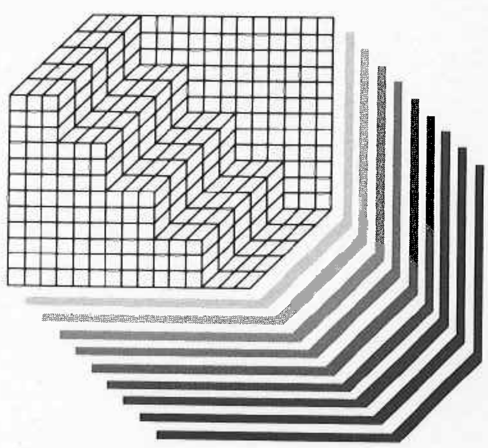
Patterns 7



Patterns 7

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Contents

The ability to both apply and develop a body of knowledge is central to successful consulting engineering. In the struggle to understand more about the prediction of behaviour and the management of design, construction and maintenance, the key to good decision making lies in studying the past. Understanding behaviour comes from examining what happened – which is why carrying out refurbishment, maintenance or management is so rewarding.

As a firm we have not done badly in this field. It started with St Katharine's Dock, some twenty years ago. More recently, we have been strongly represented in the writing of the 'code' for Structural Appraisal, have acted as technical advisers on the Popplewell and Taylor Inquiries, and have taken a major role in organising conferences. And as the world wants to preserve much of the old, for economic as well as emotional reasons, yet also requires their upgrading, these skills we have developed are increasingly needed.

This issue of Patterns shows some recent examples of such work. They are a product of much self-education as well as fee-earning work.

Ted Happold

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Print The Midway Press

A Case Study in Appraisal and Reuse

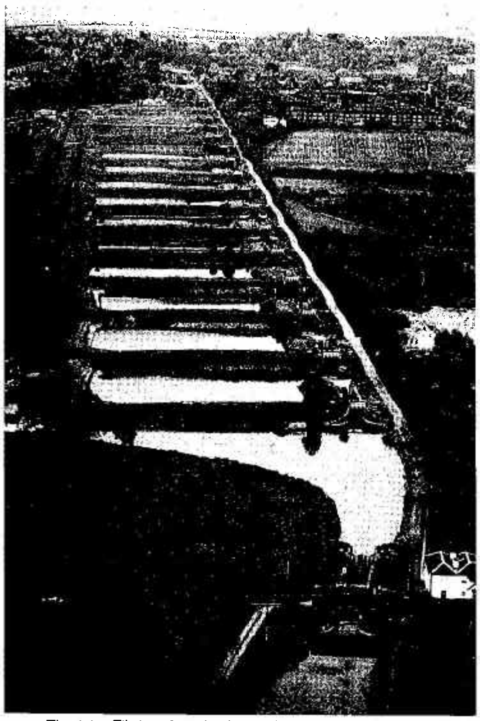


Fig 1.1 Flight of 29 locks on Kennet and Avon Canal at Caen Hill, Devizes

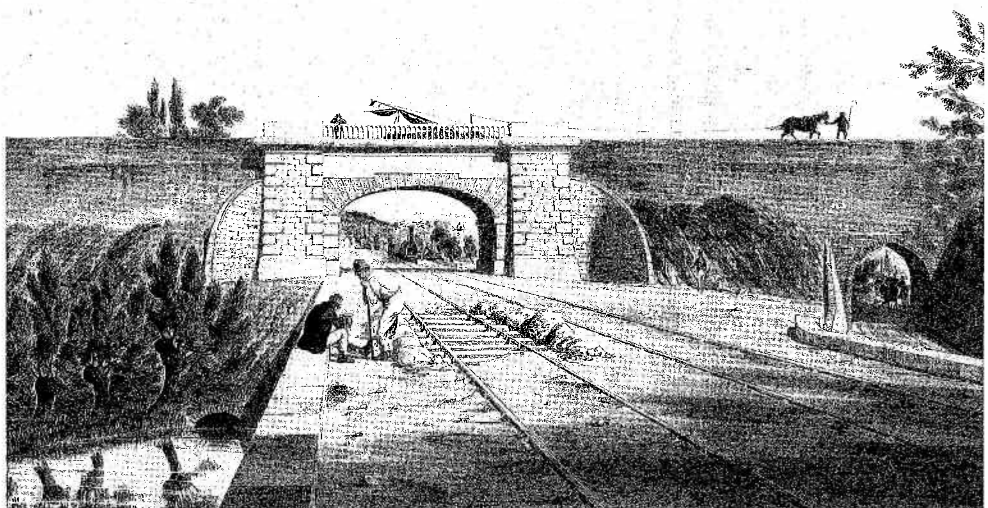


Fig 1.2 Relative locations of road, railway and river at Cromford Canal, Derbyshire

On 8 August 1990, Her Majesty The Queen reopened the Caen Hill, Devizes flight of 29 locks on the Kennet and Avon Canal so restoring navigation between Bath and Newbury on a waterway which had lain dormant for nearly forty years. (Fig 1.1) Great credit must go to those groups and individuals whose time and energies have been expended in such a restoration, one which highlights the great interest that is taken in our inland waterways. The number of schemes in which the waterside environment is an all-important feature grows. Developments at Gloucester Docks, Albert Dock in Liverpool, Swansea Marina, and Castlefield Basin in Manchester to name but a few, have all received critical acclaim. The success of these projects no doubt lies in the appreciation engendered in the restoration of buildings from our industrial past, and in the attraction of living by water. However, the engineer faces possibly greater difficulties in the restoration and rehabilitation of the fabric of the canal or dock wall itself.

Decline of the canal

In the consideration of the re-exploitation of the UK canal system we must be aware of the financial constraints that were placed on the original canal engineers, and the economies that they were required to make. The Caen Hill flight is itself a prime example – a high summit level requires constant pumping to maintain water supply where John Rennie had originally proposed a lower summit tunnel. He was no doubt aware of Pierre Riquet's observation in 1662: 'that machinery for lifting the water were things to be avoided'.

Another telling factor is the manner in which the canals declined with the advent of the railways. Once again, the Kennet and Avon Canal proves a good example. Completed in 1810 it was eclipsed in 1841 with the completion of Brunel's Great Western Railway which purchased the navigation in 1852. (Fig 1.2) Although the new owners attempted to operate the canal as a financially viable entity, the scheme made losses from 1877. Its decline in trade may have been a lingering one further complicated by the subsequent inheritance of the canal by the Railway Executive (1948), the Docks and Inland Waterways Executive (1949), British Transport Waterways (1955) and British Waterways Board (1963).

With frequently changing ownership it was inevitable that maintenance was carried out in a piecemeal fashion, a problem common to many waterways. If a small section of wall collapsed within a larger length, a repair would be carried out and all would be well – a trial and error maintenance operation, minimising the amount of work to be done at any one time, but requiring a continuous maintenance operation. (Fig 1.3) This should not suggest that our forefathers were inadequate engineers, rather that financial and political constraints were as telling then as they are now.

Engineering reassessment

Let us then consider the situation which may arise when a developer takes over the responsibility for cleaning and repairing a canalside environment, and the problems that this presents to the consulting engineer. In some cases there may be a desire to retain the existing appearance of the wall which may be a listed structure, and any works should have minimal impact on the adjacent environment.

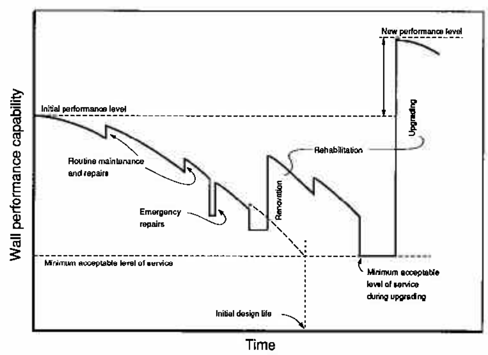


Fig 1.3 Concepts of canal maintenance and rehabilitation

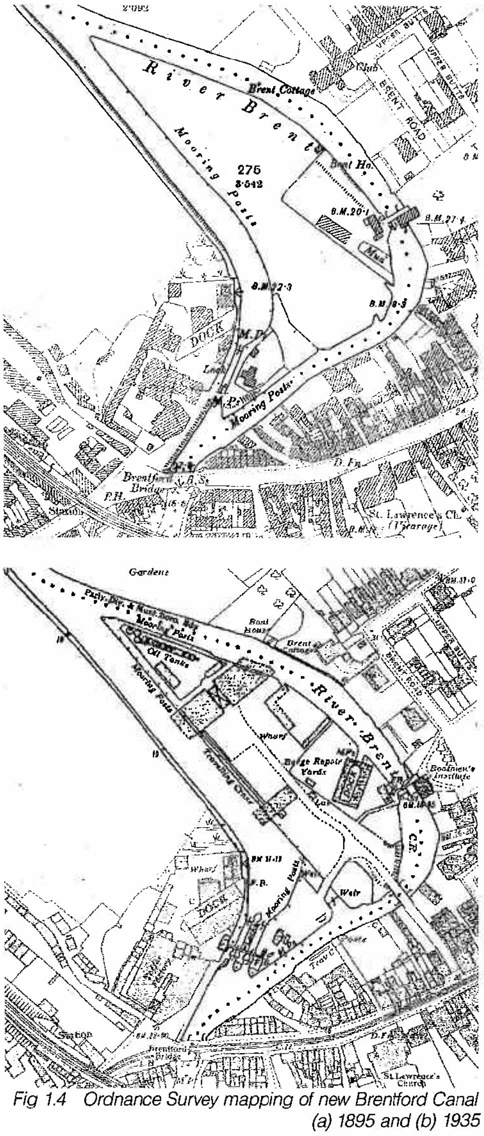


Fig 1.4 Ordnance Survey mapping of new Brentford Canal (a) 1895 and (b) 1935

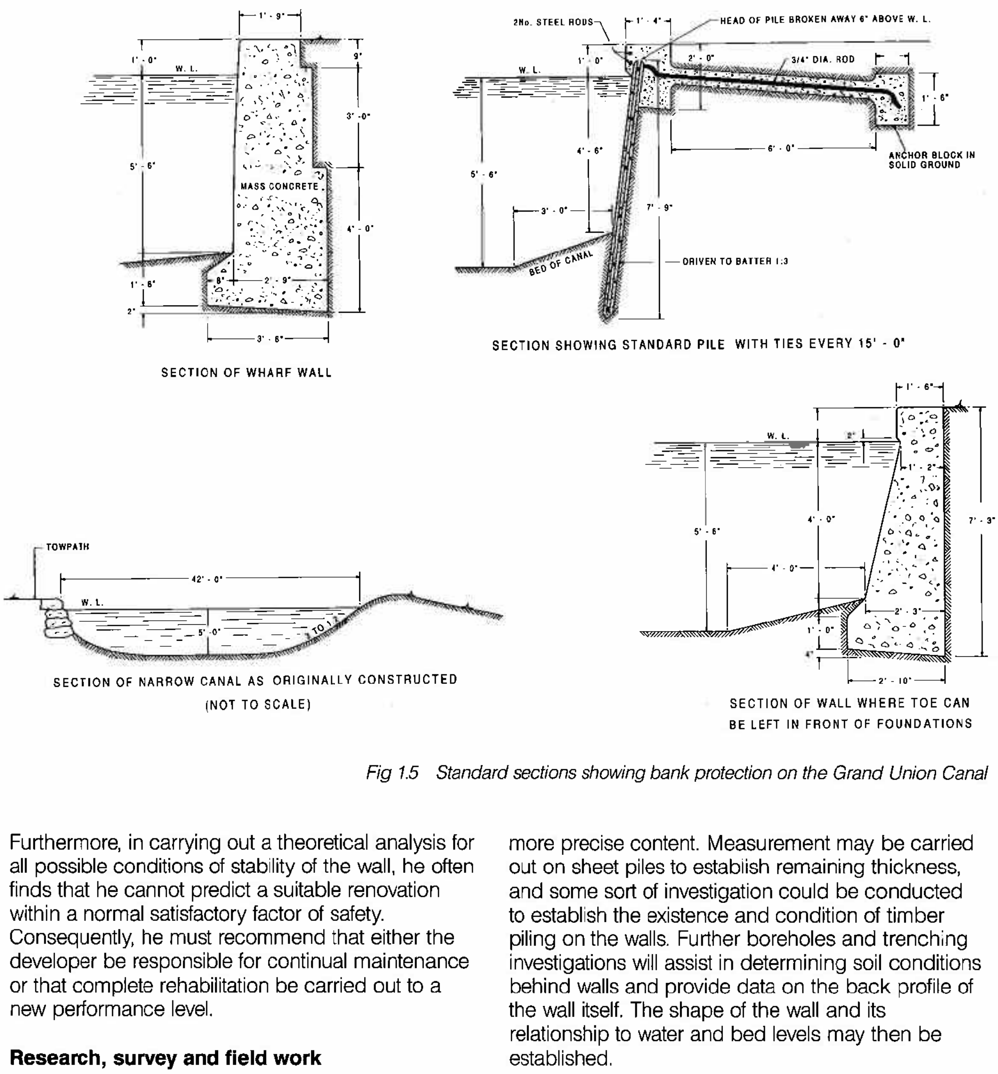


Fig 1.5 Standard sections showing bank protection on the Grand Union Canal

Restoration to the original state will be the prime objective, with further consideration necessary to upgrade the structure to the new requirements of surcharge loading.

When the consulting engineer comes to consider the renovation of an old water front he is likely to encounter several difficulties resulting from the historical decline of the waterways. Little or no record of previous work will exist and long stretches of wall subject to past maintenance and repair may be a patchwork of stone, brickwork and concrete, counterforts, tie-rods, timbers and sheetpiles.

Furthermore, in carrying out a theoretical analysis for all possible conditions of stability of the wall, he often finds that he cannot predict a suitable renovation within a normal satisfactory factor of safety. Consequently, he must recommend that either the developer be responsible for continual maintenance or that complete rehabilitation be carried out to a new performance level.

Research, survey and field work

As with all redevelopment work, the value of historical research of the canal network should not be underestimated and at the very least, reference to Ordnance Survey will provide a concise picture of development over the past 100 years. (Fig 1.4) Considerable care needs to be taken in using archive material, which may show scheme proposals rather than final design. Fieldwork and site surveys are therefore essential parallel investigations, before repair commences.

The consulting engineer will normally require investigation of both canal walls and bed by means of topographic, bathymetric and diving surveys with visual inspection perhaps using closed circuit television. Drilling through the walls may help to establish their integrity, while coring can indicate a more precise content. Measurement may be carried out on sheet piles to establish remaining thickness, and some sort of investigation could be conducted to establish the existence and condition of timber piling on the walls. Further boreholes and trenching investigations will assist in determining soil conditions behind walls and provide data on the back profile of the wall itself. The shape of the wall and its relationship to water and bed levels may then be established.

Reinstatement of stability

The detailed analysis of the condition of the wall and its capacity to accommodate existing loads and future surcharges is not considered here. However, one of the simplest and most direct methods of restoring the walls' stability is to replace materials which have been removed from the toe. This can be achieved in a variety of ways using gabions, bagged concrete and possibly free tipping of spoil – methods which will certainly enhance the factors of safety on slip and overturning. (Fig 1.5)

If this solution is to be adopted the most valuable factor to establish first is the depth of water necessary in the canal or dock. A 5m deep dock for large, sea-going vessels need not necessarily be of

Fig 1.6 Bed of drained Kennet and Avon canal

this depth for reuse as a marina. Canals are sometimes designed solely for travel with little requirement for mooring along the banks. A nominal edge depth of 300–600mm would then suffice, but this would have to be increased to about 1m if mooring was to be allowed.

Hidden dangers

In complete contrast, over-zealous removal of silt can also generate problems, and the canal should only be drained to perform such an operation if it has been ascertained that wall failure will not occur. (Fig 1.6) The canal bed profile must have also been considered and care must be taken not to perforate the puddle clay lining of the bed.

Further problems may arise with the serious risk of contamination in the silt on the bottom of the canal, and disease may be carried by flies or transmitted by rats, the latter being the carrier of Weil's disease. Unfortunately with so many unrecorded sewers discharging into canals, BWB have a difficult task of controlling and eradicating these problems. Guidance at the moment consists of advice when working alongside canals, in particular avoiding open cuts coming into contact with the water. Although water in the canal may not be contaminated itself, contaminants may lie in the silt on the bed. During maintenance these contaminants will probably be stirred up, polluting the water. Studies of the silt are therefore necessary and the choice of appropriate methods of dredging, draining and disposal to appropriate contaminant tips is important.

A new lease of life

Of the problems facing the engineer in the redevelopment of inland waterways only a few have been discussed. Difficulties of historical research and site survey, reassessment and reinstatement of engineering stability and the overcoming of unfore-seen circumstances presented by previous work-manship and pollution by contaminants have, however, not deterred development in this sector. (Fig 1.7)

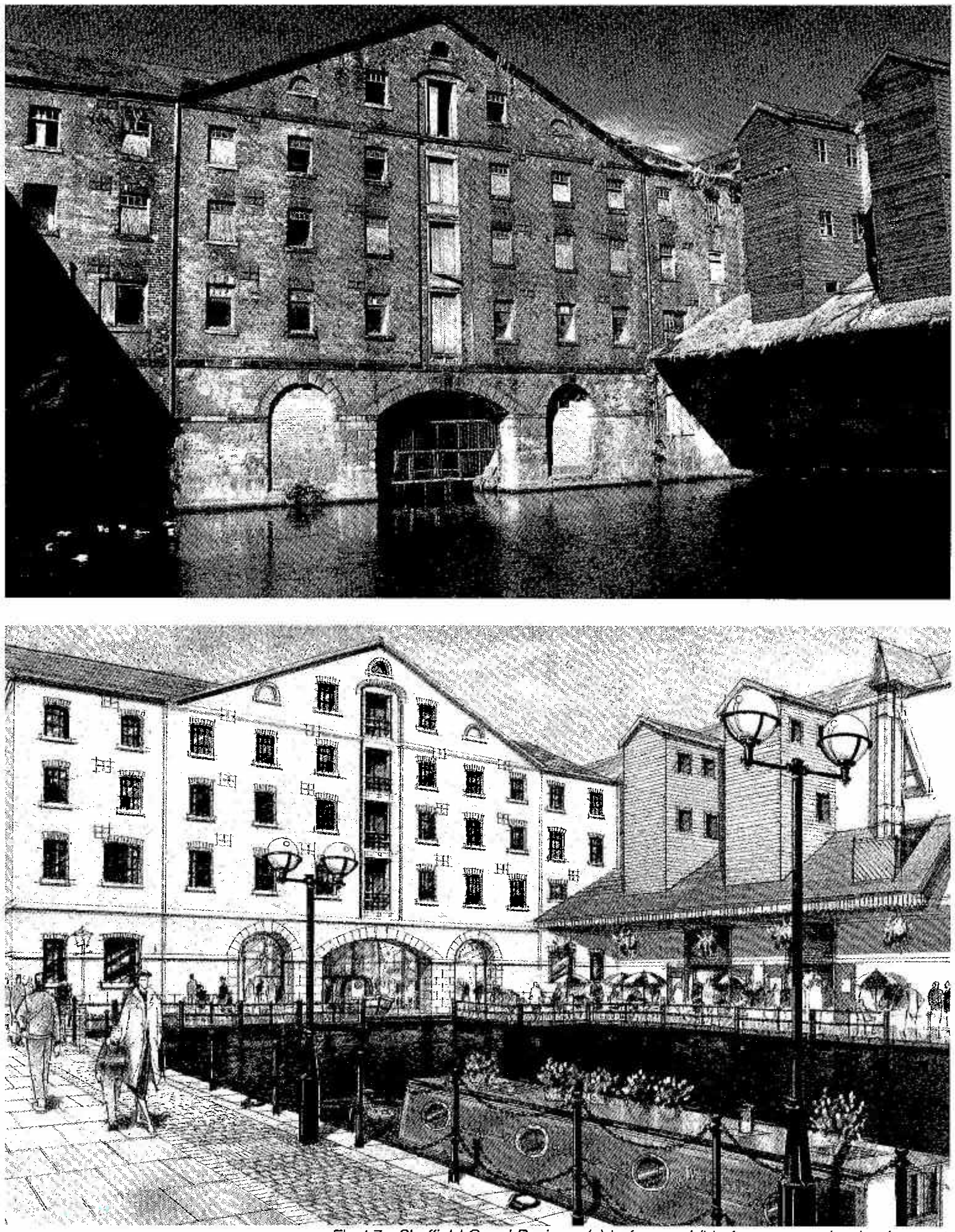


Fig 1.7 Sheffield Canal Basin – (a) before and (b) after proposed redevelopment

Canals and docklands will continue to offer the developer commercial opportunities, and provide further challenge to the engineer in the now wide field of reassessment, repair, refurbishment, redevelopment and reuse of existing structures.

Such problems recur across the entire spectrum of engineering reappraisal, and are considered in further detail in the subsequent articles of this journal.

Ted Happold and John Froud

New Headquarters for Imagination, Staffordshire House, London

Project data

Client	Imagination Ltd
Architect	Herron Associates
Structural Engineer	Buro Happold
Fire & Services Engineer	Buro Happold/EEC
Quantity Surveyor	Boyden
Main Contractor	R M Douglas
Project Value	£5.5m
Size	6,000m²
Completion Date	August 1989

An award-winning renovation design has transformed the original Edwardian building chosen to be the new West End headquarters of the design and communications specialists, Imagination – a company which exists to create ideas and make them happen. In the words of British Construction Industry Award judges, the building 'epitomises the excellence in design, construction and fitness for purpose which can be achieved in a refurbishment project'.

The transformed building, comprising two parallel blocks, linked together with multi-level walkways through a central H-shaped atrium, (Fig 2.1) has attracted critical acclaim from both the lay public and designers, winning several other awards. Covered by a highly innovative, prestressed fabric roof, a 'piece de resistance' tailored to suit the complicated geometry of the old buildings, the new 6000m² Staffordshire House building could now be said to mirror the ideals of the client.

The existing building, a rather drab, Edwardian Ministry property, presented an imposing five storey brick facade in a slight crescent off Store Street. (Fig 2.2) Six to eight metres behind, and linked by a brick-built toilet block, stood a second four storey block, reconstructed after the Second World War. The unused and extremely bleak brick faced gap between the buildings absorbed most of the light penetrating the space. (Fig 2.3)

Ron Herron of architects Herron Associates, put forward proposals to transform the building, including demolition of the connecting link between the blocks and replacement with skeletal metal bridges. (Fig 2.4) This would emphasise the narrow gap which he tentatively suggested could be covered with translucent fabric wrapped down the ends to create a unified atrium space. Following the construction of ground floor and partial first floor slabs within the atrium, the basements of the two buildings could be combined to create a very large floor area for many of the client's technical functions, including some recording studios and video production units. With alterations to the drab interior, an eighty year old building could then adequately provide the flexible, open plan space required by a high tech company, for whom image is of prime importance. The client was most enthusiastic, and Buro Happold was appointed structural, fire and services engineers for the project.

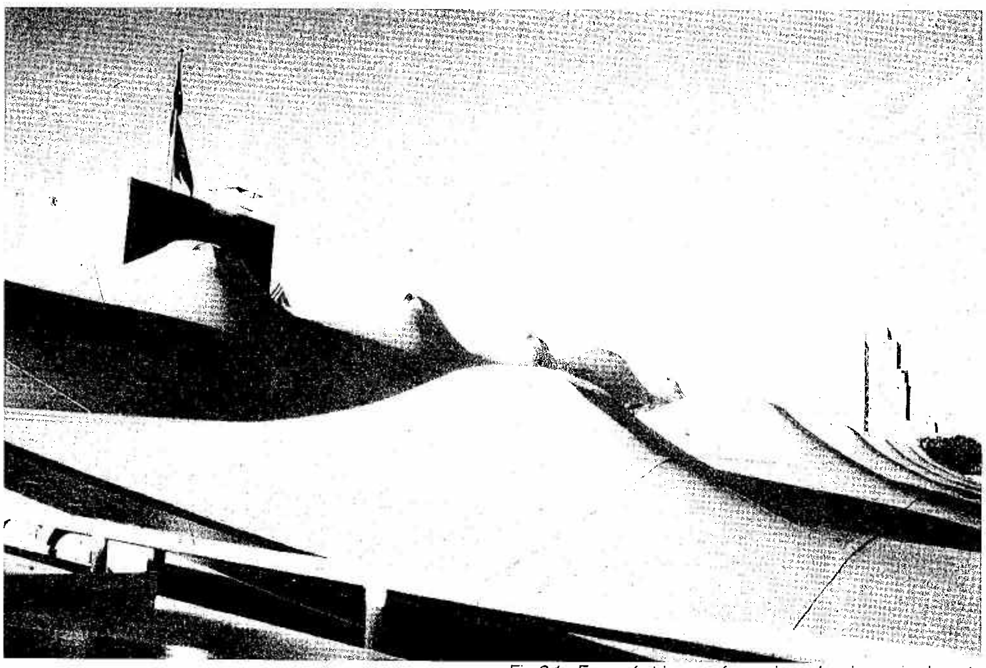


Fig 2.1 Form of atrium roof covering, showing paired masts

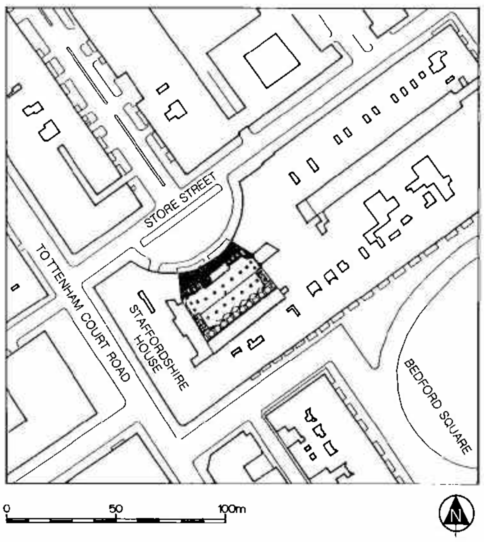


Fig 2.2 Location of Staffordshire House in Store Street, London

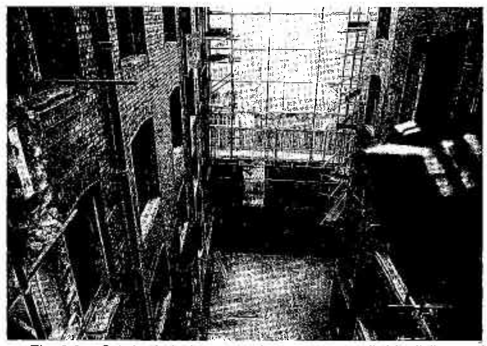


Fig 2.3 Original drab space between parallel buildings of Staffordshire House

Renovation and alteration

Survey showed the front building slabs as filler joist floors with steel beams, cast into a clinker based concrete at between 600m and 1000m centres, with floor spanning between outside brick walls and an internal dividing 'spine' wall. The rear building, of more recent construction, comprises a concrete encased steel frame with hollow pot floor slabs (reinforced concrete with cast-in hollow pots). These floors were opened up by the demolition of non-load bearing partition walls without significant disturbance to the existing structures.

All the new-build work at the basement level was of simple construction. To avoid problems associated with differential settlement, the atrium floors are

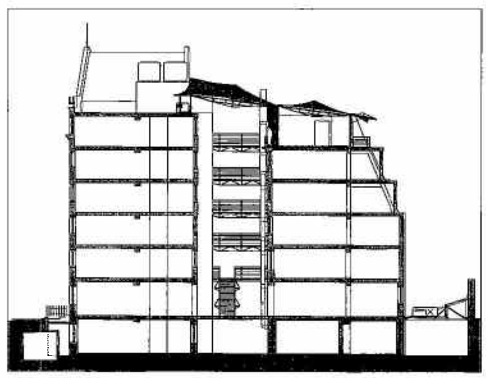


Fig 2.4 Section through development showing atrium between parallel multi-storey buildings

supported on new steel columns taken down to pad footings on London Clay, to ensure that the new floors move independently from the existing building. (Fig 2.5) New slabs were cast in-situ onto metal decking spanning between rolled steel beams at approximately 3m centres. By opting for steel, metal deck and in-situ floors, all components were of a size which could be carried through the existing building with little difficulty, and the additional dead weight on the adjacent ground or existing walls was kept to a minimum.

The central toilet block was also demolished to completely open up the dividing space, creating an atrium form. The two buildings were later linked by light weight steel bridges. The demolished central toilet block was replaced with a services core built adjacent to the existing stair tower in the front building. New bearing beams were cast over existing door openings in the wall to carry the new link bridges across the atrium. Additional brick work was also used to ensure the adjacent walls could take the loads from the bridges down to ground.

A large number of additional trimming beams and lintels were required around holes cut in the existing slabs and walls to take a new escape stair and riser ducts. These were built either as in situ RC beams or using prefabricated steel joists, the choice depending on the span required, complexity of the geometry and available depth for the beam. Load testing of the existing structure was carried out in some areas where special loads were to be applied.

Early on in the works a crack was found in the spine wall of the front building in an area where it had been intended to provide door openings to enlarge the existing rooms. The crack was monitored with tell tales and, as no movement was indicated, it was felt that this may have been the result of foundation

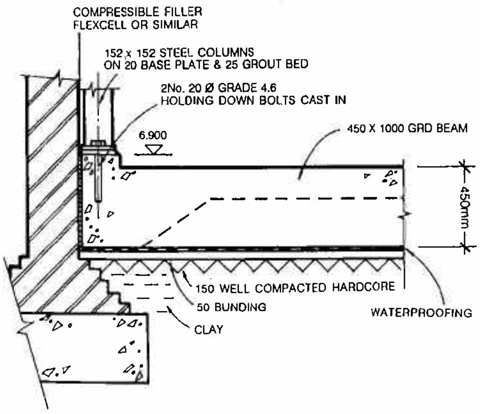


Fig 2.5 New steel columns forming pad footings of atrium

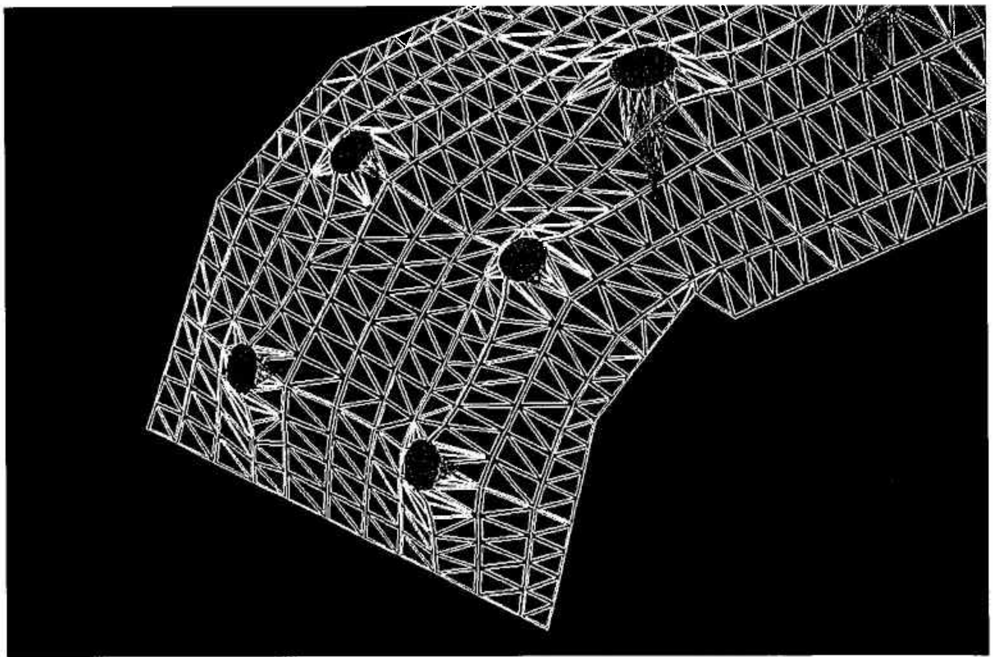


Fig 2.6 Computer derived graphic in analysis of roof form

settlement, probably occurring much earlier in the history of the building. Any concentration of load due to an increased size of opening in the walls above, may overload the foundation locally and therefore require underpinning. For this reason the spine wall was not altered in this area and the crack was stitched together with in-situ concrete ties. Recent checks show no further cracking of the plaster.

To the rear, a narrow courtyard was also roofed over to make space for additional functional rooms and a gymnasium. The new roof to the rear courtyard made use of pre-fabricated steel rafters and purlins, with a profiled metal sheet deck.

Choice of atrium roof

Initially a glazed roof was considered to enclose the inner courtyard between the two buildings. However, not only was this an expensive solution requiring a substantial support structure, but the complicated geometry of the opening would have led to a very irregular structural layout. Use of a stressed fabric structure gave greater freedom to cover the space with the minimum of support structure necessary to accommodate the complicated geometry. Such a roof has a very low self-weight, the fabric weight of 1kg/m² being only 5% that of glass. Typically such fabrics let in between 10 and 15% of visible light, sufficient to give a surprisingly strong light inside the atrium but also reflecting to the outside sufficiently to avoid excessive heat gain.

The scheme which was developed provided a roof across the inner courtyard which continued over the roof slab of the rear building. This created a gallery space on the roof, thereby providing a useful and economical additional floor area. It was also planned to continue the roof down both ends of the newly created atrium to give an impression of a fabric wrapping to the building 'Christo-Style'.

Roof structure and detailing

Even with reasonable double curvature, for fabric to be stable under applied wind and snow loads it must be prestressed typically to 150 or 200 kg/m². (Fig 2.6) Under wind these stresses will increase to about 600 kg/m², and must be resisted at the boundaries of the fabric. As it was felt that the existing structure would not be able to resist such a level of force between the buildings, a lattice strut supporting structure was developed across the building. A gutter and beam supported on columns divides the membrane on the line between atrium and gallery, and glazing on this line separates the areas. (Fig 2.7) The lattice struts are also supported on this line and a second set of struts span over the gallery to the rear elevation. The whole roof is anchored in the transverse direction to the front block only. (Fig 2.8)

The fabric is supported by umbrellas on flying masts which stand on bridle cables running back to the ends of the struts. Generally there are single masts in each bay but at the ends the masts are in pairs to

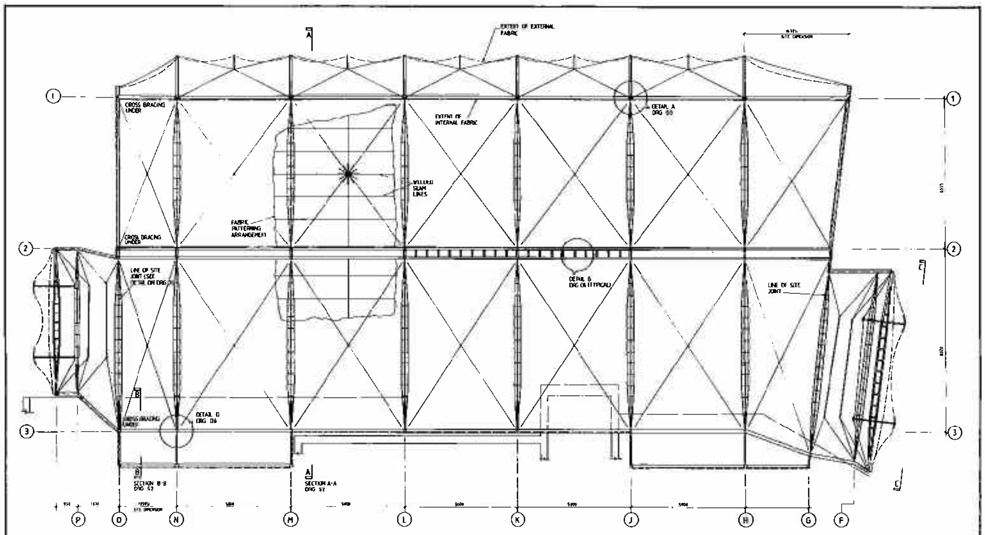
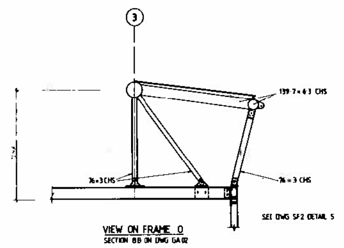


Fig 2.8 Roof plan of atrium



achieve the required shape and level of support to the membrane. At the ends of the atrium the fabric is attached to a triangular lattice truss designed to take the fabric forces in bending. Beyond the gallery the fabric oversails the glazed wall, creating a canopy. This narrow band of fabric is given shape by a series of flying struts which push the edge of the fabric down between cantilevering arms.

Details had to be designed to enable the fabric to be prestressed, and had to include means of pulling or pushing the fabric into shape and maintaining it under load. Where it is attached to steel perimeter members the fabric passes over the structural tubes. Small steel tubes running inside pockets in the membrane are screwed down to small blocks on the side of the perimeter tubes, the screws providing adjustment at the edge to ensure a good fit on the fabric. Final tensioning of the fabric is applied by jacking up the flying masts, achieved by turning a threaded shaft which passes through the lower support point.

Design of linking metal bridges

Mechanical requirements of all details created a machine aesthetic which was brilliantly exploited by Herron Associates, many of the components being specially machined from stainless steel and aluminium. The same machine aesthetic was carried through to the 8.5m span bridges linking the two blocks, the primary structure of which was a pair of 400mm deep tubular steel trusses, triangular in cross section, supporting extruded aluminium decking. (Fig 2.9) Plan bracing is required for torsional stiffness with further bracing necessary to support the handrails. The bracing members were generally connected with machined 'swing' bolts. The light nature of the structures and their precision detail is an important element in the architecture of the space.

Fabric patterning and materials

The normal flexible fabric used in the atrium roof is stiffened to resist loads by virtue of the double curvature and prestress induced by the boundary and support conditions. To achieve this condition, the fabric has to be accurately tailored to the prestress geometry, determined by a computer form-finding process where stresses are specified in the membrane surface which then moves to its equilibrium position. (Fig 2.6) The resulting numerical model is used for load analysis and finally to produce the cutting patterns to which each panel of

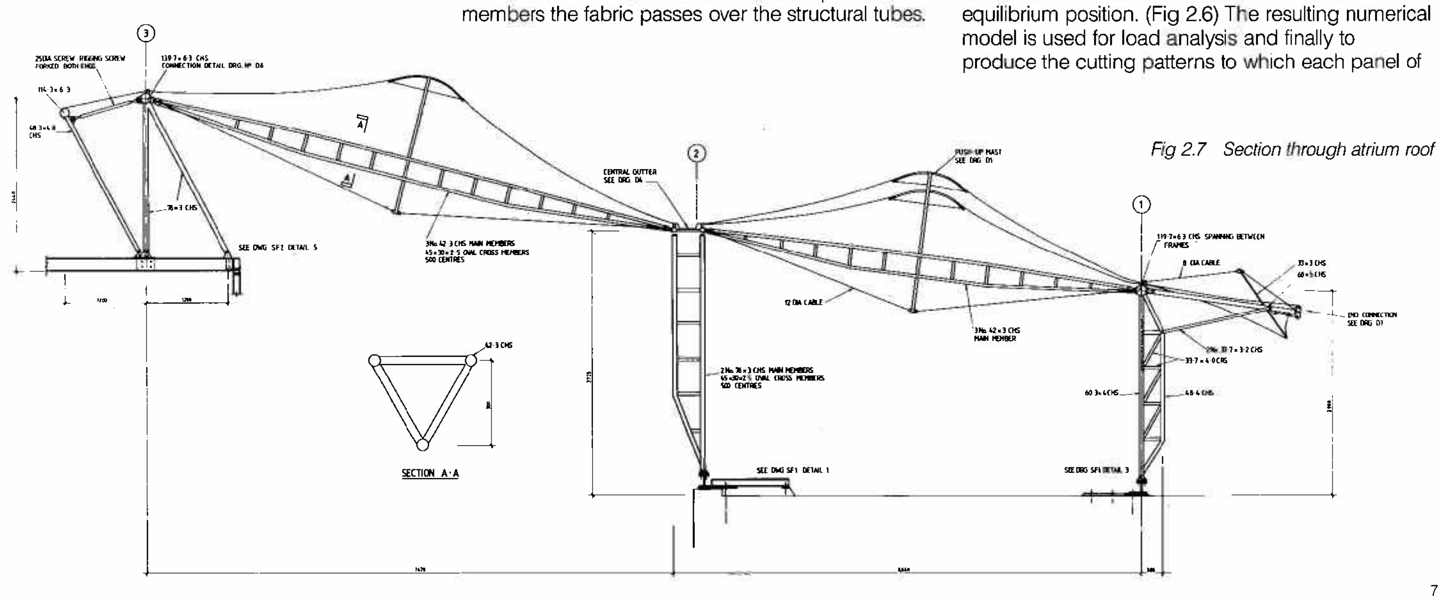


Fig 2.7 Section through atrium roof


Fig 2.9 Multilevel linking walkways within atrium

cloth is tailored. This total process is carried out in-house using specially written software (Ref 2.1), so allowing the designers total control of the fabric shape and detailing essential for such a complex roof.

Fabric was patterned with 1m wide cloths cut from a 2m wide roll to conform to the well developed curvature of the roof. Cross seams were introduced at the mast heads to create the required dome shaping in those areas. Stretch under load was measured by laboratory tests and fabric was consequently adapted by 0% in the warp and 2% in the fill direction to compensate.

During the design stage, consideration was given to using either PTFE-coated glass cloth, silicone-coated glass cloth or PVC-coated polyester for the atrium roof membrane. It was difficult at this stage to obtain approval for PTFE glass because of concern over possible production of toxic fumes during a fire. Such worries have since been dispelled and it would probably now be permissible to use this long lasting material. As an alternative, silicone-coated glass is difficult to obtain, is consequently very expensive, and problems would have arisen in obtaining an adequate supply for the project. It was therefore decided to use PVC-coated polyester fabric with fluoropolymer lacquer on the grounds of cost and expediency.

Services installation

The appointment as building services consultants under an ACE performance contract permitted an early selection of mechanical and electrical sub contractor on what was to be a fairly short design period, so allowing design details to progress in parallel with work on site. The successful contractor, Electrical Engineering Contracts Ltd (EEC) of London, had worked previously with the client and was therefore aware of the high standard required of the proposed building services. The result is a very high quality installation which complements the quality of the refurbishment as a whole.

All services are powered by electricity, electrical heating being established at an early stage as the best solution for this particular project. Offices are fitted with storage heaters whilst direct heaters are used for the central atrium space. Ventilation of the atrium is achieved by low level natural air inlets on the side walls and mechanical extract fans at high level under the fabric roof. The "white air-tubes" in the atrium operate in winter to collect the rising heat and return it to occupancy level.

The lighting scheme is a 'personalised' design, directed by Ron Herron and his team. Totally in keeping with their image, it offers a simple and elegant solution.

Fire engineering considerations

Buro Happold was further commissioned to carry out a fire appraisal of the spaces beneath the membrane roof of the atrium and roof gallery. A report was submitted to the local authority – London Borough of Camden – and its recommendations formed the basis for the fire strategy in these spaces.

The atrium was intended for transient use with a low fire load at least four storeys below the roof. It does not form part of any fire escape route as the front and rear buildings both have their own independent means of escape. Furthermore, the buildings on either side are isolated by half hour fire glass in all windows and fire doors. In the event of an atrium, fire, optical and smoke detectors will trigger an alarm and bring into action the smoke ventilation system. This comprises low level inlet panels which open automatically in the vertical side screens to the atrium, and high level louvres with extract fans. (Fig 2.10)

The roof membrane itself does not support combustion, and when impinged on by flame does not drip. It is merely burnt and vapourised locally around the impinging flame, and is then self-extinguishing. If air temperatures in the atrium reach around 250°C it is anticipated that the PVC adhesion at welds would begin to reduce and seams would slide apart and open releasing the pre-stress, so improving ventilation of smoke. If temperatures then rise to much higher levels, and flames reach the membrane, local burning will take place and ventilation would be improved even further. With such a high level of ventilation assured, internal temperatures could not reach those more common in restricted compartment fires.

Whilst this type of membrane has been in use in structures world-wide for at least thirty years, it had not been used in such a way before in London or indeed anywhere in the UK. Despite the arguments of the fire report, Camden Building Control were not willing to set a precedent by making a favourable decision on the use of membrane for the atrium covering.

On application to the Department of the Environment for a determination there was no hesitation in accepting the use of the material for a roof. However, as no large scale tests are known to have been carried out to simulate the behaviour of vertical panels of the membrane in a fire condition, the use of vertical walls of fabric was not acceptable without demonstration. As there was insufficient time to conduct such tests, the intention to continue the roof membrane down on either side of the atrium to second floor level was deferred. As an alternative, the side walls are designed as more conventional fire panels supported on a steel grillage spanning between the two buildings.

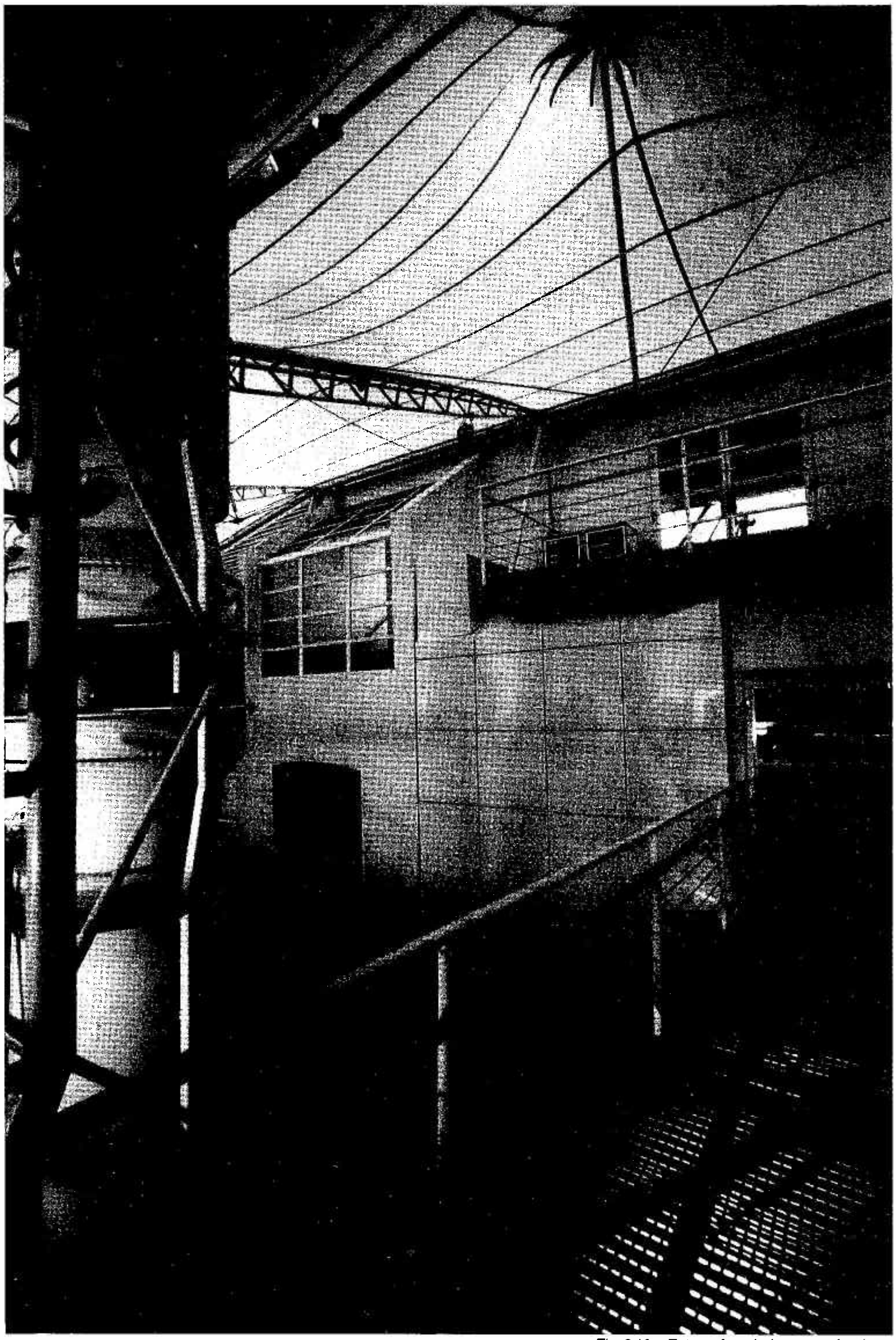


Fig 2.10 Extract fans in louvres of atrium

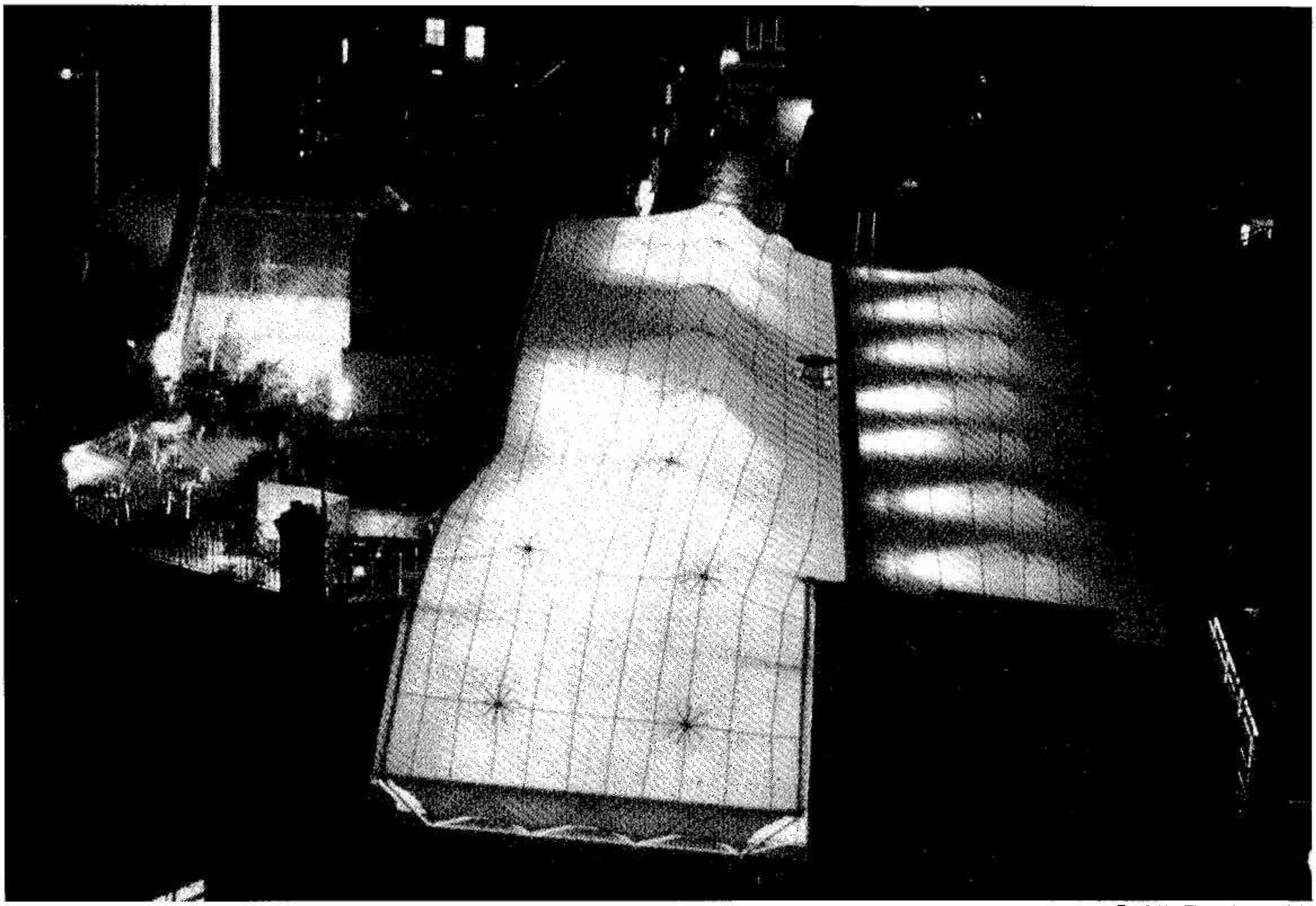


Fig 2.11 The atrium at night

An extremely rigorous £5m refurbishment programme was thus completed in less than one year, with contractor R M Douglas Construction working on upper and lower floors simultaneously. In the words of BCI judges, Staffordshire House (Fig 2.11) is a 'landmark scheme to bring new life to old buildings against which other refurbishment projects are likely to be judged for years to come'.

Mike Cook, Ian Liddell and Tony McLaughlin

References

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Refurbishment of the Assembly Rooms, Bath

Project data

Client	Bath City Council
Architects	David Brain Partnership
Services Engineer	Buro Happold
Structural Engineer	Buro Happold
Quantity Surveyors	Bare Leaning & Bare
M & E Quantity Surveyors	Buro Happold QS
General Contractor	Wickens Construction
Mechanical Contractor	Multiheat Ltd
Electrical Contractor	Lloyd Blackmore
Cost	£2m
Completion Date	September 1990

The Assembly Rooms, built circa 1770 to the plans of John Wood the Younger, were reported in the 1792 Bath Guide as: 'The most noble and elegant of any in the Kingdom'. (Fig 3.1 a, b) Located on the north side of the city, the Rooms are only a few paces from another of Bath's famous architectural works, the Circus, designed by John Wood the Elder. Present layout of the Assembly Rooms (Fig 3.2) suggests the arrangement of eighteenth century assemblies when evening entertainments would include dancing, card playing and tea drinking all taking place simultaneously. (Fig 3.3)

The building has experienced peaks and troughs in its popularity over the years, and by the early part of this century was in a somewhat sorry state. In 1921 it was converted to a cinema which proved both a financial and aesthetic disaster. Rescue came in 1931 when the building was purchased by the Society for the Protection of Ancient Buildings using monies donated by Mr Ernest Cook. It was then vested in the National Trust and leased to the City of Bath for a nominal rent. The City Council restored the rooms, a task completed in 1938. However, four years later the building was gutted by incendiary bombs and only the shell of the building was left standing.

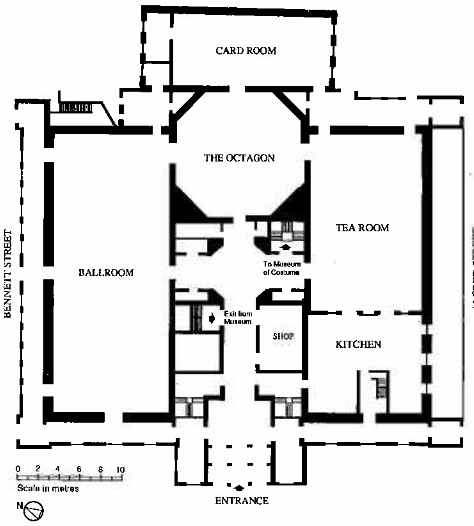


Fig 3.2 Current floor plan

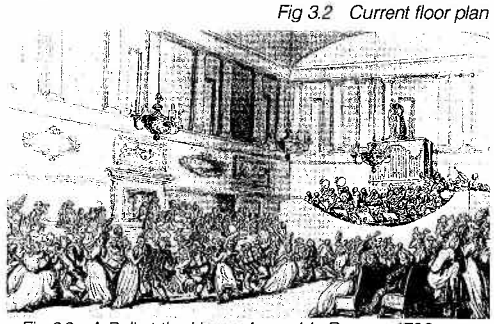
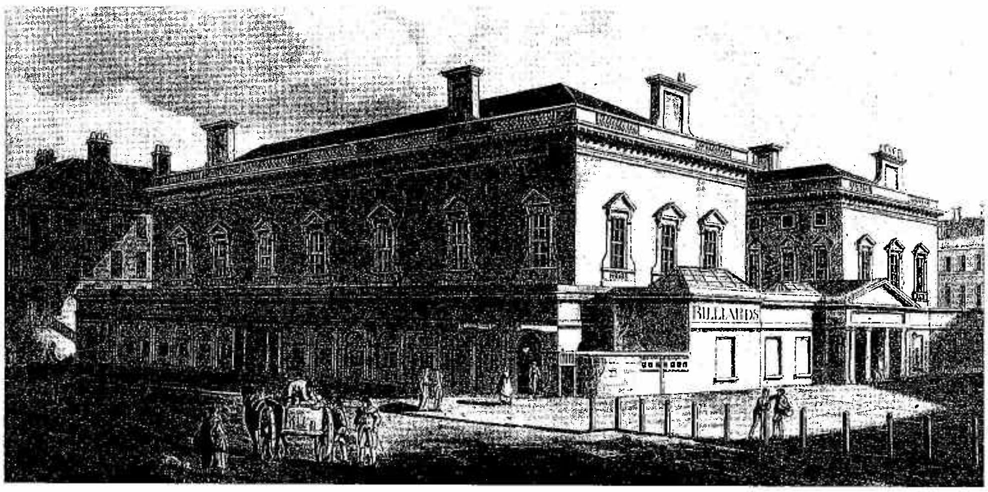
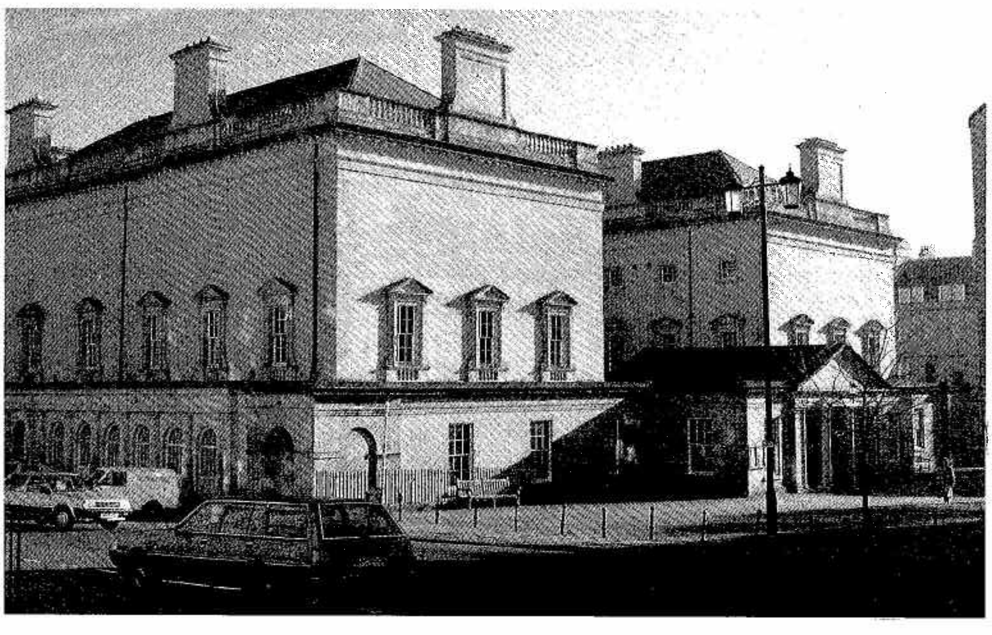


Fig 3.3 A Ball at the Upper Assembly Rooms, 1798 – one of many previous uses of Assembly Rooms

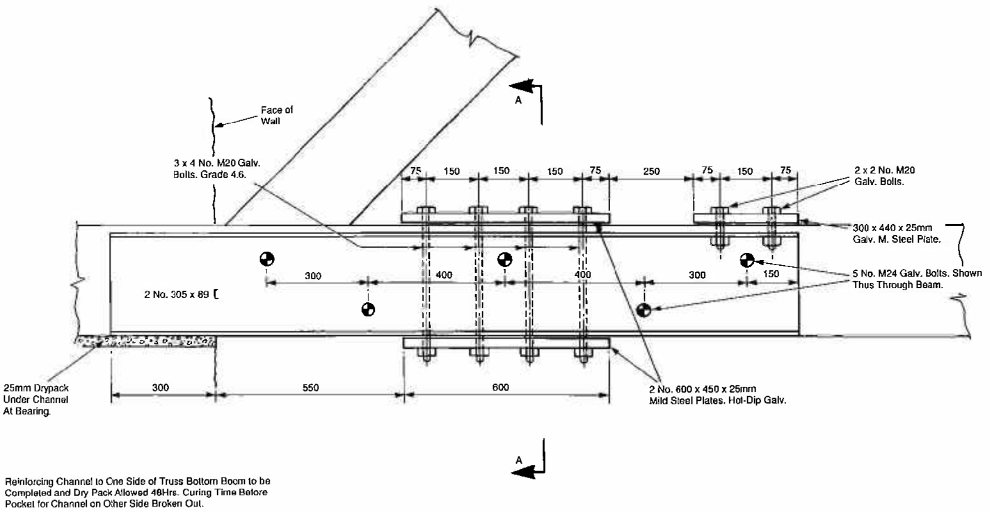




Following the war, the War Damage Commission offered to pay for the restoration of the Assembly Rooms, a task which was then undertaken by the Trust's architect, Sir Albert Richardson. This restoration was completed in 1962 and the success of the rooms in the past years has amply justified the Trust's decision for post war reconstruction.

The need for refurbishment

Attention has however, been focused again on the building, highlighting further refurbishment needs. On the night of 13 October 1987 a section of plaster fell from the ceiling of the Ballroom without any apparent cause. Through good fortune no one was hurt. The City Council acted quickly, closing the building to the public, and immediately appointing a team of consultants with an initial brief to investigate and report on the failure. As part of this initial brief the consultants were also asked to consider the implication of any repair work.



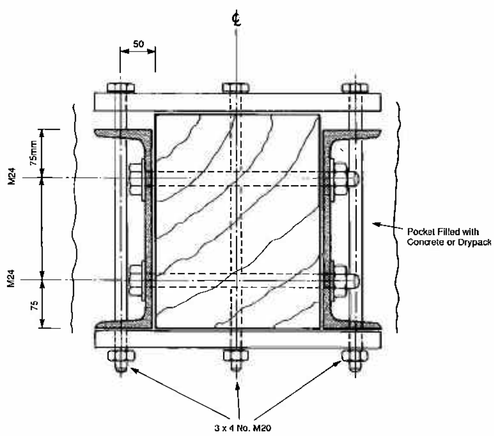


Fig 3.4 (a) Repair to decayed roof timber
(b) Section through truss repair

While the architects, the David Brain Partnership, were surveying the plasterworks to ascertain the cause of collapse, Buro Happold carried out their initial brief. This included the investigation of the support structures for both the ceiling and chandelier to indicate any inadequacies which could have contributed to the failure of the ceiling plasterwork. Although Bath City Council had no reason to believe that the Assembly Rooms were structurally unsound in whole or in part, any proposed refurbishment might be invalidated if at a later date such problems became apparent. A structural survey was therefore conducted to highlight any visual signs indicating inherent structural instability.

Initial survey and investigation

The ceiling support structure comprised both straight and curved ceiling joists fixed to the underside of the horizontal tie members of the large section timber roof trusses. There were no apparent defects in the structure which could have caused the failure of the ceiling. The chandelier support structure comprised structural steelwork sections supported directly on the top of the horizontal tie members of the timber roof trusses. Again there were no apparent defects.

Survey revealed no signs of major structural weakness and so no reason to instigate a full structural appraisal of the building. However some minor repairs to timber connections were recommended. (Fig 3.4 a, b) Further recommendations suggested that checks be conducted at regular intervals on the roof timber and that walkways be installed in some of the roofways to provide safe access for maintenance staff.

Recommendations were also made on upgrading the existing building services systems, work which could be carried out during the period of closure. These included an acoustic appraisal of the Ballroom which is primarily used during the Bath Festival as a venue for music concerts. This room however, was originally intended as a place of assembly and not as a concert hall, and its acoustics have somewhat detracted from public enjoyment of the concerts and been a frequent source of complaint. Proposals were also requested for the incorporation of cooling into the ventilation system of the Museum of Costume, which was felt to be too hot on warm summer days, and for enhancing the lighting of the Ballroom, Tea Room, and Octagon which are lit by unique chandeliers. The practice was asked to consider ways in which the appearance of the rooms could be further enhanced by the use of additional light sources.

A comprehensive report was presented to a full Council Committee in February 1988. The Council members accepted the findings of the report but on the grounds of costs would not approve any enhancement measures for acoustic treatment to the Ballroom, cooling of the Museum of Costume or upgrading of lighting of the major rooms. The reduced scheme which was approved in full was costed at just under £2m. The contract was tendered in November 1988 and was awarded to Wickens Construction. Work commenced on site in March 1989.

Improvements to building services

The existing building services installation, completed in 1962, had reached an age and condition where repair and replacement would soon be required. The Council was advised that since repair and replacement to the building services was necessary, the opportunity, albeit unplanned, should be fully utilised to ensure that the building achieved modern day standards when re-opened to the public.

The extent of repair and replacement of the existing systems was determined by their condition, any mechanical failure of moving parts, and the inadequacies of the systems to meet the users' requirements. Furthermore, the client required a full ten years usage of the building without further major disruptions following refurbishment.

Consequently, work was carried out on the mechanical systems, replacing the heating system pipework and emitters throughout, with the exception of one part of the building. The recently installed boilers were retained and overhauled, but all boiler room pumping, pipework and controls were renewed. The Ballroom and Tea Room are heated by radiant panels concealed within the wall between skirting and dado. (Fig 3.5) The Octagon is heated by an underfloor system whilst the Card Room and Little Octagon are heated by fan convectors concealed behind ornate wooden enclosures. Each of the major rooms is provided with its own zone control system and the Ballroom is further divided into four individual control zones. Corridors are heated by radiators. Concealed pipework which runs in the ceiling space, is heavy grade steel with welded joints and the system is valved in such a way that runs of pipework can be isolated should a leak occur.

The electrical systems were renewed and a new 400 amp main distribution panel was installed to replace existing equipment in the basement. General work included rewiring of old circuits, installing new distribution boards and providing adequate power outlets to enable the system to meet present day standards. The only major lighting replacement was in the Museum of Costume where old recessed fittings with 60w tungsten lamps were replaced with

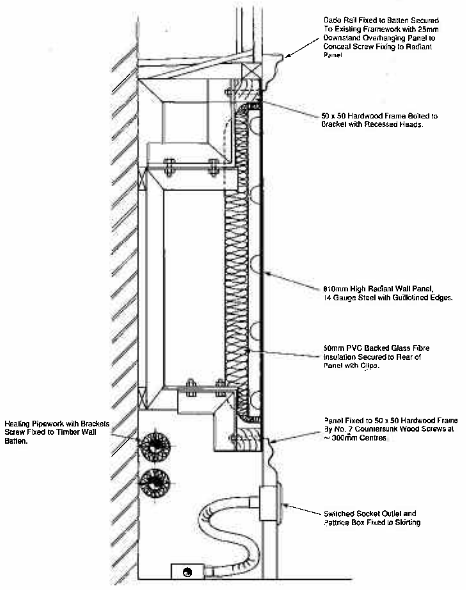


Fig 3.5 Detail of radiant panel heaters in the ballroom

wide beam 35w low voltage fittings.

Every effort was made to render all building services installations inconspicuous. Power points, light switches and thermostats were finished in the same BS colour as the surface on which they were fixed. However, difficulties arose in concealing smoke beam detectors mounted on the cornice of the larger rooms.

Chandeliers taken down promptly after the first fall of plasterwork underwent a lengthy refurbishment programme and were finally reinstalled in their original positions.

A new fire alarm system was finally installed covering the whole building to provide the level of protection expected of a building used for public entertainment. An addressable analogue system was selected allowing management to isolate particular rooms as necessary.

Work was completed at the end of September 1990, three months ahead of the original programme – a credit to all who were involved. But what of the failure of the plasterwork which started it all? Research by the architects and their advisers has indicated that failure was due to a mismatch of plaster layers. Simply stated, browning plaster had been used over metal lathing plaster and the two layers had separated. The rescued ceiling rose (Fig 3.6) has now been successfully reinstated, once more resplendent in this beautiful building.

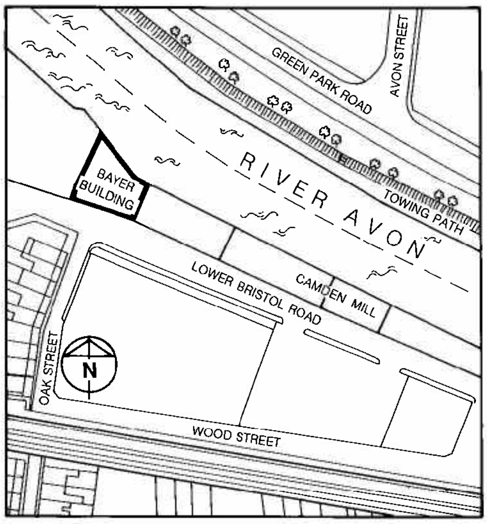
Tony McLaughlin and Terry Ealey

Fig 3.6 Fallen plasterwork of ceiling rose

Marples Wharf – A Transformation of the Bayer Building, Bath

Project data

Client	Marples Developments Ltd
Architect	Tektus
Structural Engineers	Buro Happold
Services Engineers	Buro Happold
Quantity Surveyors	Norman Drake Partnership
Preliminary Contractor	Walter Lawrence Construction Ltd
Main Contractor	Longs of Bath
Project Manager	Stonechester Ltd
Project Value	£650,000
Completion Date	March 1988



0 10 20 30 40M

Fig 4.1 Location of Marples Wharf on Lower Bristol Road, Bath

In undertaking refurbishment, the engineer must not only consider the current performance of the original building but must also assess and make allowance for any incumbent faults or shortcomings. An old building possesses characteristics which a client will wish to retain, but will also present problems due either to faults in the original building design, or to the demand imposed by modern performance requirements. Most problems will be solved at the design stage but not all can be predicted from the initial surveys or client requirements. As works progress and more of the original building is exposed, changes must be made for both engineering and architectural reasons, and decisions on these changes are necessary at short notice if the contractor is not to be delayed. A study of the refurbishment of one such building in Bath highlights the flexibility required of the engineer in the solution of these problems.

The Bayer Building, a sturdy four storey Victorian building on the Lower Bristol Road in Bath, (Fig 4.1) and fronting the River Avon, was constructed in approximately 1895 by local builders Hayward & Wooster as a corset factory (Ref 4.1). In recent years the building had suffered much deterioration (Fig 4.2a, b) before being acquired by Marples Developments in 1987 for redevelopment as office accommodation. Buro Happold were appointed structural and services engineers, together with architects Tektus, and Norman Drake Partnership as quantity surveyors for the refurbishment project. The building has now emerged as Marples Wharf, a modern office suite incorporating design features expected of the 1990s.

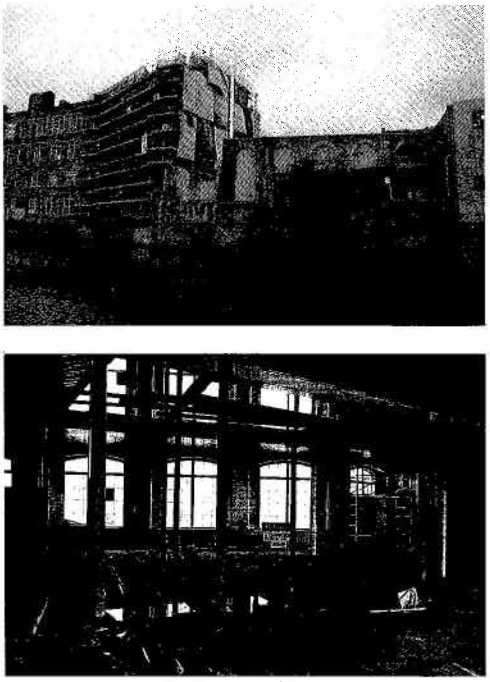


Fig 4.2 (a) A deteriorated riverside elevation
(b) Interior before redevelopment

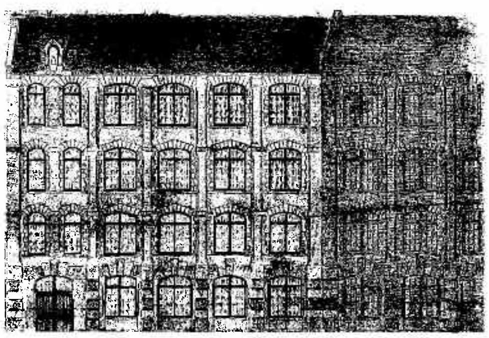


Fig 4.3 Original drawing of front elevation

Site investigation and survey

Initial investigations included a study of old records, the taking of core samples from boreholes, a laboratory analysis of timber and steel floor beams to determine loading limits and a full structural analysis of the building. The original drawings were still available for inspection at Bath City Council Building Control Office (Fig 4.3) and further information was obtained from site investigations and structural analysis of the building.

Boreholes not only gave information on soil conditions, but cores also proved that the Victorian foundations on the riverside were 5 metres deep mass concrete, not requiring any further strengthening, providing full consolidation settlement had occurred. Internal cast iron columns were on brick and concrete piers. All foundations were in the soft clay which overlies strong limestone within the Lias. This founding strata would not however be considered adequate for a modern building because separate bases would now have much lower limits on foundation settlement than those for a building constructed 100 years ago.

Laboratory analysis of the timber and steel floor beams provided information on material strengths. Samples of the timber joists were sent to TRADA who identified the species as Baltic Fir (European Redwood) and advised that it was equivalent to class grade 75 to Cp 112, the original code for timber design. Old design guides confirmed that an allowable bending stress of 10N/m² was therefore acceptable. Samples of the steel beams were analysed by Sandberg's metallurgical laboratories. It was confirmed that beams were of steel which was readily weldable, and equivalent to grade 40 of the current BS 4360. A check on existing floors using these allowable material stresses showed that they would not be capable of carrying the required modern office design loading of 3.5kN/m² without further strengthening.

With a large timber staircase in one corner of the building and no internal partitions except the enclosure around the staircase, analysis showed that vertical loads were carried by timber floors spanning between the brick external walls and steel beams supported on cast iron columns. Floors were generally sound although the boards were uneven due to the wear of many years of corset manufacture. Some deterioration in the roof had resulted from both water penetration and excessive deflection caused by undersized purlins. Overall, however, the building was in good condition with no structural cracks in walls and no signs of settlement.

Refurbishment needs

Consequently, the problems to be solved were not due to shortcomings of the original building. The requirement was to upgrade the load-bearing capacity of the floors and provide fire protected escape routes, a lift, toilets and vertical service routes. In discussion with the client, architects Tektus determined that the key to the reuse of the building was simply to provide a central core to contain a new fire resistant staircase, toilets on each floor, a lift, service ducts and plant areas. (Fig 4.4)

At the entrance to the building, a rather precarious riverside wall was all that remained of a previously demolished building which had abutted the Bayer Building. The client wished to retain this wall as a feature and so screen the car park from the river frontage.

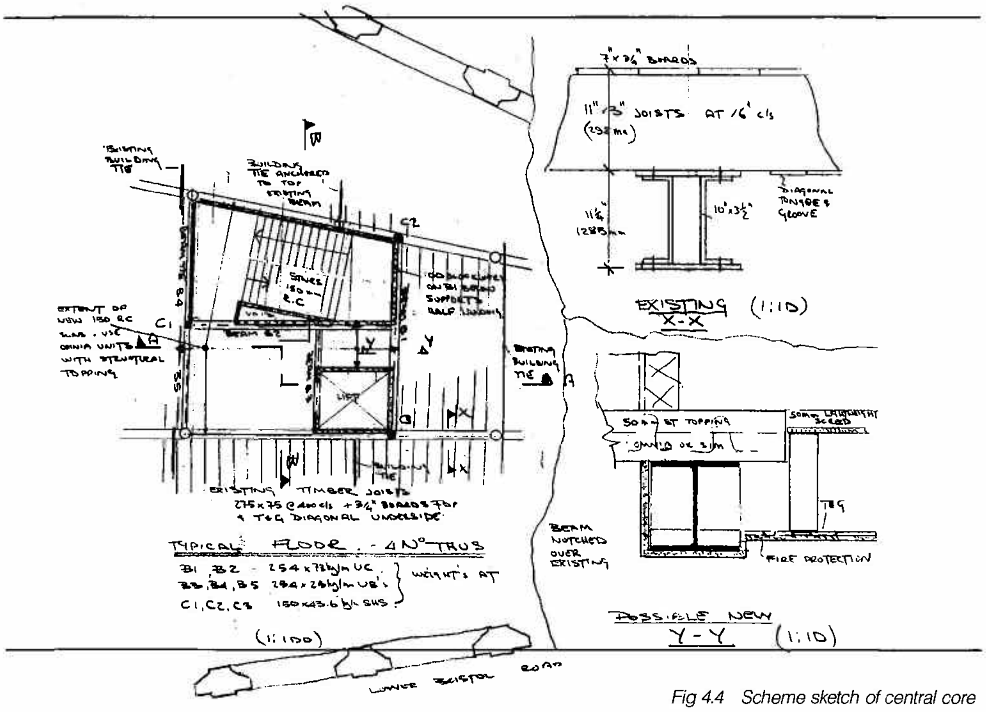


Fig 4.4 Scheme sketch of central core

Structural alterations

On the assumption that long term settlement of the old building was complete, it was decided to support the proposed central core on new end bearing bored piles founded in the limestone. This would ensure there would be little differential settlement between the existing building and the new structure, which would consist of standard steel columns and beams, reinforced concrete floors and staircases, and blockwork walls. The floor spans in the rest of the building were reduced by installing steel beams beween the core and the existing walls. (Fig 4.5, 4.6)

Careful design was necessary to ensure that, in cutting out the required openings in the floors to the new central core, the existing ties across the building and the plate action of the floors were not inadvertently removed. Diagonal boarding of the original ceilings results in floors acting as stiff plates which, combined with the original ties, are adequate to provide the nominal linkage required by current codes to ensure continuity in case of explosion.

The original ground floor was formed of a thin screed over existing ground which required upgrading to a properly designed reinforced concrete ground bearing slab. On the river side, consideration had to be given to any increased load this new slab would apply to existing river walls. However, it was determined that any increase would be small and could be safely sustained.

The new core provides modern office space all round the perimeter of the building, allowing the offices to benefit from the character of the existing windows and the views across Bath. It also facilitates provision of improved support for the existing roof where it has been weakened by the dormer installation. New blockwork walls are supported on the core structure and provide fire and sound resistant separation for the stairs, lift and toilets.

Contracting of work

To allow as much time as possible to develop the design of the building as a whole, some of the essential structure of the core was tendered in advance of the main contract. This preliminary contract covered boring of piles, cutting out of timber floors in the core area, and fabrication and installation of the new steel frame. Timber joists removed in forming the core opening were stored for reuse in filling the existing stair opening.

Main contract work included the placing of reinforced concrete floors and stairs, and attention to the roof, both to repair it and to add a large new dormer window in the north-facing river elevation.

During construction work it was discovered that the building was out of plumb. No cracking was associated with these deviations from vertical which were worse at lower levels. It was concluded that the movement was due to original construction

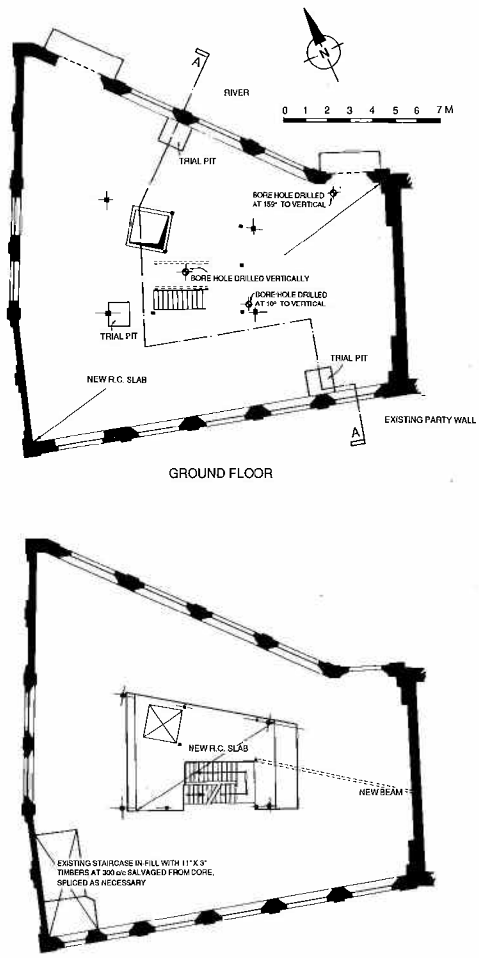


Fig 4.5 Floor plans of ground and second floors

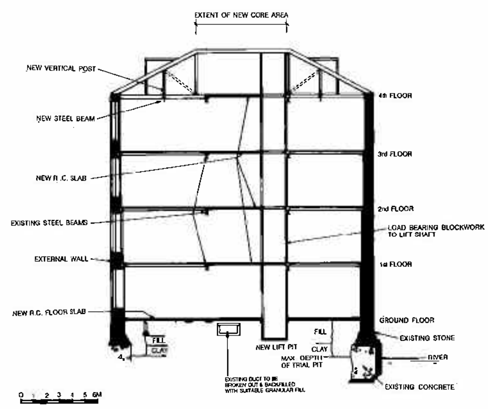


Fig 4.6 N/S section through Bayer Building

Fig 4.7 Lighting on third floor

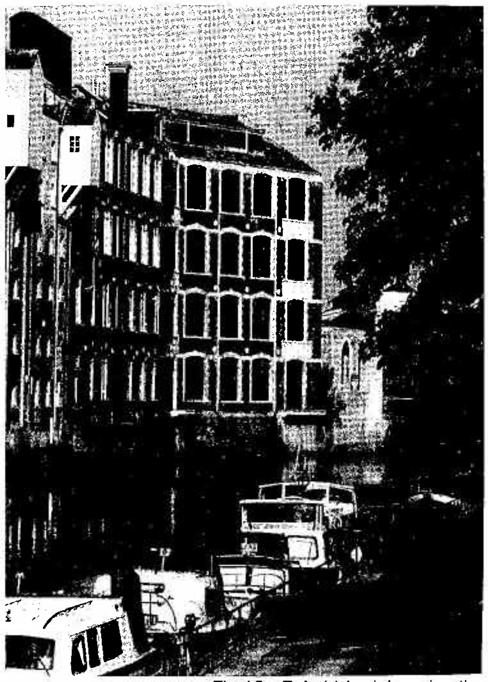


Fig 4.8 Refurbished river elevation

settlement and there was no concern over continuing movement. However, it is interesting to speculate on the differing reactions between now and 100 years ago on the occurence of substantial movements during construction!

Provision of services

Services installations were centred on the new core. Heating was provided by radiators, the gas fired boiler being located on the fourth floor. Air extraction was provided at the toilets into a rising duct in the core, and at the area on the ground floor adjacent to the road where traffic noise prohibited the use of windows. New electrical services included lighting and power distribution to switched socket outlets in the floor. (Fig 4.7) To level the uneven floor and provide space for cable distribution, chipboard was laid on 75mm battens and packers. With the provision of sufficiently wide slots in the chipboards, some flexibility was achieved in the positioning of outlet boxes. Space between the boxes was made up using plywood spacers which could be cut to any desired length.

The asymmetric shape of the building precluded use of a regular grid of luminaires in the office area. Although not the most efficient in energy terms, 600 × 600mm modules with low brightness reflectors were chosen as a compromise solution which achieved both an acceptable visual appearance and the required lighting level.

Finishing detail

Finally, the outside of the building was cleaned and new windows were installed. New facing brickwork supported on stainless steel angles was added in the entrance area where the original building lacked such detail.

Work carried out on the riverside wall, to be retained as a feature screening the car park, was a close representation of the complete refurbishment of the building. As originally constructed, it was entirely adequate as an external load-bearing wall of a building. The client however wished to change its use to that of a free standing screen to the car parking area where horizontal wind rather than vertical roof weight becomes the dominant loading. Survey and analysis of the existing state of the wall revealed unbonded piers and large pieces of timber built into the brickwork, all limiting the wall's ability to resist horizontal loading. A scheme was produced to show how, with strengthening provided by the careful insertion of reinforced concrete beams into the brickwork and new ties between existing unbonded buttresses and the wall, the refurbished wall could perform its required new function. As the strengthening work was carried out, deterioration and built-in items which had not been evident in the original survey were revealed and details had to be adjusted to suit. The finished wall, (Fig 4.8) showing little evidence of the successful strengthening work, and in close parallel with the Bayer Building itself, has had its original character restored but is now performing a new function undreamt of by the original designers.

Richard Harris

References

4.1 Harper D. – "Bath at Work" p39.

Phased Refurbishment of York House, London

Project data

Client	Dixons Commercial Properties
Services Engineer	Buro Happold
Structural Engineer	Buro Happold
Quantity Surveyor	Murdoch Green & Partners
Main Contractor	Gilken (Contracts) Ltd
Services Contractors	
(Mechanical)	Swan Building Services Ltd
(Electrical)	CAG Ltd
(Mechanical & Electrical)	Abrey Garland Group Plc
Project cost to date	£1.8m
Completion Date	Third and fifth floors – end 1989 Ground floor – early 1990

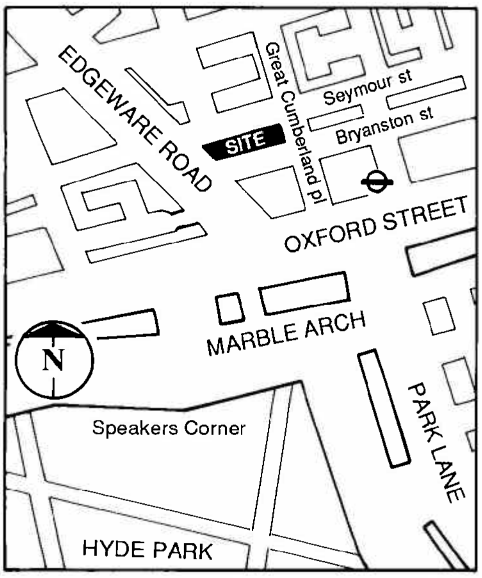


Fig 5.1 Location of York House at junction of Great Cumberland Place/Seymour St. London

York House is a six storey building situated on the west side of Great Cumberland Place at the junction of Seymour Street, close to Marble Arch, in London. (Fig 5.1) Previously known as ATV House, it had been the headquarters of Lew Grade's Associated Television. The building was later acquired by Dixons Commercial Properties in 1989. Built in 1959, it was still structurally sound, but services had reached the end of their useful life and were in need of complete refurbishment.

Since 1959 office standards have improved dramatically. Criteria established thirty years ago fall far short of what is considered acceptable today. With regard to present design standards, York House had a number of shortcomings, including inadequate lighting, poor fabric thermal characteristics, insufficient electrical power for air conditioning and computer equipment, and lift equipment that had reached the end of its serviceable life. Entrance foyers, lobbies and toilets had a dated appearance and were in need of upgrading. Buro Happold were commissioned to carry out a full mechanical and electrical design for refurbishment. An additional commission for a further more detailed survey of electrical systems was later included. A substantial refurbishment programme has now been undertaken to provide first class office accommodation appropriate to the West End market.

Initial survey and investigation

Before commencing preparation of the refurbishment proposals a comprehensive survey of the building services and fabric was necessary. As frequently happens, any 'as built' information had been lost and no records were available of subsequent modifications. Investigation was therefore a difficult and time consuming exercise which included extensive checking of the existing electrical installation to determine the configuration of the main distribution board, and tracing the route and destination of the many wireways and cables emanating from it. A detailed survey of the building fabric was required to estimate the building's thermal performance, while a study of the five lifts established the serviceability of the drive motors and control systems. A refurbishment masterplan was then drawn up, based on survey information.

Assessment of building fabric

The existing fabric of Portland stone clad walling with large metal framed, single glazed windows, is poor. Heat losses and gains are high, resulting in high energy costs for heating in winter and cooling in summer. Complete recladding was considered the only realistic way to significantly improve the building's thermal performance. However, this was found to be prohibitively expensive. Plans remain for a future reglazing of the building, using double glazing with a form of solar control.

Electrical supply upgraded

The electrical supply to the building originates from a 750 KVA LEB substation located in the basement. When the supply was first installed it was adequate for the building's requirements of lighting, office power, lifts and boiler plant, with a small allowance for further increase in demand. However, survey had shown that the power supply available was insufficient for future air conditioning loads and requirements of technical equipment.

Negotiations with the LEB resulted in preparation of proposals for an additional substation within the existing basement area. This substation with 450 KVA capacity, is primarily to serve air conditioning plant and represents a near 60% increase on the original supply. Existing power supplies provided tenants with a total supply for lighting and small power of some 37 w/m². Electrical power for air conditioning plant was based on 80 w/m². With the proposed increase in power supply, tenants would have the ability to both install air conditioning and accommodate a reasonable density of information technology equipment.

Refurbishment of lifts and common areas

Survey revealed that all lifts were coming to the end of their expected useful lives. Consequently, having reviewed and costed the various options, it was concluded that all drive equipment would be totally stripped down, refurbished and repaired, or replaced as appropriate, and cars would be refurbished. Control systems also required total refurbishment. Careful planning of the work ensured that a reasonable lift service was available to the tenants, as the building remained occupied

Fig 5.2 New entrances and air conditioned foyer

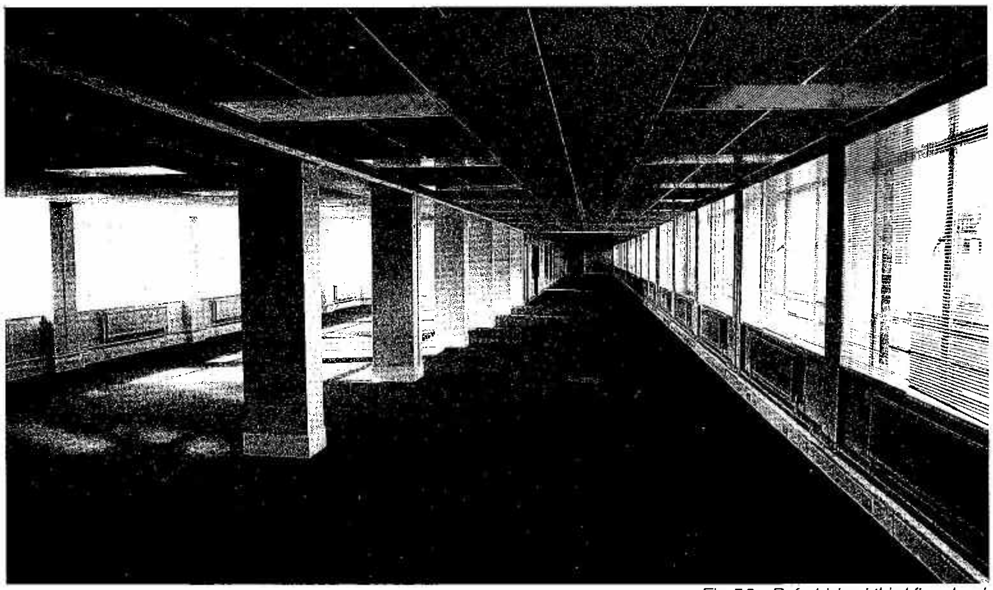


Fig 5.3 Refurbished third floor level

throughout the works. At no time was more than one lift out of service.

Each of the two main entrances to the building, located in Great Cumberland Place and Seymour Street, was completely stripped of all services and finishes. New entrances were constructed and both foyers provided with air conditioning. (Fig 5.2) The staircases and lift lobbies associated with the entrances were refinished, and new lighting and heating provided. Toilets on each stair landing were also refurbished.

Phasing of work on office floors

Refurbishment of the office floors has taken place as space has become vacant, but while other areas have remained occupied. This required very careful planning to ensure that especially noisy or dusty activities took place outside office hours.

Modern office buildings require careful consideration in the means of installing air conditioning, lighting, ceilings, power, data and telephone service distribution. In York House the original construction provided floor to ceiling heights no greater than 2.65m. If in refurbishing, a 150mm raised floor was to be provided and a ceiling zone for air conditioning equipment was to be accommodated, the floor to ceiling height would be reduced to unacceptable levels. A compromise solution with no raised floor, and with all power and data cables housed in perimeter trunking was therefore adopted. The ceiling void was reduced to 450mm, the minimum compatible with the installation of a fan coil air conditioning system. The fan coil system was selected as the most suitable having taken into account the spatial restrictions and the flexibility required for office sub-division.

In the refurbishment of the third and fifth floors, tenants had the option to select and install air conditioning systems suited to their individual requirements. Ceilings, lighting and finishes were completely removed on each floor, together with all existing perimeter cast iron column radiators which were deemed too bulky and aesthetically unpleasing. New lighting, with an illuminances level of 500 lux, was provided and thermostatically controlled panel radiators, three compartment perimeter trunking and new power distribution boards were installed. Finally, new floor and wall finishes were applied. (Fig 5.3)

The ground floor area was refurbished for a specific tenant and although work was similar to that on the third and fifth floors, it included the installation of a fan coil air conditioning system. The existing floor to ceiling heights are greater than on other office floors and a raised floor giving a 150mm deep void was successfully provided.

To date, refurbishment of the ground, third and fifth floors has been completed and work is shortly to commence on the sixth floor.

This comprehensive refurbishment programme for the majority of the building has produced a dramatic transformation of both office accommodation and entrances. (Fig 5.4) The building has been given a new lease of life, ensuring that it offers highly desirable West End office accommodation to major companies for many years to come.

Howard Bays

Fig 5.4 Exterior of refurbished York House

Kingsmead Revitalised – Redeveloped Neighbourhood Housing in Bath

Project data

Client	Bath City Council
Structural Engineer	Buro Happold
Services Engineer	Buro Happold
Architects	Feilden Clegg Design
Quantity Surveyors	White, Finch and Rider
Main Contractor	Tarmac Contract Housing
Project Value	Phase 1 £1.75m, Phase £1.25m
Completion Date	Phase 1 – Nov 1990

The Kingsmead Flats development in Bath, located north of the River Avon at a point some three quarters of a mile downstream from Pulteney Bridge, was originally built by Bath City Council in the 1930s – intended, as the City Improvements Committee put it at the time 'particularly for slum dwellers'. It consists of three blocks, forming three sides of a quadrangle, the fourth side being formed by Green Park Road. Each of the three blocks is of four storeys – on each floor, Kingsmead North contained five one-bedroomed flats, Kingsmead West seven two-bedroomed flats and Kingsmead East eight three-bedroomed flats. (Fig 6.1) Originally, one side of each block faced onto a communal garden within the quadrangle while the other side of each block featured communal balconies and access routes.

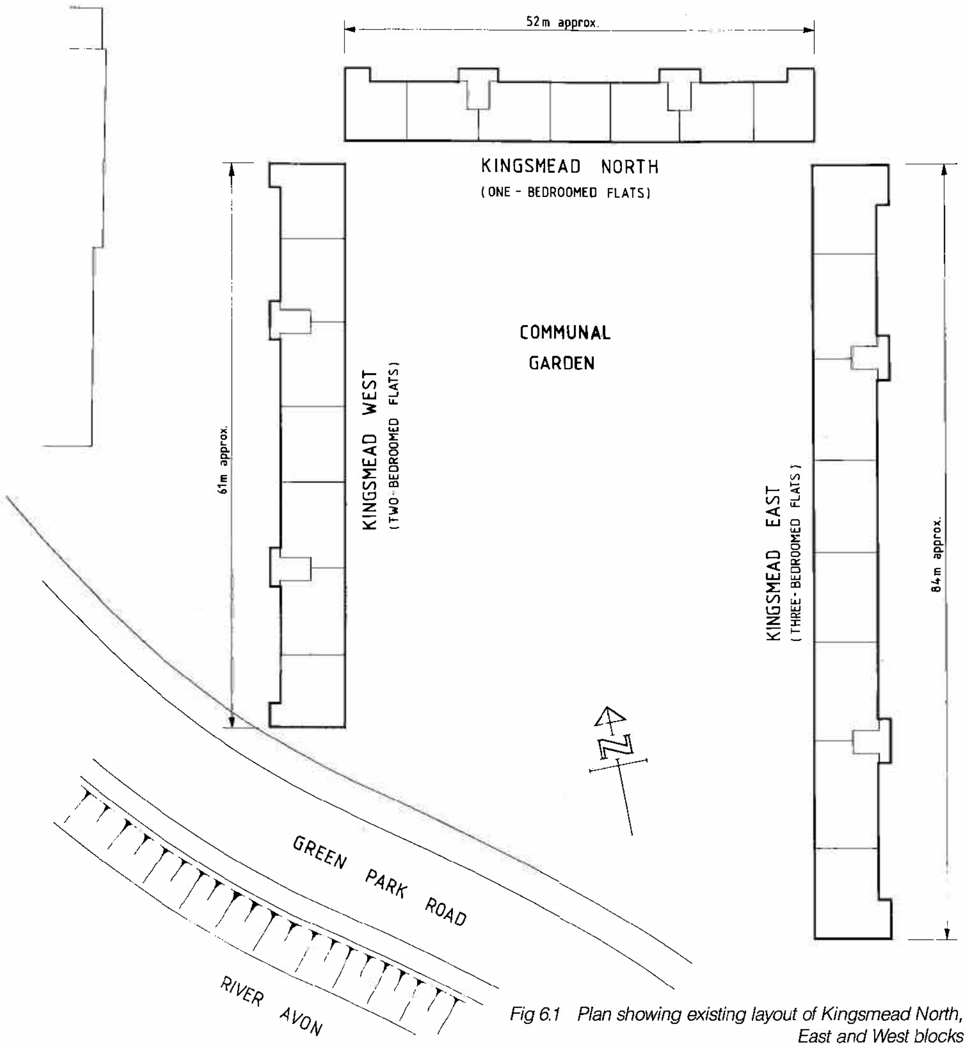


Fig 6.1 Plan showing existing layout of Kingsmead North, East and West blocks

Need for redevelopment

During the mid 1980s Bath City Council started planning the redevelopment of the entire Kingsmead/Milk Street area and during 1987 commissioned Feilden Clegg Design as architects, White Finch and Rider as quantity surveyors, and Buro Happold as structural and services engineers, to prepare a report investigating the feasibility of refurbishing and upgrading Kingsmead North and East. A similar report was subsequently prepared for Kingsmead West.

The report found that many of the rooms within some of the flats were too small, such flats requiring either enlargement or complete replanning, and that fire escape routes from the flats did not conform to modern standards. Recommendations included the introduction of additional internal staircases in Kingsmead East and West, and alterations to balconies which should no longer be communal, and further suggested that Kingsmead North should be converted to warden-controlled sheltered housing for the elderly, and fitted with a new entrance tower with lift. Additional accommodation could be provided by building new blocks to infill the open north east and north west corners. Elevations of both balconies and gables were considered unattractive and modifications were recommended. Finally the internal communal garden was under-used, and it was suggested that landscaping and private gardens could be provided to ground floor flats and a community room built for the use of the tenants. (Fig 6.2)

The Housing Committee of Bath City Council accepted the reports' recommendations, and detailed design work on the refurbishment of Kingsmead East and North began in 1988, followed in 1990 by similar work on Kingsmead West.

The impossibility of temporarily re-locating residents from all of the 80 flats simultaneously, combined with the difficulty of allocating funds to allow all of the work to proceed together led to the need for a very careful planned phasing of renovation and construction. The details of this phasing have been revised even during the works to accommodate new and unforeseen requirements.

Survey of existing structure

No drawings of the original superstructure were available, although some early architectural drawings did suggest that the structure comprised a steel-frame. This was confirmed by a celebratory brochure on the original construction which had been prepared by Bath City Council in October 1932. (Fig 6.3) Drawings of the substructure were available however, and indicated that the building was supported on groups of driven, precast concrete piles, with a system of in-situ concrete pile caps and ground beams.

A series of structural investigations were carried out inside a vacant ground floor flat, allowing a picture of the form of superstructure to be built up. It generally comprised a steel frame supporting precast concrete suspended floors via shelf-angles. (Fig 6.4 a, b, c) These floors consisted of hollow, precast reinforced concrete units with a structural concrete topping poured to infill the gaps between adjacent units. Continuity reinforcement over supporting beams had been placed between adjacent units prior to pouring the topping. This was still in sufficiently good condition to be retained, requiring only some filling with an epoxy grout in cracks between units. The roof originally comprised steel angle trusses supporting a system of timber purlins and rafters,

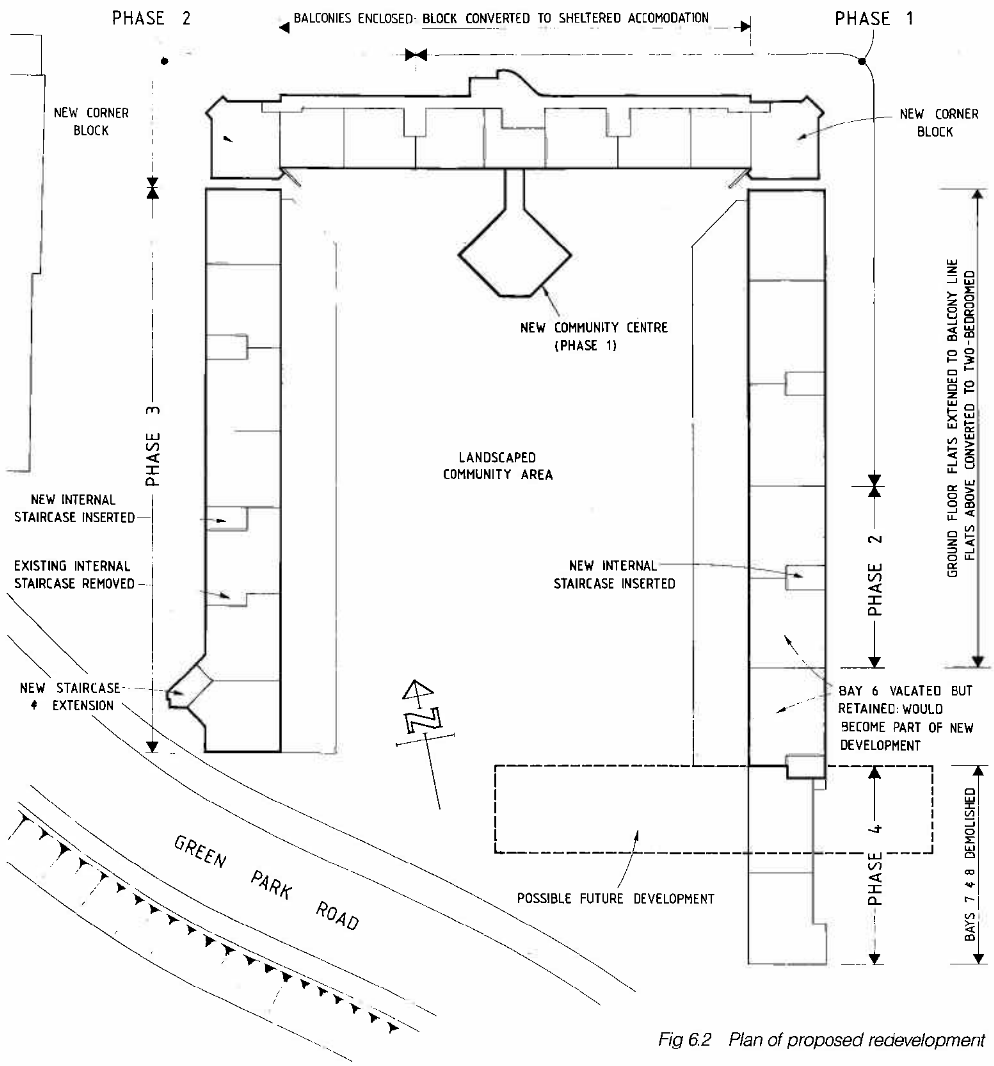


Fig 6.2 Plan of proposed redevelopment

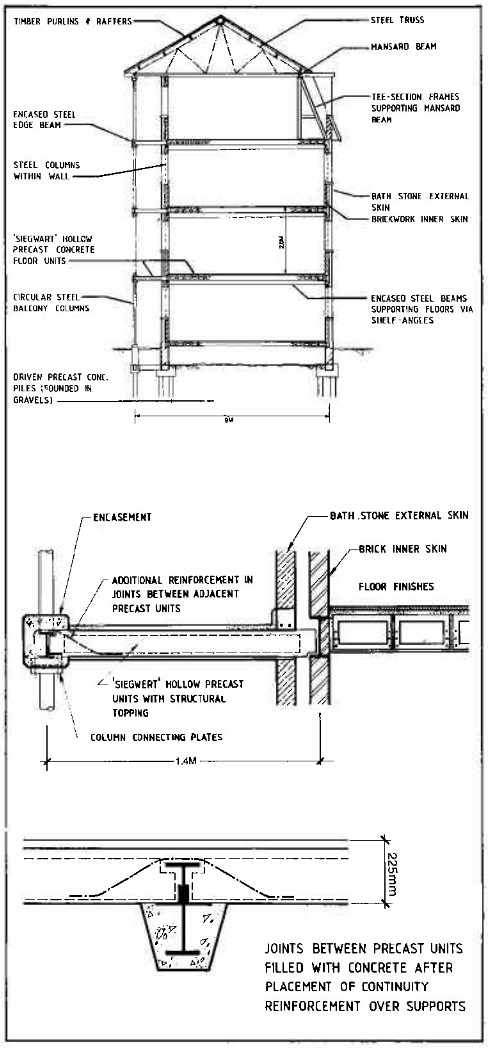


Fig 6.4 (a) Cross section through existing building
(b) Detail of balcony
(c) Filled joints between precast units

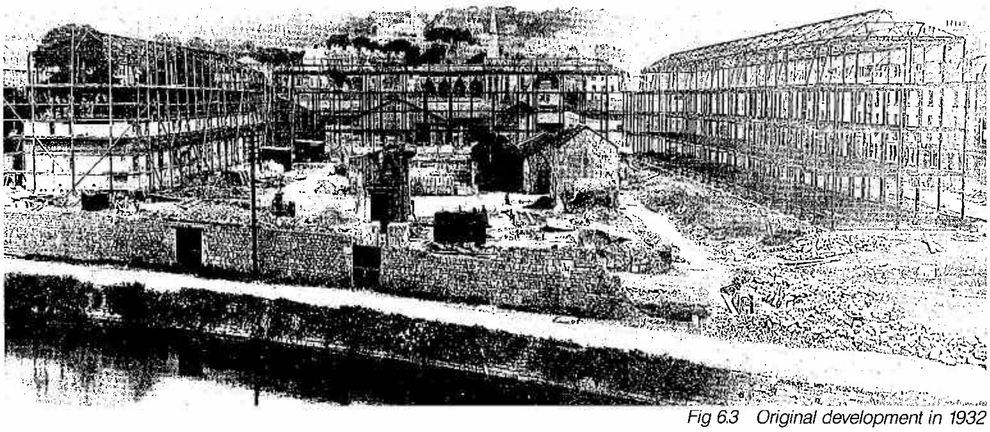


Fig 6.3 Original development in 1932

though war-time bomb damage had led to some parts of the roof being rebuilt using timber trusses. This added to the complexity of tying new structure into the old at the junction between the existing roof and those of the new infill corner blocks.

An assessment of the existing loads and stresses or various members of the steel frame suggested that most members had very little extra capacity. Clearly, the original design had been kept very economical! The structure to the refurbishment therefore had to be planned in such a way that any additional loads could be carried either on strengthened or on new structure. At the same time a site investigation was carried out revealing that the site was built on approximately 3m of fill, overlying soft alluvial clays, river gravels in layers of various thickness, and Lias clay to depths in excess of 30m. Standing groundwater was located at approximately 2.5m depth. Piling therefore continues to be the optimal foundation solution.

Structural refurbishment

Much of the structural work was associated with changes to the balcony elevations on each block. On Kingsmead North, the balconies at each level were to be enclosed by a new masonry cavity wall incorporating long panels of glazing. This was achieved by supporting the masonry at each level on large section angles spanning between box-section columns which were positioned between each pair of adjacent existing columns. Such a system ensured that the additional loads were supported only by the new structure.

Work on Kingsmead East and West included the removal of the existing recessed external wall at ground floor level and the construction of a new external wall on the balcony line, thus enlarging the ground floor to include the balcony area. (Fig 6.5 a, b) This was extended above to form a masonry parapet to the now individual balconies at first floor level. In all cases, additional piles needed to be installed along the balcony line to carry the additional loads. This necessitated the removal of existing tie beams to the columns, and so the provision of temporary lateral restraint to the existing columns was yet another factor to be accommodated in the design. A new system of ground beams was then cast connecting the new piles to the existing piles and ground beams. The limited access, restricted headroom and proximity to both existing and temporary structure led to the choice of 450mm diameter, bored and cast-in-situ piles that could be installed by means of a simple tripod-mounted percussion rig.

Kingsmead East and West further required the insertion of new internal staircases both to provide fire escapes to current standards, and to enable the existing communal balconies to be sectioned off for the exclusive use of individual flats. This was achieved by first propping the existing suspended floors, breaking out these floors to a point beyond the line of the new staircase, constructing the in-situ concrete staircase within a new loadbearing blockwork enclosure and, at each floor level, casting an in-situ make-up strip to re-support the existing floors on this enclosure. New walls were again supported on piles and ground beams installed by manoeuvring the rig inside the building itself. This proved very successful, being completed more quickly than anticipated.

Kingsmead North, a block of warden-controlled, sheltered flats, featured an extension with an attractive curved facade (Fig 6.6), to incorporate a lift and a lobby area at each floor. The structure generally comprised in-situ concrete floors, cast to become monolithic with the areas of pre-cast connecting floors, supported on a combination of new loadbearing masonry and in-situ concrete frame. In order to create the open lobby area at each floor, it was necessary to remove one of the existing columns. This was achieved by using the structure of the new extension to support two bays of the existing balcony.

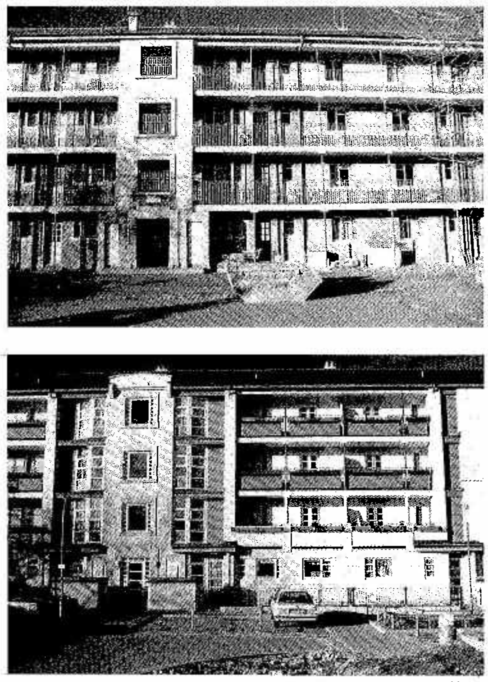


Fig 6.5 Elevation of Kingsmead East
(a) Before refurbishment
(b) After refurbishment

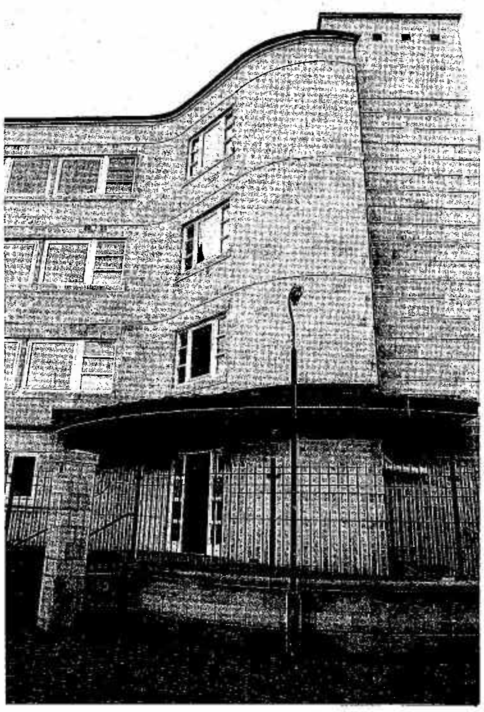


Fig 6.6 Curved facade of new entrance lobby

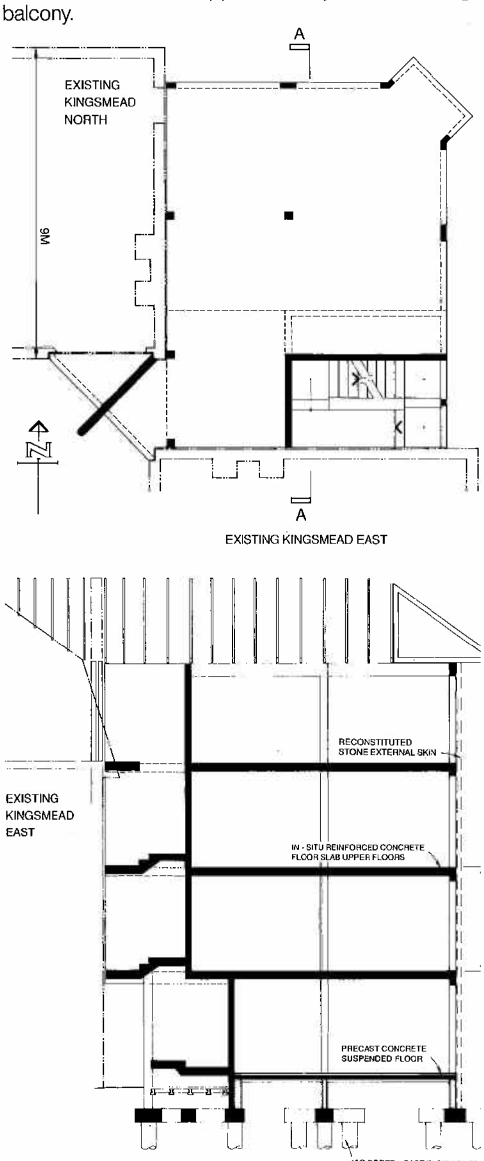


Fig 6.7 (a) Plan on first floor of new corner block
(b) Section through corner block

Fig 6.8 Elevation of new community room

The additional community room, a single storey heavily glazed timber framed building, featured large areas of exposed timber inside and out.
(Fig 6.8) The slated roof was supported on rafters, onto a central visible roof truss, splayed in plan, and onto a series of perimeter eaves beams. (Fig 6.9) These eaves beams were supported on profiled timber posts which were bolted to the top of a cill-height, reinforced hollow block wall, built off the edge thickening to the raft foundation. Stability was provided by combination of plywood panels within timber frames and internal masonry walls.

Installation of services

With the North block primarily for the elderly, and the East block to house families, the differing needs of tenants dictated that services installations for each block be considered independently. Where possible, however, every effort has been made to achieve continuity of hardware for architectural, aesthetic and maintenance reasons.

New structural work

The newly built corner blocks comprised a fairly simple masonry clad in-situ RC frame, made up of rectangular columns supporting flat slab upper floors and a timber trussed rafter roof. Stability was provided by shear walls around the new in-situ concrete staircase. (Fig 6.7 a, b) The design and construction of these presented few problems beyond the integration with the existing buildings on either side.

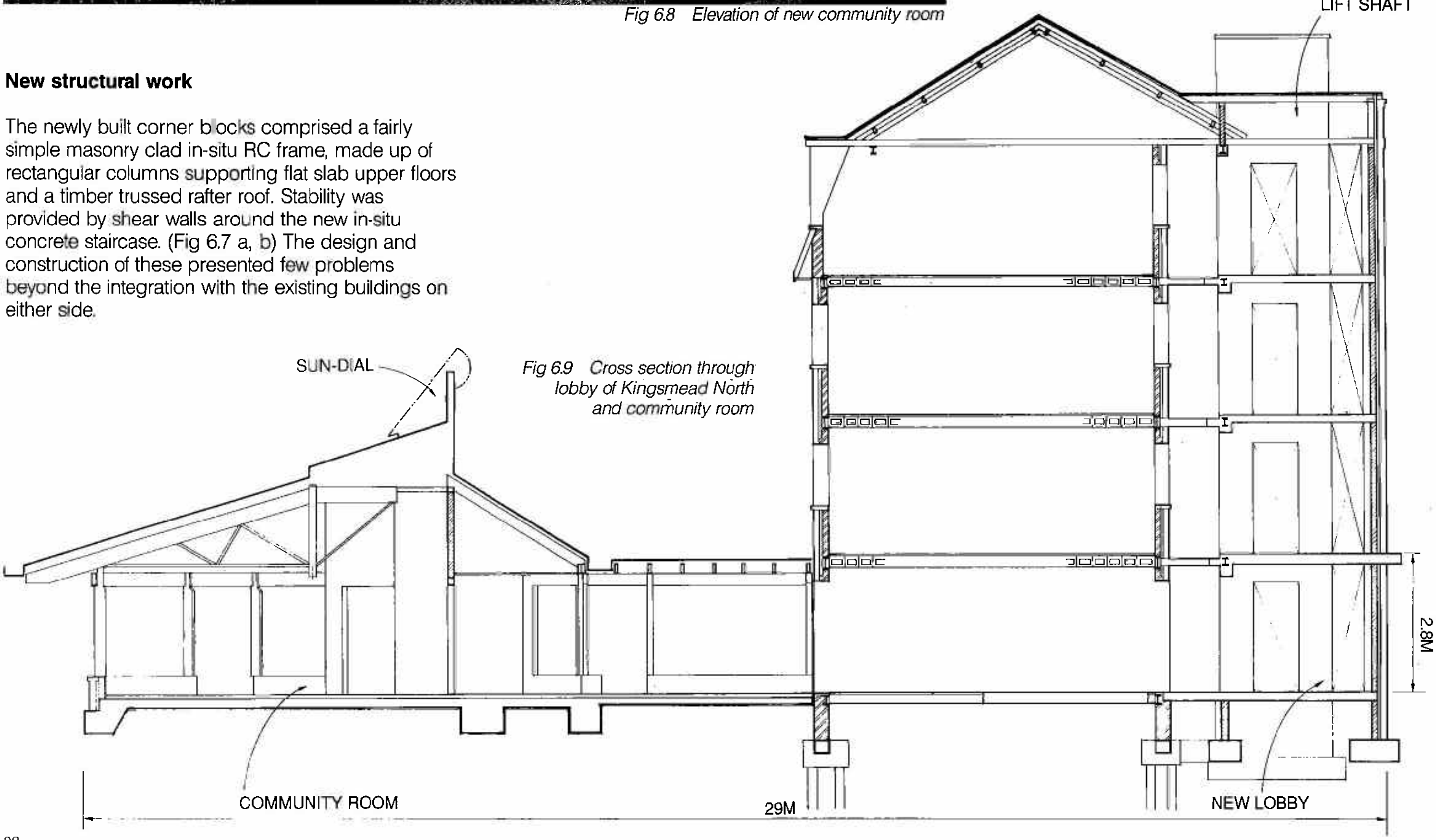


Fig 6.9 Cross section through lobby of Kingsmead North and community room

The existing mechanical, electrical and drainage services were not only uneconomic to run, but were extremely antiquated and failed to comply with current regulations. The architectural necessity to reorganise the internal room layouts to maximise usable floor space, and consequently the structural requirements to alter the building form, resulted in the need to strip out completely the existing services. It was thus necessary in this case to design proposals for full reservicing of all blocks.

Work on the East block included the installation of a gas fired heating system, provision of metered water supplies, internal hot and cold water distribution within each flat, and a metered gas distribution from the main (under the public highway) to each flat. Further, the new design made provision for mechanical extract ventilation to all kitchens and bathrooms, internal drainage from all appliances, lighting and small power installation, and the installation of cabling for both telephone and television, including options for satellite systems. Emergency lighting, standard lighting and heating on the communal staircases were all connected to the landlord's electrical supply.

Due to limitations of space, it was not possible to satisfy the Gas Board regulations in siting gas supplies and meters in the North block. Flats within this block therefore had to be entirely powered by electricity. The heating system in each flat utilises off-peak electricity by means of electric storage heaters, and mains water supply feeds an off-peak controlled hot water storage cylinder before distribution to appliances. The small power, lighting, telephone and television systems are all similar to those of East block, but in addition the North block flats have a warden call system. This comprises pull cords within each room and a central call module located within the hall, thus providing a round-the-clock resident/warden link. A fire alarm system has also been provided. A communal laundry within North block, for the use of North block residents only, is connected by a corridor to the community centre, the latter incorporating full kitchen and lavatory facilities. In order to enable residents to move around more freely, a lift has been installed within the entrance lobby extension to the North block. Changes in level inside the block have been ramped to facilitate full disabled access.

The original main drainage systems running to the north and east of the development used the now outdated combined system. The new drainage scheme installed has separate foul and surface water discharge in accordance with modern practice and thereby goes some way to relieving the public foul sewers of rainwater surcharges.

Successful phasing of works

Problems of allocation of funds and temporary relocation of residents called for a careful, planned phasing of construction. The appearance of the now completed Phase 1 is very pleasing, (Fig 6.10) in stark contrast to the appearance of the as yet, unaltered areas. Work on phases 2 and 3 is due to commence in late 1990.

The project, whilst not requiring technically innovative design, does offer the challenge of designing works to be constructed in tight spaces within the existing buildings. This, together with the appreciation for structural and architectural requirements, has ensured that the refurbishment of Kingsmead Flats has been a most challenging and rewarding project, one which could not have been achieved without a high degree of closely-monitored, inter-disciplinary co-ordination. We look forward to the similarly successful completion of the remaining phases.

Geoff Werran and Tony Williamson

Fig 6.10 View of new NE corner block

From Car Repair to Designer Wear in Brompton Road, Kensington

Project data

Client	Katherine Hamnett/Aguecheek Ltd
Architect	Foster Associates
Structural Engineer	Buro Happold
Services Engineer	Buro Happold
Quantity Surveyor	Monk Dunstone Associates
Management Contractor	Woolf Construction Management Ltd
Project Value	£500,000
Completion Date	1986

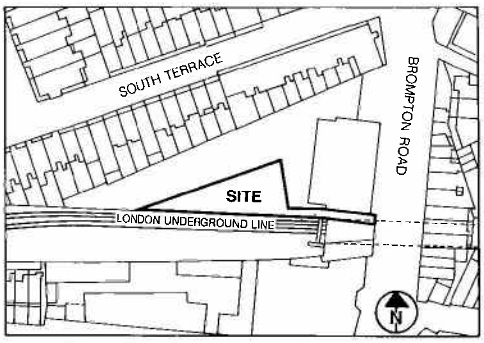


Fig 7.1 Location of development on Brompton Road, London

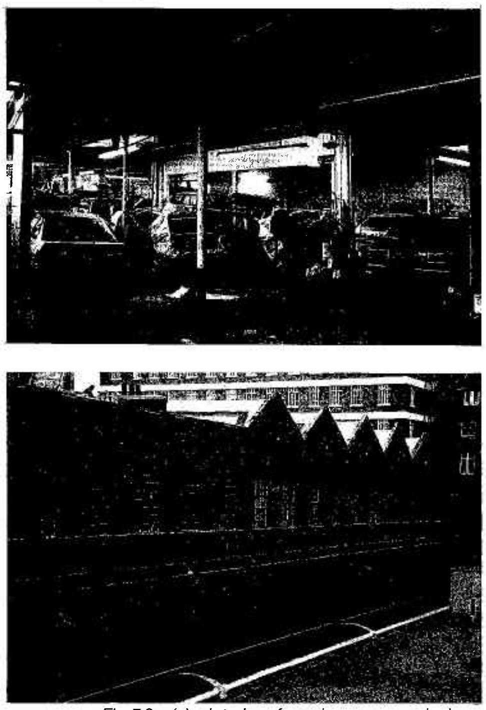


Fig 7.2 (a) Interior of previous car repair shop (b) South elevation overlooking underground line

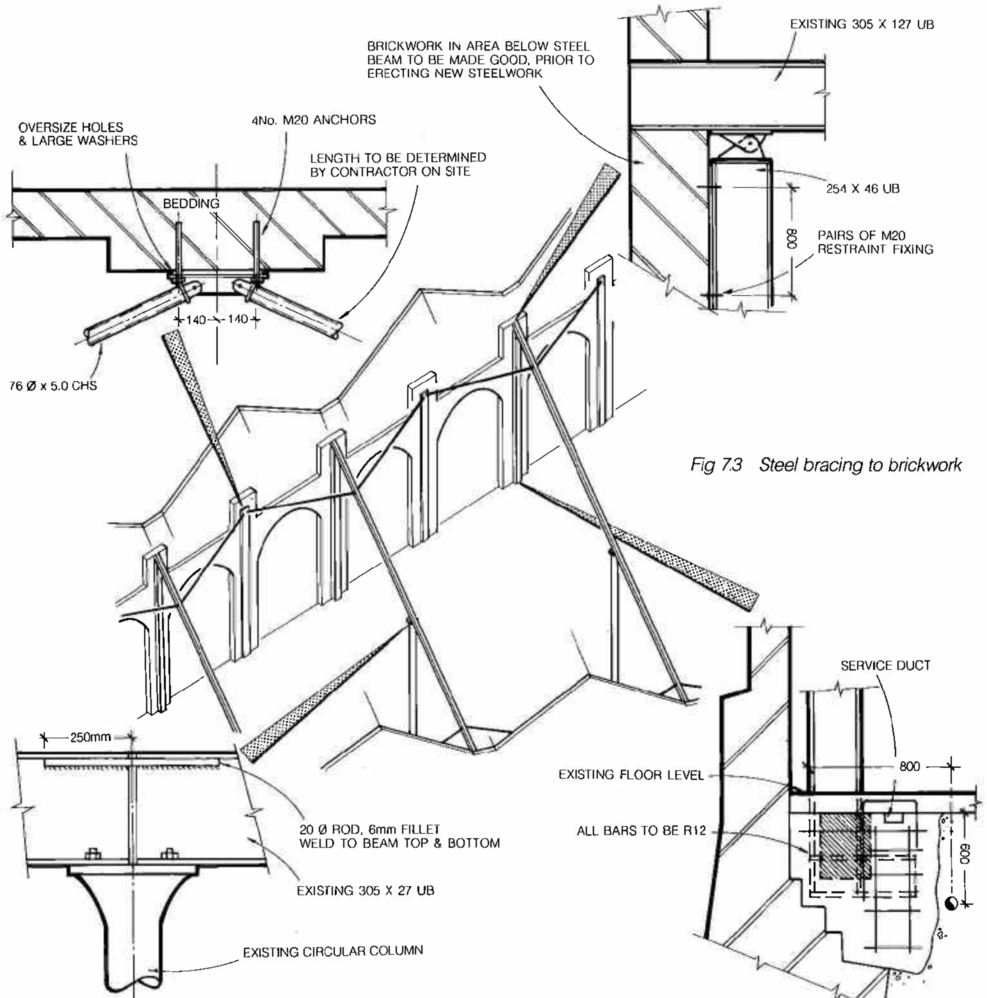


Fig 7.3 Steel bracing to brickwork

A dilapidated, triangular-shaped two storey car repair shop, located adjacent to a West End underground line (Fig 7.1) and connected to Brompton Road only by a long passageway, seemed at first an unlikely setting for a 'high fashion' clothes shop. (Fig 7.2 a, b) With the roof leaking profusely, and the only external wall not propped by a neighbouring building, the building looked ready to slump onto the adjoining Circle Line railway. Furthermore, existing building services amounted only to a perforated rainwater pipe. The prospect of turning this particular site into clothes designer Katherine Hamnett's first shop was somewhat daunting. The rapidly approaching fashion shows left little time for major reconstruction. However, in only a very short period, Buro Happold, as structural and services engineers, together with architects Foster Associates and Woolf Construction Management as management contractors, were able to complete the successful transformation of the premises.

In an eleven week contract period, asbestos was found and removed, existing internal walls and first floor were completely stripped out, internal strengthening steelwork was erected, the roof was recovered, a new concrete ground floor was laid, the wall adjoining the Underground was strengthened and repaired, new mechanical and electrical services were installed and the shop fitted out.

Structural alterations

The removal of the first floor and the 25mm tie rods would have resulted in the wall overlooking the Circle Line becoming unstable. The proposals therefore required very careful co-ordination of temporary and permanent work to meet the stringent requirements imposed by London Transport for work over their lines. Internal cantilever steel columns were provided to stabilise the roof plane, prop the walls and as a primary support for the scaffold cage over the underground line. All work on the erection and removal of the scaffold and safety nets was carried out at night, which then allowed daytime access for strengthening and repointing of the wall. Internally, new strengthening steelwork was designed to be simple and elegant and in accord with the existing steelwork and new building services. (Fig 7.3)

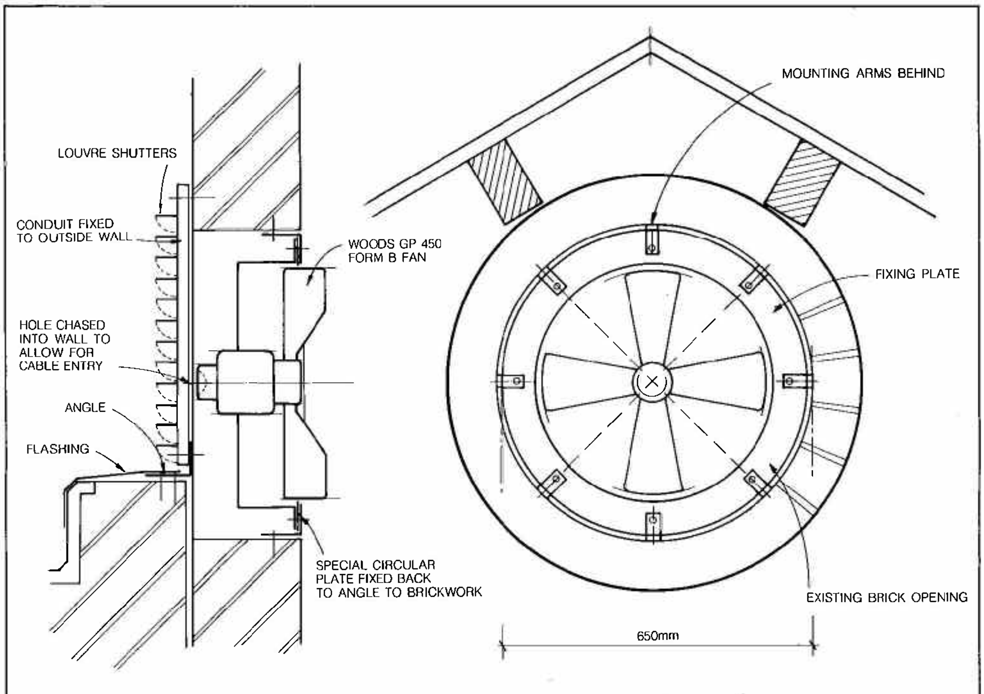
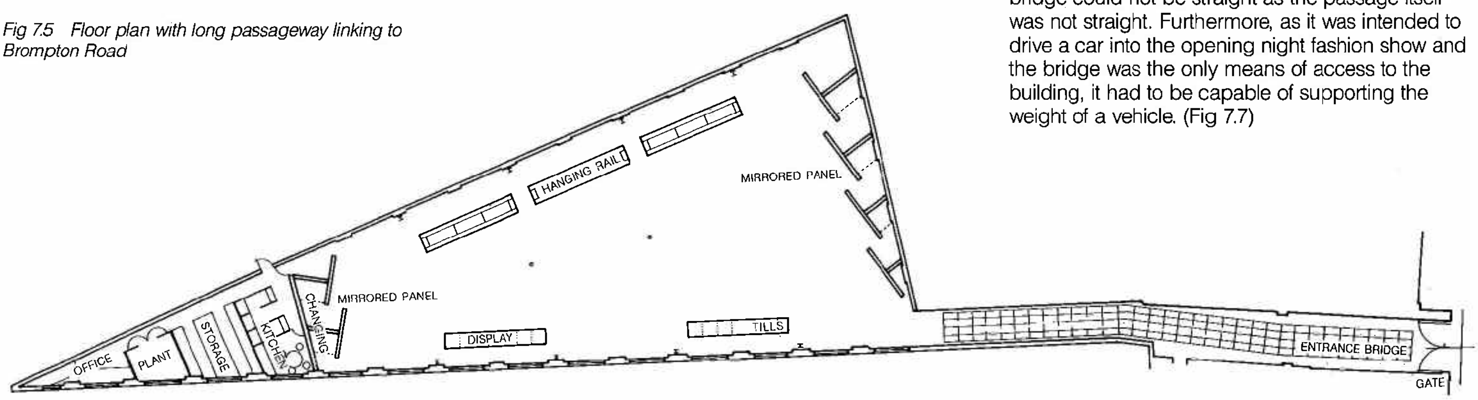


Fig 7.4 Fans and louvres replacing "bullseye" windows

Fig 7.5 Floor plan with long passageway linking to Brompton Road



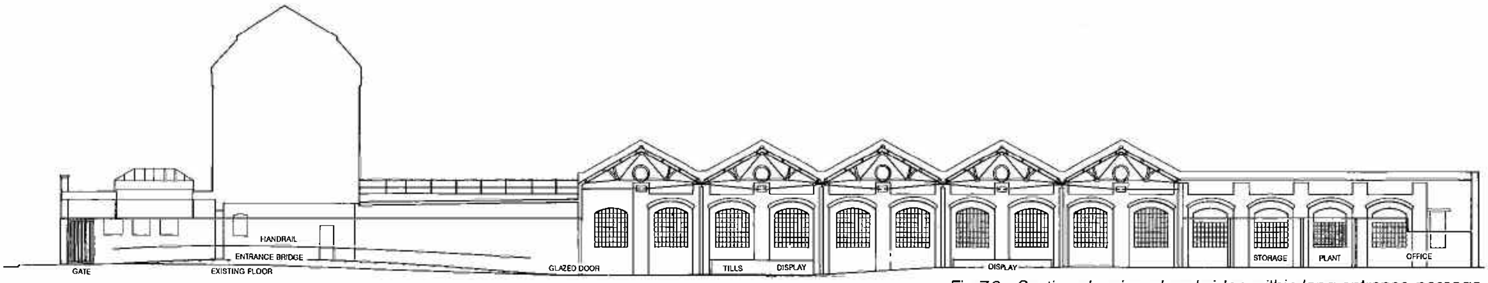


Fig 7.6 Section showing glass bridge within long entrance passage

Services requirements

With large areas of single glazed roof lights and windows and a poorly insulated structure, both substantial winter heating and summer ventilation were required. To achieve the architect's desire for 'an elegant warehouse' appearance for the building, services engineers designed a heating system utilising bare pipes and finned tube. Pipework anchors, supports and fixings were specially designed to give the desired appearance. Ventilation was provided by replacing high level 'bulls-eye' windows with propeller fans and individually designed and fabricated louvres. (Fig 7.4)

Lighting was an important feature of the completed building. The main space was lit from vertical and horizontal track mounted on the structural steelwork. To overcome the depressing feeling generated by roof lights at night, external floodlights were provided. These were controlled to come on at dusk lighting the shop through the roof lights.

Innovation in glass

It is unusual for a shop to be connected to the outside world only by a long passage. (Fig 7.5) To draw the attention of passers-by, the installation of a glass bridge running the full length of the passage and lit from below was proposed. (Fig 7.6) The bridge could not be straight as the passage itself was not straight. Furthermore, as it was intended to drive a car into the opening night fashion show and the bridge was the only means of access to the building, it had to be capable of supporting the weight of a vehicle. (Fig 7.7)

Fig 7.8 Long walkway of glass bridge

Fig 7.9 Side mirrors within finished interior

The design of the glass and its immediate supporting structure was carefully considered and fabricated to meet requirements varying from goods servicing to pointed high heels. Ordinary float glass with finely ground and profiled edges was used to prevent crack propagation and increase the resistance to impact loads. The 25mm thick glass had a load capacity of approximately 20 kN/m², which is clearly more than the normal 5 kN/m² for shopping. Impact loads such as that from a dropped spanner or similar hard object were the critical condition. The tolerances on the supporting steelwork were very tightly controlled to avoid in-situ curvatures in the glass causing excessive stresses which could have arisen if normal steelwork tolerances had been used. A neoprene cushioning bearing was also provided to isolate the glass from the supporting steelwork.

The bridge represented an important feature architecturally (Fig 7.8) and to achieve the desired effect required the combined and co-ordinated efforts of the architects, structural and services design engineers, support fabricators and installers, glass manufacturers, management and services contractors. The design and installation of this bridge perhaps typified the effort put in by both the designers and contractors throughout the project.

To turn a dilapidated car repair shop into a spectacular fashion shop (Fig 7.9) required an extraordinary amount of imagination, co-ordination and co-operation by a large number of people. Such a commitment should, and hopefully will, in the future, be applied to unlikely buildings and sites wherever they may be.

Peter Brooke, Michael Dickson and Mick Green

Control of Ground Water Rise at the Souk Al Kuwait and Souk Al Kabir Buildings, Kuwait

Project data

Client	Kuwait Real Estate Company
Consulting Engineers	Buro Happold
Quantity Surveyors	MEQS
Main Contractor	Consolidated Contractors Co (Kuwait)
Cost	£475,000
Completion Date	December 1987

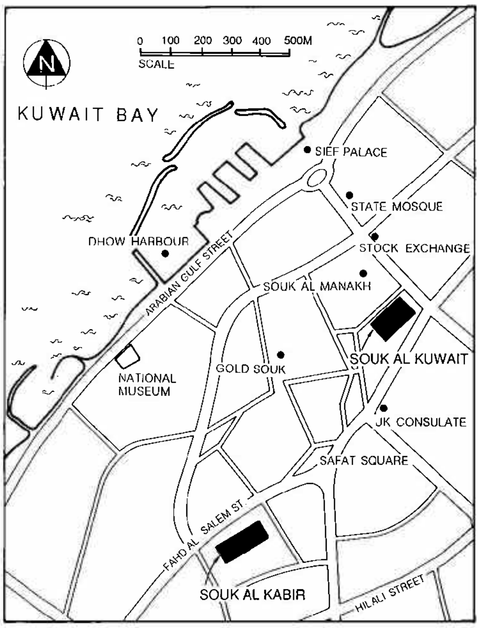


Fig 8.1 Plan showing location of Souk Al Kuwait and Souk Al Kabir in Kuwait

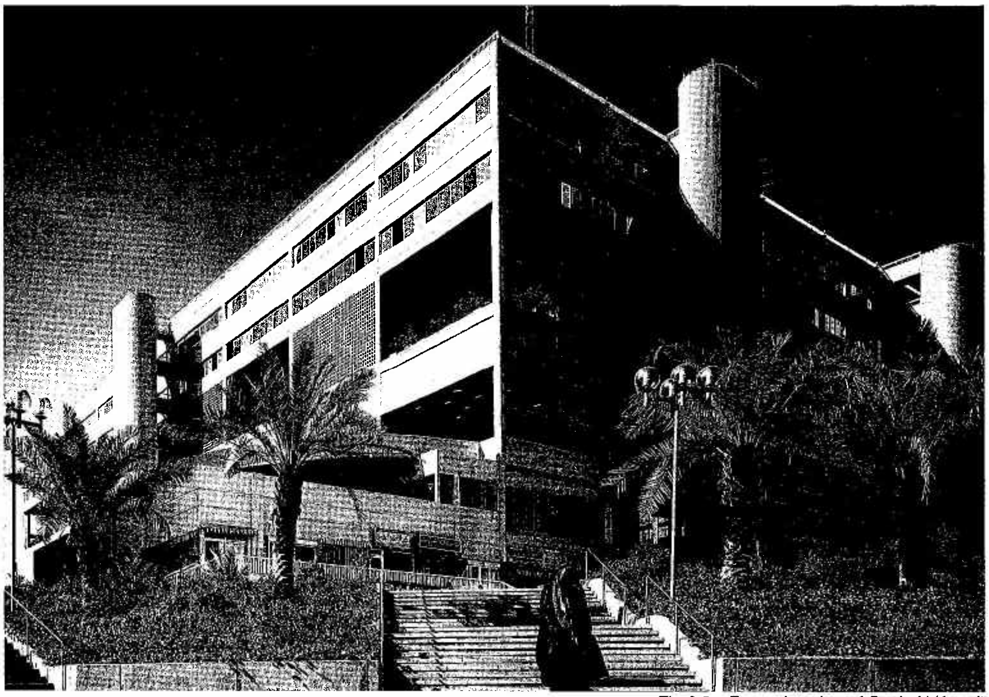


Fig 8.2 Front elevation of Souk Al Kuwait

Many cities in both developed and developing nations are having to face problems resulting from a change in ground water level, the many causes of which are invariably man made. In developed nations, the rise in ground water level is often due to a reduction in the demand for water taken out of underground aquifers, for example for industry as in London. In developing nations, the cause is generally development itself, whereby a significant proportion of the generated water consumption is brought from outside the city and finds its way into the ground through a variety of means, including leaking water mains, septic tanks and irrigation. Conversely, in such countries an increase in storm water drainage, use of paving and the introduction of wells may also be responsible for a fall in ground water level.

The problem of ground water rise in Kuwait is acute, with approximately 90% of water requirement being met by sea water desalination plants. The city of Kuwait has grown considerably since the early 70s, and water which was formerly delivered by tanker is now largely supplied through underground water mains. A significant proportion of the water supplied finds its way into the ground, and as a result the ground water level has risen substantially. In the old city area, near the coast, the rise in water level has been approximately 1.5m over this period, and in new suburbs further inland the rise has often been 5m and more.

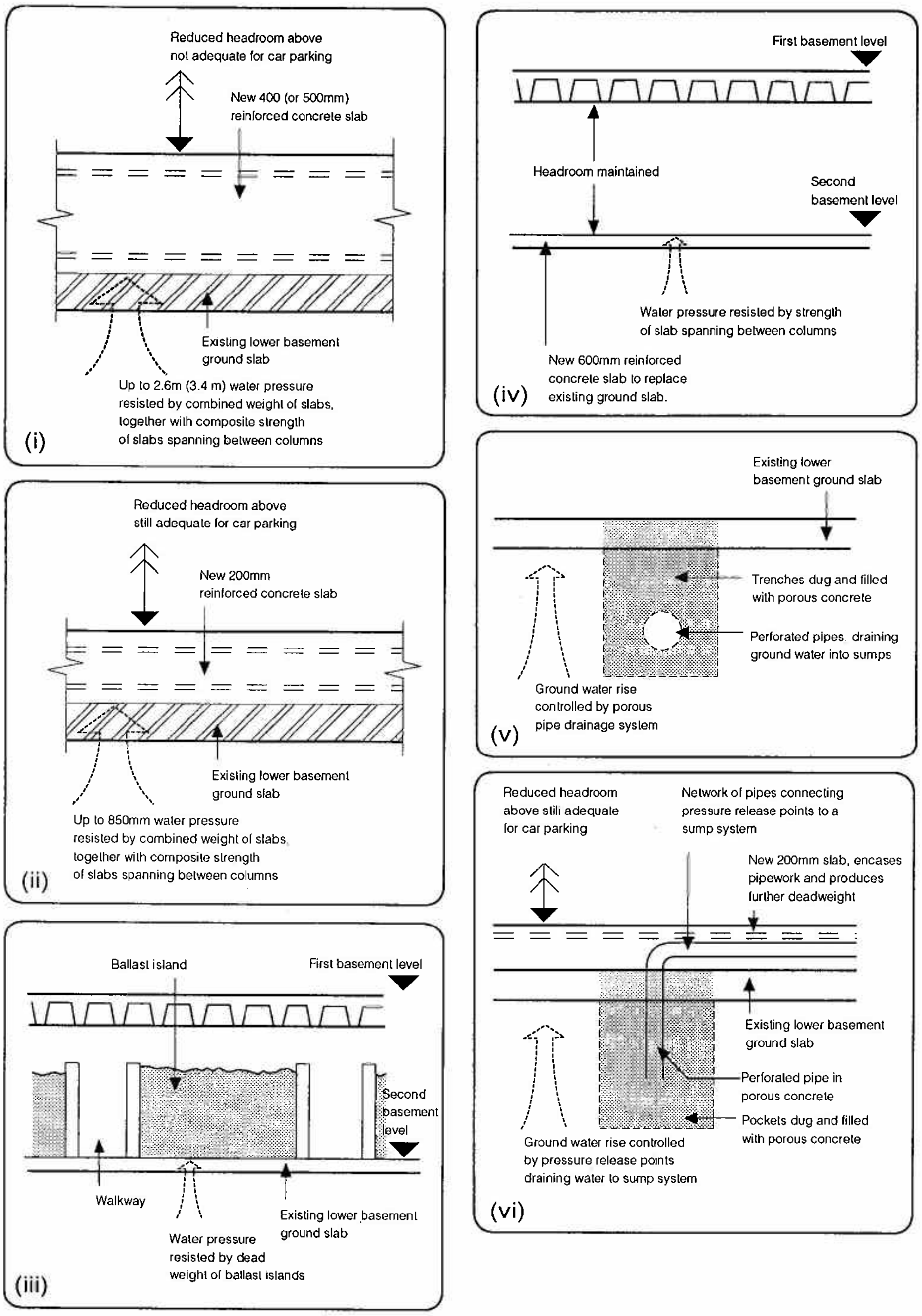
The consequences of this change in ground water level on buildings with basements have in some cases been extremely serious. Ground bearing slabs, which were formerly at least a metre above water table level, and not designed for water uplift pressures, have both leaked and failed as the water rose to a level where the uplift pressure exceeded the weight of the slab. Further, it was not the practice in Kuwait to provide buildings with ground drainage systems to drain off occasional excess water, largely because rainfall is low. Whilst there are occasional heavy rain storms, average annual rainfall is often less than 100mm, and rarely more than 200mm. In building developments it has now become the engineer's responsibility to mitigate against the effects of these ground water rises.

Leaking basements at the Souks

The Souk Al Kuwait and Souk Al Kabir buildings were built by the Kuwait Real Estate Company between 1973 and 1975. (Fig 8.1) Skidmore Owings and Merrill provided the conceptual design of these buildings, with detail drawings and engineering being carried out by local consultants. They were the first such 'complexes' which nowadays are common in the Middle East. These two significant buildings each in excess of 60,000m², are comprised of two floors of basement car parking, shopping on ground and mezzanine floors, multistorey car parking over the shop levels, and offices at top levels. (Fig 8.2) At the time of construction, the water table had been around 1.6m below the underside level of basement slab, a simple ground bearing slab with no waterproof membrane, in both buildings.

During early 1986 ground water began to seep into the lower basement of the Souk Al Kabir. Whilst initially water ingress could be controlled by simple housekeeping measures, with occasional sweeping of water into sumps, the intensity of seepage became progressively greater and it was clear that action should be taken. Buro Happold were asked to assist, and piezometers were installed around both the Souk Al Kuwait and Souk Al Kabir buildings to monitor ground water levels. Over a short period of about six weeks the ground water was seen to be rising progressively adjacent to both buildings. By late 1986 the water table had reached nearly 200mm above top of basement slab level in the Souk Al Kabir building and to within the basement slab thickness in the Souk Al Kuwait building. There was concern in relation to this water ingress and its consequences to both buildings, simple housekeeping measures no longer being sufficient to control the problem in the Souk Al Kabir. As a precautionary measure the lowest basement of this Souk was closed to parking.

A report considering the effect of further rises in water table, the range of factors contributing to its rise over recent years, and the action which could be taken to counter the effects of further rises was then



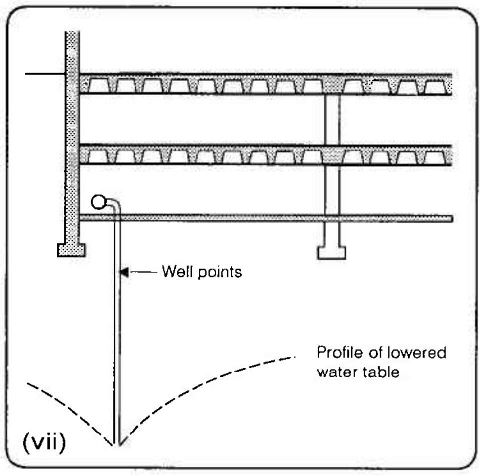


Fig 8.3 Solutions considered in control of ground water rise

prepared by Buro Happold. Whilst measures could be recommended for various rises in the water table, solutions varied widely in cost. It was therefore most desirable to obtain a well considered and researched view on the projected future rise in water table. The Kuwait Institute for Scientific Research (KISR) had carried out an extensive city study on the problem of ground water rise, but this had been undertaken confidentially for the Ministry of Electricity and Water (MEW) and permission to release it to other parties was first required. The MEW were reluctant to release copies of the city study, which ran into many volumes, but subsequently agreed that KISR be allowed to provide specifically requested information to Buro Happold, including such data as range of ground permeability, water purity, and projected water table rise in the commercial areas of Kuwait City.

A range of solutions

The ground study information and water table level projections provided by KISR enabled Buro Happold to evaluate a number of alternative proposals for dealing with the problems created by water rise, namely resisting water pressure on the ground slab, and preventing ingress of water into the basement. Seven alternative solutions, as displayed in Fig 8.3 were considered:–
(i) to case a 400 to 500mm reinforced concrete slab over the existing basement slab and close the car park;
(ii) to case a 200mm slab over the existing slab, and adjust services to give adequate headroom – this solution providing resistance only until the ground water level rises to 850mm above existing slab level. A greater rise would lead to structural failure of the ground slab due to uplift;
(iii) to provide a series of deadweight ballast islands with corridors for personnel, but closed to traffic – a

solution which could have provided the additional measures needed if the second solution above had been used but the water table had eventually risen greater than 850mm;
(iv) to replace the existing 200mm slab with a new 600mm reinforced concrete raft slab to provide resistance to any rise in water level;
(v) to provide a ground drainage system below the existing ground slab;
(vi) to provide a drainage/water pressure release system within a 200mm thick additional slab case above the existing slab;
(vii) the use of well point de-watering.

The rise in water table at both buildings was projected by KISR to be around 1m in the next five years. Therefore the second solution whilst the cheapest, could be found in the near future to be inadequate. On the other hand, the fourth, the most costly and time consuming, would be excessive. The Kuwait Real Estate Company felt that existing and projected car parking demands in Kuwait City obligated them to continue to allow the lower basement to be used for parking, and therefore the first and third solutions were inappropriate. The last solution was never seriously considered because of the unknown long term effect of reduction in ground fines on the foundation of these and surrounding buildings.

Of the two remaining preferred solutions, to provide a ground water drainage system below the slab (v), or to provide a pressure release system within an additional thick slab (vi), the latter was most favoured by Buro Happold. This was the most passive ground drainage system, since water would be forced up into the pipework rather than drained from under the slab.

Agreement was reached with both client and Authorities, and the detail design was prepared on the basis of a possible eventual rise of water table to 2m above existing basement slab level. This was felt by both Buro Happold and KISR to be a conservative long term assumption.

Laboratory testing and detailed design

Ground permeability in Kuwait City was assessed from laboratory testing of undisturbed samples to be between 0.5 × 10−6 and 5 × 10−6 m/s. Using the upper bound figure in a flow net calculation for a 2m differential in water level, a total flow of around 40 litres per second was predicted for each building. Whilst the rise of a further 2m in water table level was not anticipated for a long time, and the calculated flow was a conservative figure, it was decided to install two pumping chambers, each with pump capacity of 30 litres per second. The provision of two chambers and pumps provided standby capacity in case one failed, and the initial overcapacity allowed intermittent pump working for a small water table rise.

Calculations of flow for the individual pressure release drainage pipes, which are encased within a porous concrete surround below the old slab level, were made on the assumption of a blockage at adjacent pressure release points. The same procedure was followed for calculations of uplift pressure on the slab between pressure release points.

Preparing for construction

After tendering, a contract was let in June 1987 to Consolidated Contractors Company (Kuwait). By this time the water table at the Souk Al Kabir building had risen to 350mm above existing ground slab level, a level near to which the slab would be expected to start lifting, though serious damage to the ground slab would not be expected to occur until the water level reached 550mm.

As there is a high demand for car parking spaces in Kuwait City centre, work in the basements had to be carried out as quickly as possible. As soon as the second level basements were closed to traffic, sandblasting commenced to remove oil and dirt and roughen the existing slab surface for bond. This was a hazardous operation in the poorly ventilated areas, especially in store and plant rooms around the perimeter, where it became impossible to see for dust, and lighting had to be protected from flying sand particles. The sandblasting teams, mainly Afghanis and Indians, generally preferred to wrap their faces in cloth rather than use the filter masks provided. Eventually they were persuaded to wear full face masks, particularly after one foreman suffered a minor stroke!

At the same time, trial mixes for porous (no fines) concrete were carried out using full size mockups of de-watering points. A block of porous concrete was cast around a perforated plastic pipe and lowered onto a bed of sand, then surrounded in more sand which was kept waterlogged. Flow rates from the pipes indicated that cement content did not significantly effect porosity. As crushing strength was not critical, nominal cement and water/cement ratios were chosen. As long as aggregate size was not less than 15mm and not too much water was added which would wash cement off the aggregate, the result was a well bonded and porous concrete. There was some concern that permeability may be reduced over a very long period, by fine particle clogging. It was decided to modify the de-watering points to include access for flushing. The L bend in the new slab became a T (Fig 8.4), with a screw cap and cover plate, and the porous concrete could now be flushed by inserting a high pressure hose into the perforated pipe.

Construction problems

Before excavations could commence it was

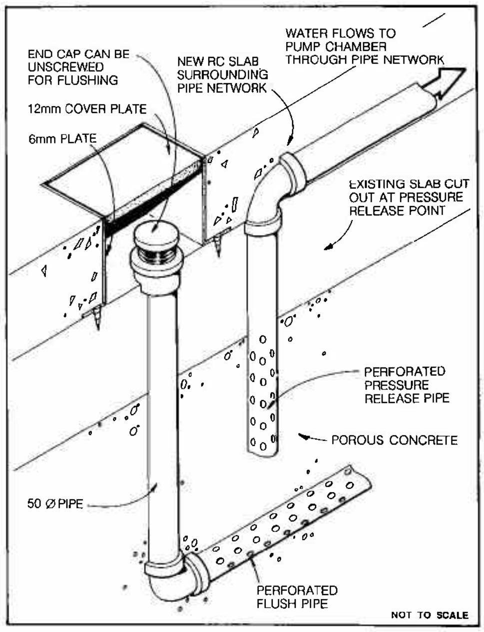


Fig 8.4 Isometric of pressure release drainage pipe

necessary to lower the water table. Temporary dewatering pipes were hand driven up to 5m into the sand, using high pressure water to clear the sand at the tip of the pipe. Consolidated Contractors had assessed the risk of flooding and decided to carry out temporary dewatering for a fixed sum. In fact, they had over-estimated the extent of temporary de-watering pipework and pumping required, but having brought the equipment to site they had to be persuaded not to overdo it, as there was a significant loss of sand around the pipes during installation. Intense local de-watering was required for excavation of the deep pump chambers and it became apparent that reducing the water level in these areas alone was sufficient to allow excavation for the pressure release points throughout the basements.

Throughout the six months work it was necessary to keep the upper basement car parks open. There were two build ups of traffic around the two souks during the day, which were made worse by the reduction in parking capacity. Unfortunately, construction vehicles could only gain access via the upper basements. This slowed down the project significantly and much work had to be carried out at night, as shopping in Kuwait continues until around 10.00pm.

Porous concrete was mixed in small tumble mixers on the spot and the existing slab was made good around the protruding plastic pipes. A network of pipes was then laid and tested (Fig 8.5), and covered in reinforcement in bays, prior to concreting during

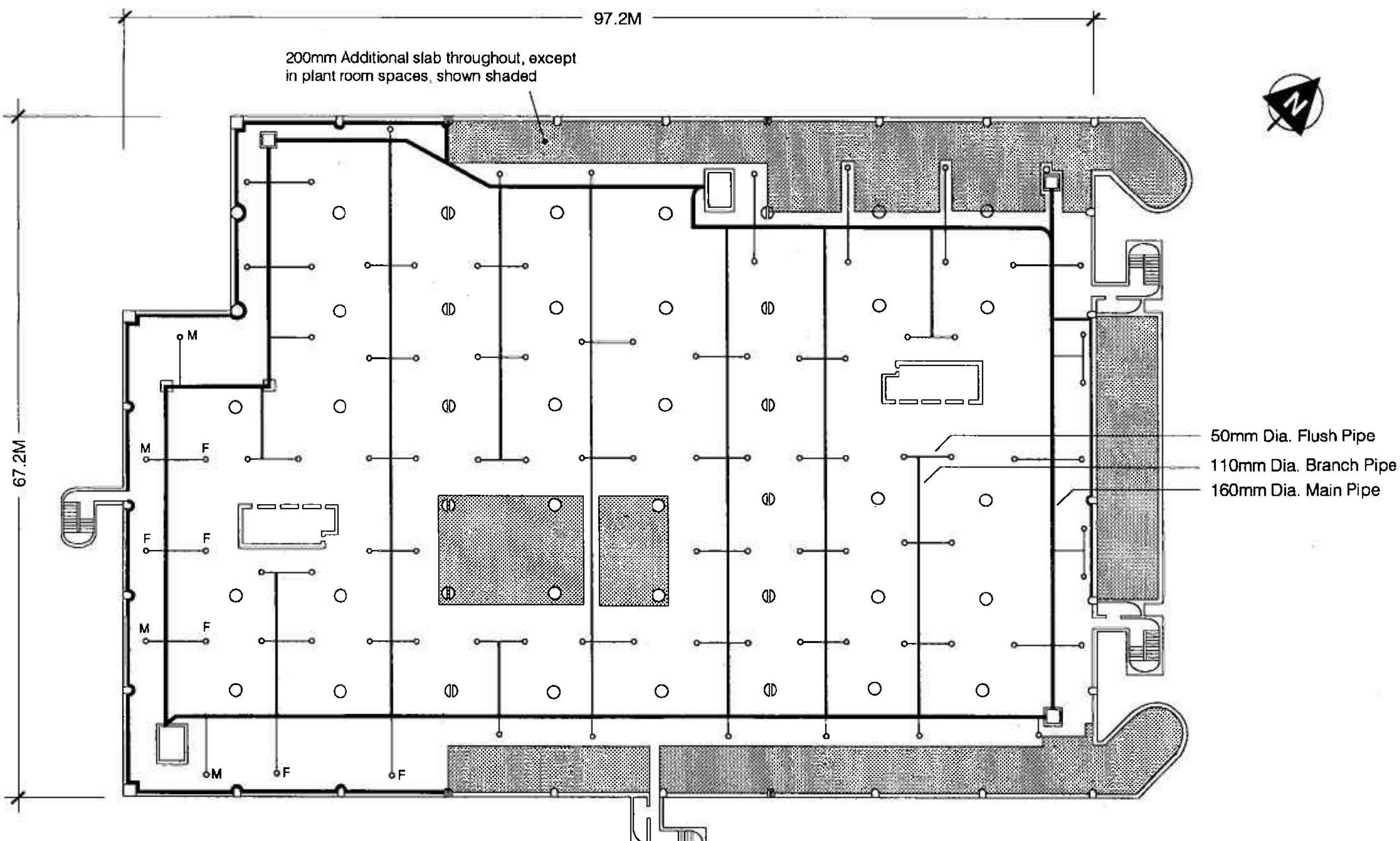


Fig 8.5 Layout of flushing points, pits and chambers at Souk Al Kuwait

the night. All concreting had to be done at night because of day time temperatures and traffic, so allowing the project to finish as early as possible. In Souk Al Kabir it was possible to pipe concrete through ventilation shafts from ground level. In Souk Al Kuwait holes had to be broken through RC walls at ground level and the upper basement slab. Inside the lower basement concrete was delivered by dumper trucks, taking care not to segregate the mix on the way.

There were inevitable complications arising from raising the finished slab level. Firstly headroom was reduced to less than 2m in some places, even after ductwork and pipework was raised as far as possible. As a precaution, all low slung services were painted in bright colours. Secondly the stair and lift cores were now level with, or even lower than the car park. Previously they had been above car parking level for protection from traffic and from flooding. This was resolved by fitting bollards and chains around the cores, and installing local drain points.

Completion of works

A final check of the system was carried out by filling it with water. The pipes into the pump chambers were plugged and, since the rate of escape of water into the sand was relatively slow, it was possible to fill the whole network of pipes from two points at opposite ends of the basement. This took about two hours in the larger of the two Souks. The concern was that plastic pipes may have been broken during concreting, but every flushing point was checked and found to be full. Finally, dewatering was discontinued and the main chamber pumps were connected to the city storm water drains and commissioned.

The successfully completed project demonstrates that rehabilitation need not necessarily be associated solely with the use of a building. Changing external factors may also require a review of the original design, calling on the engineer for a sympathetic solution.

Terry Ealey and Peter Beresford

A Full Repairing Lease

'No generation has a freehold on this earth.
All we have is a life tenancy with a full repairing lease.'
Margaret Thatcher

It is perhaps, unwise to indulge in word play but as we all know, the terms of a covenant offer different meanings to the word repair. 'Put into repair' – the tenant must do this at the beginning of the lease. 'Keep in repair' – means what it says (though it does subsume 'put into repair') – to keep the premises in repair during the currency of the tenancy. 'Leave in repair' – the premises must be put into repair before leaving – regardless of their prior state. Alas, in many cases all of the above are impossible. Some matters have gone too far to allow rectification and, where there is yet hope, we are talking of decades or even centuries before they can be rectified. And the penalty for failure to comply with the covenant is forfeiture of the lease.

Buildings play a fundamental role in the environment. They enhance human resources by providing micro-environments which support the productive, creative, intellectual and spiritual needs. Yesterday's needs were concentrated upon enhancing our capacity to produce – tomorrow's needs must be such as to extend our creativity and our vision. Forfeiture of our tenancy will not fall upon us but upon our heirs and assigns – and even without forfeiture they will have a large inheritance tax to pay.

In the reappraisal and reuse of existing buildings as examined throughout this journal, the engineer is posed with many problems – lack of accurate previous survey material, phasing of works in occupied property, unforeseen technical problems during works and allocation of funds to list but a few. Consideration must also be made however, of wider issues if such development is to continue. What of the hazards of materials themselves, the energy accountability of the structure and the operational costs of the whole?

Hazardous materials

Hazardous to whom, in what measure and in what ways? The need to build on reclaimed land, especially that which has been used for now-obsolete activities presents problems to the site operatives and possibly to the ultimate users of the site.

Some contaminants inhibit plant growth but are not a danger to humans – others may be merely irritant while some may be toxic or even carcinogenic. But there are no rules, no codes of practice, only guidelines. And so it has been necessary to look across at international recommendations to try to establish a set of values at three working levels – those presumed safe, those needing further investigation, and those where remedial action has been indicated. It involves the application of professional judgement – but that is what engineering is all about.

Then there is the building itself – here we are now reasonably well appraised of those materials which pose threats to the safety, stability and durability of the fabric such as high alumina cement, chlorides and alkali-aggregate reaction. But new ones will appear, possibly as a result of an increasing need to use substitute, recycled or reclaimed materials. Hazards to the occupants are only just beginning to surface – as are hazards in disposal. Asbestos we know – but there are more and a tabulated guide to to the selection of others provides useful guidelines. It also makes the task of the designer more difficult and the clients' decisions more crucial than ever before.

In global terms one is very much in the hands of the manufacturers. If we really feel strongly about chlorinated fluorocarbons (CFCs) and their effect on the ozone layer then we preclude materials in which they are used. This may lead to a decrease in the efficiency of say, the insulation, with consequent higher usage of energy. Or we may accept the fact that a less efficient material increases the thickness of insulation needed with a consequent reduction in usable area. These are but some of the questions we must ask. In a recent seminar Christopher Stewart-Smith summed it up (Ref 9.1) by stating these criteria for the use of materials:–
(i) are they reusable and can they be recycled or disposed of safely after use? Marble, stone and brick certainly are, and ships' timbers were used as beams in houses. But what becomes of plastic coated metal when it begins to rust or steel sprayed with asbestos?
(ii) the question of aesthetic acceptability. Traditional materials weather well and blend with their surroundings. Is this true of concrete, for instance?
(iii) the energy required to produce and reuse them.

Energy accountability

That buildings should be designed to minimise energy consumption is now a byword – and rightly so. Not only is energy expensive in purely fiscal terms, it is expensive globally, whether it be the effect on the ozone layer of burning fossil fuels or the need for the disposal of radioactive waste. Much has been written about this, and much more will be. The question that needs to be addressed is how much energy goes into building a building? – in winning, processing and producing the raw materials, in erecting and fitting out even before the building starts to consume energy in its own right. But at present, we have no reliable means of performing the task of energy accountancy. Various methods have been used, including the use of energy statistics. These simply divide the output of a production industry by energy which it consumes. It therefore excludes indirect energy consumption in the form of chemicals, machines and transport. Input-output tables take into account the energy needed to produce one unit of product but, since industries are aggregated it is not always possible to distinguish between different industries making the same product. The use of process analysis is the most reliable but also the most tedious and the least readily available method of energy accountancy.

Of these, input-output methods are the most widely used, and standard economic theory is used to present the data in purely fiscal cost such as energy input/£ worth of product. But surely it is more sensible to consider energy cost/production unit such as energy/m³ of concrete or as engineers, perhaps as energy cost/unit of design parameter.

Consider for instance, the elastic modulus and look at the energy cost of producing one unit of stiffness. The data in Table 2.1 are by no means canonical, but since the energy input figures are all from the same source (input-output) they are at the very least, comparable.

The table shows quite clearly the pre-eminence of timber, though it is interesting to note that brick and mass concrete are also economic in energy terms. The data must however, be regarded with some caution since the energy required to win the raw

Table 2.1 Material Stiffness Energy Cost Data

	Elastic Modulus (MN/m²)	Density (Kg/m³)	Energy (KJ/Kg)	Cost of one unit of E (KJ)
Timber (sawn)	110000	500	1170	53
Mass concrete	14000	2400	720	124
Brick	30000	1800	2800	167
Reinforced concrete	2700	24000	8300	738
Steel	210000	7800	43000	1598
Aluminium	70000	2700	238000	9180

Table 2.2 Thermal Resistivity Energy Cost Data

	Resistivity, r (MK/W)	Bulk Density (Kg/m³)	Energy (KJ/Kg)	Cost of one unit of r (KJ)
Foamed polystyrene	29.4	25	120000	74
Glass wool	23.8	145	150000	91
Timber (softwood)	7.7	500	1170	110
Gypsum plaster	2.7	1200	1800	800
Lightweight concrete	0.7	1200	720	1252
Mass concrete	0.48	2400	720	3600
Glass	0.95	2500	15000	3947
Rigid PVC	6.2	1350	116000	25270

materials is not necessarily included.

Let us put the question in another guise – how much energy do we need to spend to save energy? We need to make a few more guesses here since we can save energy by using a thinner layer of an efficient material or by a thicker layer of a less efficient one. But if we take as a convenient parameter the 'cost' of buying one unit of thermal resistivity r (the inverse of conductivity) we obtain Table 2.2.

As might be expected, rigid polymers are atrociously expensive and even glass and concrete look pretty dismal. Open structured materials such as glasswool polystyrene must of course win, but that then brings us back to the hazardous material problem discussed earlier.

Another means of reducing energy is to use the building as a 'thermal flywheel' storing heat during the day and releasing it at night. The method has been around for some time but appears to have fallen into disrepute. Perhaps we have not found the right parameters; one most obvious parameter is that of thermal capacity – the product of specific heat and density. Unfortunately we have little information, but neglecting the units, the energy cost of conserving energy by this method comes out as 0.27 for mass concrete, 1.9 for brick, 2.1 for timber and 9.2 for glass.

Clearly then, the way in which we do our energy accountancy depends upon the sort of buildings that we want and the sort of performance we expect of them. Data collected some years ago now suggests that in terms of energy, the initial building cost in high rise flats represents some 26% of the total, running costs about 70% and maintenance costs about 4%. More recent data suggests that the initial energy content of a building is much higher. But as shown above, many common building materials have a comparatively high energy cost, and the justification for recycling buildings and building materials deserves further study as indeed, does the whole assessment of the life-cycle energy cost.

Operational problems

But in addition to these there are more recent problems. Legionnaires Disease and the sick building syndrome have received wide coverage in the press. Leaving aside the fact that people differ widely in their susceptibility to each of these, there is little doubt that, so far as Legionella is concerned, the fundamental problem (given sensible design) is that of efficient and effective inspection and maintenance. Some authorities consider that the same applies to sick building syndrome, though here again we have little hard data on such matters as absenteeism, staff throughput, productivity and the correlation of these with the working conditions within the building.

The need to refurbish

An alternative title for this article might have been 'Are we asking the right questions?' I suspect not. Indeed, I suspect that the mistakes we have made in the past, and are still making are not the result of getting the wrong answer but rather that of getting the right answer to the wrong questions. As Richard Lorch puts it: (Ref 9.2) 'The most significant challenge is reorientation. The past approach was piecemeal ... if air pollution was the problem regulations were made ... if asbestos was the problem the industry responded with a programme for its controlled removal. An integrated approach is necessary which considers the environment at global, transnational, national, regional, local and individual levels.'

What then, is the role of the consulting engineer? The same as it is in design and construction, to ask the right questions and validate the answers. We must also be honest and admit that in the past our approach, too, has been piecemeal, we have considered each problem only as it arises. But in doing so, we have built up a wider understanding of the problems and a more coherent picture is beginning to emerge.

Bill Biggs

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