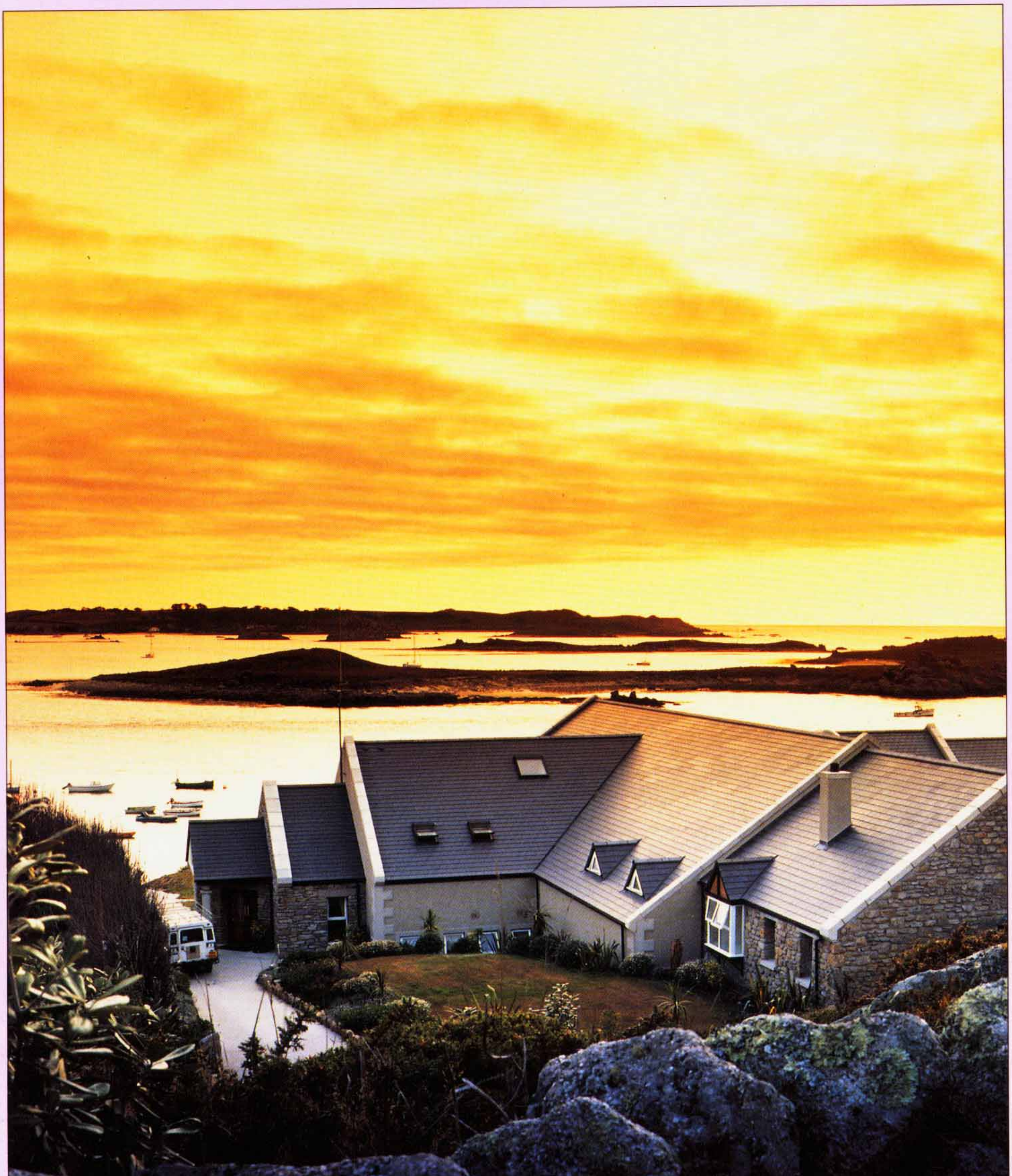
CONCRETE QUARTERLY



WINTER 1989

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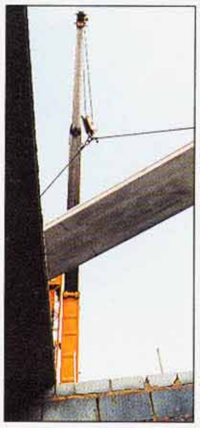
Frontispiece *West Germany's prototype maglev train has already topped 400 km/h on its precision built concrete test track (p.28). Photograph – Schöning Fotodesign.*

BCA



Invited contributors to *Concrete Quarterly* are encouraged to express their own opinions; these do not, of course, always reflect the views of the British Cement Association.

Front cover *Imaginative on-site precasting was one of the solutions adopted to overcome difficulties of supplying the inaccessible site of the new St. Martin's Hotel in the Isles of Scilly. The scheme, designed by architect Alan M. Cook, will be featured in the spring issue of CQ. Photograph – Redland Roof Tiles.*

CAMBRIDGE CLASSIC

CRIPPS COURT, PHASE THREE, QUEENS' COLLEGE

Charles Knevitt BA (Hons) Arch

Charles Knevitt is Architecture Correspondent of The Times. *His books include* Space on Earth, Monstrous Carbuncles *and, with Nick Wates,* Community Architecture. *He wrote and presented Granada Television's award winning documentary* Rebuilding the Region. *This is his second article for CQ.*

Photographs – Trevor Jones

Oxbridge, to most of us, conjures up dreaming spires and groves of Academe, May balls and punting on a summer's afternoon, and the annual varsity Boat Race or gladiatorial contest on the playing field of Twickenham. But think again and the two complementary, if donnishly antagonistic, cities comprise some of the finest post-war British architecture to be encountered anywhere.

In Oxford you can see Sir Leslie Martin's English Faculty Library and Zoology Laboratory; James Stirling's Florey Building for Queen's College; Ahrends Burton and Koralek's Keble College and Catholic Chaplaincy; Powell and Moya's Christ Church Picture Gallery; and Gillespie Kidd and Coia's Wadham College and Blackwell's Music Shop.

Cambridge is no less well endowed: it boasts Casson and Conder's Arts site; Chamberlin Powell and Bon's New Hall at St John's; Sir Leslie Martin's William Stone Building at Peterhouse; and with Colin St John Wilson, Harvey Court for Gonville and Caius; Sir Denys Lasdun's New Building for Christ's College; Howell Killick Partridge and Amis's Darwin College; and Gillespie Kidd and Coia's Robinson College.

The Queens' heritage

On balance, perhaps, Cambridge has more to show of the two. Among the buildings most popular on any itinerary are those by Powell and Moya: the Cripps Building at St John's College, of 1963-67; and a second Cripps Building, in two phases, built for Queens' College in the 1970s. But take a walk along the Backs today and you will notice what might well be a phase three Powell and Moya addition to Queens'. You would be wrong, of course, for they have not worked there for ten years. Bland, Brown & Cole, a local Cambridge practice, were the architects of the multi-purpose hall and sports complex, but they would take it as a compliment to be so mistaken. The iconography, the materials (by and large), even the feel of the place is the same as phases one and two, as if the three were one seamless garment.

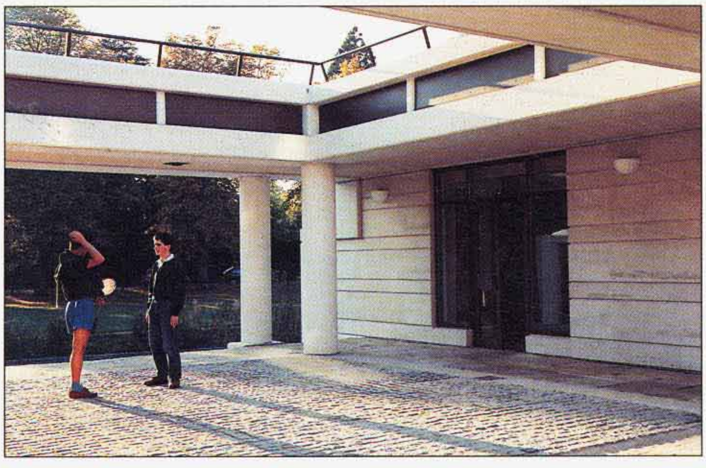
Queens' College's fame goes back more than 500 years to Margaret of Anjou, wife of Henry VI, who thought the city should have a college named after a Queen of England to "laud and honneure of sexe femnine". When Henry was deposed by Edward IV

The new buildings seen across the Drain, from Queens' Green, with the earlier phases behind.

his wife, Queen Elizabeth, took over responsibility and hence the plural, s apostrophe. Its mellow redbrick courts are among the university's finest; a tower in one of them is where Erasmus, the great scholar and theologian, is said to have had rooms while he taught Greek from 1511-14. Sir Basil Spence's Erasmus Building of 1959, the first modern architecture on the Backs, caused a storm at the time, and rightly so; Powell and Moya's work is in a quite different league by comparison.

But mention should also be made here of the curious Mathematical Bridge, which spans the Cam and links the college across its narrow banks. Built in

A terrace spanning the court at first-floor level overlooks the Drain.



timber in 1749-50, it is alleged to have been put together without the aid of nails. Some students took it apart, like some giant puzzle, to establish how this had been achieved, but the job of reassembling it defeated them. And so the present structure is a 1902 copy of the original, firmly nailed together!

Given received wisdom about building in context with immediate surroundings today, Cripps Court phases one and two would – or might – have been very different from what we find. Powell and Moya's recent Queen Elizabeth II Conference Centre at Broad Sanctuary, Westminster, doffs its cap to its neighbours – Methodist Central Hall, Hawksmoor's West Front of Westminster Abbey, and the Palace of Westminster across Parliament Square – while simultaneously holding its own as a typical modernist statement. Lesser architects would have been intimidated by either site. Not so Powell and Moya, nor Barry Brown and Julian Bland except in so far as they took the immediate predecessors at Cripps Court as their talisman.

Enlightened benefaction

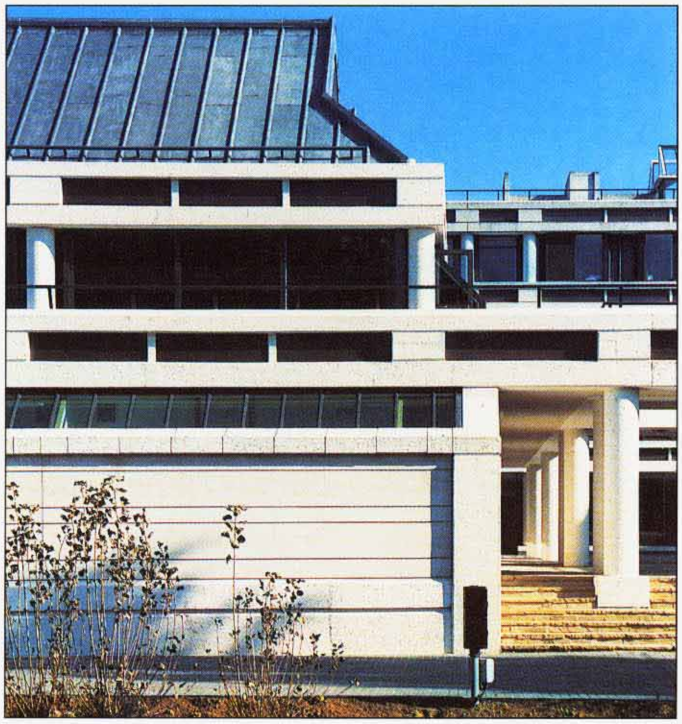
When Sir Humphrey Cripps, a Midlands industrialist and former chairman of Northampton Development Corporation, decided to complete all the proposed works at Queens', in 1984, six local practices were invited to take part in a limited competition; four submitted entries. The third and final phase had been planned, but never built, in the post-oil-crisis inflationary period which had curtailed completion of phase two (dining hall and kitchens, and the balance of residential accommodation left over from phase one).

But unlike some great benefactors of Oxbridge colleges, Cripps believes in a hands-on approach; he does not donate cash, but rather college buildings whose design and form and materials he can influence. Not only is he a keen advocate of modernism (hence the original appointment of Powell and Moya), but he likes to get involved in nuts and bolts decisions. What is more, he believes in quality and is prepared to pay for it, whether for concrete ("Brick! Baked clay – doesn't last," he is once alleged to have said), or bronze for spandrel panels and window frames, handrails and above ground rainwater drainage.

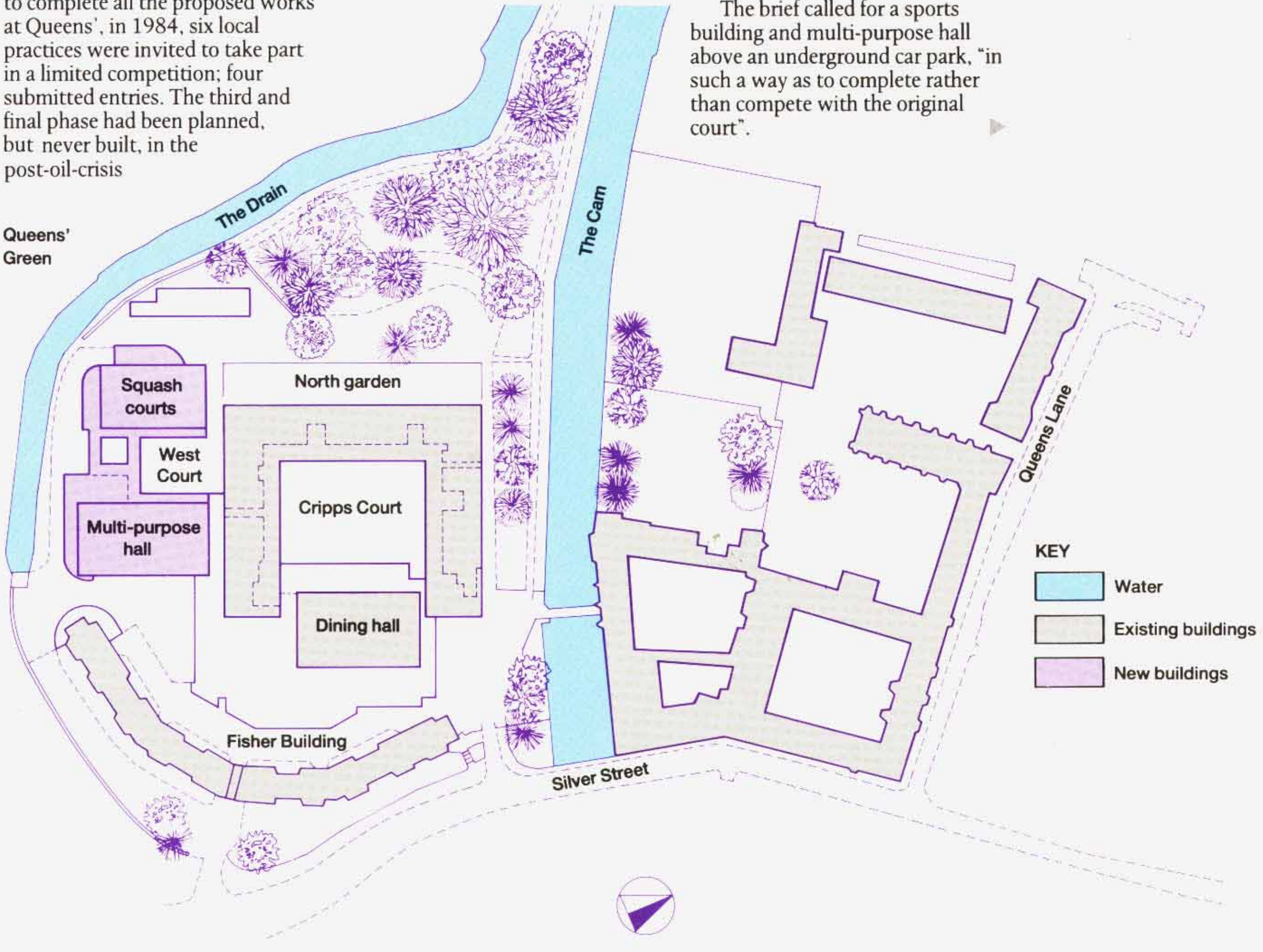
Brief and development

Within months of leaving their former practice, Cambridge Design, Bland and Brown had submitted a winner. They did not have much room to play with, between the existing Cripps Court, and a site bounded by the 1936 Fisher Building, squash courts of the same date, and the site boundary overlooking Queens' Green on the Backs, a conservation area of international fame. They wanted to 'soften' the edge of the earlier phases to the Backs, an approach which won the immediate approval of the Royal Fine Art Commission, and to go for the restricted use of materials as Powell and Moya had done – white Calcite flint concrete in an identical pattern, and with a similar articulation of space, inside and out.

The brief called for a sports building and multi-purpose hall above an underground car park, "in such a way as to complete rather than compete with the original court".



The quality of the crisply detailed, lightly bush-hammered white concrete is exceptionally high.



Externally, the buildings are organized very much as the brief dictated: to the south is the large multi-purpose hall, its bulk and height broken down by four pitched roofs with gabled ends facing across the open court to the smaller sports building to the north, whose gables mirror the multi-purpose hall. To the west is a terrace which spans the court as a bridge at first-floor level; and to the east is the Powell and Moya scheme. On plan, in section and in elevations, it reads as simply as it sounds. The car park is approached by a ramp which sweeps round under the sports building. Eventually there are plans to span a ditch at the west front (rather unromantically called the Drain) to lead out onto Queens' Green on the Backs, giving a second, formal entrance to the scheme. The roof form is a conscious echoing of the gables of the redbrick Fisher Building; the patent glazing and curtain walling are used to help break down the scale of the whole scheme from east to west and south to north.

Three squash courts, one with a glass back wall (so that through the glazed circulation space play can be observed from West Court), form the ground floor of the sports building. In addition, there is what is called the Billiard Room, even though it has been colonized as a gym, with changing rooms next door. On the first floor, a spectators' gallery overlooks the courts, and above the gym is a Table Tennis Room, used more for meetings and receptions. This has fine views over Queens' Green and along the Backs.

The sports building seen across West Court.

A true multi-purpose hall

Across the court is the multi-purpose hall. This is exceptional among halls which bear a multi-purpose tag because, for once, it lives up to its description. Traditionally, such spaces are full of compromises. Given adequate thought, design flair and a handsome budget, at Cripps it has worked out as a fine room equally at home with *Hamlet* on stage, or for a host of other more sporting and social activities. With an 8 m high ceiling, it serves as a badminton court, overlooked by the viewing gallery behind a gridded timber screen.

For parties and other functions, its generous floor area of 12 m by 28 m provides room for more than 250 guests, including the ancillary spaces. But, at the same time, it can serve as a theatre which would grace any provincial town. Retractable seating which slides out from a store at the rear provides a capacity of about 220 when used in conjunction with the galleries. In this form it is suitable for drama, cinema, lectures and concerts, although its acoustics were designed for speech rather than music. The stage can be raised and lowered in five different configurations, providing at its largest an acting area of 8 metres square. This makes the stage the largest in Cambridge, including the Arts Theatre.

A solid screen divides it off from the rest of the hall, at the press of a button. This allows the former to be set up for evening performances while the latter is in use during the day. Alternatively, the stage area can be used for studio productions in the round, with the centre of the stage lowered to produce an acting area of about 5 metres square. When used in this way, entrance is via a separate rear foyer adjacent to the dressing rooms and Green Room. The main entrance and foyer is at the junction where phase three meets the earlier phases at the existing Angevin Room, which will one day provide an interval bar. Theatre-goers enter the main hall at first-floor level, which has a glazed gallery to be used for temporary exhibitions and which overlooks West Court.

The care which has gone into designing the hall extends to the way it is serviced, to get the maximum out of it. The control room is huge, sufficient for all the technical paraphernalia which accumulates for different uses; and a technician's gallery enables every part of the hall to be reached without disturbing the audience or actors. A lighting bridge is incorporated in the flush ceiling which is lowered by means of either manual or motor-driven winches. Stage lighting, sound equipment and audiovisual controls are all state of the art. Barry Brown's amateur acting career – he was president of Footlights in his student days – put him in good

The roof forms of the sports building and the multi-purpose hall echo the gables of the adjacent Fisher Building.

stead to know precisely what is required and how to provide it, even for 18-year-olds to operate.

Construction echoes earlier phases

Construction of phase three follows the lead of phases one and two, in technical, material and aesthetic terms. The site is in the middle of a flood plain and is subject to serious flooding every ten years or so. For this reason the whole building is raised up, apart, of course, from the underground car park which has a floor barrier gate at ground level at the start of the ramp. Plant rooms, a wine cellar and store are provided at the lower level, as well as space for 32 cars.

Above ground the new buildings take up the grid of the earlier phases, including the use of double, round columns, spandrel panels and so on. Underreamed bored, cast in situ concrete piles of 750 or 900 mm diameter are founded in the Gault clay, a minimum of 7 m above the Lower Greensands which are water-bearing. There is a single pile under each superstructure column. The basement slab is constructed from in situ reinforced concrete, which acts as a pile cap and as a solid flat slab to resist the hydraulic uplift pressures. An in situ retaining wall rises from the basement to the ground floor slabs.

The superstructure up to roof level is also in situ reinforced concrete. Floor construction is a combination of solid flat slabs or beams and slabs supported on concrete columns; these are generally circular externally, and square or rectangular internally except where they are expressed. External columns and beams are in white concrete, lightly bush-hammered.

Around the multi-purpose hall are two levels of cantilevered slab galleries. At the level of the upper gallery a builders' work duct runs around it. The roof is supported by steel trusses onto primary trusses which span the width of the hall, as well as providing stability to the duct. Roof construction is of reinforced, aerated concrete panels, supporting a timber and lead finish. Walls to the hall are of in situ concrete or 190 mm thick concrete blocks, so that the whole space acts as an acoustical barrier to the noise generated within, and to keep external noise out.

For the sports hall block, the roof structure is of steel A frames, spanning between reinforced concrete beams. Aerated concrete panels are also used to support a timber and lead finish. Stability throughout is provided by the frame action of the columns. The surrounding terrace at first-floor level, between the multi-purpose hall and the sports hall, is a solid slab with upstand beams supported on circular columns. The lead roofs and handrails act as an air terminal network and form part of the lightning protection system. Steel rods cast into the concrete columns and foundations form the down conductors and earthing rods.

Various old buildings had to be demolished to complete Cripps Court; a new gardeners' compound was erected and a fire path in the Grove was extended to service phase three. The main work got underway with the letting of a substructure contract to Stent Foundations in August 1986 for the piles, temporary sheet piling and excavation. The main contract was let to Sir Robert McAlpine & Sons in March 1987, with practical completion (apart from the kitchen and cycle stores) in March 1989. External works to Fisher Court, the Kitchen Yard, the access road along the Backs frontage to the car park, a substation wall and brick facing to the concrete wall and boiler house at the West Court end of the Fisher Building, were completed during the autumn.

Workmanship and finishes are of a very high order.

This leaves the proposed bridge onto the Backs, an embankment to the Drain, and the reorganization of the Round and Porters' Lodge for a later date.

Construction follows the lead of previous phases in technical, material and aesthetic terms.

A logical conclusion

For a building whose brief required, in essence, a windowless box or boxes, Bland, Brown & Cole have pulled off something of elegance and panache. Theirs was the only competition entry to continue the courtyard theme of Cripps, Queens' and the medieval Cambridge colleges in general, and it works extremely well in relation to Powell and Moya's original phases and the Backs. Seeing the net result, it is hard to imagine an alternative approach to completing what the original architects started almost 20 years ago.

ARCHITECT
- Bland, Brown & Cole

STRUCTURAL ENGINEER, MECHANICAL AND ELECTRICAL CONSULTANT
- Ove Arup & Partners

QUANTITY SURVEYOR
- Davis Langdon and Everest

ACOUSTICS CONSULTANT
- Fleming & Barron

MAIN CONTRACTOR
- Sir Robert McAlpine & Sons Ltd

SUBSTRUCTURE CONTRACTOR
- Stent Foundations Ltd

SUPPLIERS
- Durox Reinforced Units Ltd (Aerated concrete roof panels)
- Lignacite (Brandon) Ltd (Concrete blocks)

QUIET REVOLUTION

Andrew Stroud

"And when you look around upstairs, do jump up and down on the bedroom floors". Not an invitation you expect when visiting the showhouse on a new housing development. But, after putting concrete first floors into selected developments on a trial basis, a leading quality housebuilder is now inviting visitors to all its new developments to do just that.

In new flats, maisonettes or terraced houses, it is taken for granted that the separating walls or floors are designed and built to minimize the transmission of sound. Yet *within* our own homes we seem to accept the noise generated by other members of the household as a fact of life, however unwelcome or intrusive it may be.

Almost without exception the upper floors in new houses are of suspended timber construction, predicating the use of lightweight partition walls in most positions. Hardly the most effective sound barriers.

Photographs – Trevor Jones

Concrete the norm

Concrete floors are the ideal means of controlling sound transmission, and also provide a platform for solid masonry partition walls in any configuration. They are the norm in apartment construction, and widely used in Continental housebuilding. So why are they hardly ever found in new British single-family houses?

The simple reason is that British housebuyers have not yet started to demand quieter houses. But change is in the wind. A recent MORI survey, carried out for the Traditional Housing Bureau, revealed that 90% of potential housebuyers would prefer internal walls to be built in masonry rather than lightweight partitioning. This reflects a growing wish for greater privacy and less noise pollution within the home.

Benefits on trial

One leading quality housebuilder, at least, has recognized this pent-up consumer demand and is now providing unrivalled levels of built-in sound insulation.

Installing the 1200 mm wide prestressed concrete floor units on a development in Maidenhead.

The Weybridge, Surrey based Berkeley Group specializes in small, high-specification housing developments often of less than five units in prime locations (leafy lane sites, as they are known in the property world). Since it was formed some 14 years ago the company, which now operates through autonomous subsidiaries throughout southern England, has successfully established its place in the market through a policy of quality construction, and continuous refinement and improvement of its product. Traditional masonry external wall construction, with concrete beam and block ground floors, was adopted from the outset. Last year the company built and sold well over 600 houses.

Some 18 months ago the company decided to install concrete first floors, with masonry partition walls to all upstairs rooms, on a trial basis on selected sites. This stemmed from the recognition that purchasers could be offered enhanced quality and benefits: virtual elimination of sound transmitted through the floor, and of the later risk of squeaky floors, greatly improved privacy of bedrooms, improved comfort levels through increased thermal capacity, and a reduction in combustible components.

The purpose of the trial was to assess constructional and cost implications of the change, and also customer reaction. The learning period proved remarkably quick.

Lessons learned

A number of possible constraints were recognized from the outset:

- possible need for design modifications to foundations and walls
- changes to construction methods and sequence
- critical programming of construction to accept delivery and installation of floor units on a date arranged several weeks in advance
- provision of access for a mobile crane and lorries delivering the floor units
- provision of vertical and horizontal service runs.

The first houses with concrete first floors were built by Berkeley Homes towards the end of 1988, after detailed discussions with Bison Concrete who were to supply and erect the prestressed concrete 1200 mm wide hollow core units. Berkeley quickly discarded preliminary plans to take over erection after the first few schemes. Because of the relatively light loadings, a reduced level of prestress in the floor units was specified initially, but the additional production complications outweighed any

Masonry partition walls can be built in any configuration at first-floor level at the same time as the external walls.

advantages, and fully stressed units were quickly adopted as standard. Scheme by scheme ordering was also superseded by a group supply arrangement which resulted in reduced delivery periods and increased flexibility.

Consequential design changes were minimal and restricted to increasing the strength of ground floor inner leaf blocks and upgrading the capacity of lintels at door and window openings.

One of the most significant changes to site operation – other than programming discipline – related to materials storage and handling. A large, clear area was needed between the site road and each house to accommodate the mobile crane and delivery lorry. Stockpiles of bricks, blocks and roof trusses had, therefore, to be relocated. And it was quickly discovered that it was not practicable to accept other bulk deliveries during floor delivery and erection.

Like the ground floors, first floors are finished with a 50 mm pumped concrete screed. Horizontal service runs have been accommodated in discreetly boxed out skirtings which are surprisingly unobtrusive and provide easy access. Ceilings to the ground floors are formed by plasterboard on battens nailed to cast-in wood

The discipline of delivery dates eliminates delays in bringing walls to first-floor level.

fillets in the soffit of the floor units. Wiring for ceiling lights runs between the battens, and the provision of coving simplifies subsequent access.

Advantages identified

As experience grew, so too did awareness of a number of significant advantages to the builder. Above all, houses with concrete first floors are being built faster, disproving some of the sceptics who had predicted the opposite. Firstly the discipline of delivery dates eliminates delays in bringing walls to first-floor level. Secondly, the immediate availability of a complete, safe working platform means that blocks can be lifted onto the floor, and partition walls can be built at the same time as the external walls Thus first-fix work can start earlier In addition, safe covered working can continue at ground floor level as soon as the floor units are in position.

The tighter time discipline involves closer supervision, with the result that quality standards have been further improved. Adoption of wide-slab precast flooring permits almost total flexibility of first-floor partition wall layout. Early purchasers can, therefore, if they wish, specify modifications to the standard configuration.

The masonry partition walls accept firm fixings in any location – a benefit both to the builder and to the subsequent home owner. Plastering throughout is over a cement-sand render.

A further spin-off benefit was the facility to form shower trays in concrete to receive tiling, thus dispensing with the less satisfactory lightweight units.

Showhouses on the trial sites included a temporary 'panel' of timber flooring in an upstairs room where visitors could do the 'jump test' to see (and hear) the benefits of the surrounding concrete floor. More scientific sound testing to quantify this superiority is being planned.

All change

In Autumn 1989, when some 80 quiet houses had been built and sold to very satisfied purchasers, Berkeley took the policy decision to adopt concrete first-floor construction, with masonry partition walls throughout, on all future developments. The company concluded that the enhanced product quality, coupled with faster completion and consequential savings more than offset the increase in direct construction costs (around one percent of selling price). It is now considering completing internal solidity by switching to precast concrete staircases.

Given housebuyers' quest for a quieter life, the revolution started by the Berkeley Group seems destined to gain rapid momentum throughout the housebuilding industry. ■

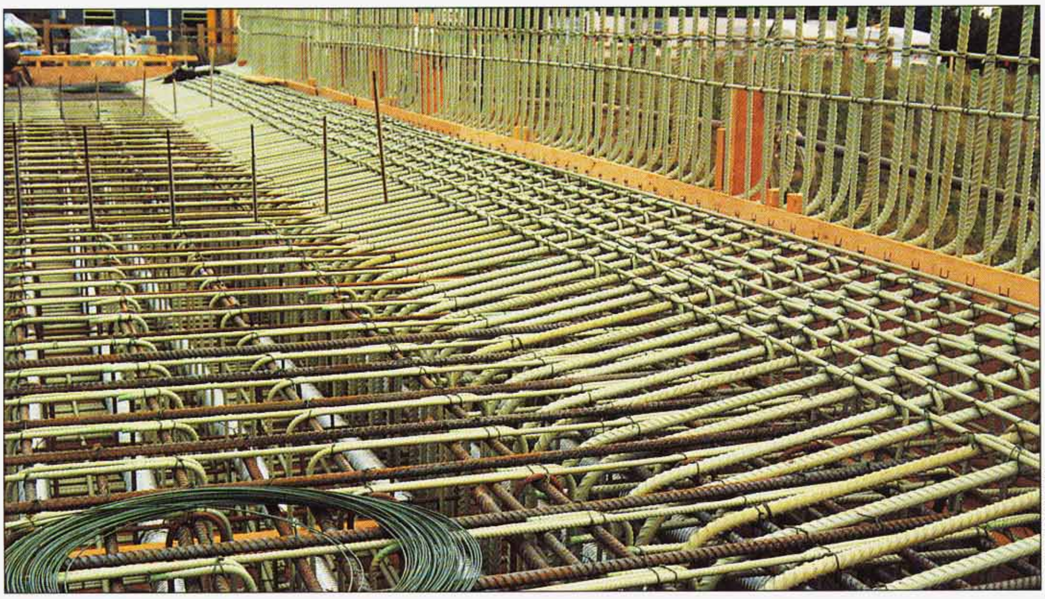
DESIGN AND CONSTRUCTION
■ The Berkeley Group plc

PRESTRESSED FLOORING UNITS
■ Bison Concrete Ltd

Concrete first floors will now be an additional quality feature in all new Berkeley homes.

INTRODUCING CORROSION RESISTANT REINFORCEMENT

John Clarke MA, PhD, MICE, MIStructE, CEng



ALLIED BAR COATERS

Epoxy coated reinforcement in a bridge recently built for British Rail near Reading. The soffit will be exposed to salt-laden spray.

John Clarke is a Principal Engineer in the Structures Department of the British Cement Association. Since joining the organization in 1971 he has carried out research on many aspects of reinforced and prestressed concrete for unusual applications such as offshore platforms and major projects such as the Channel Tunnel. Recently his work has included tests on concrete members with corrosion resistant reinforcement.

Reinforced concrete was probably the most significant innovation in the building and construction industries since the concept of the arch in Roman times. The steel reinforcement which provides the tensile strength that the concrete lacks can, however, also damage the concrete when it corrodes excessively, and if rust-staining and spalling occur the image of concrete is tarnished. So, how can the problem be eliminated?

This is not the place for a description of the mechanisms of corrosion. It is sufficient to say that the concrete round a reinforcing bar will protect it until the alkaline environment is destroyed by the ingress of carbon dioxide or chlorides. Then, if water and oxygen are present, corrosion will start. Hence the simple solution is good quality concrete, well made and well placed, providing adequate cover to the reinforcement. Careful attention to detailing, for instance making sure that there is adequate drainage, will also enhance the design life considerably.

In the vast majority of cases, these measures will ensure a satisfactory structure, easily able to reach its design life. But there will always be structures in highly aggressive environments, such as bridges subjected to de-icing salts, marine structures and chemical works, where something more radical may be required. There are a number of different approaches such as provision of a surface coating on the concrete or application of cathodic protection to the steel.

This short article looks at another solution, the use of corrosion resistant reinforcement. Two approaches are considered – the use of epoxy coated reinforcement, and the replacement of conventional steel with non-ferrous reinforcement. Other methods such as the use of stainless steel or galvanizing may be the subject of a future article.

Epoxy coating

Epoxy coated reinforcing bars were introduced into the USA in 1973, where they have since been specified by many highway authorities and widely and successfully used, and they have been available in the United Kingdom for the last few years. The coating consists of a layer of epoxy fusion-bonded to the surface of a conventional reinforcing bar. The thickness of the coating is obviously critical. If it is too thin it is easily damaged and does not protect the steel, while if it is too thick the ribs on the bar can no longer provide adequate bond with the concrete. The coated bar is produced in straight lengths in a continuous process. Handling and transport have to be done with reasonable care as the coating is relatively easily damaged. Bending is by means of conventional equipment modified with soft contact surfaces, again to minimize damage, and reinforcement cages are tied using plastic coated wire. Any damage that does occur must be made good with an epoxy paint, and the manufacturer provides standard covers for the cut ends of bars.

American experience suggests that the cost of epoxy coated rebar is not more than twice that of uncoated reinforcement. However, when used in a bridge, for example, epoxy coated rebars add only one or two percent to the total cost of the structure.

While there have been one or two widely publicized problems with epoxy coated rebar in its short history, correct specification and careful use should ensure a wholly satisfactory structure, and a British Standard on the material will be available shortly. Epoxy coated reinforcing bar produced by Allied Bar Coaters, at present the only UK manufacturer, is approved under the CARES (Certification Authority for Reinforcing Steels) Scheme.

One limitation on the use of conventional epoxy coated bars is that it may be difficult to repair damage to the coating caused during bending and fixing in complicated and congested areas. It goes without saying that welding is not an appropriate means of fabricating a cage from coated bars. This has led to the idea of coating complete fabricated cages using fluidized bed dipping. Trials on both small scale and full scale

There have been successful trials of coating complete fabricated cages by fluidized bed dipping.

MOTT MACDONALD

reinforcement cages for precast tunnel linings have been carried out successfully and plans are now in hand to use it for a major project in Denmark.

Non-ferrous reinforcement

Instead of protecting the steel reinforcement by means of an epoxy coating, why not replace it completely by a material that does not corrode? While there are a number of such products, I will only refer to those presently available as a direct replacement for steel bar (or strand in prestressed members), and not to the range of cut fibres that are on the market. Typical properties are given in the Table.

At least two companies in this country are offering fibreglass reinforced plastic rebar. This has a tensile strength similar to that of high yield steel, but the modulus is about one third. Because it does not corrode, the material has been used on a number of projects in the USA and elsewhere for structures in particularly agressive environments. In addition, as it is non-conductive, it has found applications in hospitals and other facilities where stray electrical and magnetic fields can upset delicate equipment. Because this and other replacement materials are less stiff than conventional steel, the resulting structures may be more prone to cracking and deflection.

An alternative method of using glass fibres is to make them into a prestressing tendon to compensate for their low elastic modulus. This has been done successfully in Germany under the trade name Polystal. Following extensive laboratory research and development two full scale bridges have been built. The first is a footbridge in West Berlin which has external tendons running beneath it. The second is a road bridge in Düsseldorf, with two spans each of over 20 m, opened in 1986. These bridges also include a novel form of monitoring, using fibre optics and copper wire sensors, which allows the stress in the tendon to be checked at any time.

Tensar polymer grids are manufactured by Netlon by means of a process in which a perforated heavy duty polymer sheet is stretched in two directions. The resulting mesh typically has ribs at a spacing of about 25 mm in one direction and 40 mm in the other. The manufacturing process aligns the polymer molecules leading to a strength comparable to that of steel, but the elastic modulus is considerably lower. Though the chief application has been in the stabilization of weak, low load bearing soils, the grids have also been used successfully in concrete in very aggressive situations, such as coastal structures and in the reinforcement of repairs. Their low modulus means that they are mainly of use as an anti-crack reinforcement. However there are situations where high ductility is required, such as impact resisting structures. Because polymer grids are well bonded to the concrete they would hold the pieces of the damaged structure together and hence provide a very suitable form of reinforcement.

Parafil rope, manufactured by ICI, consists of parallel filaments of either polyester or aramid in a thermoplastic sheath. The highest grade materials have an ultimate strength equal to that of prestressing strand but the elastic modulus is only about 60% that of steel. Though this material has been used extensively in geotechnical applications, limited tests on prestressed concrete beams have demonstrated that it would be a suitable replacement for conventional steel strand.

Solution on high-risk applications

Corrosion resistant reinforcement takes a number of different forms. I would not suggest that it is necessary in the vast majority of structures, where well detailed, good quality concrete will ensure adequate durability. Rather, it should be seen as a further weapon in the armoury of the design engineer offering him solutions for situations where there is a very high risk of corrosion. Epoxy coating has been used for the last 16 years and, when properly specified and used, has performed well. And now the new generation of non-ferrous materials offers an exciting alternative approach.

Typical properties of ferrous and non-ferrous reinforcement.

Material	Characteristic strength N/mm^2	Modulus of elasticity kN/mm^2
High yield steel	460	200
Glass fibre reinforced plastic	680-1000	40-55
Tensar grids	300*	Not available
Steel prestressing strand	1600-1800	195-205
Polystal	1900	50
Parafil	1650	125

*As the material is supplied in sheet form the strength is usually quoted per metre width, say 17-30 kN/m.

STRABAG

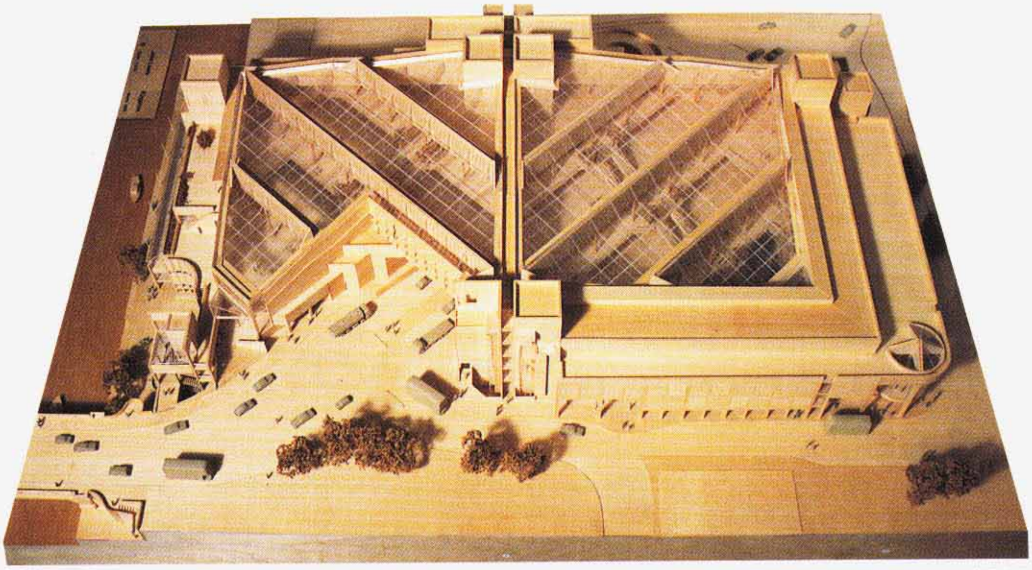
External Polystal prestressing tendons used in a Berlin footbridge.

NETLON

Tensar grids were used to reinforce the concrete promenade walkway at Swansea.

RIVERSIDE STORE

Sutherland Lyall MArch, PhD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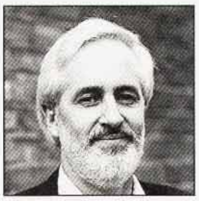

Sutherland Lyall has been editor and editorial consultant to a number of design and architecture magazines including Building Design *and the author of several books on the same subjects. Now a full time writer he is principal of The Word Company.*

It's not as if John Lewis Partnership went looking for a department store with a four-lane carriageway running through the middle. But they wanted a store in the centre of Kingston upon Thames. And the best site available, next to Kingston Bridge, happened to have a major town centre diversion road scheduled to run diagonally across it.

That was nearly ten years of negotiating, planning inquiries, 145 000 cubic metres of excavation and tens of millions of pounds worth of building ago. The road is now built and by the end of the year John Mowlem will have handed over to John Lewis a building which breaks new ground in department store design – quite apart from having traffic hurtling through the middle of it. The aforesaid traffic is of course invisible to customers – and inaudible thanks to some nifty engineering and acoustic design by Ove Arup and Partners.

The building had been under discussion with consultants since the beginning of the decade and between John Lewis and Kingston some time before that. The length

The best site available, next to Kingston Bridge, had a major road diversion scheduled to run diagonally across it.

of time involved was largely a matter of having to go to planning inquiries over the road and several compulsory purchase orders. The first application failed on technical grounds with the inspector outlining the conditions under which a subsequent application would be granted. In April 1986 consent was given and the Building Agreement called for the relief road to be opened by October 1988. That meant starting work by

Location plan, showing the relief road running through the building.

September or October 1986. That start date was possible because the architects and engineers had completed a considerable amount of work in anticipation of a successful planning outcome – Kingston were in full support of the scheme.

JOHN DONAT

A giant stairway of sales floors connected by escalators.

Design

Designed by Paul Koralek of architects Ahrends Burton and Koralek, the store promises to be an extraordinary shopping experience for Kingston residents and visitors. Entering the store they will be faced with a giant stairway, each step an entire selling floor connected by great escalators and lit by natural light cascading down from the all-glazed roof far above. Says Paul Koralek, "We went back to the origins of shopping buildings with their atriums and glazed vaults, and used those principles in designing John Lewis". He is talking about those turn of the century Parisian stores with vast central glazed domes and the great shopping arcade in Milan with its glazed vaults. It is a complete reversal of the conventional enclosed sales environment in which every single square inch is dedicated to maximum selling. It is not of course that John Lewis, Kingston is prodigal with space – it's the road running through which has to a large extent determined the configuration of the store on its five major selling levels – and that in turn suggested the virtue of a naturally lit interior. With hindsight it is difficult to see how more elegantly the store could have been organized.

The great internal space is divided into two sections by a light column and beam walkway which follows the junction of the two adjoining squares and supports the ends of the main trusses overhead. It is there primarily to give a second lift and stair access to the triangular upper selling floor.

Internal finishes will mostly be in steel panelling with false ceilings.

Sixteen metres above the entrance and rising at an angle of eleven degrees the vast roof is supported by tubular steel trusses below which are hung louvres to filter out direct sunlight. Sail-like fabric panels are fixed between their struts to filter out sunlight from the side – and serve as smoke baffles.

The street elevations are in brick and surprisingly bland after the sensational interior. They reflect the structural grid – square panels divided up into smaller squares which can be either brick, windows or cladding panels. In theory these elements can be rearranged to form other patterns on the façade although the chances of that actually happening are probably remote.

There are public and partners' restaurants (John Lewis prefer to call their staff partners) on the river elevation above a riverside walkway and an arcade of shops. In the basement below are a group of archaeological ruins dug out of the site, of which more later, and probably a health club.

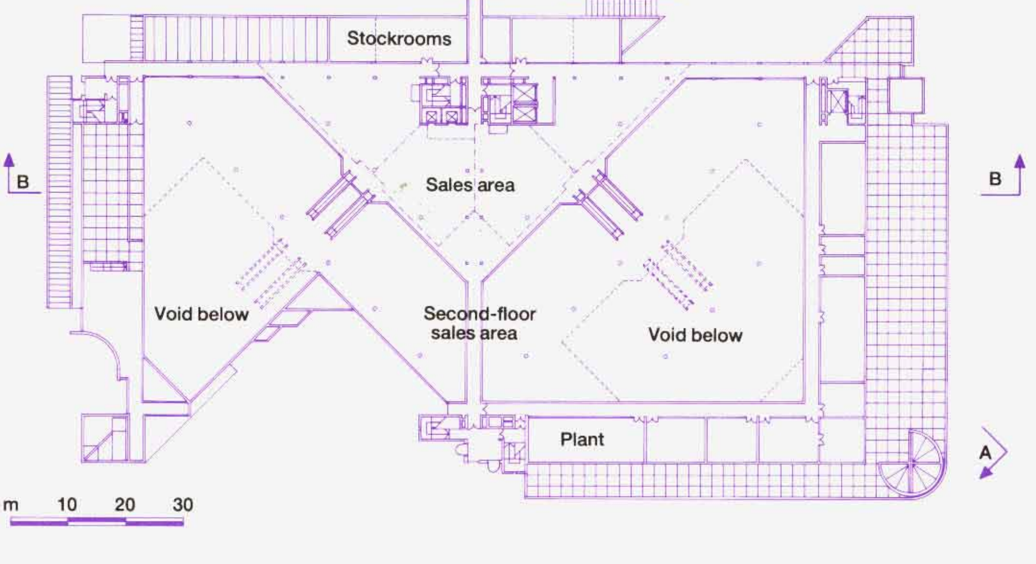
On the north side is a large loading bay, the entrance to the two-level basement car parks and a semicircular structure, known affectionately in the office as Koralek's Folly, which is intended as a lettable shop or office or showroom – whose visual virtue is to enliven a bland off-highstreet elevation.

In the triangular ground floor section on the other side of the road tunnel is the main entrance at the south east corner, flanked on the east side by lettable shop spaces. Customers have the option of shopping on the floors in front of them or below. There is to be a Waitrose food hall at basement level accessed by a pair of escalators and visible through two large voids either side of the entrance lobby.

Two squares and some outworks

The building is planned as two top-glazed squares, the western one with a triangular bite out of it marking the point where the road dives through the building at ground floor level, emerging at a lower level on the north east side. The main shopping volume is contained in these squares. Wrapped around them is a range of ancillary accommodation – restaurants, work rooms, store rooms, fitting rooms, lettable offices and so on. Only on the access road side are these more than three storeys in height and the main feature of the riverside elevation is a glazed veranda enclosing the restaurants. It is ▶

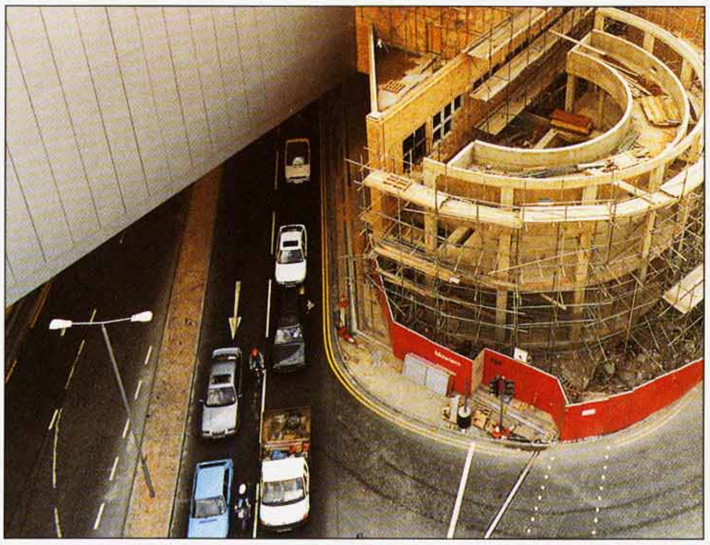
Third-floor plan – sections overleaf.



RIVERSIDE STORE

easiest to understand them as a kind of metaphorical defence, lower-rise outworks which diminish the scale of this enormous 155 × 95 m building in the middle of a town centre and protect the semi-mystical act of shopping. That's not entirely over the top for shopping is now classed as a major *leisure* activity.

On the south west corner adjoining the abutments of Kingston Bridge is a tower structure containing public stairs to the riverside walk below and a public entertainment and catering area. The tower's primary function as far as Kingston is concerned is to act as a visual termination to the bridge, reflecting a tower feature on the building opposite.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'Koralek's Folly' under construction adjacent to the north east tunnel portal.

Down below

There are three levels below ground: two basement floors for car parking and another above which will be partly used by the Waitrose food hall and partly for loading, storage, M&E plant and some staff facilities. Shoppers using the car park have a choice of three lifts to the shopping floors above – a number of them all-glazed. The River Thames is only a couple of metres away from the basement's west wall and it is down here that much of the construction excitement took place.

Fire safety innovation

Buildings of this scale normally call for fire compartments – which is one of the reasons for the dullness of most contemporary stores. At Kingston the design team and Alan Parnell of Firecheck came up with the solution of a fully sprinklered space. Says Paul Koralek, "As far as we know there have been no major fires in fully sprinklered buildings."

They are common enough in the USA but rather too frequently the sprinkler heads are at high level – rendering them ineffective until the heat reaches them. At Kingston the high level sprinklers are activated by sensors at shopping floor level. In the case of a fire any smoke is gathered in the compartments among the trusses and sucked out to the open air through the c. 2 m square plenum which runs around the perimeter of the roof. This plenum has the day by day function of exhausting stale air from the store.

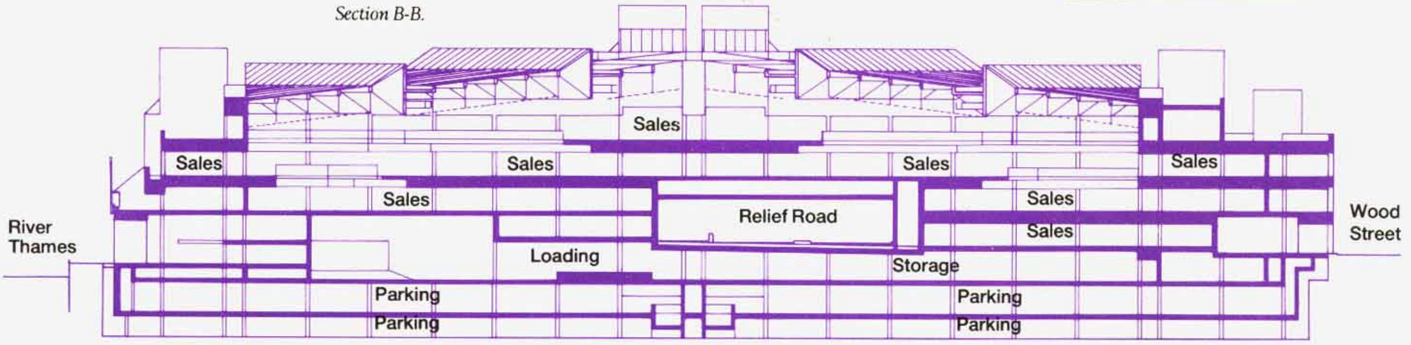
Because the design incorporated a multi-level walkway marking the junction of the two building squares the fire officer asked for automatic shutters on either side, effectively dividing the space into two fire compartments – still much bigger than is normally accepted.

Why concrete?

The decision to go for concrete was relatively straightforward. Arup had carried out steel frame studies. But constructing the building in steel would have been difficult, not least because there was very little repetition between floor levels: there would have been too many specials for economies of repetition in steel. Concrete also had an edge because the decision

Section A-A.

Section B-B.



had been reached to use brick as the main cladding. The complicated specially crafted details needed for brick walls and columns can be carried out much more easily in concrete. There was a possibility that the massive transfer beams across the roadway could have been in steel but this would have meant special and complicated design and construction problems to no particular advantage. However, steel was the logical material for the trusses supporting the glazed roof.

Unbraced structure

The building is unusual for one of its size in not having any stiff cores: it is an unbraced frame in which the lateral loads are carried by the reinforcement at the junctions between beams and columns and slabs. Walls are in concrete blockwork infill and have no stiffening function. On the exterior they are clad in brick. Because the structure is only three and four storeys in height the main design loads were for notional horizontal loads required by the Code rather than wind loads. There are lift and stair shafts around the perimeter of the building but they are also merely frame and infill structural systems. The bracing effect of the diagonal run of stairways in practice contributes little to stiffness. Arup ran computer models of all the joints, and in practice only a little extra reinforcement turned out to be necessary.

The structure has no expansion joints. The geometry of the design (grid and diagonal road) made an expansion joint difficult to establish anyway. Unusual in this country, unbraced no-expansion joint concrete structures are common practice for even very long buildings in the USA. However, without expansion joints the structure has to be designed to accommodate thermal expansion, and in any case the construction of cross walls would have added to the complications of the engineering design and probably hindered construction.

Transfer structures

A major element of the design was the transfer structure carrying the loads above the roadway. The spans involved were long because the beams had to run diagonally across the road to preserve the integrity of the column grid above – 22.5 m in some cases and at the north east side of the building as much as 33 m. That wouldn't have presented a problem in the open. But this was a building with floor levels which could only be stretched so far. Headroom was critical and the beams could not reasonably be more than 2.5 m deep in most cases. That meant massive reinforcement – and very careful design of the placement of reinforcing bars. Arup and the steelwork fixing subcontractor liaised very closely about the best way of arranging the 40 mm diameter bars, which in the end were arranged in lapping layers, between 50 and 70 of them in each beam.

Long span transfer structures present particular problems of rotation at the supports which affect the rest of the building structure. At Kingston the transfer beams rest on the side walls of the tunnel which act as very deep beams supported at intervals by the standard network of columns. Where beams do not meet columns, the walls were reinforced to take the rotation. The tender provided an alternative for precast transfer beams but in situ casting proved more economical.

On the north side of the building there is a transfer structure of similar spans over the loading bay. Here headroom was not particularly critical and the reinforcement design less complicated.

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A 2 m square plenum runs round the perimeter of the roof.

JOHN LEWIS STORE, KINGSTON UPON THAMES

VITAL STATISTICS	
NAME	John Lewis store, Kingston upon Thames
LOCATION	North east corner of Kingston Bridge
USE	Department store, food hall, shopping, car parking
PROGRAMME	October 1986 to Christmas 1990
FLOORS	Ground, three upper, three basement
STRUCTURE	Unbraced in situ reinforced concrete frame
CLADDING	Brick, glass, metal cladding
FOUNDATIONS	300 large diameter bored concrete piles, 800 mm × 18 m (avg) diaphragm wall around whole perimeter, 80 × 13.5 m sheet piling to Thames river bank
CONCRETE	55 000 m³ concrete, 8000 tonnes reinforcement

Because the transfer beams were 2.5 m deep the architects took the opportunity to sling a broad pedestrian bridge between two of them linking the two triangular first-floor selling floors. Without the bridge the western first floor would have been an awkward cul de sac – rather like the basement of a department store but at first-floor level.

Stepping up

The four selling floors, like the basement, are in standard in situ Grade 35 concrete slabs with partial cement replacement using PFA and are coffered to reduce loads. They will not be exposed as, for example, at the National Theatre although with a bit of cleaning up some of them could pass muster as off-the-form concrete ceilings. Basement floors are plain in situ concrete. Open roofs and terraces around the perimeter are of inverted construction with plain concrete pavers holding down the insulation and forming a walking surface.

Construction

In October 1986 John Mowlem was awarded the first contract for site preparation, and appointed Stent Foundations for the piling ▶

After completion of the diaphragm wall and piling, excavation to pile-top level could begin, leaving a 45 degree berm around the perimeter.

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RIVERSIDE STORE

and Stent/Soletanche, a joint venture, for the diaphragm wall. The whole contract involved sheet piling the river bank for a length of 80 m and to a depth of 13.5 m alongside the east boundary of the site, and installing the 800 mm wide diaphragm wall which ran 480 m around the perimeter of the site. An average of 18 m deep, including an 8 m toe-in, its function is to retain the ground surrounding the three-level basement structure and keep the water out – the surrounding water table is around 2 m.

The diaphragm wall was formed as a series of primary and secondary panels each 6.15 m long. The deep trench was dug under bentonite for which Stent/Soletanche installed a 30 t bentonite batching and cleaning plant on site. Two 18 m long reinforcement cages were used in each panel and ready-mixed concrete was used. Busy Kingston traffic slowed down concrete pouring over the Christmas period but within a few months 600 m^3 of concrete a week were being placed.

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The contractor opted to use bottom up construction for the central section and top down for the perimeter. Temporary H beam columns were placed in the berms.

Piling

The whole structure sits on an 8 m grid of around 300 large diameter piles (most 1200 to 1500 mm), underreamed up to three times the pile diameter. They are 30 to 32.5 m long running through several metres of fill and around 4.5 m of gravel overlying London clay. Intermediate piles take localized loads. The piles were reinforced and concreted only over their lower 20 m because they were to be trimmed at the eventual basement level 10 or so metres below grade. The top sections of the bore holes were cased through the gravel down to below the top of the London clay to stop water getting in.

At one time during piling there were no less than ten cranes on site which had taken on the appearance of a busy riverside wharf. The fact that none of the materials was shipped by barge indicates that there may be a gap in the market. Bored with bladed augers the completed pile bores were cleaned out and inspected – the larger diameter bores by men working inside protective cages lowered into the base of the shaft.

Reinforcement cages were craned into place and concrete placed to the tops of the reinforcement around 10 m below ground level. The empty shafts above were backfilled and the casing withdrawn. The site was then ready for excavation.

Towards the end of this contract it became clear that tender documentation was not going to be ready on time so the contract was extended to include the excavation of the basement to up to 13 m below grade. This involved the removal of 100 000 m^3 of ground leaving a 45 degree berm around the perimeter of the site supporting the diaphragm wall. Four months of excavation later, in June 1987, the second contract for the superstructure was let – again to John Mowlem.

Building it

A major problem of construction was how to temporarily maintain the integrity of the 18 m deep diaphragm walls surrounding the site while construction extended outwards towards them. Given the constraints imposed by the need to get the foundation work completed early, Arup had envisaged that the middle section of the basement would be constructed first. The central section of the three-level basement would then be constructed and the perimeter sections of slabs extended out to the diaphragm walls using conventional propping, with raking props and waling beams at the upper car park and lower ground floor levels. Arup invited tenderers to use this or their own alternative schemes as long as they met the performance specification for supporting the diaphragm wall and limiting ground movement. Movement would be monitored using the inclinometer tubes which had been cast into the wall at regular intervals.

Mowlem had made the decision that the construction method should be a mix of top down and bottom up: bottom up for the central section and top down for the perimeter zone. It has been an interesting process and not without its difficulties.

The excavation had exposed the tops of the piles in the central area of the site and work started on casting the pile caps and laying the lower car park slab over a 700 mm anti-heave undercroft followed by

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After the top extension slab had been cast, the berm was excavated to the next level down. One of the temporary columns can be seen on the left.

the construction of the middle section of the three levels.

At the same time, Mowlem bored 600 mm diameter piles into the berms. Steel columns embedded into the tops of the piles were located at 8 m centres in a single or double line according to the distance between the central structure and the diaphragm wall, positioned at intermediate points between the grid of the piles. Their function was to serve as temporary supports for the extensions of the structure to the perimeter wall. Because they were offset on the grid Mowlem and Arup engineers had to work very closely together in designing the extension slabs and their reinforcement: when the permanent columns were built they would be supporting the floor slabs in what had temporarily been mid span. It made for complicated reinforcement design.

With the temporary steel columns in place and the central structure up to ground level and some horizontal shoring fixed at the top of the diaphragm wall, Mowlem laid formwork between the permanent structure and the diaphragm wall and began casting the top extension slab leaving holes for the permanent columns.

During construction of the perimeter zones horizontal shoring supports the top of the diaphragm wall.

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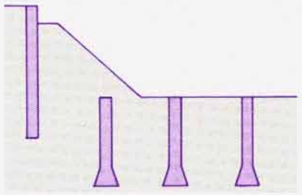
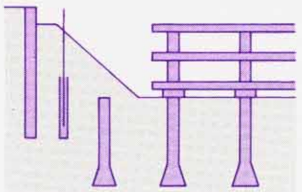
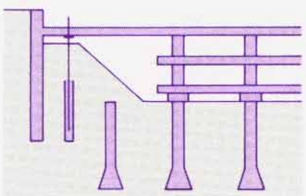
Top down perimeter construction



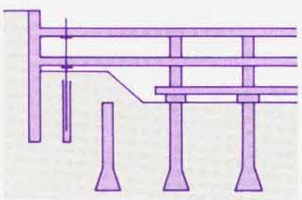
Diaphragm wall, piling and excavation of central portion to pile tops completed, leaving perimeter berm



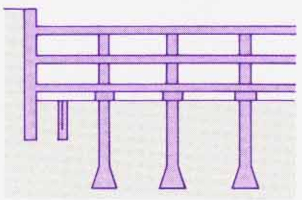
Three floors built conventionally in central portion, temporary columns installed



Top perimeter slab cast and tied to diaphragm wall



Process repeated for second and third perimeter slabs



Temporary columns removed

Then the builders turned miners. Using a mixture of mechanical and hand tools, they dug out the top section of the berm down to just below the next level. The same procedure was followed for the next floor levels. Contemporary reports make much of the eerie atmosphere with grabs descending from above, workmen on trolleys striking shuttering in the 700 mm undercroft below the lowest floor and small mechanical diggers scurrying around in the artificial light.

With the basement floor slabs extended to the diaphragm wall the permanent columns were cast and connected to the reinforcement of the slabs. Mowlem removed the temporary steel columns and the basement structure was ready for perimeter cladding and the first services installations. Because of the deep plan the basement ventilation system is massive.

The contractor had installed tower cranes on the lowest level rising through cut-outs in upper floors for the duration of the job. Later, when traffic had been diverted through the new tunnel a mobile tower crane was installed along the eastern flank of the site.

The early priority was constructing the road and its enclosing tunnel. The massive supporting structure for the road was constructed at the same time as the centre section which surrounded it, and its walls and roof were finished in October 1988.

Road and vibration

A primary concern with the road was vibration. It was crucial that customers and staff in the store should not be aware of the traffic a few metres away from them. So Arup Acoustics carried out detailed studies. They went to a number of typical John Lewis stores and investigated what made stands rattle – establishing a set of criteria for dealing with vibration. Using data from the Transport and Road Research Laboratory and vibrations measured on a number of bridge structures they put the data into a computer model which existed as a program used regularly by Arup's industrial engineering division. They tested the model for a number of acoustic scenarios.

Their final solution was to isolate the road from the structure of the building in order to eliminate sideways vibration, and to deploy massive structure to damp out the critical frequencies. The building effectively forms an inverted U tunnel over the road which itself stands as a separate bridge structure dropping from grade at the south.

The road is a sloping 750 mm reinforced concrete slab supported on large diameter columns on massive piles. These also act as columns for the basement floors so there are paths for vibration – the lateral vibrations stopping abruptly at the edge of the structural gap along the two sides of the road. But, because of their mass and the fact that vibrations are attenuated when they have to make a major change in direction, very little is transmitted back to the selling floors.

The road was clearly going to be subject to lateral temperature movement. Very considerable forces are involved, so the tops of the columns supporting the middle strip of the road are necked to allow a degree of bending. Where the movement was likely to be too great for this solution to work, mostly at the ends of the road slab, there are steel sliding bearings. Standard PFTE bearings on top of the columns have an allowable lateral movement of plus or minus 20 mm.

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The north east portal of the tunnel, completed in October 1988.

The road is isolated laterally from the building structure by a complicated junction between the edge of the road and the pavements – which are cantilevered out from the adjacent building structure. It is complicated because it has to take up to 20 mm shear movement, isolate any road movement and vibration from the structure and remain waterproof at the same time. There is a final line of defence in the form of a gutter below the junction.

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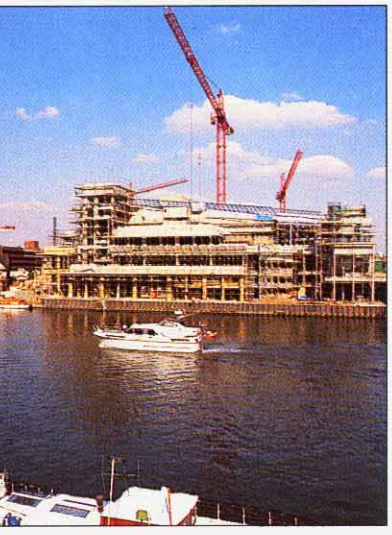
At about the same time as the road was completed, the contractor installed six pairs of escalators.

The problem of vibrations from heavy axle-load vehicles going over a pothole was understood and Arup have produced a maintenance specification: good maintenance was a far cheaper solution than increasing the mass of the structure.

RIVERSIDE STORE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The river elevation – May 1989.

An additional problem was that the building agreement called for the road to remain as a unit in the event of the building being demolished. There were some nice problems in the design, for the road was designed to Department of Transport standards, and the building in accordance with Building Regulations. So the supporting concrete structure is designed to external standards in terms of mix, cover and reinforcement. Should the building be demolished there would have to be some additional bracing to the road substructure, a provision which was acceptable to the highway authorities.

Does it all work? One test is to stand astride the movement joint and wait for a reasonably heavy van to pass by. You can feel the vibrations in the road foot but not the other.

Moving up

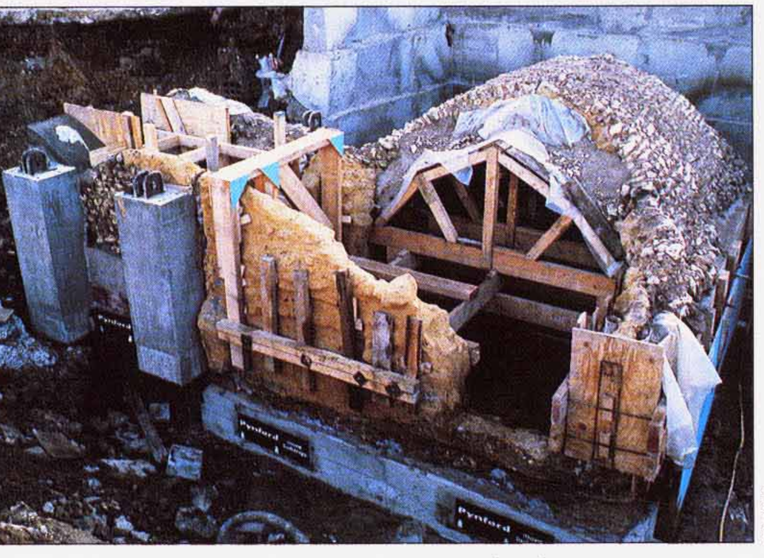
At around the same time as the completion of the road Mowlem brought in and installed the six pairs of escalators: one pair down to the Waitrose basement, three up from the entrance to the top shopping level and two down from the other side of this triangular floor to the east sides of the second and first levels. They have remained there, cocooned in their plastic protective wrapping, since October 1988. Escalators are massive structures in their own right and manoeuvring them in later would have presented major problems.


OVE ARUP

September 1989 – glazing complete, and the airy shopping space takes shape.

With the diversion of traffic into the tunnel from roads around the site it was possible to bore the remaining piles for a single basement level located outside the diaphragm wall. In the main they

SITE OF MEDIEVAL STORE ?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The staircase and undercroft, strengthened and underpinned.

Medieval ruins are a common enough feature in construction contracts. At Kingston the planning consent included a condition that medieval ruins known to exist on the site should be removed, stored and relocated in the new building. The Royal Borough had agreed to contribute to the costs. It had been agreed with the planners that leaving the ruins in place would have affected too greatly the design of the new building. The archaeologists were against taking the old structures apart: they included a medieval merchant's cellar and, closer to the river, causeway walls, piers and abutments from the original Kingston Bridge, originally the only permanent river crossing permitted above London Bridge.

The cellar, technically an undercroft with a vaulted roof, was still more or less intact with the remains of a stairway leading down to it. Made from chalk blocks there were still traces of flints forming a checkerboard pattern. This together with the high quality of detailing suggested that its original owner used it in the course of his trade with the public.

Pynford were called in under a negotiated contract based on a performance specification developed with the co-operation of the archaeologists. Work started in September 1986 on the 12 week contract. Time was tight because the programme called for an autumn start on the main foundation contract.

In theory the procedure was simple: build new concrete foundations under the old structures and lift them out. But the old cellar presented big problems. First a retaining wall had to be constructed behind the undercroft to support an adjacent road. Here a top down method was used to avoid vibration, in which each successive drop of wall was supported on Pynford's steel stools.

English Heritage suggested that the internal surfaces should be plastered to prevent drying out and cracking – and to protect the old stones from splashes of the resin bonding used to consolidate and bind the inner facing stone joints. The vault was supported with arched trusses and boarding and tie bars threaded through the walls.

With the structure consolidated, the surrounding earth was removed, voids filled with resin and plates and strongbacks fixed to the ends of the tie bars to prevent the weight of the roof from pushing out the side walls. Then the underpinning started.

Pynford's system deploys steel stools with concrete pads top and bottom which are inserted into holes dug at regular intervals underneath the old wall structure. Drypacking is rammed between the top pad and the underside of the old structure. With the stools firmly in place the sections of earth in between them were dug out, reinforcing bars threaded through the stools and concrete poured to create a ring beam under the whole support the perimeter brick 'jacket' of accommodation which was now started in earnest. By the beginning of 1989 the main concrete frame structure was up and the seatings for the long span tubular steel roof trusses established high on the perimeter walls, defining the two squares. The primary trusses run diagonally across each square in chevron formation. Supported at 11.3 m centres on circular tube columns they in turn support the sloping secondary trusses to which the roof glazing structure is fixed. The secondary trusses span 22.6 m at 5.6 m centres.

The glazing system above each secondary truss has a flat section across its lower portion and a steeply sloping clear glass upstand at the top. The flat section acts as a walkway giving access to the vertical glazed side of the upstand – and to the pitch of the glass roof. The whole roof is accessible from underneath as well, with catwalks slung around the perimeter of the roof and moving gondolas running alongside each primary truss. The roofs were erected using a bird cage of scaffolding and staging, up to the underside of the glazing, which was progressively lowered to enable the fixing of fabric smoke curtains and the sun louvres which span between the lower chords of the secondary trusses.

The final lap

The last tower crane has been dismantled; structural work is now complete with the basement ventilation system and its controls in place. Fitting out has already started with shallow raised floors and much of the internal panelling. John Lewis plan to open by Christmas of this year.

The new John Lewis store will be open for Christmas shopping.

JOHN DONAT

CLIENT
- John Lewis Partnership
- Royal Borough of Kingston upon Thames (road and external works)

ARCHITECT
- Ahrends Burton and Koralek

PROJECT MANAGER
- Clarson Goff Associates

CIVIL, STRUCTURAL AND PUBLIC HEALTH ENGINEER
- Ove Arup & Partners

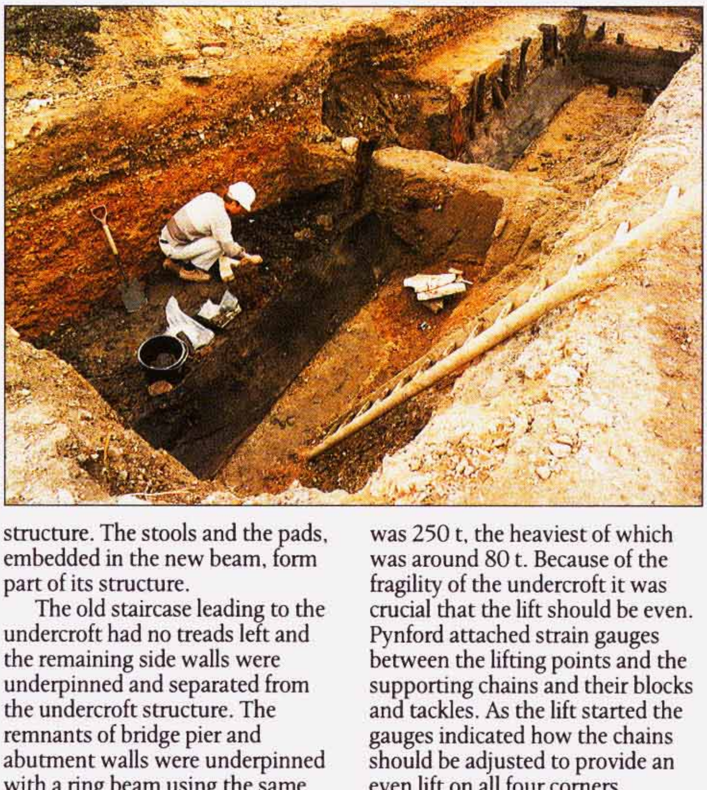
QUANTITY SURVEYOR
- Davis Langdon and Everest

M & E SERVICES
- John Lewis Partnership

CONTRACTOR
- John Mowlem and Company plc

SUBCONTRACTORS
- Stent Foundations Ltd (bored piling)
- Stent/Soletanche joint venture (diaphragm walling)
- Pynford South Ltd (archaeological work)

READY-MIXED CONCRETE
- Willment Ready Mixed Concrete Ltd



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structure. The stools and the pads, embedded in the new beam, form part of its structure.

The old staircase leading to the undercroft had no treads left and the remaining side walls were underpinned and separated from the undercroft structure. The remnants of bridge pier and abutment walls were underpinned with a ring beam using the same procedure, resin bonded, strapped up and then boxed in with a temporary frame filled with sand. The massive bridge pier had its rough core removed.

Before lifting out the old structures their ring beams were jacked up to break any adhesion with the soil – and to allow Pynford to calculate their weights. The total was 250 t, the heaviest of which was around 80 t. Because of the fragility of the undercroft it was crucial that the lift should be even. Pynford attached strain gauges between the lifting points and the supporting chains and their blocks and tackles. As the lift started the gauges indicated how the chains should be adjusted to provide an even lift on all four corners.

The old structures stored for a time by Kingston council are now being incorporated into the riverside section of the development as an archaeological amenity. Further archaeological digs have uncovered the old river wall, a timber quay and ship timbers dating from the middle of the 13th century.

OVE ARUP

PERSONAL VIEW: JOHN TURNER, BUILDER

Concrete is the ubiquitous material of the construction industry. Without it, the form of our buildings would be very different. Its usefulness is unquestioned, its versatility is exhaustive, yet in the public's mind it still has connotations of the second rate.

HOGGETT LOCK NECREWS

The new concrete framed, reconstructed stone clad headquarters for the Principality Building Society – three years from idea to occupation.

John Turner CBE, FCIOB is a Director of the Principality Building Society and was until recently Chairman and Managing Director of Turner Group (Holdings) Ltd. He is currently Chairman of the Council for Building and Civil Engineering at BSI, Chairman of the Building Regulations Advisory Committee, and a Member of Council of the British Board of Agrément. He is a past President of the Building Employers Confederation and also of the Concrete Society.

Concrete Quarterly in its former guise sought to seduce us with the delight of what could be achieved; it was always a joy to receive and read. Today the magazine seeks to uncover more basic matters, be they problems or solutions, whilst at the same time applauding the best. I believe the change in format meets a need and I particularly welcome the 'Revisit' articles. I only hope we will learn from them, because we are not an industry renowned for good communications or for learning from others' experience. Are we getting better? I wonder. In *Concrete Quarterly* 118 11 years ago, the editorial on 'keeping it simple' quoted Sir Maurice Laing's assertion that much of the efficiency of the construction industry in the United States stemmed from its adoption of the KISS principle to design and construction (keep it simple, stupid). Whilst the disparity of construction costs between the two countries has now largely disappeared I have not noted that our buildings have become much simpler; but there has developed the matching concept of buildability. Bring the two together and the world's our oyster!

But I digress, that's not what I wanted to write about. The trouble with concrete is that it is so ubiquitous you can use it as an excuse to talk about anything concerning the industry.

A changing industry

During my time in construction I have made a lot of friends – we all do, it's that kind of industry. A number of these friends are now retiring, and quite a few say they are glad to get out, the industry is so different and it's no fun any more. Well, yes, the industry has changed, quite dramatically. True, there are no longer the cushions we used to have, and competition is cutthroat and, in that respect, far less comfortable; but the rigidities have gone, attitudes have changed and are still changing. It is more the rule that members of the project team realize that their own success is entirely dependent on the success of the project; they are not always looking over their shoulders and protecting their own backs. Clients now become involved in their projects, have learned much about our industry, indeed have become part of the project team. The industry today is far more effective, inventive and efficient, and less of a mystery to those outside. All common sense, of course, but 30 years ago almost unthinkable.

Perhaps in those days it was not the same industry. The last job I sat on as a project manager started 25 years ago. It was for the last phase of a hospital redevelopment scheme in West Wales; our tender was, then, about £1.7 million, and the contract ran for three years. The basic design had, I believe, been established 15 years before. It was a happy job which went steadily and well. There were in situ concrete frames, and we had our own mixer set-up; a curved central core block joining up existing ward blocks gave interest; reconstructed stone column facings used as permanent shuttering gave us an interest we could well have done without. The daily bus run started from Swansea (and it was a bus, a post-war Leyland with a streamline fin at the back). It picked up our bricklaying gangs, nearly all of whom lived in the same village. Everyone knew everyone else on site, and I swear the canteen served the best breakfast in the whole of Carmarthenshire!

Speed and confidence

Today, as a director of a building society, I am responsible to our board for the construction of a new headquarters building. It is a concrete frame, eight floors up and two down, on a confined city centre site. An added complication is that we shall house the Local Authority Music School in part of the building. Value today about £13 million.

It was only in October 1988 that our Chief Executive had an inkling that this site might be available, and it was the end of March before we bought it. After demolition, piling started last October, and we shall be in occupation in the late summer of 1991 – less than three years from that first grasping of the nettle. Is it fast-track? Well, fast-track is many things to many people. The construction works are being let through a management contract, so all members of the project team are totally and equally involved in their commitment to the client, and the flexibility the industry has now embraced enables so much of the design, project planning and construction to be carried out concurrently. We no longer have the luxury of spare time, but we do have the confidence that we can meet the needs of the client – and in this case the client knows it!

What will the building look like? Its elevations are modern; it is not a pastiche, but it reflects some basic disciplines of our existing building which is next door. It will stand alone but will not dominate. That it will enhance its surroundings I have no doubt. I make no bones about my excitement for the scheme. Perhaps one day it will be reported in *Concrete Quarterly;* the Welsh School of Architecture have already asked if they may monitor the project, which they believe to be of considerable interest.

And that inevitably brings me onto the sidelines of the current debate on architecture.

The great debate

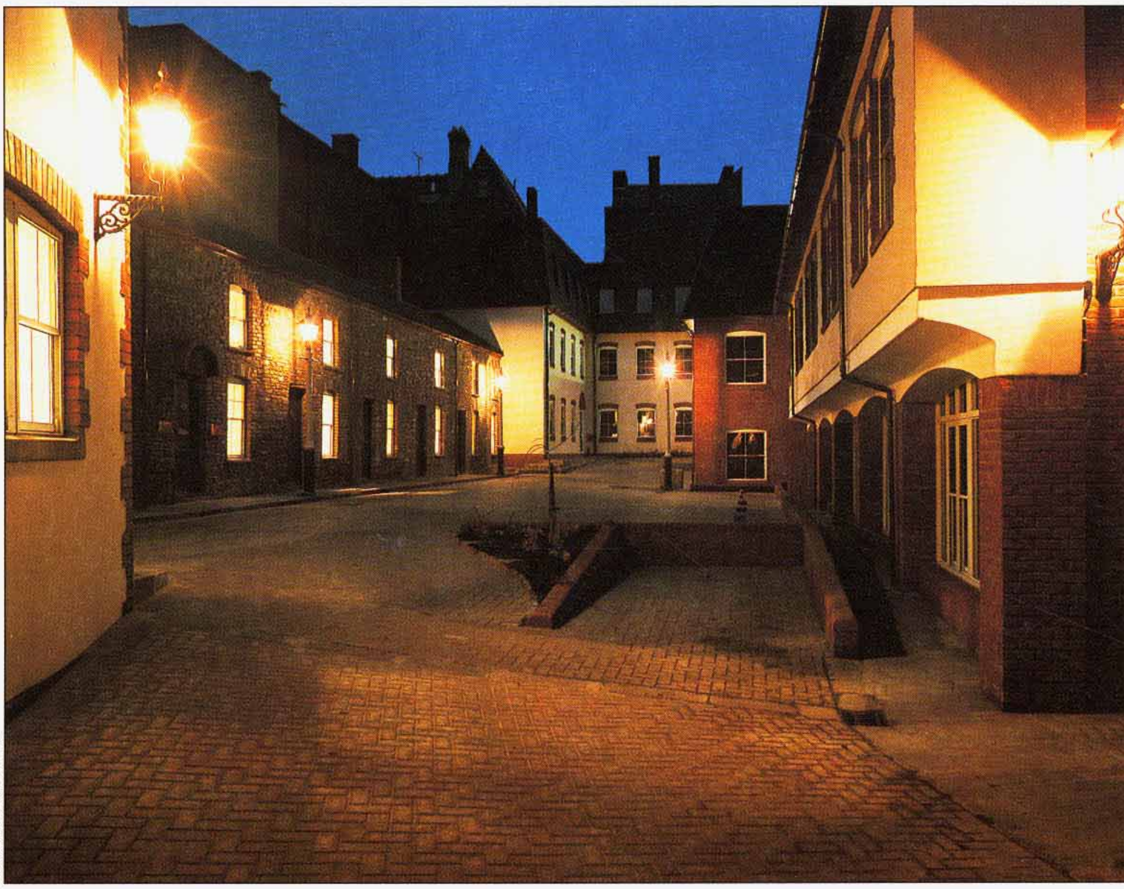
What is happening to our architects? I hasten to add that I have not read any of the books (are there more than two?) but I have seen the television programmes, and I do seem to have read quite a number of articles in newspapers and magazines. Over the last five, six, seven years the quality of architecture I have seen has improved immensely. True, some of it is a bit stylized, but I don't believe every building should be a great work of art. For an ordinarily funded building, domestic, commercial or industrial, if its scale is right, if it sits comfortably in its surroundings, if it is pleasing to the eye, then it is a marvellous success. In such cases I take it for granted that it works inside. If the designer draws inspiration from colleagues long dead, so be it; tried and proven proportions are very pleasing. And anyway in most cases what is the life of the building? My father and grandfather between them built three major buildings on the same site in central Cardiff in a period of 60 years.

On the other hand, if a building is to be created with the intent to excite generations to come, then that is a different matter, and commercial funding no longer applies. True, good design costs no more than bad, but the elegance required of a great work of art will surely embrace more space than the use of the building will truly need; and perhaps enrichments will set the building off. It is lack of elegance in our major buildings that disappoints. In years of financial constraint, have we asked too much of our architects?

Two buildings in London bear the brunt of the discussion. The National Theatre is a huge success as a theatre, both for audience and players; it works well as a building. Its structural design is innovative and exciting, and largely unappreciated. But from outside it looks just what it is, a functional theatre with a great blank box clothing the 'innards', finished with a coating of bumpy concrete. (I thought Ray Moxley was rather kind in his article in CQ, Autumn 1988). Looked at from one vantage point it has a certain style about it, the style of a modern multi-decked motorboat, but none of the elegance of a seagoing yacht. It is a brave design, a good building, but surely not great architecture. Can we not leave it at that – until the day, of course, that the concrete becomes so weathered that the building has to be re-clad...?

The Lloyd's building is a later generation of another brave building, the Pompidou Centre in Paris. What an exciting concept that centre is. It is a visual feast, but I wish I had seen it when it was new; two years ago it was beginning to look a bit tatty. I loved the Pompidou Centre for three reasons: it housed a favourite Picasso, a Harlequin; it displayed a small selection of Ernst sculptures; and it enticed into the open space outside a kaleidoscope of movement and colour, and a myriad different sounds. It is to me a building of breathtaking imagination, but it does not excite me as great architecture. Its half sibling, the Lloyd's building, whilst it is impressive, does not move me. It seems to me to have the modernism of a thirties' film. My friend on the Clapham Omnibus said it reminded him of the introductory credits to Monty Python... and he was still waiting for the foot to come down! No, no, no, I cannot believe that building has anything to do with art. But perhaps I'm a Neddy Seagoon! ▸

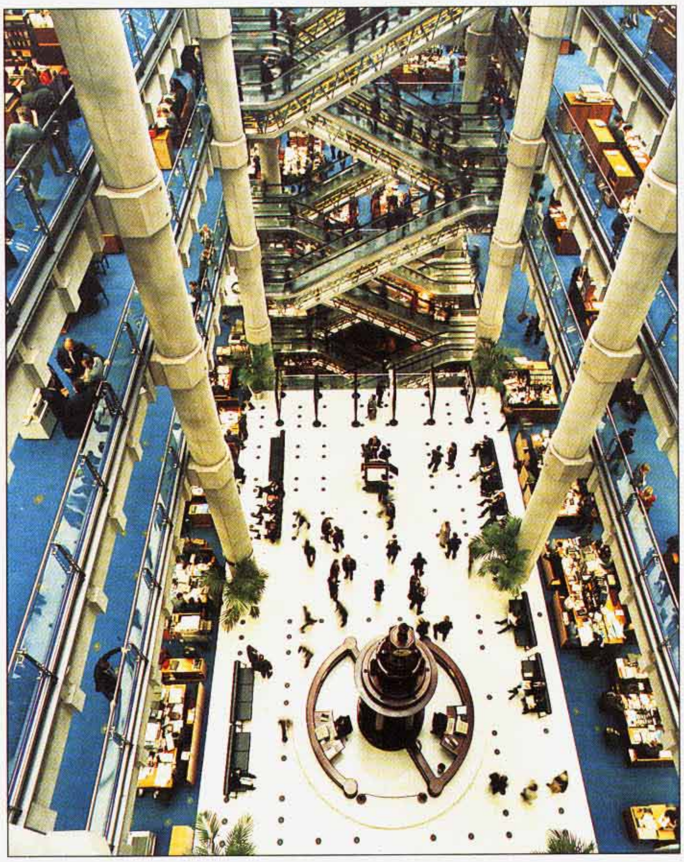
If the scale is right, if it sits comfortably in its surroundings...



HOGGETT LOCK-NECREWS

PERSONAL VIEW

continued



The Lloyd's building – modernism of a thirties' film?

Humanity and humour

Why do our great architects hide behind town planners and developers? The greatest architects of yesteryear would have caused mayhem if they thought they were being put over. And what's all this whinging about bimbo architecture and façadism? I have always collected apt verses and I quote two here:

The first by Longfellow:

In the elder days of Art
Builders wrought with greatest care
Each remote and unseen part
For the Gods are everywhere.

The second, attributed to Pugin:

They made the front, upon my life
As fine as any Abbey;
But thinking they could cheat
the Gods
They made the back part shabby.

Great artists devour criticism for it gives them a platform.

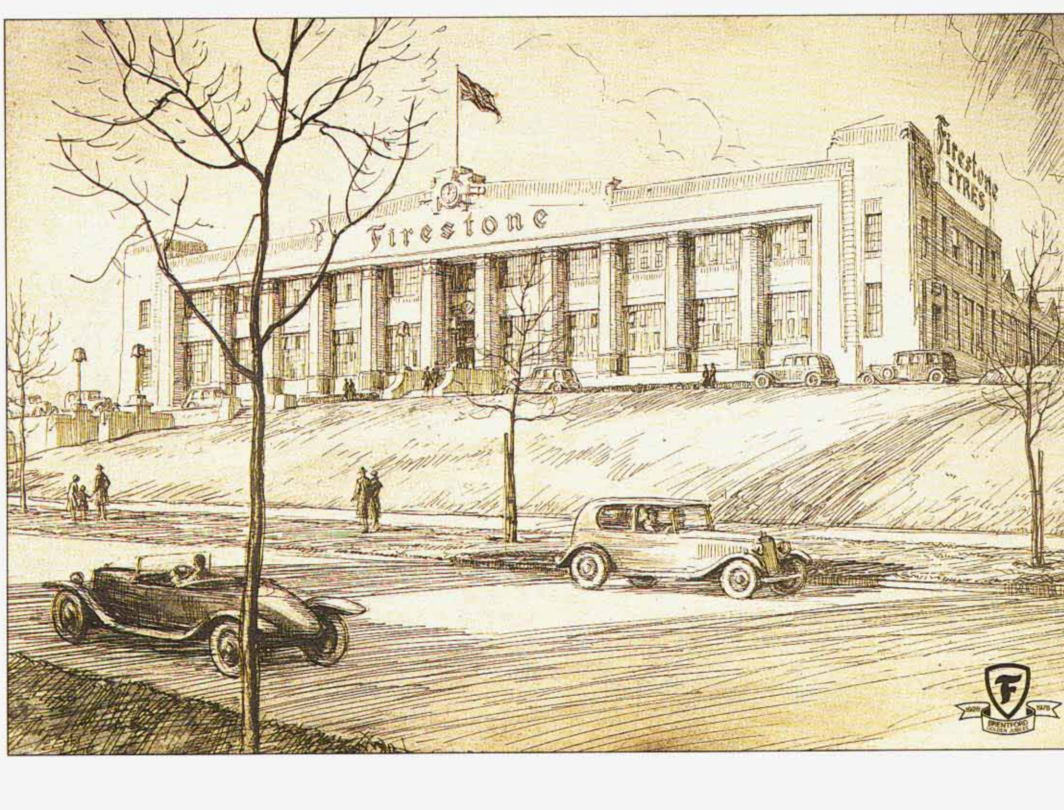
And how would I judge the elegance of a bulding? It is personal, of course, but if I and others are held captive by it, stop and stare and are moved by it, then I believe it must have a certain greatness about it. Some examples? Well I'd rather refer to an architect whose work flourished into such glorious elegance in the twenties, Thomas Wallis. The other day I came across a book of his work and I show a couple of details of his Firestone Building, now sadly demolished. He had energy and convinction.

Talking about Paris earlier reminds me that poor architecture has not occurred just in Britain; look around, all of Europe has suffered a similar problem. Mentioning Picasso and his Harlequin studies – to me amongst the greatest line drawings I have ever seen – prompts me to assert that art cannot be created by a CAD terminal. I mentioned Ernst because his sculptures make me chuckle and laugh. I told an architect friend that I like driving past one of his buildings because it made me smile and feel happy, I thought his design had humour. He looked at me blankly as though I had been critical. But surely architecture must reflect human emotions and seek to give joy and inspiration as well as dignity and security?

I know we are in the midst of a resurgence of good architecture, but architects must tell us about it and not rely on others; and not be so defensive!

WALLIS GILBERT WOLSTENHOLME

The captivating entrance to the Firestone Building.



Glorious elegance of the twenties – the Firestone Building designed by Thomas Wallis and built in reinforced concrete by Sir Robert McAlpine in 1928.

The European dimension

Architecture is on the move, construction management is on the move, and 1992 is beckoning us. I have no doubt that, during the next decade or so, the way we work, the materials we use, the structures we build will be influenced far more than today by what is happening elsewhere in the European Community. We shall be embraced by, and we shall embrace, our colleagues in similar organizations. Contractors, housebuilders, material producers are already working closely with their equivalent organizations throughout the EC; others in the industry must be doing the same.

There is a lot of hard work to be done to create harmony and understanding between us, and the very pressures I spoke of earlier – the growing efficiency of the industry, the cutthroat competition, the changing roles and flexibility – mitigate against us giving time to this work. But if we do not give the time then I believe we shall lose out.

In the EC, there are of course 12 partners – but in CEN, the European Standards body, there are 18, for the EFTA countries are also members. My involvement is through BSI, and concerns both Codes and Standards. There is great pressure to achieve as much as possible by 31 December 1992. Whilst the Commission has yet to tell CEN what sort of Standards and Codes it wants, and this is negotiation at government level, CEN itself has embarked with enthusiasm on the preparation of Standards that it believes the Commission will want. We are members of CEN through BSI, and BSI has reorganized itself, not least in order to ensure that it is effective in the work of CEN.

And on the construction side we *have* been effective, but oh! it has been painstaking. A strategy for the production of CEN Standards, which will be British Standards, has been agreed, but it took two years of pedantic argument. Not only are we negotiating in different languages, and since the English vocabulary is wider than that of other languages there are problems in translation, but we are also negotiating against a background of competely different practices and cultures. Even with the greatest goodwill there are bound to be misunderstandings, so infinite and exhausting patience on all sides is required. We have had our successes, and are developing a good working relationship. The workload, however, is increasing, and I believe will rapidly expand in the next two years. Manufacturers in construction have given staunch support, but the users, professions and contractors have had less and less time to give, and we need their practical input. Remember we are developing daily bread-and-butter documentation for our future work!

STANLEY TRAVERS

Building as art – the striking concrete organ arch in Llandaff Cathedral, a particular favourite of the author.

It is interesting to learn from other delegations we meet that they believe we are better informed and better in touch with our government departments than anyone else – if we are ahead, let's build on that!

What a prospect before us: increasing efficiency, enthusiastic and enlightened design, a growing demand for our technical expertise and a widening market. The challenges are there and it must be fun! My friends, it is not a time to get out!

That almost takes me back to my starting point, but not quite, for I opened with ubiquitous concrete. Yes, we are getting better! We have learned a great deal about the material in the last 25 years – about its durability, its weathering, its chemical reactions, its use in composite construction; we even acknowledge it is sometimes good to paint it! We abuse it less and less because we understand so much more about it.

But I am sure concrete's full potential has by no means been reached. It is sad that many still think of it as mundane, for it is the very foundation of our industry.

As with Ernst's sculptures, humour in a building can give delight.

KEEPING UP APPEARANCES

Frank Hawes DipArch, RIBA

The 'Revisit' series, initiated in CQ 158, has featured buildings and bridges whose performance, over time, can offer useful lessons to today's designers. In this article the author takes a step back and examines some of the broad issues relating to design for good appearance and acceptable levels of maintenance over time.

Frank Hawes, who has specialized in the architectural use of concrete, and particularly in design to control long-term appearance, now practices in Norfolk. This is his fifth article for CQ.

Readers who know the BCA publication *Appearance matters – 6: The weathering of concrete buildings*, or who have heard me talk on the subject, will recognize the graph shown in **Figure 1**. I have been using it for at least 15 years. However, the preparation of this article on the maintenance of concrete buildings has, after all this time, led me to the conclusion that the graph now needs modification. It is for the reader to decide whether this is the result of changes in our understanding of concrete and other materials or whether the graph was too simplistic in the first place.

It was always rather an unsophisticated diagram – certainly not a scientific graph – with time unquantified on the horizontal axis and undefined quality of appearance represented vertically. The three lines on the graph represent three different strategies for the design of building and structures, whether of concrete or any other material, and are drawn on the assumption that all buildings start quite high on the vertical scale.

Three strategies

The first line relates to buildings which attempt to defy time, buildings that are intended to look the same throughout their lives. This strategy was always offered, on the basis of my observations of the performance of buildings in all materials from glass and glazed tiles to brick and timber, with little prospect of achieving its aim and with the suggestion that the line must eventually turn down.

The second line accepts that a building will change with time but also that it can be brought back to its original appearance by painting or cleaning; while line three represents my particular obsession – the design of buildings that will accept change and weathering without being spoiled.

Weathering is a natural process and concrete buildings can be designed to mature and change attractively. It is the flow of water on the façade reacting with the characteristics of the surface, controlled or not by the details, which determines whether dirt will be deposited or will be washed away. Dirt that is deposited in neatly controlled areas of the façade will not necessarily harm good concrete so, following my third and favourite strategy, a visually acceptable pattern of weathering need not be disturbed, but can be allowed to develop as part of the character of the building.

The second strategy on the graph could be said to have been a realistic acceptance of the need for maintenance, but that was not my intention. At the time the graph was first drawn I was considering visual matters only, but even all those years ago I would not have accepted the myth of maintenance-free buildings. Maintenance-free materials perhaps, but by the time these materials have been assembled into usable buildings or structures with junctions and fixings, the whole must require, at the very least, periodic checking and inspection to ensure that all is still working as intended – and such checks are themselves a form of maintenance.

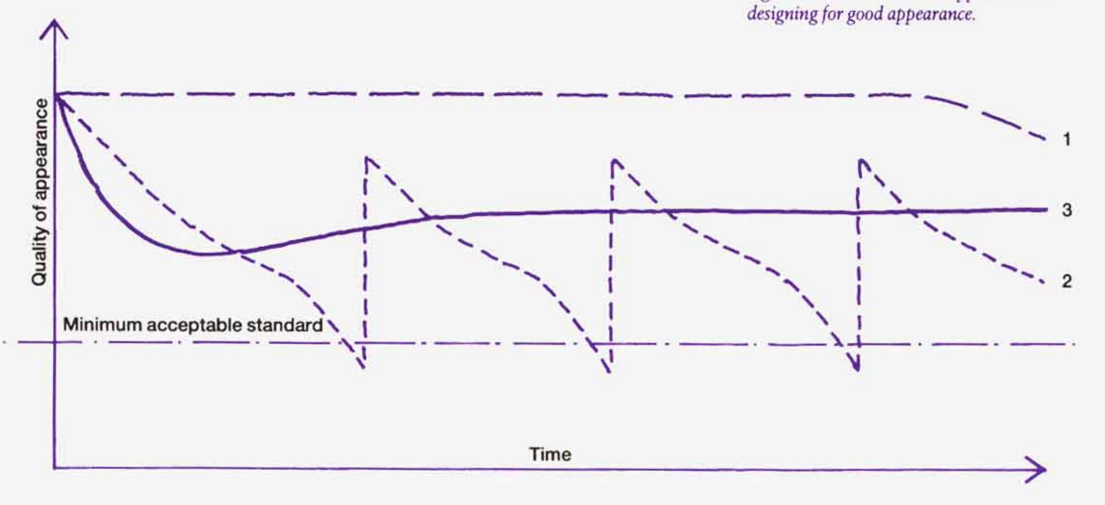


Figure 1: Three alternative approaches to designing for good appearance.

Design life

However, if my graph is to be used to make a case for planned maintenance, we should think more carefully about the two scales on which it is based. With regard to the vertical scale I used to say that if the building in question was at the top of the scale the architect would get the RIBA gold medal but if it was at the bottom people would be appalled by its appearance.

For visual purposes perhaps that is definition enough. However, if maintenance is our concern, the vertical axis could have many indices, including such quantifiable data as lettable value or maintenance cost per square metre per year, while the horizontal axis must relate to the design life of the building or structure.

What that design life should be is rarely given sufficient thought at the outset. It ought to be discussed and agreed between those who are designing the building and their clients who are instructing them and providing the money. If the building is only needed for a definable period that should be easy, but new uses are frequently found for redundant buildings, and 'long life, loose fit' is still a worthwhile aim.

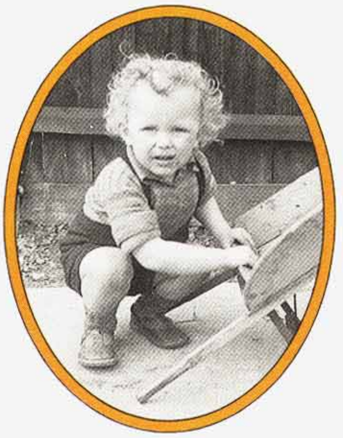
But even if a design life is agreed, what does this mean? It cannot be the time to structural collapse! Most buildings last rather a long time whether they were expected to do so, like our cathedrals and churches, or were designed for a finite period, like the postwar 'prefabs' of which many are still around after more than four times their allotted span. I saw one the other day forming the top floor and roof of a three-storey office in a quarry.

Planned maintenance

If buildings stand for a long time, whether they were intended to or not, then, for reasons of civic pride, commercial prestige or just good manners they should retain an acceptable appearance. Maintaining a good appearance should be a concomitant of longevity. Yet the temptation to hang onto a building which is still sound though visually unacceptable makes the definition of design life as 'the time to visual unacceptability' as impracticable as 'the time to structural collapse'.

The purpose of maintenance is to ensure that a building and its components function properly, and the only sensible definition of design life must be 'the time until the cost of maintenance becomes uneconomical'. Functioning properly must, however, include maintaining an acceptable appearance. That is not to say that the components or buildings should necessarily remain visually unchanged. I may not be as appealing now as I was as a child but I trust they will not shoot me yet!

A reasonable level of maintenance of appearance has to be decided and sustained. Polite



The author before dilapidation.

company reasonably expects that we bath frequently, clean our nails and comb our hair, but not that we go in for plastic surgery! Our friends accept our changing appearance as we mature – I am not expected to appear the same as a half century ago when the photograph was taken. Similarly I prefer buildings that show their age, to those that attempt to look forever new in a world of change. It is in deciding what constitutes a reasonable level of maintenance of appearance of a building that my ideas are changing. Yes, well made and well detailed concrete can be virtually maintenance free and the same can be said of some other materials, but none of these materials can stand alone. There have to be joints in every structure and they are the chinks in any building's armour.

Most problems in buildings arise from water penetration. Water promotes corrosion and deterioration and, because it expands on freezing, can even cause physical damage.

Joints

Connections between any two materials or components, such as concrete panels, have to be designed to accommodate the variations in joint width arising from inaccuracies of the supporting structure and from manufacturing tolerances in the units themselves, together with the variations inherent in erection and positioning procedures. Techniques developed to accommodate these variations divide into two basic types: those using a baffle or gasket, or other pre-made strip, for instance the 'open drained' joint; and those in which the joint is bridged by a compliant sealant or 'mastic'.

In current practice, joints are designed to have two lines of defence, usually with the space between them ventilated to equalize as far as possible the air pressure in the cavity with that on the face of the building. It is important that the second line of defence should be airtight. If the wind can blow through a joint, wind-borne rain is almost certain to get in.

All buildings have joints, notably where windows are set into walls, and we rely on these systems to keep them watertight. As with ▶

Concrete, well made and detailed, can be virtually maintenance free – the Russell Building at Wexham Springs after more than 20 years.

continued

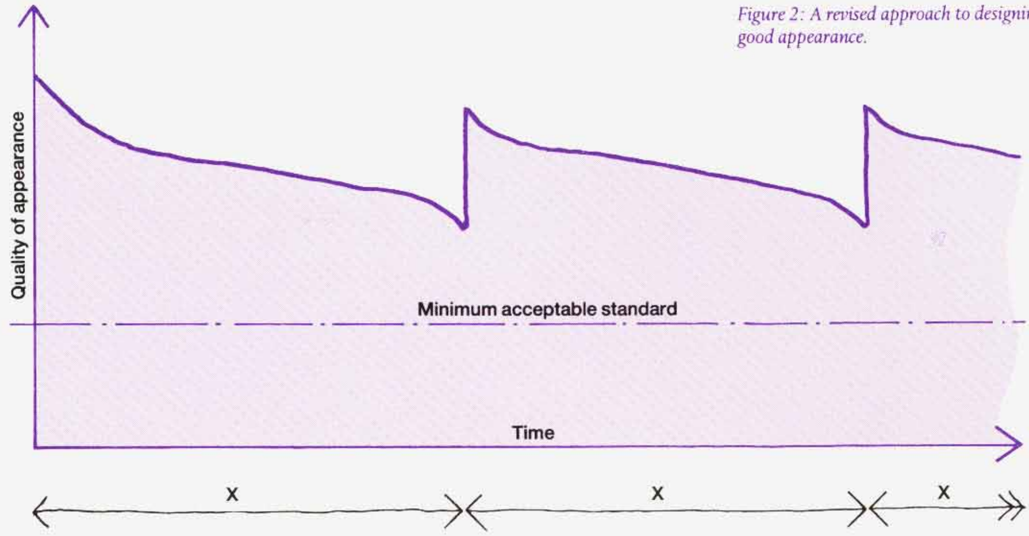


Figure 2: A revised approach to designing for good appearance.

most things, the more expensive the system the longer the trouble-free life expectation, but I have yet to come across a truly maintenance-free jointing system.

Sealant materials for instance vary in their elasticity, their adhesive properties and in their ability to retain these qualities in the rigorous conditions encountered on buildings. Although modern sealants have high elasticity it is sensible to design for a maximum of 25 % elongation. Sealant-filled joints can fail through the material splitting and tearing or by losing adhesion to the surfaces it is meant to join. Alternatively, if adhesion is very good it is not unknown for poorly made concrete to spall when the jointing material is unable to stretch sufficiently as panels contract. The maximum contraction of panels, requiring the maximum elongation of sealant, happens, of course, in the coldest weather when most such materials are at their least flexible. Contraction and expansion in buildings is rarely a smooth gliding movement but tends to proceed in jumps as friction forces are overcome. Some sealants which can be shown to withstand considerable gradual stretching cannot accommodate these quick changes.

FOSROC CCD

The cost of access can be a major part of maintenance costs.

Strategy refined

Now the reason for discussing the problems of jointing at such length is that a reasonable level of maintenance must include ensuring the continuing satisfactory functioning of this weakest link. One dare not wait for it to fail before acting. Routine inspections of joints must be undertaken at intervals less than the expected life of the jointing materials and, in my experience, routine inspection of joints involves sufficient brushing down and clearing of spiders' webs, etc. to disturb the visually acceptable pattern of weathering I have written about so often. I fear that each time a building is clambered over by a maintenance crew it is only sensible to get them to brush down or even to pressure wash the whole façade. When the cost of scaffolding a building is calculated it is clear that advantage must be taken of the access to the façade to do all that is – or may become – necessary.

This does not mean that we can forget all about detailing for the control of weathering. That will always be sensible in order to make buildings act as much as possible in the manner indicated by lines one and three on my graph.

My new graph, however, is going to have only one line. Instead of three strategies, I can see that there ought to be only one – that buildings ought to be designed always bearing in mind that the effects of time and the weather can be kept under control. The strategy is to design and detail to reduce the changes in appearance that will develop between one maintenance session and the next and to extend the time between these periods as much as possible.

The graph should look like **Figure 2** and the aims of the design team should be to maximize X and to minimize Y and to keep the line above the 'minimum acceptable standard'. Both causes will be served by careful detailing to control water but, as far as concrete buildings are concerned, the quality of the material is of even greater importance because if the concrete is poor the problems will not be solely visual. On the original graph, line 2 dips below the minimum acceptable standard because most building owners are reluctant to spend money on cleaning or painting until the building's appearance leaves them no alternative.

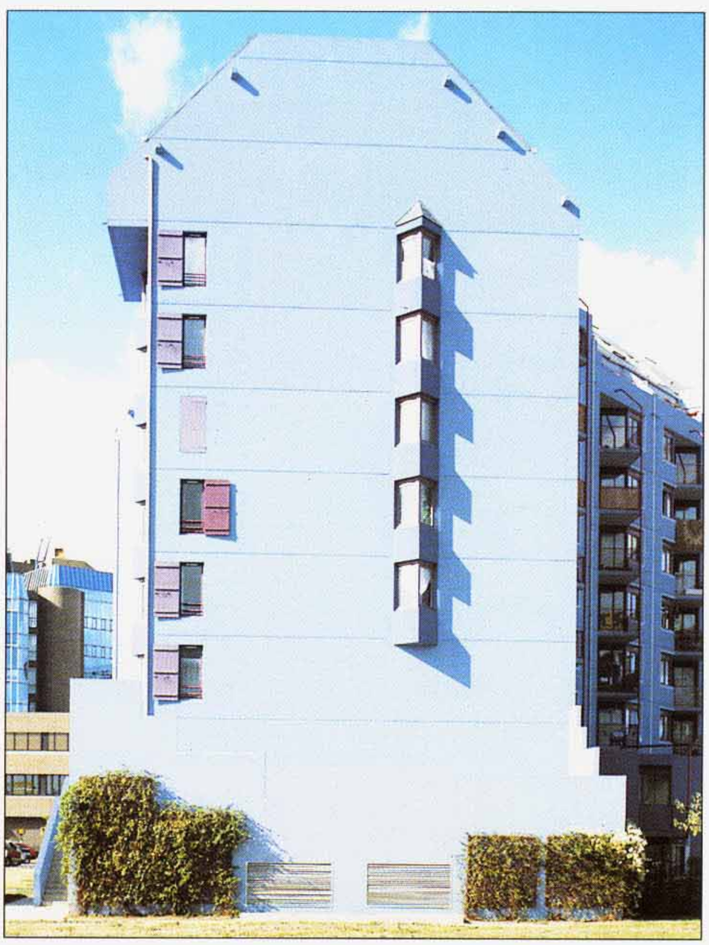
FOSROC CCD

The concrete on this building in Brentford was recently coated with Fosroc Nitocote Dekguard.

Quality counts

How much of the concrete at present undergoing remedial work was cast by firms that are still in production? I suspect that the firms which survive are the ones who were supplying a good product all along. After nearly 90 years of production of reconstructed stone, reinforced concrete and GRC, Empire Stone, for instance, have no knowledge of any problems due to lack of cover or poor concrete quality on any of their work! The credit for this lies with a conscientious, well led work-force carrying on a tradition of quality started by C. K. Smith 60 years ago. They always had their own standards for quality of concrete and cover to steel, and they never used calcium chloride.

Imaginative use of colour on concrete flats at Marne la Vallée.



C. K. Smith was the father of M. J. K. Smith, captain of Warwickshire and England, but more importantly he might perhaps be remembered as the father of quality control in the industry. Such quality, which is now available of course from many other firms, costs money, but we are surrounded by the false economies of the recent past, and neither we nor the Prince nor the public like it.

Concrete buildings can remain looking good. My preference is to achieve that by good detailing and good quality, but paints and coatings can also make a contribution – even sometimes putting into concrete some of the quality that was left out at the start. We ought, however, to recognize that painted or coated concrete is quite different in appearance and in the way it performs from what I would call good natural concrete. It has a much more dead appearance, and water runs down it in narrow streaks rather than on a broad front, so it needs no less care and attention to detail.

As the painting of concrete becomes more common, I hope that it will be used imaginatively. Concrete that is painted grey to look like concrete never does, and always seems to represent a missed opportunity.

I doubt if we will ever persuade the majority of British clients to spend money on purely visual matters, but any measures which are taken to lengthen dimension X on the graph must at the same time have the effect of diminishing Y, and that will be to everyone's benefit.

GERMAN FAST TRACKS

CONCRETE INNOVATION

Andrew Stroud

CLIENT AND OUTLINE DESIGN
- Deutsche Bundesbahn

DESIGN OF STRUCTURE AND LAUNCHING BEAM
- Harries & Kinkel

DESIGN CHECKING AND ON-SITE SUPERVISION
- Krebs and Kiefer

CONTRACTOR
- J G Müller and Co. mbH

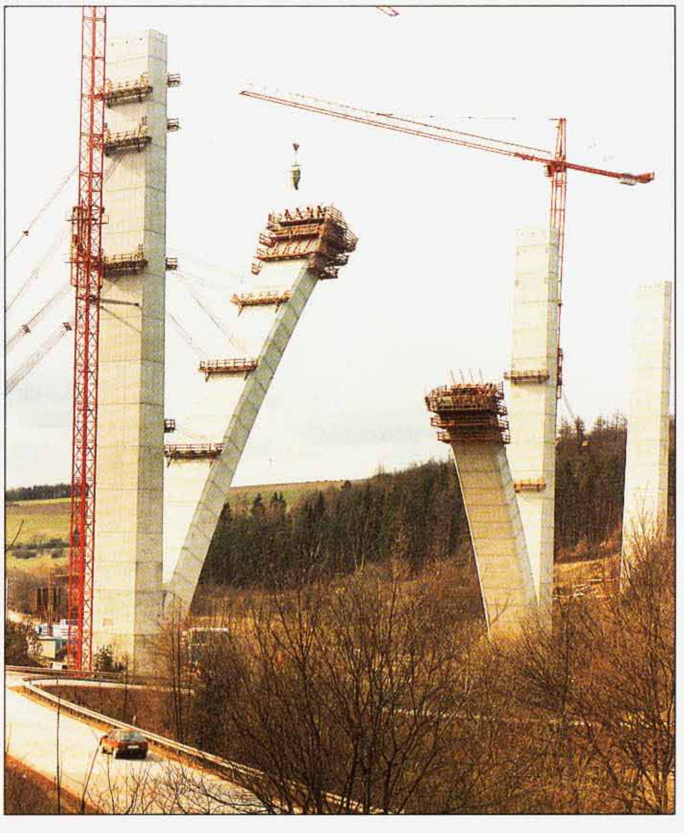
Innovative design and construction in concrete are embodied in one of the longest and highest bridges on the new high-speed rail network being developed by the Deutsche Bundesbahn, the German federal railway authority.

The 1400 km network will link the country's main economic centres from north to south. While 1000 km of existing lines are being upgraded, construction interest is focused on two entirely new routes – between Hannover and Würzburg (327 km) and between Mannheim and Stuttgart (99 km).

Planned operating speeds are up to 250 km/h, so the railway authority has set minimum radii at 5100 m and maximum gradients at 12.5%. Moreover, the new routes bypass many towns and villages so that environmental impact had to be minimized. Thus the choice of route options was limited, and some bald statistics indicate the scale of construction entailed on the Hannover to Würzburg section: 110 km (34%) is in tunnel, 99 km (30%) is in cutting and 36 km (11%) is in the form of viaducts or bridges.

R. EGGERT

The 'A frame' portal provides the only fixed point in the 1 km long bridge.



GEORG PRAGER

Progressive, cantilevered construction was used for the curved A frame piers.

Concrete is making a major contribution to almost every facet of the work. One of the many bridges already built on the Hannover-Würzburg section, which is scheduled to come into operation in May 1991, illustrates the scope such great projects offer for ingenuity in both design and construction.

The 1 km long bridge carries the railway some 95 m above the bottom of the steep-sided Rombach Valley in the Hessian hills to the north of Fulda.

Design

The concept scheme, produced in accordance with design standards laid down by Deutsche Bundesbahn in 1982, envisaged a superstructure made up of a series of simply supported beams 58 m long. In this way maintenance would be minimized and individual span replacement facilitated, should it ever prove necessary.

However, the unusual height of this bridge, coupled with its heavy vertical and horizontal loadings, and the possible effects of any differential settlement of the piers, dictated a somewhat different approach.

The solution adopted was to create a continuous deck over the full length of the bridge and to provide a fixed point at its centre. This was achieved by inserting an 'A frame' of inclined piers, springing from the bases of the two central vertical piers, 116 m apart, and meeting at the mid-point of the deck, where they 'interlock' through elastomer bearings with the ends of the two central deck beams. Thus the longitudinal forces generated in the deck are transmitted through the inclined piers into the foundations. In this way, the sensitivity of the structure to differential settlement was reduced, and it was necessary to provide track movement joints only at each abutment.

The bridge deck is curved on plan to a radius of 6000 m, and has a vertical gradient of 12.2%. It is made up of 17 prestressed concrete trapezoidal box beams, 58 m long, 5.3 m high, over 6 m wide, and with the deck cantilevered some 3.3 m on either side. After completion of the deck structure a 1.7 m high precast concrete noise barrier was installed along each edge.

Sliding bearings, incorporating lateral restraint, are provided on each of the vertical piers. Compressive forces are transferred through elastomer bearings mounted between steel plates at mid-height on the webs, and horizontal transverse forces through a single bearing at bottom slab level. The specially developed prestressing tendons used to couple adjacent beams carry the tensile forces. The 54 strand BBRV tendons are protected by grease-packed ducts which, in turn, are housed in larger ducts cast into the concrete. The anchorages, similarly protected, are accessible and tendons can be inspected, and replaced if necessary.

The vertical piers range in height from 16.6 m to 86.4 m, and are slightly tapered from their base section of 7.6 × 3.5 m. Wall thickness is constant at 500 mm. The inclined, curved piers forming the A frame are of similar section.

Foundations

Deep pier foundations were needed because of the variable and faulted geology of the valley, and detailed pile testing was carried out. The central piers incorporating the A frame are each supported on 25 inclined 1.8 m diameter bored piles, and built off a 20.5 m square, 3.8 m deep pile cap. Fourteen piles and a 16 m square pile cap support each of the remaining piers. Maximum pile length is 17 m.

Construction

Climbing formwork was used to construct the piers, which are hollow to permit access for inspection, maintenance and, when necessary, hoisting of materials to superstructure level. A 5 m lift was completed every two and a half days. Progressive cantilevered construction was adopted for the inclined, curved A frame piers, which were temporarily stayed back to the two adjacent piers as construction progressed at the rate of 3.3 m every three days.

A bit of history

A notable 'first' in the construction of the deck beams was the use of a prestressed concrete, self-launching casting girder over 100 m long in place of a conventional steel structure. It was made up of a 47 m nose section (27 m steel beak and 20 m prestressed concrete), a 58 m long concrete trough form, and a 2 m rear extension to support the forward end of the previously cast beam.

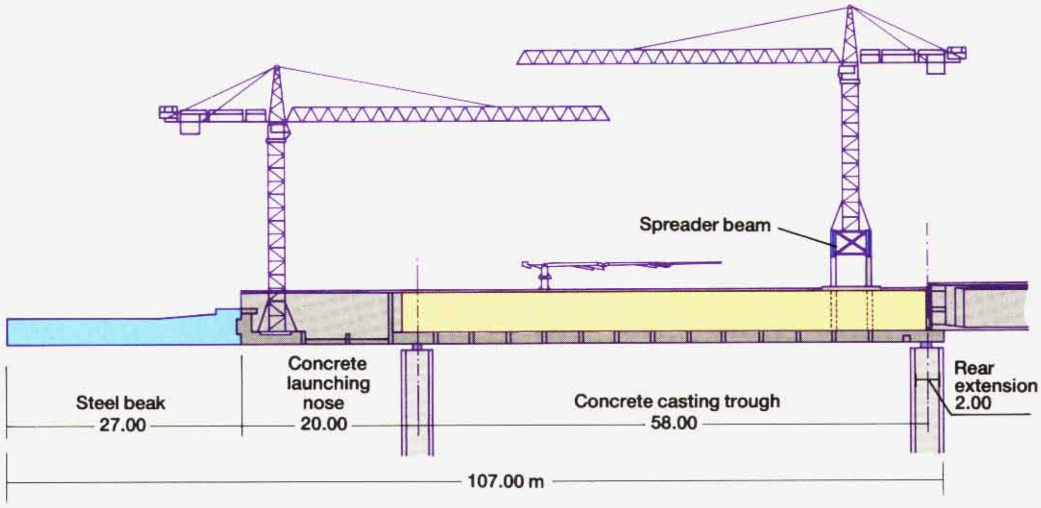
Tower cranes were mounted in the concrete nose section and on the transverse steel spreader beam, and hydraulic concrete pump booms were mounted on either side.

Large formwork panels, which were subsequently to line the trough for casting the 17 deck beams, were themselves used for its construction.

Concrete was chosen for the launching/casting girder because it offered a number of advantages:

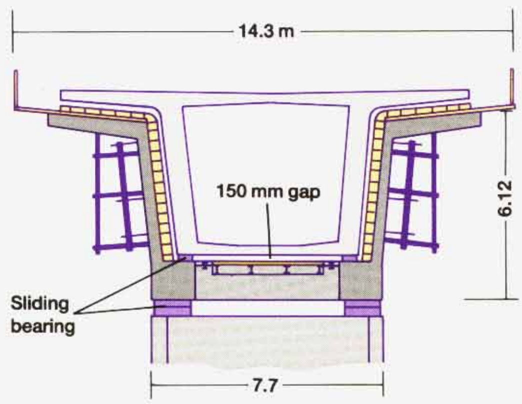
- Cost of production, handling and subsequent demolition was significantly less than for an equivalent steel structure which depreciates by at least one third on each project.
- The rigidity of the structure greatly reduced both deflections and vibration amplitude.
- The added insulation provided by the concrete casting beam reduced dissipation of heat of hydration. Thus early age shrinkage cracking was reduced resulting in particularly high-quality dense concrete with a very good finish.

Each superstructure beam took three weeks to complete. Casting was carried out in two stages, first the bottom slab and webs, and five days later the cantilevered deck slab. Some 900 t of concrete and 160 t of reinforcing and prestressing steel were used in each beam.



Superstructure beams were cast in a prestressed concrete self-launching girder.

After stressing, the beam was jacked up 150 mm in the mould, and sliding bearings were inserted (slide face down) at each end. The bottom chords of the launching beam rested on face-up sliding bearings on the piers. With the new beam anchored in position, and the spreader beam lowered into a 'holding down' position to slide along the new superstructure deck, the launching girder was jacked forward into its new position on the next span. Finally the rear of the new beam was lowered 150 mm onto its permanent bearings, the temporary supporting jacks removed, and the new abutting beams coupled together.



Beam lifted after casting.

In the few cases where small adjustments needed to be made to line or level, this was easily done by insertion of a thin mortar packing at the bearings.

The concrete casting girder completed its first contract with flying colours, and was demolished with due ceremony after the last beam had been cast.

The Rombach Valley bridge took three years to build at a cost of approximately £12 million. In total some 820 t of prestressing steel, 5150 t of reinforcement and 48 000 m^3 of concrete – nearly all ready-mixed – were used in the project.

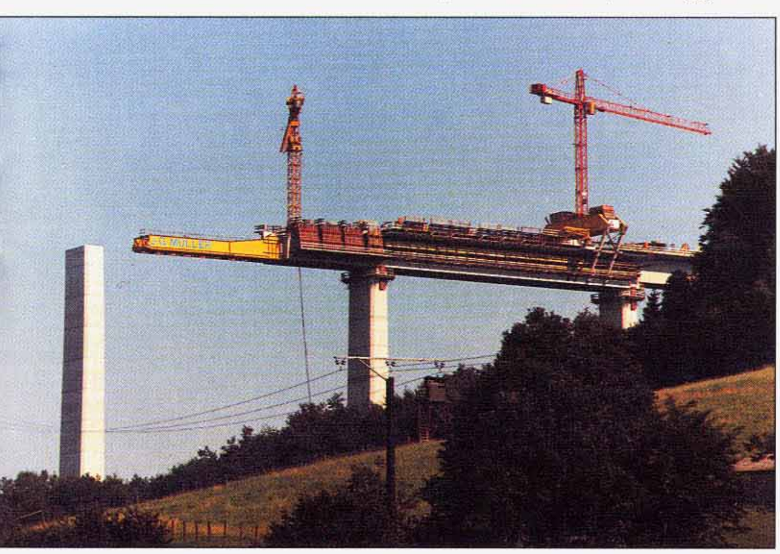
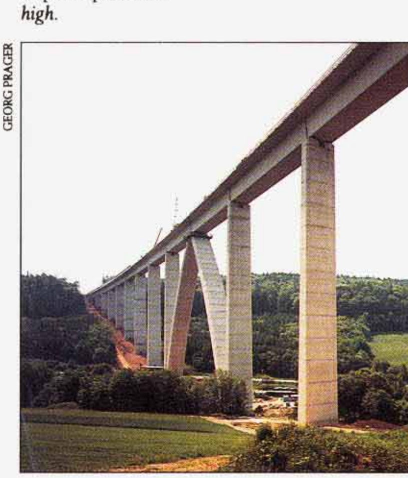


FOTO DIEGELMANN



GEORG PRAGER

The seventeen 58 m long beams are carried on piers up to 86 m high.

GERMAN FAST TRACKS
CONCRETE PRECISION

BETON-VERLAG

TRANSRAPID MAGLEV CONSORTIUM
- AEG-Telefunken; Brown Boveri & Cie; Dyckerhoff & Widmann; Krauss Maffei; Messerschmitt-Bölkow-Blohm; Siemens; Thyssen Henschell.

CONCRETE TRACK DESIGN AND MAIN CONTRACTOR
- Dyckerhoff & Widmann AG

While work is well advanced on the German high-speed rail network, commercial introduction of the next generation of high-speed, land-based passenger transport may not be far behind. A 31.5 km test track, involving high-precision in situ and precast concrete, has successfully demonstrated the potential for magnetic levitation (maglev) trains, in which the traditional and limiting wheel on rail contact is eliminated.

With the continuing increase in demand for short-haul travel, and the growing congestion of airspace in Europe and other major industrial areas, a new high-speed system to link city centres, and also to distribute passenger load between overcrowded and under-used airports, is almost certain to be needed sooner rather than later. Studies have shown that a system capable of operating at speeds of up to 500 km/h would be fully competitive with air travel for journeys up to 700 km, and could potentially take over what is known as the 'third-tier' air travel market.

The first successful tests on 'electromagnetic levitation' were carried out in the 1930s, but it was not till the late 1960s that serious study of its application to passenger-carrying systems began in Germany, with funding from industry and government. Some ten years later maglev technology had been sufficiently developed to justify simulation and outline planning of its commercial application.

In 1978 the companies which had been engaged in the development work formed the Transrapid Maglev Train Consortium to build a complete test facility to examine the efficiency of the new technology under full-scale operational conditions. After detailed study, a site in the Weser-Ems region was chosen, and a 31.5 km long figure-of-eight test track, incorporating two sets of 'points', was built in two phases, in 1981 and 1987.

The maglev train is equipped with electromagnets and the track incorporates ferromagnetic armature rails. Levitation magnets lift the vehicle clear of the track, and guidance magnets, operating on the side guide rails, keep it centred. Propulsion and braking is provided by long stator linear motors mounted beneath the outer edges of the track. A clear gap of 10 mm is maintained between the base of a moving train and the upper surface of the track beam.

Exceptionally tight tolerances

A system operating to such fine tolerances called for a track manufactured and installed to extraordinary levels of precision, so concrete was chosen for over 70% of the test track. The facility is elevated to a clear height of 4.7 m over its entire length, with a guide track superstructure of 2.8 m wide beams spanning 25, 28 or 37 m. The maximum superelevation is 12%.

Each carried on four raking bored piles up to 16 m long, the pairs of inclined in situ concrete piers meet to form a saddle in which the track beam is supported. Pockets are provided for inserting the jacks used to align the superstructure during erection, and also to permit any subsequent adjustment which may be required.

The precast, prestressed concrete beams vary in depth from 1.8 to 3 m, depending on length. The longest, deepest beams are used on curves (minimum radius 1690 m) to ensure that maximum permitted deflections are not exceeded.

The entire structure was built to a tolerance of ± 20 mm. This enabled the exceptionally tight tolerances for the operating components mounted on the track beams to be achieved. For example, the maximum permitted vertical variation on an unloaded 28 m beam is 4.5 mm under any temperature conditions.

The concrete track system has performed exceptionally well in the trials, in which the maglev test train has achieved a top speed of 412 km/h. The success of these trials, and of the concurrent commercial investigations, suggest that the key question remaining is where – rather than whether – the first commercial maglev train route will be built.

Erection of a prestressed concrete track beam.

SCHMIDT-LUCHS

FORTHCOMING EVENTS

Brief details of some of the forthcoming BCA events follow. For copies of the full programme of events contact the Events Department.

Reinforced concrete – achieving total QA in design, materials and construction
Edinburgh – 7 Feb 1990
Sutton Coldfield – 8 Feb 1990
Wilmslow – 7 Mar 1990

Will familiarize designers, specifiers and middle and senior management with the testing and certification relating to ready mixed concrete and reinforcement and how these are integrated into a specification calling for quality assured materials. The cost and quality benefits to be derived will be outlined in full.

Advances in construction technology and practice
Slough – 15 Mar 1990

Elements of successful fast-track construction will be reviewed in detail. Speakers with extensive recent experience in all aspects of rapid concrete construction will take participants through the key points of design and construction.

Specification for economic concrete construction
London – 20 Feb 1990

In order to extract the full benefit from a rapid construction programme, it is essential that specifications are produced to realize the full benefits of the various concrete elements. Many specifications are not up to date. This meeting will concentrate on those aspects of a specification where updating can offer the maximum economic benefit.

An introduction to Eurocode No. 2
Hinckley – 13 Feb 1990

Eurocode No. 2, design of concrete structures, is already at an advanced stage in readiness for 1992. This seminar will introduce senior design engineers to the Code, and should be regarded as essential early learning in the run-up to the single European market.

For details and programme of events telephone the Events Department, Fulmer (0753) 660428. Access/Barclaycard/ American Express holders may book by phone.

NEW PUBLICATIONS

The following new publications are now available.

Concrete – the high-speed building option
Ref. INF 087. Price £3.50. 6 pp.

Makes the point that time is money, and no building system moves faster than a reinforced concrete frame. Outlines the concrete systems available and discusses their benefits. Several projects are highlighted, demonstrating what can be achieved in terms of speed, cost and flexibility. A Reinforced Concrete Campaign publication.

Advances in concrete construction technology
Ref. 97.309. Price £3.50. 16 pp.

Intended to assist designers and constructors in evaluating the benefits of adopting alternative techniques to those traditionally used for in situ concrete construction. Describes the latest technology in formwork systems and appraises new construction practices to maximize speed and economy. A Reinforced Concrete Campaign publication.

Project profile: South Quay Plaza
Ref. 97.310. Price £3.50. 12 pp.

Describes the development of London Dockland's South Quay Plaza, a prime example of a well designed, well constructed and efficiently engineered project that exploits the versatility of in situ concrete to achieve speed and economy. Discusses the reasons for the choice of concrete and examines the design and construction of each element from substructure through frame to cladding. A Reinforced Concrete Campaign publication.

BCA Bulletin No. 6
Free in the UK (overseas subscriptions £10.00 p.a.). 8 pp.

Provides an update on the Association's work. Topics in this issue include NAMAS accreditation for BCA, chloride ingress into concrete, the structural performance of concrete affected by ASR, mix-in-place recycling and slipforming kerbs.

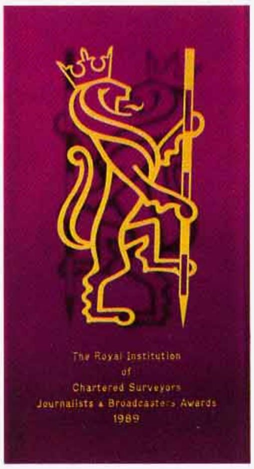
For BCA Catalogue and orders phone Publication Sales, Fulmer (0753) 660440. Access/Barclaycard/American Express holders may order by phone.

NEW SERVICES

BCA granted NAMAS accredition

The British Cement Association has been granted accreditation by NAMAS, the National Measurement Accreditation Service, for its testing of cement and concrete. NAMAS accreditation is an essential part of quality assurance in the UK, and all sectors of industry are increasingly recognizing that, in today's competitive markets, products and services must be underpinned by authenticated measurements and testing. The accredited tests will form the backbone of the commercial activities of C&CA Services, the research and technical services division of BCA, and will include both routine tests and a large number of specialized in-house procedures, mainly used in projects with a high R & D content. The accreditation brings several advantages to BCA's clients: they are assured of the validity of the test data; the accuracy as well as the reliability of the tests has been demonstrated; and the test results are formally traceable to the national primary standards held at the National Physical Laboratory. BCA's schedule of 225 tests covers all the main concreting materials, fresh concrete, concrete products and large structural units as well as subsidiary materials such as soils.

Further details and a full schedule of tests are available by writing to The Director, C&CA Services, Wexham Springs, Slough SL3 6PL.



Triple success...
On the strength of his case studies in the last five issues of CQ, Russ Swan, now on an extended world tour, has won three major 1989 awards – the RICS Journalists and Broadcasters Award *(magazine category), the International Building Press Association (IBP)* Building Writer of the Year Award *and also the supreme IBP* Journalist of the Year Award.

Addendum
The name of the Danish consulting engineer for La Grande Arche, Erik Reitzel, was inadvertently omitted from the credits for the project (CQ 161, Summer 1989, p.16)