard excavation is best modelled by an axisymmetric analysis, Neasden in contrast is nearer to the plane strain case. Model LC gives good correlation in both cases.

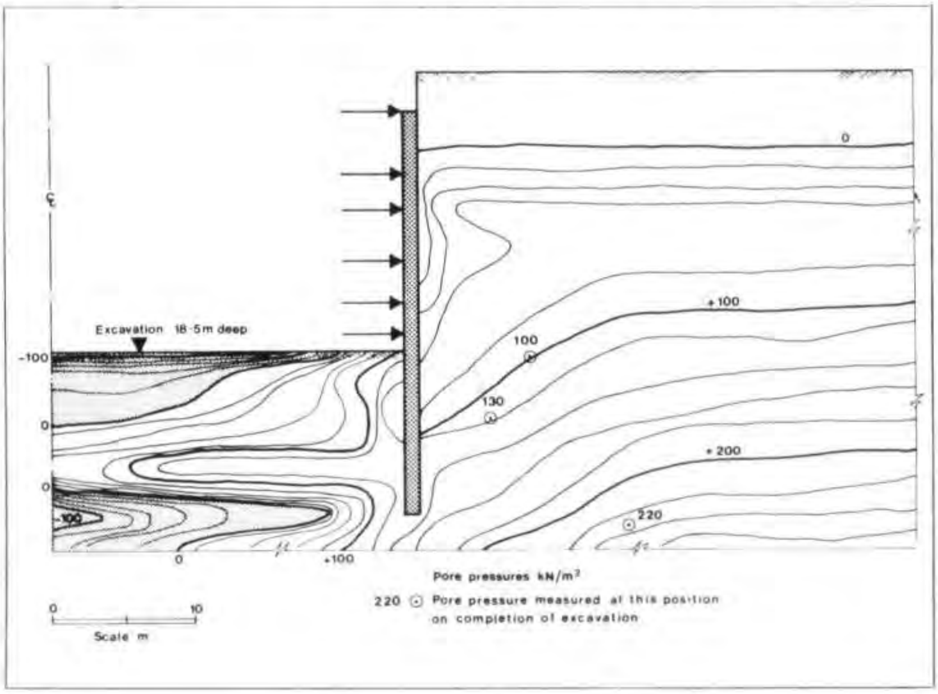


Fig. 15
New Palace Yard:
pore pressures computed and measured

Conclusions

The geotechnical problems associated with the design and analysis of the basement retaining walls have been described. A non-linear elastic-plastic model for London Clay, which has been developed, is described and the results of predictions made using this model have been compared with measured values obtained from laboratory and field tests and from instrumented excavations.

Model LC is currently being used in the analyses of the deep basement construction of the British Library. At the time of writing this article the base analysis has been completed and work is continuing on the various parametric studies that are required in order to assess the sensitivity of the results to the values of the input data. When these have been completed then appropriate values for the final design of the diaphragm walls will be available. It is intended that future articles will describe this analysis and will contain predicted values for deformations that will be compared with the values measured during construction.

Credits

Client:
The Department of the Environment
Architect:
Colin St. John Wilson and Partners
Services Engineer:
Steensen, Varming, Mulcahy and Partners
Quantity Surveyor:
Davis, Belfield and Everest

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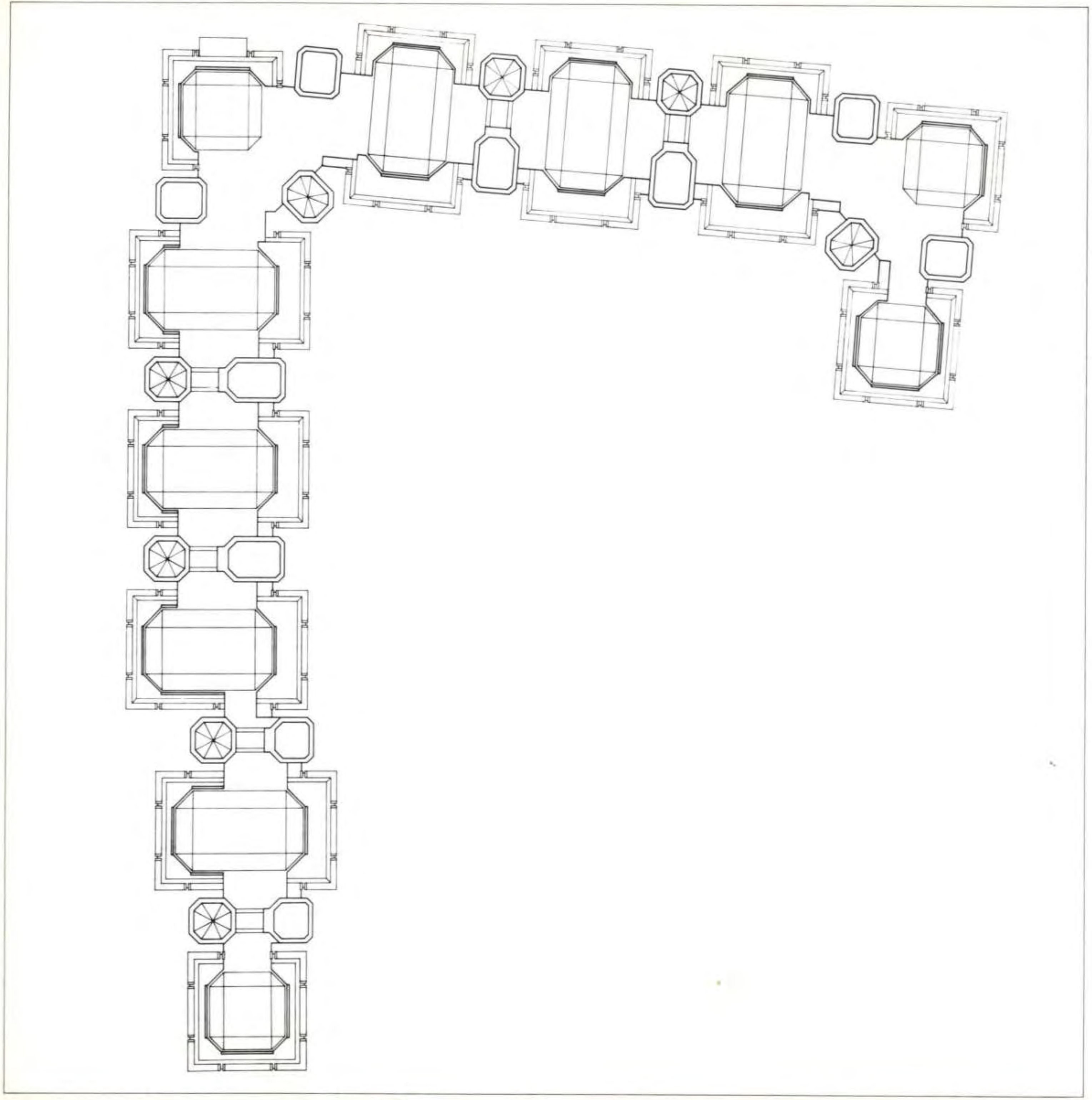

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