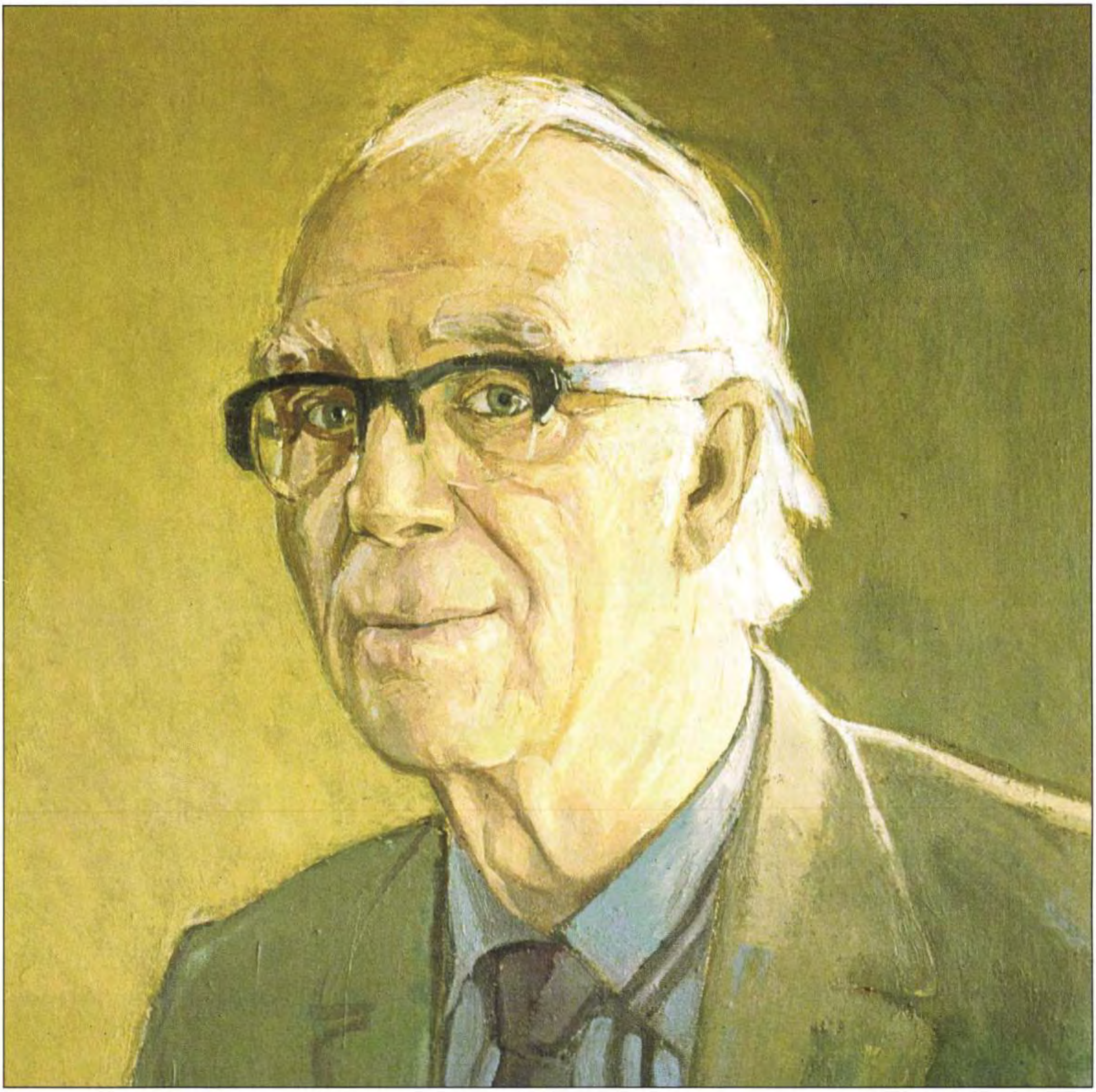
THE ARUP JOURNAL

OVE ARUP'S 90th BIRTHDAY ISSUE

SPRING 1985



THE ARUP JOURNAL

Vol.20 No.1 Spring 1985
Published by
Ove Arup Partnership
13 Fitzroy Street, London W1P 6BQ

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Foreword

Ove's commitment to 'Total Design' is probably his greatest contribution to our profession in particular and to society in general. Whether the totality refers to the integration of design and construction, the place of structure in architecture, the place of architecture in society or on the impact of modern technology on society, Ove brings his intellect to bear on the issues with a directness and integrity which has set an example to us all. His quest for truth is tempered by the knowledge that it is elusive and many-sided at best — non-existent at worst. He would agree with Einstein who said that 'whoever undertakes to set himself up as a judge in the field of truth and knowledge is shipwrecked by the laughter of the Gods'. It is the freshness, honesty, lack of pomposity and above all the humanity of Ove and his writings which are special to us all.

What better way to celebrate Ove's 90th birthday than to collect some of the papers and lectures which he has produced over more than 60 years. This issue of the Journal is a token of our esteem and gratitude on this marvellous celebration.

Bob Hobbs
Jack Zunz

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Front cover: Portrait of Ove Arup by Benedict Rubbra
Back cover: Kingsgate Footbridge, Durham (Drawing: Roger Rigby)

The world of the structural engineer

This paper was the Institution of Structural Engineers 1968 Maitland Lecture delivered at the Purcell Room, London, on 14 November 1968; reprinted from The Structural Engineer, *January 1969, by kind permission of the Council of the Institution of Structural Engineers.*

I am sure you all agree that the Structural Engineer needs no introduction to this audience. But actually it is a bit hard to define the term 'structural engineer'. It could be one who has passed certain examinations, who is a member of this institution — in which case he would even be a chartered structural engineer — one who holds a certain position or does a certain job. For the purpose of this talk, I would prefer to define the structural engineer simply as one who is competent to design stable and economical structures of different kinds to meet the requirements for which these structures are needed. This means of course that one can be more or less of a structural engineer, and that civil engineers, mechanical engineers and some who are not called engineers at all might be so called.

But *the world* of the structural engineer cannot be thus defined — it would vary with each individual — and they vary widely, as a glance at this audience will show. The structural engineer can only be an abstraction, a figment of the imagination.

Since, therefore, we must imagine this structural engineer of ours, let us at least imagine a man who will serve our purpose this evening — who will provide us with a critique of his professional milieu. We'll make him a civil engineer specializing in structures, and we will make it his job to design structures in different circumstances, as employee or employer, as contractor or consulting engineer, as principal or consultant to an architect. He should also be a difficult, critical sort of chap, always thinking that things could be better than they are. Being a mere convention he can of course afford to be outspoken. Perhaps we should make him a foreigner — that would after all explain a great deal. But all the same there must be some sense in what he says, for if not the whole exercise becomes pointless. We'll make him, also, a bit of a dreamer, a man to whom dreams are at least important, and not too much a man of action; for, as it says in Ecclesiasticus: 'The wisdom of a learned man cometh by opportunity of leisure: and he that has little business shall become wise'.

And while we're at it, we really must give him a name, otherwise we'll never get to know him. I think Ernest would be a good name for him; it is not impossible that he may turn out to be a bit of a prig.

I imagine that even as a child Ernest had an inquisitive sort of mind, a curiosity about what's inside things, how they work, how they're made. And this being so, he was naturally attracted to science. You must remember that this was a long time ago, when Science stood for Truth, and Art for Beauty, and when Goodness was the purpose of life. They were absolutes — to begin with. And for him they never quite lost that aura. Especially truth: he thought he would one day be able to discover the secret of Kant's 'Ding an sich', the secret of being.

Of course he was disillusioned. He soon ceased to expect any absolute solutions. But truth remained important to him, and so did beauty — or rather, art. Still, he was no artist, and he decided to become an engineer. But of course: a good engineer; because he chose this way also in search of an opportunity for artistic fulfilment, the satisfaction of a job well done. This was not surprising. Young people are often idealists, they believe they can do better than their elders. They may not know exactly what they want to do, but they are far from being aimless. Ernest realized that he wouldn't solve the world's problems, no matter how much science he studied; and he saw engineering in terms of solving problems that could be solved, problems of designing exciting structures. Engineering is not a science. Science studies particular events to find general laws. Engineering design makes use of these laws to solve particular practical problems. In this it is more closely related to art or craft; as in art, its problems are underdefined, there are many solutions, good, bad and indifferent. The art is, by a synthesis of ends and means, to arrive at a good solution. This is a creative activity, involving imagination, intuition and deliberate choice, for the possible solutions often vary in ways which cannot be directly compared by quantitative methods.

But I had better let Ernest get on with his career. He studied mathematics, physics, chemistry, mechanics, and the rest, learned about materials and their properties, about forces, stresses, and all the other things, mostly theoretical; and he took his degree in engineering, specializing in structures.

Designer and contractor

He was particularly interested in the potentialities of a comparatively new material called reinforced concrete and therefore joined an international firm which specialized in the design and construction of reinforced concrete structures. This firm had come in on the ground floor, so to speak, building quay walls, jetties, bridges, silos, water towers, coal bunkers and so on, in competition with firms using established structural materials — mostly steel, timber and stone. It seemed a wonderful opportunity for anyone wanting to use his imagination and creative power.

He got a bit of a shock when he first visited a building site and realized how far reality is at variance with theoretical assumptions about the placing of bars, the density of concrete, and dimensional tolerances. (These were early days, remember — concrete looks different now.) And he soon realized the futility of pressing calculations to an exactitude which exceeds that of the basic assumptions.

It also very soon dawned on him that what he had learnt at school didn't get him very far when it came to actually designing, for instance, marine structures. If you are faced with building a breakwater in deep sea, with huge waves rolling in, what on earth do you do? You know there are various possibilities, blocks, caissons, piling; and you can at a pinch decide which will stand up when it is built — although it proves difficult to get anyone to commit himself about the force of waves. But how do you get it there? Won't it be smashed to bits before it is built? And above all, how much does it cost? Because so far as his firm was concerned, the whole point was to find a solution which they could offer at a lower cost than that of competitive schemes, so securing a job and making a profit.

Fortunately older members of his firm were well versed in the practical business of building in difficult circumstances, and he accepted their guidance with gratitude. After a couple of years he grew quite good at designing plus estimating. He found out about the costs of materials from the buyer, and about the labour expenses involved in each type of operation from the firm's weekly cost sheets. So far he had nothing to do with deciding about overheads and profits, dealing with customers or visiting sites. But he did learn one useful lesson that he was never to forget: namely that *a designer must have a clear idea of what he wants to achieve; and must know the means of execution available to him and how to evaluate their effectiveness, both theoretically and practically.*

There was no difficulty so far about the first part: he simply had to fulfil the client's requirements for less money than his competitors could, while satisfying the building authorities and providing a stable structure with no obvious defects. With whatever imagination and ingenuity he could summon he had to battle with the facts and possibilities, and try out alternative solutions, costing every step to make sure he was not taking a wrong or expensive turn. It required an effort on his part if the result was to be good. A sudden inspiration could help, of course; but it very seldom came without prior intense absorption of the relevant facts.

Let us now imagine that one day Ernest, this structural engineer of ours, was posted to London. He arrived in mid-winter in the early 'twenties in a real old-fashioned pea-souper; policemen in white nightgowns armed with flares or white sheets walking carefully in front of whole rows of red two-decker buses. There were coal fires in stations, even in drawing offices, cosy and dirty, roasting one side, freezing the other. Surveying in gumboots on the mudbanks of the Solent, staying at a little pub, darts, warm beer, kippers, joint and two veg; a hot humid December, tea with crumpets, lovely old Christmas carols — he was enchanted with it all. I don't suppose he was actually asked whether he thought our London policemen were wonderful — but of course that's what he did think.

After a while he grew more used to the ways of the natives. His firm had lost heavily on two major contracts because their estimates were based on continental rates for output per man-hour; and reinforced concrete was looked on with the greatest suspicion by the majority of potential clients. But Ernest learned, and we will suppose that he presently became chief designer in the London branch of his firm, responsible for designs and tenders. He soon realized that his chief headache was not to design the structures, but to get the *chance* to design them. The firm tendered for jobs designed by consulting engineers, city engineers, railway engineers, etc., in order to get enough work; and much that Ernest saw appalled him. He frequently saw marvellous opportunities for suggesting much more economical solutions. But he discovered the naiveté of assuming that engineers would be interested in his ideas, even if they led to better solutions to their problems: they very rarely were. A contractor who dared to offer an opinion on the design of a consulting engineer might find his firm excluded from tendering at all.

To begin with he put his foot in it good and proper, and was several times shown the door.

It would be too much to say that Ernest learnt tact from such experiences; but he learnt some caution, and scored some successes.

There was a design for a wharf put out to tender by a railway company, which proved to be a mechanism that would collapse as soon as the backfill was placed. Ernest managed to get an interview with the chief engineer, and indicated delicately that his firm was worried about taking responsibility for the design because of so-an-so: would the chief engineer perhaps be good enough to explain, or would it be in order to put forward an alternative solution? The chief engineer saw the light, and whilst not admitting that anything was wrong, refrained from kicking Ernest downstairs, and agreed that he could put in an alternative solution provided that everyone else was allowed to tender on it as well. Of course there would be no question of paying for the design commandeered in this fashion; Ernest was none too happy about it; and when the QS was called in and estimated that it would take him six weeks to prepare the bill of quantities for the alternative design — which would not therefore be ready until long after the date of tendering — things looked black indeed, and Ernest wondered whether the chief engineer had really understood the situation. But a bargain was finally struck. Ernest would quote on the unworkable original scheme in competition with the other firms, and only if his firm submitted the lowest tender would his alternative scheme be considered, and probably accepted if the price were lower still. Other firms would after all not have to quote on it.

The rest was easy, because the alternative was indeed cheaper, even with a good profit; and Ernest could safely put in too low a price for the official scheme, knowing that it would not be built. And so it came to pass.

I am sure Ernest could tell you many such interesting stories, if there were time for them, and if we could rely on the accuracy of his memory. But we must return to his career. He began to feel that as a contractor he was rather frustrated. He remained a novice in the subtle art of cultivating clients, and at that time people were just not interested in ideas. He had many such; but he couldn't get manufacturers, crane-makers, or brickworks to collaborate in evolving new handling plant or new facing materials for concrete unless he had bulk orders ready. He couldn't try out new methods, for nobody would take any risk; he couldn't even get the firm's own foremen to make really good concrete with a decent surface, since it cost more, and profit margins were narrow. And when he did succeed in getting out a design that ought to beat all competition, it still didn't mean that his firm would get the job or that it would be built if he did. Sometimes the client sent the design to all his competitors, so that they could quote on this idea as well. Sometimes an appreciative but just a little too greedy head office abroad, to which all important tenders had to be submitted, clapped on an extra 10 or 20%, thinking to cash in on an opportunity which was thereby lost.

I am afraid that Ernest is given, in some moods, to complaining that all his best ideas came to nothing. No one takes him too seriously; he had his frustrations — who hasn't? — but he achieved a good deal, and most people would consider him lucky. But I must say I can sympathize, for I sometimes feel the same way myself. I have rather surprisingly reached a position where I am — for instance — honoured with this invitation to give the Maitland Lecture; and if only certain designs I produced as a younger man had been carried out, I might not feel quite such a fraud.

A minor annoyance was caused by the growing practice of extending quantity surveying as known from the building trade to steel and reinforced concrete structures. When his firm received a bill of quantities — a thick volume, beautifully printed, which had taken months to prepare — they had laboriously to pick out all the items of concrete, steel, etc., from hundreds of different entries describing different members of different sizes; collect them all together; and prepare an estimate on their own model, perhaps two or three pages long, giving the amount of concrete in different mixes in cubic yards, the different kinds of formwork in square yards, the reinforcing bars in tons, plus whatever excavation and extra items like pipes, bolts, and whatnot had to be provided. Then plant, staging, sheds, foremen's time, and so on were added, after it had been decided how to lay out and organize the job. And then came the tedious business of distributing the tender price over the thousands of items in the bill — including thinks like 'extra over for rounded edges', though no one has ever put in a rounded edge without placing the concrete at the same time. The trouble was that there could be no correspondence whatever between the items in the bill and the information the contractor received from his weekly cost sheets — and that, after all, was where he got his costs.

Of course the idea was to make the bill a legal document defining the job, so that the consulting engineer or architect could obtain a price without having to finish the drawings. A thoroughly bad excuse for a bad practice, thought Ernest. The whole method breaks down if you are faced with an original design introducing new methods — which was what Ernest was always *trying* to achieve. And he couldn't share the QS's faith in these rates as cost indicators, since he well knew that the way the total price was distributed over the different items was guided by political motives rather than by devotion to accurate accountancy. Ernest used to claim that in the time it took his staff to deal with all this clerical work they could have designed the job, taken out *their* kind of quantities, and priced it. But then he wasn't very fond of clerical work. And besides, the business of multiplying a quantity of steel expressed in tons, hundredweights, quarters and pounds, by a rate expressed in pounds, shillings and pence, using a ready reckoner, seemed to him faintly ludicrous.

The Modern Movement

At this time still before the war, he happened to meet some of the pioneers of the Modern Movement in architecture, because some of them approached his firm asking them to tender for some buildings in reinforced concrete.

Here he met a number of young people who really *were* interested in new ideas, who in

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1 Bungalow for Berthold Lubetkin, Chiltern Hills (1933-4)
Architects: Lubetkin and Tecton
(Photo: Dell & Wainwright; copyright *Architectural Review)*

2 Penguin Pool, London Zoo, Regents Park (1934)
Architects: Lubetkin and Tecton
(Photo: John Donat)

3 Bear Ravine, Dudley Zoo, Worcs. (1936-7)
Architects: Lubetkin and Tecton
(Photo: Herbert Felton; copyright *Architectural Review)*

4 Entrance foyer, Highpoint 1, Highgate (1933-5)
Architects: Lubetkin and Tecton
(Photo: John Donat)

5 Whale pierhead fenders, Mulberry Harbour (1944)
Designed by Arup & Arup
(Photo: Reproduced by courtesy of the Trustees of the Imperial War Museum, London)

fact had plenty themselves, and were very fond of discussing them. It was stimulating, amusing, and also puzzling. The puzzling part was that these architects professed enthusiasm for engineering, for the functional use of structural materials, for the ideals of the Bauhaus, and all that; but that this didn't mean quite what you might suppose. They were in love with an architectural style, with the aesthetic feel of the kind of building they admired; and so they were prepared and indeed determined to design their buildings in reinforced concrete — a material they knew next to nothing about — even if it meant using the concrete to do things that could be done better and more cheaply in another material.

But here was a group that both welcomed and needed Ernest's ideas. He joined the MARS Group and the Architectural Association, and started to help architects with their reinforced concrete schemes — mostly on paper only. He also helped some architects to win some competitions, and they celebrated together with a trip to Paris to look at modern architecture. Corbusier's Swiss Pavilion made a deep impression on him. This *was* something. But what was it? Why did it have that effect? He shared the enthusiasm of the architects, but not perhaps their reasoning. He suspected that what mattered was not that the building was 'modern', but that it was great architecture, architecture produced by an artist.

He joined a new firm in order to have the opportunity of working with architects; and he was busy designing, tendering for, and obtaining contracts for jetties, silos, cooling towers and other structures, including reinforced concrete frames for buildings in imitation of the more usual steel frames. Ernest deplored this method of using concrete, and in the building carcasses which the firm designed for modern architects he adopted what he at that time called slab construction.

This attracted the attention of at least the architectural profession, for and against. But his position as designer of the reinforced concrete carcass, when he was at the same time employed by a contractor who tendered for the building, was really quite untenable. The architects wanted Ernest's firm to get the job, because they wanted him as designer; and he had to persuade his firm to quote a low price, so that the architects could in turn persuade the client that the job would be cheaper than traditional building. Whereas it really should have been more expensive, if it were to be done properly, in view of all the innovations it contained. Ernest was far from happy about the whole position, and realized that if he were to help architects to design buildings, it would have to be as a consulting engineer. And in any case, he had had enough of this political game, of the pressure to temper truth with expediency, and the assumption that he had done so whatever he did.

Contracting and consulting

Nevertheless, when he was offered help to set up as a contractor himself, he did so, planning at the same time to act as a consulting engineer independent of the contracting firm, and to use any surplus profit to initiate new methods of construction by design-research combined with practical tests. For he was still convinced that the designer should be able to choose and control the method of construction, to achieve the proper integration of the two. He had seen enough of impractical designs produced by consultants. This was before the war, of course.

He was in fact trying to ride three horses at the same time:

(1) As plain contractor — to make a living

(2) As designer-contractor, carrying out structural work to his own design

(3) As consulting engineer for the design only of structures, in the first instance to help modern architects mostly wanting to use concrete as a structural material.

To the outsider (and Ernest remained something of an outsider) the proposed combination looked fairly sensible; but it was in a way an act of defiance. He was perfectly aware that it would meet with resistance and suspicion; but he hoped to overcome it by sticking strictly to the rule of *not* involving his contracting firm if he was chosen as consultant. He wanted of course to give up carrying out other people's designs as soon as he could afford it, because it was design he was interested in, and he only wanted a link with construction in order to improve design. It worked for a time, but war intervened. This put an end to architecture, other problems loomed ahead.

I think we must skim over Ernest's experiences during the war. There were satisfying moments, and there were frustrations; and in a situation where the nation needed more than ever before to husband its resources, the frustrations could be hard to bear. Ernest served on a number of quasi-political committees, and discovered something of the process whereby planning decisions are arrived at: his experiences here could be counted among the frustrating ones. The problem of deciding correctly what to build, and how to relate different social priorities, is enormously important; but let us tackle that question in a different context. Suffice it to say that at the end of the war Ernest took the plunge and set up as a consultant.

Two reasons impelled him. The first was that this seemed the only way in which he could really concentrate on design. Construction was useful both as a stimulus to and as a test of design; but in itself the exacting task of organizing all this complicated activity with its trivial setbacks and conflicts did not appeal to him — which in no way diminished his admiration for professional and dedicated building contractors. And the second reason was that for him all the excitement had gone out of contracting during the war. The sporting element, the adventure of getting an idea, the thrill of beating your competitor on merit, the risk of offering a lump sum price for the job, all that buccaneering spirit had gone. You were paid for so many quantities at controlled prices, with controlled labour, extra for canteen, bus transport, and what not, all registered and counted up, and whether or not you made a profit depended entirely on whether you were able to persuade the client's quantity surveyor to allow extras for difficulties encountered. Bad weather, increased haulage, too little or too much rock-excavation, supply of too little or the wrong kind of labour by the Ministry of Labour, acts of God — it was quite unbelievable what could be done. He found contracting at that time a thoroughly uninspiring, even degrading business.

The period after the war started with great expectations and also a good deal of apprehension. The brave new world might be round the corner, but large parts of Europe were in ruins, and austerity reigned unabated.

Yet there was a new spirit abroad. In the contracting world, and among architects and engineers, the atmosphere was certainly different. New ideas were actually welcomed, or at least considered. Prestressed concrete swept the country with unprecedented rapidity. Contractors and engineers undertook in scores and hundreds the pilgrimage to Freyssinet in Paris and Magnel in Ghent.

Structural consultant

At first he worked almost exclusively as structural consultant to architects. He was sorry to leave marine work, which (compared to building) offers so much more scope for dramatic cost-saving through inventive design; and he was sorry to lose the life-giving connection with actual construction; but a consulting engineer cannot choose his work. And he was determined to join in the adventure of helping to create a new and better architecture. He first had to try to learn what architecture was about.

He soon realized that architecture is a very personal thing. Architects are certainly influenced by theories — some, indeed, have to find theoretical justifications for almost every decision; the theories can't produce good architecture. Only good architects can do that. Ernest's job would be to help the architects in their task. Of course it would have to be left to the architect to decide what constituted good architecture; for *he* was the principal who had to interpret the client's wishes. The architect might certainly experience a conflict of loyalties, loyalty to his art, to the client who commissioned him, to the people who would use his building. Since visual or sculptural art — delight, for short — is what an architect's reputation depends on, and what he is most praised for producing, it was not surprising that architects were generally most excited about their loyalty to art, sometimes at the expense of function or economy. This might make it difficult for Ernest, too, to see where his duty lay; but in general he saw it as his task to side with the architect in his battle for good architecture against the prejudices of clients and authorities.

He brought to this task his experience in handling reinforced concrete, and in using its plastic qualities; and he was often able to surprise the architect himself, showing him possibilities he had not dreamt of. He therefore fulfilled a need, his help was appreciated and his practice grew. He found plenty of enthusiasm for new ideas — his battles were not with the architects, but with the authorities. But very often his task was one of debunking, of putting a brake on ideas that were too advanced or fantastic, of fighting for sound construction.

He accepted of course that the aim of designing a structure that would convey the forces to the ground in the simplest, most direct, and economical manner would have to be modified by the additional demand that it should form an acceptable — perhaps a vital — part of the architect's composition. This might mean that the structure should as far as possible remain hidden; or that its arrangement, the size and form of its members, might be determined by other than structural and economic considerations, so long as stability was not endangered. But sometimes he could not help thinking that equally good architecture might have been achieved without loss of structural efficiency by a little extra effort. Sometimes even some of the best architects made demands leading to structural contortions which could have given Ernest the satisfaction of difficulties surmounted, had he not suspected these difficulties of having been artificially created. But the architect would be pleased and appreciative, and his faith in the omnipotence of reinforced concrete was confirmed: not necessarily a good thing. The firm even got a reputation for making complicated structures — which was hardly what they aimed to do.

Basic anomalies in the building industry

Nevertheless his collaboration with architects was on the whole very happy and satisfying. The jobs involved were of course limited in scope: single buildings or groups of buildings, designed to a brief, inside a given budget, and making use of the existing resources and organization of the building industry. Within this framework it was possible for a good architect to make buildings of architectural merit. But from a technical point of view, the framework was too narrow for more than variations and minor improvements of routine solutions. It was difficult to make effective use of the new techniques and materials which were being developed by the building industry at a rate impressive by pre-war standards. Such things as the increased use of factory production and site mechanization, new and improved materials, new methods of jointing, scientific thinking applied to organization and communication — they could all enable him to build better and more with less; *but only if they were backed by the right designs*. And the need was pressing. He could not meet his targets — desirable projects were being cut down and postponed. But as structural adviser to the architect there was not much he could do about it.

On the one hand basic design decisions belonged to the architect. Any alteration in the technique of building would affect the way in which the architect built up his artistic concept from familiar structural elements, he might have to change his intuitive thinking, follow the lead of the new technology and familiarize himself with its details instead of dictating to it — which was both distasteful and troublesome. Architects were not master builders any more, cut off, as they were, from the grass roots of practical building and building costs by the interposition of quantity surveyors and technical advisors. In this Ernest saw a danger to the renewal of architecture.

On the other hand, there could be no proper integration of design and construction, owing to the complete segregation between the two, which is such an odd characteristic of the building industry. As long as Ernest stuck to routine designs, all was well; and that was what he had to do in the majority of cases. But where he saw an opportunity for introducing new or improved methods, he needed the collaboration of the contractor, and he needed cost-information *before* his designs were finalized. With the growing variety of available methods, this information was increasingly essential for choosing the right design, and increasingly difficult to get hold of. Contractors were reluctant to plunge into the unknown, departures from normal would be discouraged by high rates, and in case costs were guarded as a secret. Understandable, perhaps, in a competitive world. But Ernest felt that there was something wrong with a system that allows costs to be withheld from the designer. Engineering design *is* creative accountancy. And architects, too, design buildings that have to be built. If the hard facts of building do not form part of the artistic vision, architecture is brought into disrepute.

But Ernest realized early on that the real fault lay neither with the architect nor the contractor, but with the whole way in which the building industry was organized, and geared to an out-dated technology. The new technology required assured markets to allow mass production, larger contract units, discarding of old habits and professional and other barriers, multi-disciplinary teams given steady employment, standardization, time and capital for research, testing of prototypes, and other things which taken together would amount to a drastic change in the whole social order. This would take time, it could not be forced through by government action without unacceptable dictatorial measures, and it lay in any case outside the sphere of structural engineering. Only concerted action by the building industry might have speeded things up, and this was effectively prevented by its fragmentation.

On this somewhat pessimistic note we will abandon our account of Ernest's career. He has served his purpose, his grumbling has highlighted some problems which, more than 20 years later, are still with us. Much has happened in these years, technology has advanced in leaps and bounds. The building industry for a long time lagged behind, but we are now all aware that great changes are upon us.

The situation today

I should now like to review the situation as it exists today, not statistically, for I have not got the figures, but intrinsically, as I perceive it to be from my undoubtedly somewhat restricted viewpoint.

For most of the work designed by architects with the help of consultants, the situation has not changed much since Ernest's days. More precasting, more factory production, more mechanization has been squeezed into the existing organization of the building industry. The barriers between authorities, professions, private interests with fingers in the same design pie are still difficult to surmount, causing frustrations to progressive designers wanting to break with routine. The best architecture has improved partly at least because architects have now become more familiar with the new materials and techniques, but quantitatively the urban scene is dominated by bulky building blocks, brutally disposed as dictated by financial and political pressures, and to this must be added the devastations caused by the motor car, indiscriminate proliferations of street furniture, and the vulgarity of much private display. Uniform mediocrity tends to destroy the identity of our cities.

Good architecture has always been produced by good artists, and it is the same today. The impact of an architectural composition is produced somehow by the creation of spaces, sculptural relationships, light and shade, colours and textures and not least by the clarity or ingenuity with which its functional and structural problems are solved. Exactly how, we do not know — and we cannot know beforehand. There is no infallible recipe. Were it otherwise, we could do it by computer. It is the artist's sensitivity, his humanity or personality which speaks to us, if we are receptive to it. But artists differ even more than structural engineers, and there are many ways of producing good architecture. And this is how we wish it to be — we would soon get tired of uniformity.

Value for money

But we don't build to produce art. We produce useful hardware to fulfil various functions. And we want to get it with the least effort, the least expense. We want value for money, and we can therefore measure efficiency by the simple formula

$$E = \frac{\text{Commodity}}{\text{Cost}}$$

where Commodity stands for what we want to achieve.

In 1945, in the first number of the Architects' Yearbook, I proposed a modification of this formula to:

$$E = \frac{\text{BC plus EC plus D}}{\text{Cost}}$$

where BC stands for basic commodity, EC stands for excess commodity, and D stands for delight, recognizing the fact that what we are getting as a result of a particular design is not only the basic commodity defined by the brief, but many other qualities or features peculiar to this design, and that these have a commodity value, positive or negative, which we must take into consideration when comparing different designs. Likewise, the 'delight' produced, which stands for all the intangible values associated with good architecture, should certainly also be considered, even if it is impossible to put a money value on it. This may apply to the more material excess commodity as well, for if you haven't asked for something you may not be prepared to pay for it, even if it is useful — for instance, extra thermal insulation, longer life, more flexibility, etc.

In connection with the recent Ronan Point block disaster the excess commodity of relative safety against progressive collapse due to an internal explosion was not included in the basic requirements and therefore not provided, which is likely to happen when cost is the major consideration. As a result of the accident, it may now be included, as are fire regulations against fairly unlikely contingencies. It is a normal thing that excess commodity becomes basic commodity as standards are raised.

Of course commodity, delight and costs are interrelated in all sorts of ways. I mentioned that an ingenious and simple solution of the structural and functional problems can itself produce delight without incurring extra cost, and that therein lies the art of designing. It may even be produced at less cost. But unless drastic measures are taken to pull the whole design together in this way and provide a balanced and total design, embodying all the available knowledge, wherever it resides, and knitting it together in an artistically controlled pattern, it cannot be achieved. Without it, art tends to be expensive.

The trouble is not lack of talent, enthusiasm and idealism. There is plenty to be found in the architectural profession, mostly amongst younger architects, who will work day and night to produce quality. The best human endeavour, that which produces outstanding quality, delight, the great works of art, the really human and satisfying environment, that which lifts humanity above the soulless efficiency of an ant-heap — with due apology for a possible injustice to ants — this cannot be bought. The driving force behind it is a passion for perfection, a dream of a better world, an artistic urge or something equally absurd to the proverbial hard-boiled business man — apologies again — but naturally mixed in various proportions with ambition, dreams of fame, recognition, applause.

But the odds against such endeavours suceeding are formidable. The bulk of what we build is subject to severe financial restrictions. Rightly or wrongly, private and public finance is not prepared to put a high value on excess commodity and delight. In most cases those who control the money have no strong feeling for architecture, certainly their ideas of delight are likely to differ from those of the architects who naturally have given the subject much more attention. It is difficult to break through this crust of indifference. The fact is that if art is expensive, it can only survive as a kind of luxury for the few. Technology will then take over, and it is happening now.

Technological demands

What can we do about it? To get what we want and not just have to want what we get, we must control technology, and therefore we must first understand its needs.

What are its needs?

Technology achieves economy in three ways: by invention; by repetition or mass production; and by specialization.

Invention requires freedom from convention, an ability to look at a problem with fresh eyes. Accepted ideas are not easy to escape from. In the very first motor cars, the driver's seat remained high up, so that he could see what his non-existent horses were up to; and he had a little tube fixed to the board in front of him, in which he could deposit the whip. Similarly, when reinforced concrete replaced structural steel as the structural material in buildings, the familiar three-dimensional orthogonal frame was retained, with its secondary and tertiary beams of different sizes. The first LCC codes were based on this conception; concrete panels had to be supported by this frame, in spite of the fact that

Kingsgate Footbridge, Durham (1961-4)
Designed by Ove Arup
(Photo: de Burgh Galwey; copyright *Architectural Review*)

they formed the stiffest members of the whole assembly. And panels in coal-bunkers, reservoirs, bridge-parapets, etc., were set back from the frame, sometimes in several steps — an architectural anachronism adding unnecessarily to the cost of formwork. Or again: when extruded aluminium sections were introduced as a replacement for steel under certain conditions, the industry issued catalogues showing angles, channels, and I sections similar to those made in structural steel. They had failed to grasp the basic fact that this was a different material, which could be extruded, and which could therefore be manufactured in quite different shapes. It was only by exploiting this potential, so saving material and supplying sections to serve dual purposes, that extruded aluminium sections could be made competitive.

There is a German tag I have often found useful: 'Umgekehrt ist auch was wert' — or in English: 'The other way round may be equally sound'. Invention comes from forgetting how a thing was done before, so that apparently insoluble problems cease to be problems at all when they are seen from a new viewpoint.

And equally, of course — 'Umgekehrt ist auch was wert' again — each new invention creates a whole row of redundancies, posing problems of change and resistance to change. Every solution to a problem is made possible because other solutions to other problems have been made previously; and it in turn affects solutions to quite different problems, without regard to boundaries.

This *Integrality of Technology* is matched by, and partly identical with, the network of means and ends. A structure may be made to stabilize a building, a building to shelter human activities — the education of children or the manufacture of tools — to make other things to serve other ends. And you can't solve a problem in a really new way without first knowing why you want the problem solved: you must be able to see the problem from a distance of at least one step along the network. In this way technology is a radical force, demanding fluidity of outlook and freedom from preconceptions.

The second important ingredient in economic production, *Repetition* or *Mass Production*, is of course made possible by invention. If you can repeat the same process, use the same component or the same detailed solution over and over again, you can automate production and carry out complex processes cheaply; and in particular, you can save skilled creative labour, which is suspect because it is fickle, unreliable, slow and expensive. In its demand for standardization, technology has a built-in tendency to megalomania.

A friend of mine with a very large farm wished to rationalize the milking of his herd of several hundred cows. Cows are creatures of habit; and he trained his cows to come every evening, in a long file, always in the same order, to the milking shed. Here they climbed, one at a time, onto a huge circular revolving platform. One man or girl put on the milking machine as each cow arrived; and another took it off again when the platform had completed a round. The speed was adjusted so that one round corresponded to the milking time for an average cow.

The only snag was that the cows varied. Cows with exceptionally high yields were an expensive nuisance. They could not stay on the milking platform for a whole second round; they had to be disconnected, and milked dry by hand. So very good cows — like very bad ones — had to be replaced; the whole herd had to be normalized.

It would obviously be a great advantage if human beings could be standardized in the same way, so that they were all of the same size, weight, and shape, had the same preferences and tastes, and never asked for variety. They wouldn't be human any more; but think of the money we'd save. And already we sacrifice functional and aesthetic amenity in thousands of ways for the sake of standardization and economy. The only question is: where should we draw the line? Technological megalomania is evident in the expanding size of building operations. Whole towns, town centres, residential or industrial areas, new universities, are designed by one team. Or in industrialized building, one system is used to build identical high-rise flats, for example, in many different districts. Under such conditions, we may ultimately save money and labour; but we won't even do that unless we get the design right, and unless we solve the total design before operations begin. Standardization is, I think, an evil *per se*, though it is so powerful a tool that we cannot afford to neglect it. But at least let us refrain from making standardization an end in itself. On the other hand we cannot expect the benefits of standardization unless we are willing to create the conditions which are needed to bring them about. Which brings me to the third ingredient of successful technology: *Specialization*. This is not peculiar to technology, of course, it is a characteristic of all progressive human activity. Concentration on a narrow field makes it possible to achieve the mastery, the penetration in depth, upon which progress depends. The need for specialization is obvious enough. But whereas invention and repetition must disregard boundaries and demolish barriers in order to be effective, specialization *creates* barriers.

We are all familiar with the proliferation of learned societies and institutions clamouring for their Royal Charter, of congresses discussing their esoteric mysteries in terms unintelligible to outsiders, of administrative bodies on ministerial and local levels cherishing their particular authority and jealous of outside interference, of specialist occupations, industrial lobbies, trade associations, and private firms. Each has its special axe to grind.

There are good reasons for all this. Like so much else, it is understandable, justifiable, beneficial — and harmful. It breeds narrow-mindedness, it hinders the effective use of our resources.

Design deficiencies

The situation today is that most designs are either:

Starved designs

Deprived of the benefit of technical knowledge which could have improved it, had it been considered. As when engineers are called in too late to an already 'frozen' design, or when the designers simply do not know their jobs or do not take the trouble to consult those who do.

Forced or lopsided designs

When put into a strait-jacket of architectural formalism or structural acrobatics or client's prejudice, disturbing the balance of priorities.

Loose designs

When no proper synthesis is achieved for lack of effort or collaboration, hardening into:

Split designs

When the design is being handled by different authorities who barely communicate with each other.

Pinched designs

Due to economic stringency, when the ship is spoilt for a ha'p'orth of tar.

Patched up designs

When the brief is altered or added to by clients, or the architect has a better idea or additional information comes to hand which is somehow tacked on to the design without taking the only course which can assure a proper digestion of the new data: that of starting all over again with the new information in mind and reconsidering the decisions made. Naturally this is in many cases not possible, but this does not alter the fact that the result is patchwork.

This judgment may be considered too harsh. I admit that I am measuring against an ideal which is unattainable, that much excellent work is in fact being done today, and that you could criticize any design, however good, from some or all of these points of view. Architectural design is by its very nature a compromise. I am only trying to pinpoint some of the defects which could be remedied by better organization, a freer exchange of knowledge, less divided responsibility. These defects are not so noticeable in 'closed' designs or limited design objects. It is when we move towards comprehensive design, large-scale planning, that these barriers have a crippling effect. But more of that later. I will first deal shortly with some of the attempts which are being made on a smaller scale to overcome them.

The multi-disciplinary team

That multi-disciplinary team work is necessary is now generally accepted, and everybody is eagerly climbing on to the bandwagon. A number of multi-disciplinary group practices have been formed, most of them led by architects or at any rate endeavouring to promote good and efficient architecture, total architecture.

Some large contractors, on the other hand, point out that large jobs nowadays demand above all efficient organization and coordination, using the latest scientific techniques, which necessity has taught them to perfect; that construction and design belong together, and that the most natural solution would be to let them handle the whole matter from A to Z, and let them deal directly with the client — the so-called 'package deal'.

Lately the quantity surveyor, who has been busy acquiring a new look, has also put in a tentative claim for the leadership. It has been pointed out that their position as disinterested go-between, acting in a quasi-judicial capacity in disputes between client and contractor, fits them excellently for this role, provided they acquire a little extra understanding of the points of view of architects and engineers. Their familiarity with money matters would endear them to the client, who would feel that his affairs would be in the hands of practical men who would not be led astray by artistic aspirations and would know how to deal with dubious claims for extras.

As far as I know no engineers have so far claimed the leadership of mixed design teams — except where the job falls into the category of civil engineering. But that engineers must play a prominent part in the creation of total design follows from the fact that all modern and progressive design must make use of technology based on scientific knowledge and method, and this is the province of the engineer.

The situation reminds me a little of a group of children clustered round a box which one of them is trying to open. All want to have a go — Let me try, let me, let me! Grown ups, if they are active and creative, never lose this urge, it is something elementary in human nature. It can, however, be an impediment to successful collaboration, especially between colleagues — two architects, or two engineers, for instance. It would tempt a consulting engineer to insist on solving a problem his way, rather than asking advice from a more experienced colleague. And it could make collaboration between two architects quite impossible, because art is personal and different points of view can rarely be resolved by hard facts or logic.

But apart from that, any of the suggested arrangements could work successfully, depending on who was involved. But if we want to find the best arrangement we should not make the accidental division into professions, etc., our starting point, we should look at what we want to achieve, and then decide what training the participants should have to fulfil their roles.

Requirements for integrated design

Don't forget we are talking about a design team, and we want them to produce a total, balanced, efficient design which can help to produce a better environment than the one which seems to emerge from our efforts at the moment.

The first condition is that all members of the team subscribe to this aim, that they all want to help to produce good architecture, architecture in depth, so to speak — not just artificially imposed formalism or applied make up — as well as efficient function and economy. Each of these demands imposes its own and quite distinct discipline, this must be understood by all, and this takes time.

The concern of the leader would then be to create the overall balance, to assess priorities; he must be a creative designer who can fuse the different parts together. The architect would be the natural choice provided he respects the need for technical efficiency, without which his art cannot survive.

But in a closely knit group subscribing to this philosophy — to use, or misuse a now popular word — the leadership tends to be shared by the group, or changes according to the subject being debated.

But it takes time to reach this stage, as we have found out in Arup Associates, which consists of several such multi-disciplinary teams. This is because all the members have to forget part of their training and acquire new understanding and skills. Barriers — which are astoundingly solid and high — must be broken down. The engineers must understand that there are other things between heaven and earth than their rigorous calculations. There are values which cannot be measured. And they must learn to understand the practical craft and technology of building, to organize the production of the job as they are designing it — or the team must include engineers experienced in the methods of contractors, and able to assess their real cost, helped by the quantity surveyors, whose function is drastically changed, and should change much more. What is needed are costs to help in the making of design decisions. Costs are of three kinds:

(1) The rates quoted by contractors which are both unnecessarily detailed and a mixture of labour, plant, overheads, profit, etc., and do not apply to new ways of doing things

(2) The contractor's actual costs, which are difficult to obtain

(3) The intrinsic cost of the operation if tackled in a rational manner as intended by the designer, and at reasonable rates for labour and profit — which can to some extent be estimated by planning the operation in detail, with the appropriate plant, labour gangs, etc.

All three are of some interest, but for the designer breaking new ground it is the last which measures the fundamental soundness of the proposition. However, as long as the usual bill of quantity is retained the quantity surveyor must master its complications. But I must admit that I think a better way would be to let the designers organize the job through the *design*, which would make taking out quantities a simple matter.

For it is a fact that today the artistic, functional and technical unity must be created by the design. The design records the constructive forethought which must precede any action in a complex situation. Nothing can be left to chance. We cannot rely on creative craftsmanship guided by a universally accepted architectural idiom and a settled way of life; it is the responsibility of the designer or the designers to create harmony out of a chaotic material. Their control must therefore extend over the whole area of design, from the smallest detail to the position of the whole in relation to adjoining areas.

Another essential requirement is that the designers should be dedicated to the interest of the clients and society as a whole. They should not have a financial interest in using certain materials, plant or methods, they should be unfettered in their choice. They may use proprietary methods but only if it is the best choice in the given situation.

This was the position when Brunel, Telford, Paxton and others created their masterpieces. They even controlled the labour to a large extent, they certainly invented the plant and tools to be used in the operations. 40 years ago designers had largely lost this close connection with execution, but they still exercised firm control over what was built. Today the large contractors have a much greater influence on the design, simply because they may be the only people who really know how to build practically and economically. But that leads to a fatal split in the control over design decisions, which will lead to loose, patched up and uneconomical designs. So either the contractor must take over the whole multi-disciplinary team, which for many reasons is undesirable, or the designers must in their organization embrace the knowledge needed to make practical designs. The latter is by far the easier to achieve, for it is not so difficult for engineers to understand the principles and the practice of economical design.

It follows that the designers should organize the job, in fact should take over this role from the general contractor, and contractors should become specialists in different types of construction or assembly techniques, working more on a professional basis. Building would, according to the nature of the job, be divided into:

(1) Site works, i.e. excavation, roads, drains, foundations, etc., which would be mechanized and organized to provide continuity of employment of labour and equipment

(2) The main structural carcass, executed by specialists in concrete or structural steel construction

(3) All the 'infilling' — walls, partitions, main ducts or spaces for services, stairs, lift-shafts, etc., if not included in the main structure. These should be mainly factory-produced, brought finished to the job and inserted in the spaces allotted to them, independent of each other.

(4) Services and equipment divided into their respective kinds — air-conditioning, electricity, etc.

The important thing is that all these items should not interfere with each other, and this condition can be met if the designers have visualized and drawn up the way it should be built before the design is frozen. Structural grids, partition grids, and service grids should by-pass each other. The critical path studies must be woven into the design, and should follow logically from it. It is too late if they show up deficiencies in the design after the contract is let.

The designers should have adequate information at their disposal about the relevant structural methods and manufacturers' products, and should deal directly with these firms so that they can together develop new methods or new products to suit a particular large-scale job, and place orders early enough for inclusion in the construction programme.

The construction should not begin before the design was sufficiently advanced and the decision should be the responsibility of the designers. Clients should understand that good design takes time — and will speed up and cheapen construction. If speed is of the essence of the whole undertaking, this must be understood from the beginning. It will affect design decisions and it must be accepted that it will increase cost or reduce quality — but the opposite can also happen in certain circumstances. Naturally this puts a great responsibility and extra work on to the design team, which will have to be supported by experts in soil mechanics, and foundation methods, costing and communication techniques, computers, analytical research, formulation of contracts and so on, servicing the several design teams. These must be kept fairly small to retain their intimate character.

Quantity surveyors would not be idle in this new set-up, but their work would be different. There is, for instance, a great need for 'buyers' — to use a term from contracting — who would find out where to obtain the different materials and items needed by the designer most favourably, or where to get new items manufactured, find out about new equipment and its efficiency, immerse themselves thoroughly in the true cost aspect of building operations and take an active and useful part in discussions leading to design decisions. But where quantities formed part of the information issued to contractors, they should be simplified to correspond to the labour costs obtained from weekly cost sheets. The contractor must of course have exact information about what he is expected to do, but that is better given by drawings and specifications.

These are dreams and idle speculations, and highly controversial as well. If anybody should get upset about them, they can draw comfort from the fact that they most likely will have no effect whatsoever. And in any case, even *I* do not think that there is only one answer. Think of how many different ways of organizing these things co-exist today. Whether they work well, depends more on the people involved than on the methods used.

I am suggesting this line of attack because I am concerned about retaining an artistic control over what we build, and also because our experience with Arup Associates encourages us to think that this is the right way to combine quality and economy in building. My suggestion would enable a closely knit design team to obtain the experience, the 'feel' for the practical problems of building, and the control, which would enable them to integrate all the relevant facts. If led or advised by good architects — and sociologists as well — there would be a good chance of producing viable masterpieces, and not just white elephants.

What to build

However, so far we are still only dealing with closed designs, where the brief is given. Today the design of single buildings, or even groups of buildings, is less important than the artistic organization of much larger units — which must then deal with transport, location of industry and dozens of other problems as well. Town and country planning, in fact. Our efforts in this direction have not been outstandingly successful. There are plenty of plans, but little action. We put all our best brains in a committee or Royal Commission, or we ask an eminent architect to produce a plan for London or Oxford or replan the area round St. Paul's or Parliament Square, or the British Museum or Piccadilly Circus — and then forget about it. Mainly, I suppose, because we don't know how to pay for it. We rightly do not want to dictate to people, and we cannot get the various bodies concerned to look much beyond their own narrower interests. And also because we don't really know what we want. This is by far the most difficult problem of all.

Engineers have not had to worry much about that, they nearly always work to a well-defined brief. Architects are not so lucky. Their briefs have always been less well-defined and their criteria for excellence the subject of controversy. And the Modern Movement brought a change in outlook, which made the architects concern themselves with the needs of society, with providing a worthy setting in which people could live, work and play. The right setting would, it was hoped, improve the quality of their life. But the setting must in turn be a reflection of the way people live. This has always been so, and it has happened mostly without the intervention of a conscious design. Can we now reverse the process and shape it by deliberate planning? This seems doubtful. What is happening now can hardly be so called. The economic and technological forces which now shape our environment — are they controlled by man, or man by them?

Technology has a habit of creating its own ends. We do things simply because we are able to do them. We glory in our power. And having created the machinery we must keep it going, and think of more things we can do with it. And, like the sorcerer's apprentice, we can't stop the process.

But if we want to curb the excesses of technology we must play the game according to its rules, for we can't do without it. We must do it with better technology. And in any large-scale planning the barriers must go, human boundaries — even eventually those between countries — must be surmounted.

System engineering

In the USA, where so many trends are set, this is beginning to be accepted. The whole March 1968 issue of *Consulting Engineer*, a weighty volume, is devoted to something called 'System Engineering'. Senator Robert F. Kennedy contributed an inspiring article to it. The method is applied to five major problems of our time:

Saving our cities

Urban revival

Untangling urban transportation

Water supply

Air pollution.

Its basis is: 'A recognition by society that its major social problems cannot be solved by looking at each problem separately, they are in fact "systems" of interacting problems'.

System engineering has developed from 'Operational research' analysis as practised for years by Federal Defence Establishments. It operates with multi-disciplinary teams, it aims at 'providing a scientific basis for management decisions' and of course: 'The systems approach stands squarely upon a quantitative description of the proposed system ... this quantitative description is reduced to a set of relationships, which frequently are represented by mathematical equations.' These can then be solved by computers.

Of course it operates through the existing private enterprise system. The idea is that 'do goodism' is made to pay by introducing legislation which provides the necessary incentives in the form of tax rebates, equity investment, etc.

So in a way it does solve the whole problem of how to get it done. No sticks, just carrots. Profit for everybody.

A somewhat similar development in England is called Value Engineering. A journal of that name was launched last April, and also stresses the need for teamwork, and a rational scientific approach to design.

System engineering is an interesting and significant development. To me it is also slightly alarming. There are two things I am worried about: first, the *quantity syndrome*: The idea that everything can be measured, multiplied with a unit rate to arrive at a value in dollars. This is the so-called scientific method, and it is invading territories where it simply does not apply. Jacques Barzun is quite right in claiming that we do not live in a world of Snow's 'Two cultures' — there is only one, the universal acceptance of science — even in such unlikely places as literary criticism. I think it was Galileo who first formulated the scientific principles:

(1) Measure everything which can be measured.

(2) Make measurable what cannot be measured.

We are taking this too literally. The area of what can be measured is being extended all the time, but it doesn't mean that we can ignore that which can't be measured. It may even prove to be more important.

To me it is surprising that so many people have no difficulty in ignoring the fact which stares us in the face, and which has been stressed by poets, saints and thinkers throughout the ages, that what has most value for man cannot be measured, bought, or obtained by force, but must be given freely. And that whether our manmade environment pleases us or not, depends on unmeasurable qualities which can only be created by artistic inspiration and dedication.

The other thing which worries me about system engineering is the complete reliance on the profit motive. Of course the sponsors and the politicians and others who get the necessary legislation passed are partly moved by a wish to improve their cities, etc. And I must admit that it is a realistic approach, and I know of no very realistic substitute. But I must confess that I distrust the dominance of money over man's mind. Think of the lobbying and the bargaining which will precede legislation. What price will society have to pay?

It is interesting that in both cases the role of the engineer is stressed. Engineering has of course always been value engineering for that matter, and system engineering is much the same as what I and others have called Total Architecture. I think both these developments show the way things are moving, but the difference in wording may be significant. The word 'architecture' somehow suggests a concern about the brief, about *what* we should build, about function and delight, whereas 'engineering' suggests efficiency in fulfilling the brief. Both are needed, for whatever we build. Civil engineering is of course also architecture in this sense. But the need for efficiency is accepted by everybody — the need for artistic control over what we build is not. Not until there is a public feeling against leaving litter about will we be successful in cleaning up our environment — therefore I prefer the words Total Architecture where they apply.

We all know the fairy tale about somebody having been granted three wishes and the disastrous consequences of that.

To wish sensibly, to dream the right dreams, is important. We have today the ability to make our wishes come true. But as soon as some of us have reached this point — we step up our wishes. It could be dangerous.

But I am afraid I am getting out of my depth — and I am sure that you are looking forward as much as I am to an end to this ordeal.

But what is the moral of all this. I am afraid that my talk may have confused you more than it has enlightened you. I can offer you no solution to the problems facing mankind, but I think engineers have an important contribution to make, and I think this contribution will be improved if we look beyond the narrow confines of our métier, if we understand that we are part of a team, each contributing his special knowledge to a common aim, which must ultimately be to help to improve the lot of mankind. Only loyalty to this aim can make our contribution meaningful.

Sydney Opera House (completed 1973)
Architects: Jørn Utzon (Stages I & II),
Hall, Todd & Littlemore (Stage III)
(Photo: Harry Sowden)

Design of piled jetties and piers

This extract is taken from the first of five articles published in Concrete and Constructional Engineering *in 1934 and 1935. There is no doubt that these papers were a major contribution on the subject. I suppose that one should not be surprised by the clarity of Ove's thinking, particularly when you remember that Professor Asger Ostenfeld was one of his mentors and Ostenfeld's textbook,* Teknisk Statik, *was a landmark on the subject of structural analysis and the way in which engineers should think about such problems. What follows here is Ove's introductory paper. I recommend all five papers to anyone who cares about the conception and analysis of structural systems in general and piled jetties and piers in particular.*

Peter Dunican

When reinforced concrete was first employed for the construction of jetties and piers the designs were close copies of traditional designs for timber jetties, with the deck supported on groups of vertical piles braced and strutted together in all directions as low as the tide would allow. It was realized later that reinforced concrete required a different treatment and bracings were largely discarded in favour of raking piles, thus increasing the strength and lowering the cost of the structure.

A jetty has to resist two sets of forces, namely, vertical loads from cranes, lorries, etc., and horizontal forces from waves, tension in mooring ropes and impact of vessels. The latter are by far the most difficult to deal with, and inadequate provision to resist them may result in total or partial failure of the structure either by a sudden collapse due to an excessive impact or by the sum of the effects of overstressing due to a number of smaller blows. Nevertheless it is probably safe to say that timber jetties are mostly designed without attempting to calculate the effect of these forces on the structure. Cross braces are provided in accordance with common practice or the experience of the designer but the problem of designing a jetty to a given specification for horizontal loading that is able safely to withstand a blow of a certain predetermined magnitude is generally left untouched.

There are good reasons for this, principally because it would be almost impossible to put forward a calculation which could lay claim to any degree of accuracy in the case of the ordinary timber jetty. It may be possible to estimate approximately the amount of energy which could safely be absorbed by a single pile driven into the ground, although the elasticity of the reactions at the bottom introduces a certain amount of guesswork in the calculations: but when it is a question of a group of piles braced together in all directions and with joints which allow a certain unknown amount of 'give' before becoming effective, and when these are connected at the top by a deck which also consists of a large number of pieces imperfectly joined together, the amount of guesswork required to complete the calculations is sufficient to make the value of the result questionable.

There are also other reasons. It is, for instance, doubtful whether much would be gained if one were able to design a timber jetty to absorb a specified amount of kinetic energy without suffering any permanent deflection. It would perhaps, in many cases result in the construction of stronger jetties, because at the moment most jetties are not so designed as to emerge unscathed from an encounter with a vessel out of control, but it is

Fig. 1

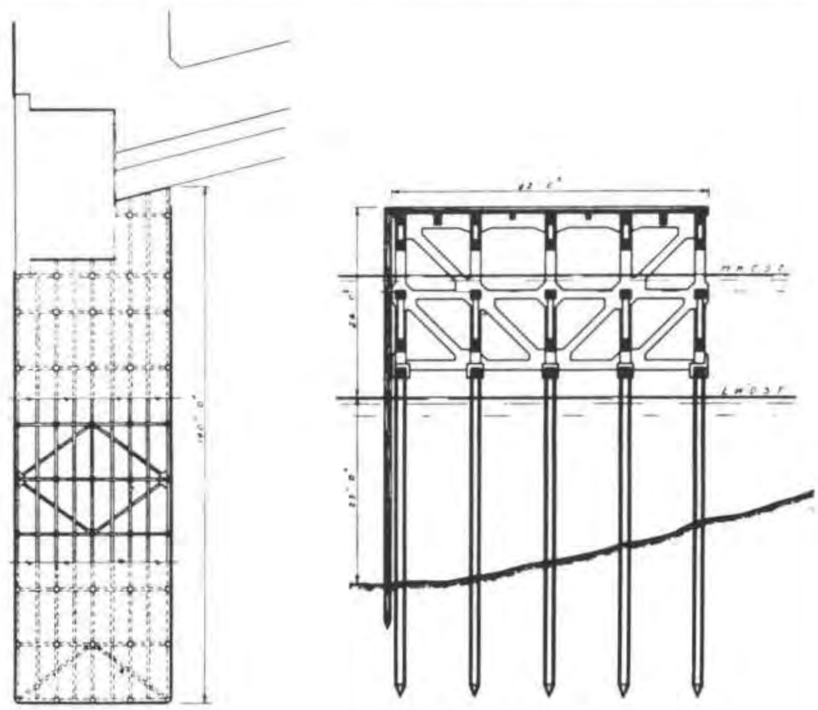


Fig. 2

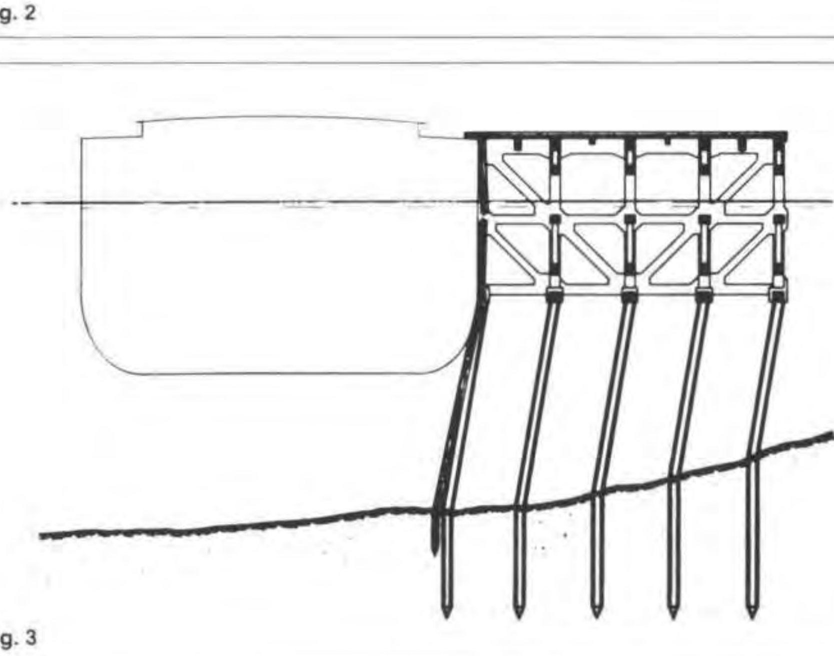


Fig. 3

doubtful whether the extra capital outlay would be justified. Most timber jetties, unless constructed of greenheart or similar timber, are of a semi-temporary nature: after a time repairs become necessary, and it may pay to increase the amount which has to be spent annually on repairs rather than increase the initial cost.

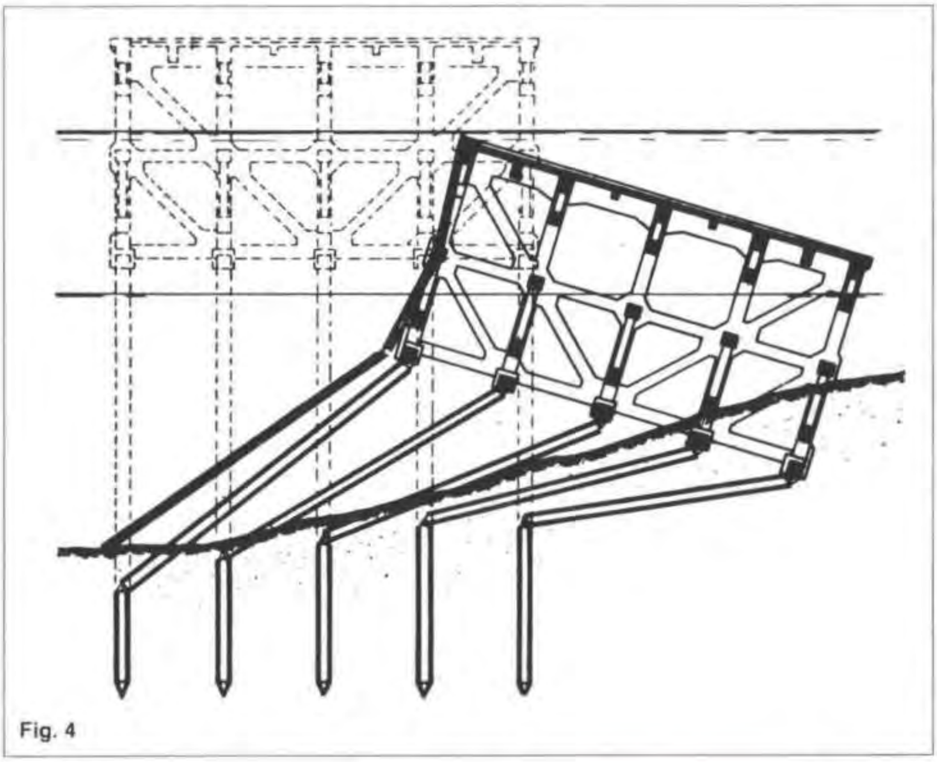


Fig. 4

Fig. 5

Fig. 6

In the case of concrete jetties the position is somewhat different. First, the depreciation of a properly designed and constructed concrete structure should not be as heavy as that of a timber jetty: second, the damage which may be caused to a concrete jetty by vessels berthing alongside, if it is not so constructed, is likely to be considerable and it is not so easily repaired; third, it is much easier in the case of concrete jetties to estimate the amount of kinetic energy which can be absorbed without damage. In other words, with reinforced concrete jetties it is more essential that a calculation of the shock-absorbing qualities of the structure should be made, and it is easier to do it on account of their monolithic character. There is no uncertainty about the joints between the piles and the bracing or deck beams, and the deck forms a very strong horizontal beam which can be relied upon to transfer a blow to practically all the piles in the structure.

Deck beam

This horizontal deck beam is a prominent feature of reinforced concrete jetties and is the main reason for their superiority in resisting impacts, since in most cases it prevents a ship which hits the jetty from doing more than local damage. Fig. 1 illustrates the point in question: it shows a jetty in the River Thames which was severely rammed by a ship below deck level; three fender piles and three or four concrete piles were broken, but although several supports gave way the deck was left intact and effectively prevented further damage. The repair of this jetty was carried out by driving new piles through holes cut in the deck.

Figs. 2 to 6 illustrate another accident to a jetty in the Thames, but this time the strong deck was of no avail. As will be seen from Fig. 2 the design was of the traditional type with vertical piles and heavy bracing. In plan the jetty was T-shaped, with the approach and a small central portion, forming the original jetty, constructed in steel, and two wings of reinforced concrete. While the ship seen in Fig. 5 was lying alongside it was rammed by another ship and pressed against one wing of the jetty, with the result that all the piles in this half of the jetty broke at the bottom and at the underside of the bracing: the jetty collapsed as a whole, leaving the deck and the system of braces absolutely intact but moved to another position.

Just after the impact the jetty remained for a while in the position shown in Fig. 3 and supported by the ship, which had been pushed under the top waling. Later it collapsed to the position shown in Fig. 4. Fig. 5 is a photograph taken soon after the accident, and Fig. 6 was taken at a later stage when the demolition of the jetty had been started. According to eyewitnesses the blow did not appear to be very severe; this is also borne out by the fact that the ships sustained very slight damage.

Horizontal forces

This accident brings home in a striking fashion the necessity for considering the horizontal forces in design, as otherwise the advantage of the strong deck may disappear or even become a disadvantage. It also illustrates how useless it is to provide extensive and expensive low-water braces if nothing is done to strengthen the structure below the bracing level.

In the following pages the capacity of various types of piled concrete jetties to resist horizontal impacts is investigated with the object of finding general rules which may usefully be applied to the design of these structures....

Planning in reinforced concrete

This extract is taken from a two-part article which appeared in Architectural Design & Construction *in 1935. A question of historical interest arises in this paper where Ove Arup describes the box-frame or cross-wall system (Fig. 7f), suggesting that it is only suitable in very special cases. But this was the system that, 15 years later, would be providing an important part of our firm's work.*

John Blanchard

Structural grid or parallel beams

If we disregard the mushroom type of floor construction, which is generally not suitable for residential flats, we can say that the floors consist of a series of reinforced concrete slabs spanning between lines of support formed by beams *or* walls. These lines of support can either be arranged in one direction only, or they can be arranged crossways with the slabs between them cross reinforced and spanning both ways, as shown diagrammatically in Figs. 6a and 6b.

It is difficult to say beforehand which system is the more economical. So much depends on the spans of slabs and beams. It is important to get the maximum regularity, and it will, therefore, mainly depend on which scheme can best be combined with the architectural requirements without too many adjustments.

Generally, we can say this:

(1) It is important from an economical point of view that the slab spans are as small as possible. The floor slab is by far the biggest item in such a construction, and if the quantities of steel and concrete in the floor go up by, for instance, 50%, the saving in beams and columns would not be sufficient to counter-balance this increase, and the cost must go up. Spans of 8 ft. to 12 ft. are very economical; the floors can then be made 4 in. thick, the amount of reinforcement varying with the span. Spans up to 15 ft. or 16 ft., are still reasonable, although the floor thickness goes up, and it will probably pay to use hollow tiles or similar special floors to keep the weight down. Above that, the increase in cost soon becomes noticeable.

(2) It is also important that the span of the beams should be kept down, if possible. The columns do not cost so much, and it pays, therefore, to have many columns and short beams.

(3) Slabs and beams should if possible be made continuous over several supports. The direction of the span should, therefore, preferably not be changed.

(4) The grid system of beams as in Fig. 6a may be economical if the spans are reasonable and if the slabs can be made approximately square. Its main advantage lies in the fact that the slabs can be cross reinforced, and a saving obtained through the fact that only two-thirds of the total load need be taken into account when calculating the moments. According to the new code not yet become law, and Continental and American practice, the moment in each direction of a fairly square cross reinforced slab is about one-third of the moment in a simple slab of the same span if the corners are adequately fixed in position. As the moments are proportionate to the square of the span, it follows that with the same thickness of slab we can span about $\sqrt{3}$ or 1.73 times as far if the slab is cross reinforced. (Actually the figure is a little smaller, about 1.65, if we make an adjustment owing to the loss of efficient depth due to the crossing of the reinforcement). But, on the other hand, the reinforcement is, of course, nearly doubled in this case. But if the advantage of cross reinforcing the slabs is not made use of, if the slabs only span in one direction, there is certainly no point in having beams in two directions. The old LCC regulations demanded it for the sake of tying in the columns, but the columns are sufficiently held in position by the slab. It is a detail borrowed from structural steel.

(5) Generally speaking, the system of the structural grid (Fig. 6a) gives much less freedom of planning than the system with parallel beams (Fig. 6b). There is no point in using the grid system unless a column can be placed at each point of intersection between the beams. This means that the position of the columns is very rigidly fixed, and this imposes a severe restriction on the lay-out of the rooms, unless one is prepared to let the columns appear anywhere they like in the middle of the rooms. Corbusier does that occasionally, and he can do it; but if others tried the same, the result might not be so good. It would also be very difficult to arrange the partitions to follow the very rigid system of beams, and we would get the beams crossing the rooms in odd places. This system is, therefore, only suitable in very special cases: it may, for instance, suit a factory or an office building. The system with parallel beams is much more flexible, because the columns need not, in this instance, be placed opposite each other; they can be moved as required along the lines of the beams. There are also fewer beams, and the system is much more suited to the principle of the structural wall. This system will, therefore, in most cases be found to be the best.

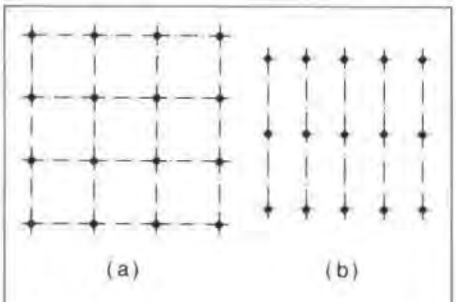


Fig. 6
Diagram showing the structural grid and parallel beam system of construction

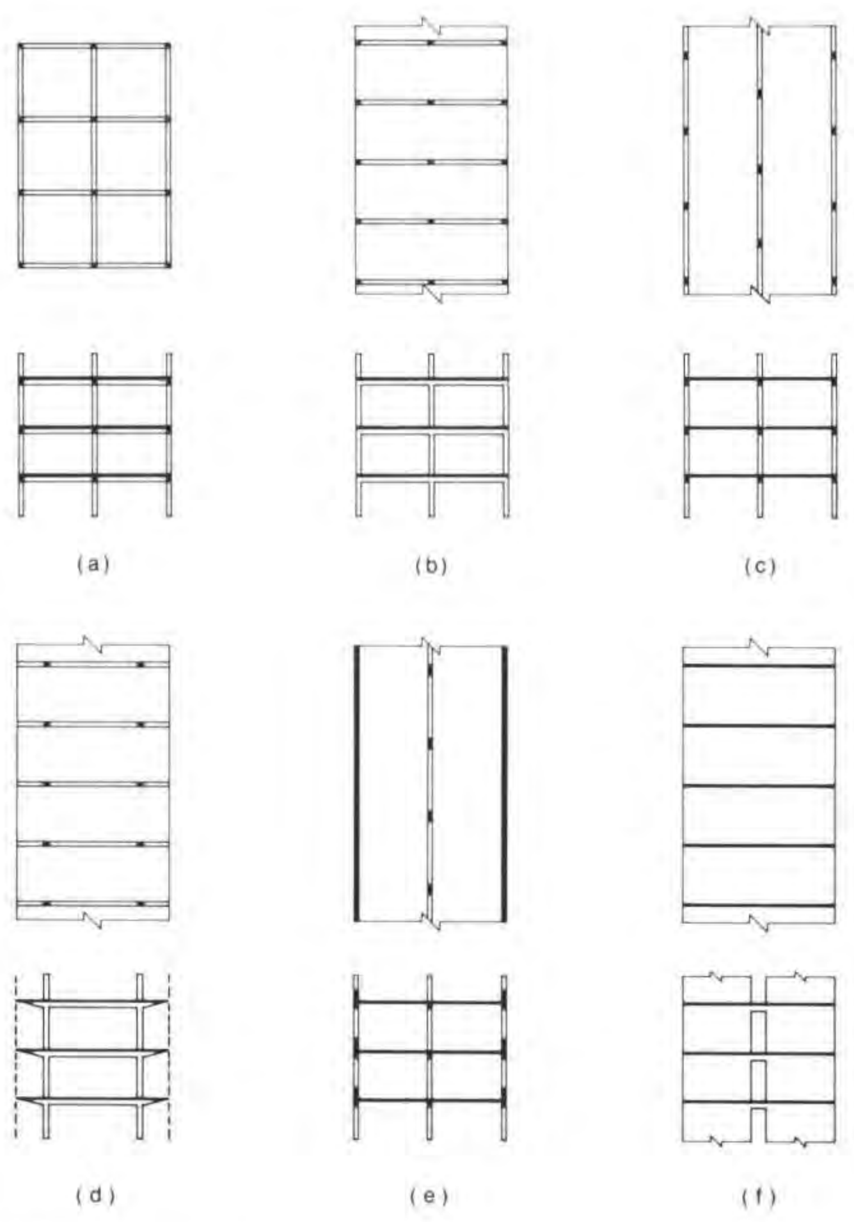


Fig. 7
Diagrams showing alternative dispositions for columns and beams in the construction of blocks of flats

Let us, for instance, take the case of a block of flats. With modern standards of planning, the width would seldom exceed 30 to 35 ft., and would preferably be smaller than that in order to ensure sufficient light and cross ventilation. According to how the floor is divided up by the beams, three main systems are possible:

(1) The system indicated by Fig. 7a with beams spanning both crosswise and longitudinally and the floor area divided up in approximately square cross reinforced slabs;

(2) The system in Fig. 7b with cross-beams only, and continuous slabs spanning longitudinally over the cross-beams; and, finally,

(3) The system in Fig. 7c with only longitudinal beams, the slabs spanning crosswise, continuous over the middle support (or supports, if more than three longitudinal beams are provided).

As far as economy of floor construction is concerned, there is not much to choose between the three systems; it would depend mainly on the spans chosen, and this again on the width of the block. But as regards freedom of planning there is an enormous difference. In Fig. 7a the columns are absolutely fixed; it would be difficult to arrange the rooms to fit this scheme. Fig.7b is already better, the columns can be moved in the lines of the cross-beams, but longitudinally it is very rigid, and it would perhaps be very difficult to arrange the windows of rooms of varying size to suit the regular bays formed by the cross-beams. This system may, however, be the right one, where it is desired to have long horizontal windows, with only narrow columns between the windows, or where the windows are to form continuous horizontal bands, in which case the columns can be pushed back from the face and the cross-beams cantilevered to carry the wall, as in Fig. 7d.

The best system

In most cases, however, the system in Fig. 7c will be found to be the best, as regards economy, freedom of planning and simplicity. It is in most cases economical, because in this case about two-thirds of the necessary beams and columns can be provided by the outer walls, at very little extra cost. These walls have to be at least 4 in. thick in any case; so why not make them 4½ in., 5 in. or 6 in. thick, as the case may require, and utilize them as the outer lines of support for the floor slabs? They will, of course require heavier reinforcement, but in most cases the extra cost is more than balanced by the saving in beams and columns (see Fig. 7e). The system in Fig. 7b can, of course, also be varied by replacing the cross-beams with structural walls, but this is only suitable in very special cases (see Fig. 7f).

There remains then only one longitudinal beam in the centre or near the centre, and this is really the best place for a beam if there are to be beams at all, because in many cases it will be natural to arrange partitions along this line, dividing the rooms facing one way from the rooms facing the other way. The centre columns can be arranged anywhere in this line, but it should be remembered that it is the most economical to have small beam spans. In order not to protrude from the partitions, the centre wall can be made narrow and deep — although the depth is limited by the door openings — and the columnns flush with the beam, but wide in the direction of the wall; in other words, we can use the principle of the structural wall, with portions cut out and filled in with cheaper materials, for the sake of economy....

London's shelter problem

These three extracts are taken from Ove Arup's book of this title, published in 1940.

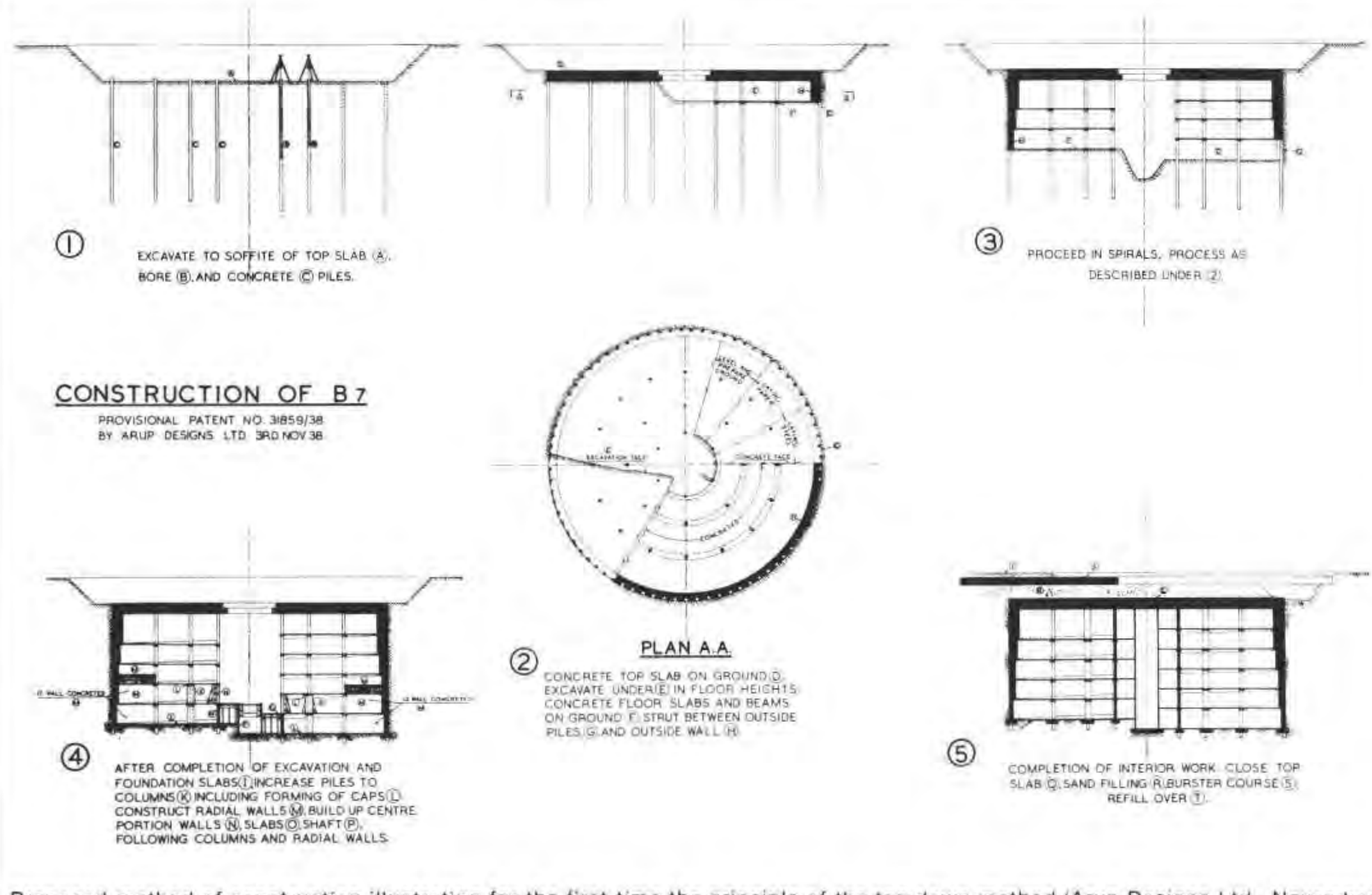
Introduction

As a result of the recent experience of night raiding, the demand for deep bombproof shelters has again come to the fore in the press and amongst the public.

As will be remembered, this demand was first widely raised by the daily Press some three or four months after the September crisis in 1938, when everybody realized that war was coming. An exhibition, sponsored by The Finsbury Borough Council, was held in the Town Hall of Finsbury showing with the aid of diagrams, slogans and cartoons the results of an investigation into the problem of providing shelters for the population of this borough. The authors of this investigation finally recommended a scheme providing for 15 large multi-storeyed shelters. The idea of deep bombproof shelters caught the imagination of the public — or the reporters, not without some gentle, but of course, quite legitimate assistance from the sponsors of the scheme.

A battle raged in the Press, at public meetings and even in the Houses of Parliament about the merits of deep shelters, the battle being conducted with great ferocity on the part of most of the Press, and with true parliamentary — or is it departmental? — dignity on the part of Sir John Anderson and the Home Office.

After an interval — the length of which presumably was a measure of the care with which the scheme had been investigated — it was duly turned down by the Home Office, reinforced for the occasion by three eminent engineers, on grounds which were partly reasonable, partly irrelevant and even absurd, and, no doubt, partly not mentioned at all. Sir



Proposed method of construction illustrating for the first time the principle of the top-down method (Arup Designs Ltd., November 1938). The necessary support to the sides of the deep excavation is provided by the floors with a minimum of temporary strutting. Temporary centering and propping to construct the floors themselves are also largely eliminated.

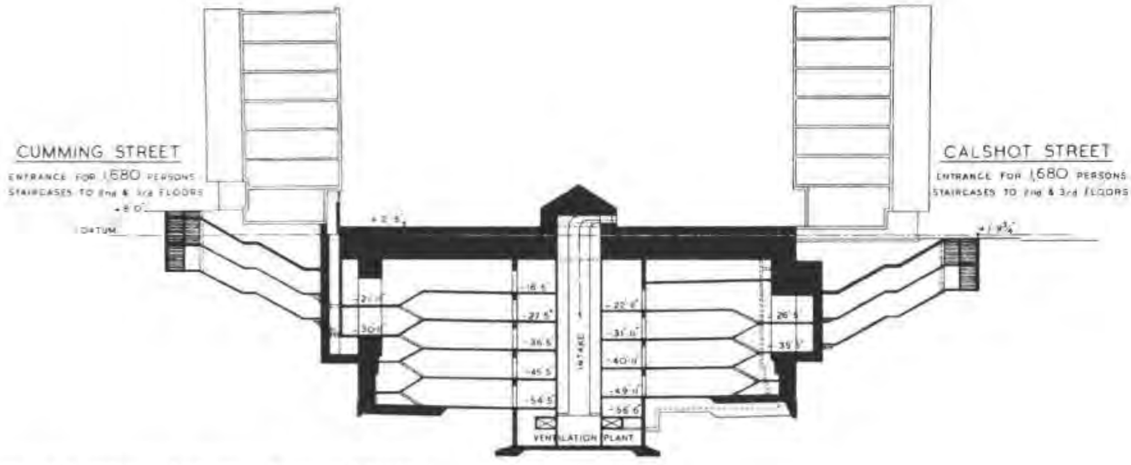


Fig. L
Cross-section of bombproof shelter, Busaco Street

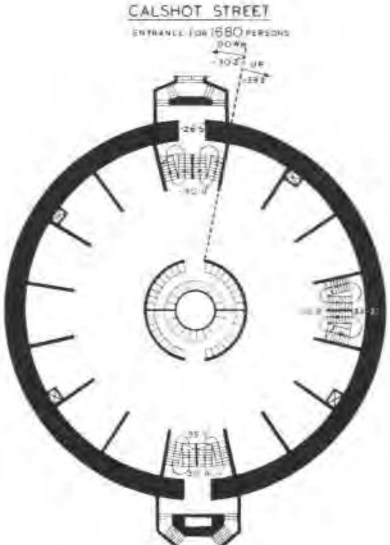


Fig. M
Bombproof shelter, third floor plan

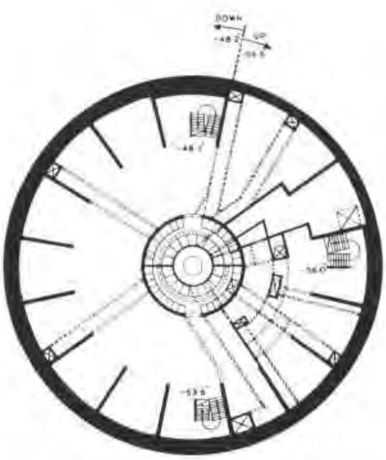


Fig. N
Bombproof shelter, fifth floor plan

John Anderson emerged victorious, the Press was unconvinced but subsided, the war broke out and people lost interest in shelters. Later Anderson shelters and brick surface shelters had an excellent Press, the impression was created that they were safe against 'anything but a direct hit' and Sir John Anderson's stock rose accordingly. Now there is trouble again, perhaps because people have been expecting too much, at any rate because it has been brought forcibly home to them that shelters giving a greater degree of safety and a greater degree of comfort would be desirable. And then they seek refuge in the Tubes, and remember the deep bombproof shelters. What can be done about it?

First of all I should like to correct a popular misunderstanding about these deep bombproof shelters. If we, as I suggest we should, define a deep shelter as a shelter which is situated deep in the ground and derives its protection mainly from the natural soil above, then the Finsbury shelters were not deep shelters at all. They were bombproof — that is against GP bombs of a certain weight, in this case ½-ton to possibly 1-ton bombs. I should prefer to call them heavily protected shelters — the protection at the top consisting of a 10 ft. thick reinforced concrete slab. They were multi-storeyed shelters — and in that sense 'deep', because they were to be constructed downwards and not upwards, so as not to obstruct the open spaces for which they were planned. They had to be multi-storeyed for reasons of economy of space and money. It is obvious that if it is decided to provide such an expensive roof protection, as 10 ft., of reinforced concrete, then it would be highly extravagant to use it for the protection of only one storey, when it can just as well protect several storeys. It comes to this, the heavily protected shelters are not bombproof because they are deep, but they have to be deep because they are bombproof....

Bombproof shelters

Bombproof shelters are shelters which are designed to withstand a direct hit from a specified bomb, the term 'direct hit' to be taken literally. It would, of course, in itself be desirable to have bombproof shelters for the whole population; the trouble is that it is so expensive that it probably is outside practical politics. The exceptions are: natural caves, existing tunnels or chalk cliffs in which new tunnels can easily be constructed. To construct new tunnels in London for use as shelters can only be an economically correct solution if the tunnels are required anyhow for peace time. Otherwise large multi-storeyed shelters offer the cheapest solution. Figs. L, M and N show a shelter of this type designed by Messrs. Tecton and myself for the Busaco Street site in Finsbury. The contract for this shelter was actually let to Messrs. Peter Lind and Company, and the construction started. Strangely enough it was stopped because the war put difficulties in the way of the financial arrangements.

The shelter provides for 6,200 people on the basis of 6 ft.² per person. If they all had to have sleeping accommodation the capacity would probably have to be reduced to 4,500 people or so. The cost was £85,450 including ventilation and filtration plant, sanitary equipment, lighting, emergency motors, pumps, etc. Of this money £4,500 was to be paid to expedite construction, the time promised being 20 weeks. The floor of the shelter is constructed so that it can be used as a car park in peace time. The top protection consists of 10 ft. of reinforced concrete — twice as much as that prescribed for the various municipal control centres which are supposed to be proof against 500 lb. bombs. It is to be regretted that the Home Office prevented the construction of at least some of these shelters in Central London, where car parks were urgently needed. They were not expensive for the protection given, and considering the possible peace time use. The main objection against them, that it took too long to fill them, has partly been removed by providing more staircases to comply with government regulations, but is in any case superseded by events....

Conclusion

It is now clear which policy I should have recommended for a city like London:

Night shelters

(a) A few large heavily protected shelters in suitable squares or open spaces, where car parks are needed.

(b) Wall shelters of the Finsbury type suitably spaced, to be constructed on open spaces, squares, yards, and where necessary on the sites of derelict buildings commandeered for the purpose.

(c) Adequate strengthening of existing large office basements.

(d) Use of tunnels where trains are not running (if any) and construction of new tunnels or Tubes and Post Office tunnels if required for peace time.

Day shelters:

More basements and surface shelters in conjunction with night shelters.

(At a still earlier time I should probably have recommended tunnels in the roads to take all services, as they have in Paris, but it is no use talking about that now).

The programme outlined above would have been expensive, but if it had been tackled in an orderly fashion two years ago, it would no doubt have produced less strain than will be caused now by the necessary alterations and additions to existing shelters.

Science and world planning

This paper was given at the Conference on Science and World Planning held on 27 July 1942, by the British Association for the Advancement of Science.

The development of modern science and technique enables us to construct buildings which are satisfactory in every respect: warm, soundproof, well ventilated, with all the amenities and labour-saving devices which one could wish for. Modern buildings as actually constructed, however, are not nearly as wonderful. They are often badly planned, badly ventilated, badly heated, etc. In other words, only limited use is made of all the existing technical knowledge. One reason for this is simply that this technical information is not available to the designer of the building. This may be because he has not got the knowledge he ought to have, but even if he were a very able architect with the best possible technical education, he could not hope to be familiar with the complete range of modern technical possibilities. He is, therefore, unable by himself to arrive at the right solution, and is a prey to the various commercial interests advocating their own particular products.

The problem is the same here as in other spheres of human activity — a wealth of new knowledge, new materials, new processes has so widened the field of possibilities, that it cannot be adequately surveyed by a single mind. Corresponding to this increase of means there are increased or entirely new requirements to be satisfied. Our needs increase with the means. Standards are raised, new services introduced.

This produces the specialist or expert, and the usual problem arises, how to create the organization, the 'composite mind' so to speak, which can achieve a well-balanced synthesis from the wealth of available detail. This is, I suppose, one of the central problems of our time. How then can we overcome this difficulty?

Apart from the obvious way of improving the technical education of the architect, which, however desirable, would I am afraid not carry us very far in this connection, there are two main remedies.

(1) One is to have the planning carried out by a team of experts whose combined knowledge covers a substantial part of the relevant technical information.

(2) Another is to have all the technical information which may have a bearing on the problem checked up, classified, standardized and made easily available.

Both these methods are being employed, but not sufficiently.

The architect does, of course, invoke the assistance of various specialists, but mostly at too late a stage to affect the main conception.

Take for instance the case of the structural engineer; his work has a fundamental bearing on the planning, and architectural harmony can only be achieved if architect and engineer collaborate intimately right from the start. At the moment, there is however no recognized machinery for such collaboration. The appointment of an architect does not as a rule carry with it the appointment of a consulting engineer. The architect must therefore either:

(1) confine himself to employing a more or less established structural system of which he has sufficient knowledge himself; or

(2) he must entice a consulting engineer to collaborate with him 'on spec'; or

(3) he must seek advice from a firm of structural engineers and contractors who will offer this advice possibly from purely altruistic motives, but possibly also in order to improve their chance of obtaining the contract by putting the architect under some sort of obligation to them.

This sort of semi-collaboration does not produce the best results. Similar remarks apply to the collaboration with other specialists.

One remedy, as mentioned, which is already being applied in some cases, especially in the USA, is the formation of larger planning units consisting of firms or companies who have on their staff experts on the various aspects of the work to be planned. The organization may be on more or less democratic lines, but the importance lies in the fact that the various experts are in constant close co-operation and learn to understand each other's points of view, so that each can see his work as part of a whole plan, and make the adjustments required for smooth dovetailing. The value of such close co-operation can be seen in every sphere of planning.

Of special importance is the close connection between design and execution. A thorough knowledge of building costs and building processes is essential to the designers, and this knowledge is best obtained if he, or his team, directly controls building operations on the site, thus taking over the function here carried out by the general contractor.

Such larger planning groups are also in a better position to cope with the modern trend towards prefabrication in building. Prefabrication obviously means studying factory production, and calls for team work. In fact the spread of prefabrication will in itself tend to eliminate the private architect. His place will be in the factory, or inside the public or private planning group.

The trend towards the formation of larger planning groups on a commercial basis which is already apparent has, however, serious drawbacks. One of the major purposes of each group is to be successful, to make profit. This may fit in with the interests of society as a whole, but often it does not. The group will try to keep its experiences secret, it may be financially interested in certain materials or certain processes, and may want to push them even if this does not make for the best possible scheme. It may even buy up and suppress new inventions, and will tend to turn any gain of efficiency into increased profit rather than benefit to the consumer.

Then again, no group covers a wide enough field. The client therefore still needs expert advice to enable him to choose between the bewildering variety of possibilities, and when large-scale planning is undertaken, the work of the various groups should again be co-ordinated, for which there exists no machinery.

Team planning of this kind does not solve the difficulty of discriminating between many new materials and patent processes, information about which is only available in the form of biased trade publications.

We therefore turn to the other remedy — the creation of a fund of unbiased information available to all. This would mean the setting up of institutions working for the benefit of society as a whole, which would therefore probably have to be financed by the State. I enumerate at random some of the services which should be rendered. One would be the proper scientific testing of all new, and for that matter old, building materials. No new materials should be generally released without having passed such tests, and the results should be available to the general public. This sounds reasonable and innocent enough, but it would have far-reaching consequences. The authorized testing institutions would require permanently, powers that are contrary to the interests of some commercial firms, which are therefore rarely given, and then only for a limited purpose and period, namely, those of a governmental commission of inquiry. To publish unbiased information, however, should logically be followed by a restriction of production to useful products, and would therefore interfere considerably with the present organization of industry. To have this unbiased testing extended to building processes, tools and plant, would obviously also be very useful and result in enormous savings, but it would call for large research stations with ample staff and resources.

Another would be to eliminate some of the unnecessary repetition of detail planning which goes on in thousands of offices. Everywhere the same or almost the same problems crop up, and are painfully solved over and over again, sometimes reasonably well, often not so well. If the best possible solutions were found to these problems and embodied in a series of standards, the task of the designer dealing with a particular job, and

Finsbury Health Centre (1935-8) Architects: Lubetkin and Tecton
(Photo: Dell & Wainwright; copyright *Architectural Review*)

also production generally, would be simplified immensely. Standardization has, of course, been carried out to a great extent already, but the process could be extended much further, provided there was a reasonable choice of alternatives, and the possibility of revision was safe-guarded.

Such a systematic standardization of the elements of industrial planning should logically embrace international agreements on the fundamental standards, such as measurements. To be forced to translate kg./cm^2 into lbs. per in.^{2} etc., is wasteful, and hinders international exchange of ideas.

Hand in hand with the standardization of those units from which planning proceeds, should go the standardization of human needs. Minimum housing standards, workshop standards, etc., should be laid down and applied universally, and from these should spring building regulations, etc., which should safeguard the interest of society as a whole, but should not be drafted so rigidly as to be a drag on progress. The service must be run on democratic lines to allow revisions and additions to penetrate from below, from local to central bodies, to avoid over-centralization, and bureaucracy, and allow for regional differences. But there must somehow be power to direct or influence production. The centre of gravity must be shifted from private enterprise to public service. The best brains should be attracted to this service, and it would be reasonable and profitable to combine these planning and research centres with the technical education of students.

Once the principle is accepted, that the public has a right to expect the elimination of the obstacles which prevent the application of scientific and technical progress, it is not easy to stop half way. Organization of industry and communications, the planning of towns and agriculture, the extension of social services are all problems which, as far as I can see, cannot possibly be left to private initiative, but which everybody now realizes ought to be tackled in the interest of humanity.

To take an example, the proper heating of houses and workshops in the winter, and the supply of hot water on tap, could be made a public service by the introduction of district heating supplied from a number of central heat-electric stations which would combine the generation of electricity with the supply of heat in the form of superheated water. Such a system would considerably reduce the total coal consumption, and would at the same time supply an abundance of electric power which could be used for heating in outlying districts. It would also affect the design, and reduce the cost of new buildings, and would improve housing conditions where improvement is most sorely needed. Again, however, such schemes could only be tackled on a national scale.

Conclusion

It becomes more and more clear, therefore, the more one delves into the question how the benefits of modern technique can be made real, that this is not a technical problem at all. It is not even mainly a problem of organization. The organization could no doubt be worked out if everyone really wanted to benefit humanity. The difficulty is rather one of getting agreement as to what benefit to humanity means, and also of overcoming the fact that people are more concerned with benefiting themselves than humanity. It becomes therefore a moral or social or political problem. It should be obvious to scientists and technicians that the value of their work depends on the solution of this social problem, and they should therefore, as citizens with a social conscience, do everything in their power to contribute to its solution.

Shell construction

This article first appeared in Architectural Design, 17 *(11) 1947.*

Architecture is concerned with the enclosure or division of space. Space is confined by curved or plane surfaces, just as a surface is confined by curves or lines. A study of surfaces, their arrangement and intersection, is, therefore, of the essence of architecture. This fundamental fact is obscured by the difficulties obstructing the physical embodiment of our ideas. We cannot simply plan according to our fancy, considering only the need of man. We must consider the stability of the structure against the forces of gravity, of wind, and so on. And we can only go so far as our limited knowledge of these materials and their behaviour under load will allow us.

Until recently, the available sheeting or cladding materials could not fulfil their function of dividing space, without being held in position by other purely structural members. Gravity walls, domes and vaults were an exception to this general rule, but their inability to resist tension or bending put a severe limit on the forms which they could assume. We, therefore, think in terms of columns, piers, architraves, beams, trusses, rafters, as the elements of architecture — all members necessitated by structural and not by functional requirements.

But new materials and increased engineering knowledge enable us more and more to free ourselves from the old limitations. The use of steel in building made an enormous change — it largely freed the architectural plan from the tyranny of load-bearing walls and piers — and reinforced concrete, properly used, can take us a step further.

In the beginning, the potentialities of reinforced concrete were only partly realized and, to a large extent, that is still the position today. Reinforced concrete was used as a substitute for timber and steel, and assumed the forms characteristic of these materials. The column, the beam and the slab were thought of as separate members. This attitude does not do justice to the salient feature of reinforced concrete, which is its plastic and monolithic character. It can be moulded and built up to any shape, after which the whole structure forms one jointless unit, and it should rightly be considered and calculated as such.

The calculation of reinforced concrete is thus complicated, but designs are consequently produced which differ essentially from the traditional beam and slab structure.

We have for the first time a material which can be formed into comparatively thin plates or shells for enclosing space — or, in engineering structures, for retaining earth, containing water, coal, grain, and so on — which can at the same time be made to resist the forces acting on the structure with only limited recourse to external structural members.

There are, of course, limitations to our freedom of design, and they are mainly of two kinds. One is imposed by the formwork; the other by difficulties of calculation.

The temporary formwork is responsible for a very large proportion of the cost of reinforced concrete structures. If we were to ask for a double curved shell, needing shuttering on both sides, the cost might far exceed that of the concrete and reinforcement, and such a structure would, in many cases, be ruled out for financial reasons. To reduce costs, forms should be simple and should be re-used often. Further, it is naturally an advantage if the slope of the surface allows concrete to be deposited without top shuttering.

From this point of view, plane surfaces are to be preferred to curved, single curved surfaces to doubly curved, and flat slopes or curves to steep ones. More important still is repetition through standardization of lay-out.

The difficulty of calculating shells of various shapes, subjected to varying loads, is considerable and it is only lately that theories have been developed which enable us to deal with some of the surfaces which can be mathematically defined.

Lamé and Clapeyron laid the foundations for the membrane theory as early as 1825, and a general theory for dealing with shells was arrived at by A.E.H. Love, towards the end of the last century. But it is only since 1910 that these general theories have been further developed and made applicable to large span roofs. Germany led the way in this development, although France also contributed some original work. Lately, however, contributions have come from many different countries. A recent British publication, R.S. Jenkins' *The theory and design of cylindrical shell structures*, gives the modern elasticity basis of design in a form suitable for practical application.

In order not to make the calculation too difficult, it is still desirable to confine the use of curved shells to spheres, cylinders of different kinds, paraboloids, hyperboloids, cones and other surfaces, which have simple geometric properties. That does not mean that other shapes cannot be attempted. I was told that a team of four engineers worked for over half a year on the calculation of a shell roof with an irregular base, covering the main concert hall of the new Broadcasting House in Copenhagen. Obviously, it is only rarely possible to go to that amount of trouble.

In the new approach to reinforced concrete design, the basic element is the comparatively thin slab, plate or shell, extending in two dimensions. Slabs have, of course, always been a feature of reinforced concrete design, but they have almost exclusively been considered as members resisting forces perpendicular to their own plane and therefore, mainly subject to bending. The fact that a slab is much stronger when resisting forces in its own plane has been surprisingly neglected.

In the British Codes of Practice and Regulations, for instance, there are no design regulations for thin load-bearing walls; a vertical slab is always considered as a panel to be held in position by a frame — a wrong way of looking at it, leading to clumsy and faulty designs. The new approach takes great note of the strength of slabs and shells in their own plane: it can almost be said to be based on it.

Perhaps the most spectacular results of this approach are the concrete shell roofs, where large spans up to 200 feet or more are achieved with shells only a few inches thick. But these are only special examples of a general tendency, permeating modern concrete design, where the structure is conceived as a spatial monolithic whole. It is easy enough to gain a rough idea of how concrete shells act.

Fig. 1 (overleaf) represents a simply supported slab, uniformly loaded. It is subjected to bending only.

Fig. 2 shows the slab replaced by two inclined slabs. Each of the slabs is still subjected to bending, but the span is smaller, and the deflections are therefore smaller. But in addition, the system is subjected to compressive forces in the plane of each slab, transferring the resultant force at the top to the bearings. These forces can, however, easily be taken by the slab, and the total result is a lighter construction, provided the bearings can withstand the outward thrust exerted on them.

In Fig. 3 and Fig. 4, the two slabs are replaced by three or four slabs, resulting in still smaller moments, without increasing the thrust, and in Fig. 5, the arched slab, the moments disappear altogether, *provided the thrust-line coincides with the arch*. This can, however, only happen for one particular set of loads — as soon as the load varies, moments are introduced.

The moments, mostly caused by wind and snow, are very much smaller than they would be for a slab of the same span (Fig. 1), where also the dead load contributes to the moments, but for large spans they are nevertheless considerable and the slab must be fairly solid and well-reinforced to withstand them. If the arch slab cannot be taken right down to the foundations at each side, but has to spring from the level of the eaves, it will, in most cases, be necessary to provide frequent ties at this level.

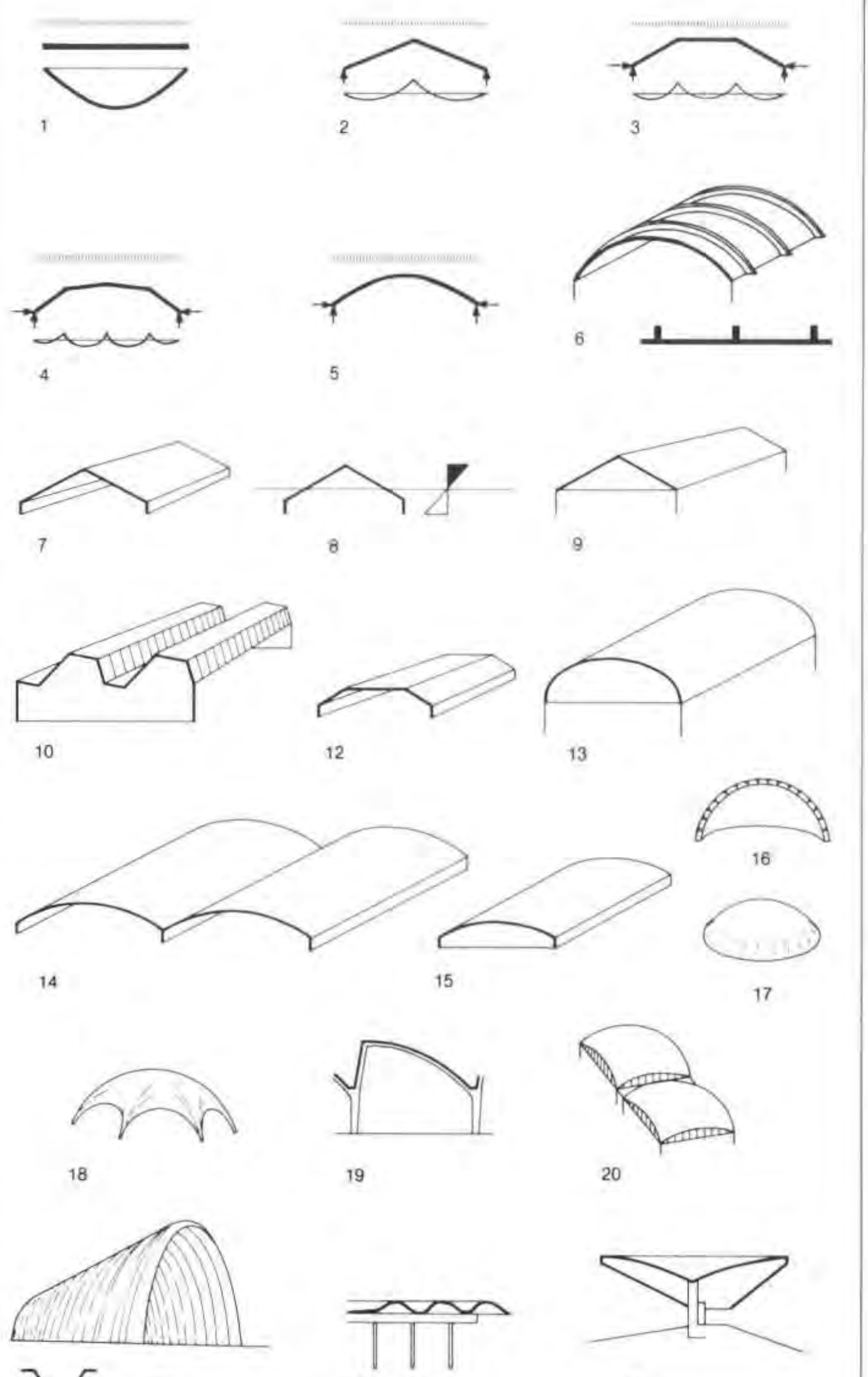
This plain, tied, arch slab has been used frequently in the past for medium spans. It is *not* what is generally understood by a shell construction, because it can only resist unbalanced forces by bending moments in the slab, whereas a proper shell is mainly supposed to be subjected to normal and shear stresses in its own plane. But if we introduce arched ribs, as in Fig. 6, then the singly-curved slab can transfer the unbalanced forces to the ribs through direct stresses in the slab, provided the latter is sufficiently stiff and the curvature is not too small. This means that the arched slab can be constructed as a comparatively thin shell.

Constructions similar to that shown in Fig. 6 have, of course, been used for many years, but before modern analysis showed the way, the orthodox method of treating them was to let the ribs take all the moments — and possibly even the whole of the thrust — and to span the slab between the ribs, disregarding its curvature.

To illustrate the action of the shell, let us look at another set of figures.

Fig. 7 is a cross-section through a structure, consisting of four slabs, joined together as shown. If this structure is supported at the two gable ends by a stiff wall or frame, which prevents any relative movements of the four slabs at these points, then it will be able to span freely between the two gables, if suitably reinforced. Each slab will act in two ways, *as a slab* transferring dead weight, wind loads, etc., crosswise to the corners, and *as a beam*, transferring the resultant forces in their own plane to the gable ends. It is obvious that at the junction line of two slabs, no movement can take place without moving one or both slabs in their own plane, and such movement will be resisted by the slab spanning as a very deep beam from end to end.

The matter does not end here, however. We must take into account that the four slab-beams are joined at the corners and therefore react on each other. In fact, if the structure is mainly subjected to vertical forces, the tension zones of the two inclined slabs are joined to the compression zones of the two lower slabs. Obviously the corner cannot both be in compression and in tension, and this is an example of the absurdities sometimes resulting from the artificial splitting up of the structure into simple elements. The structure acts as a whole, and the various parts act on each other. In order to assess the magnitude of these internal forces, we must resort to rather more complicated calculations, taking into account the elastic deformations of the structure, and as a result, we shall find that the lower part of the combined structure — up to a so-called neutral axis — is in tension, and the upper part in compression, as shown in Fig. 8.



Figs. 1-23
Shell structures

We find, in fact, that the whole structure will act approximately as a beam, but we must ensure against distortion of the cross-section. If, in Figs. 7 or 8, the two lower flanges were left out, as in Fig 9, the free ends of the two slabs would probably sag in the middle. The shape of the cross-section is therefore important if we want to reduce the moments acting in the plane of the cross-section.

Structures such as the one shown in Fig. 7, consisting of plane slabs joined at the edges, are called *Faltwerke*, in German. We might call them 'slab-frame' structures and various books and papers have been written about their calculation, but the principle is obvious and has been used widely, without giving it a name, for industrial structures. An example is the shed roof in Fig. 10, used by the writer before the war for spans up to 70 ft.

If we increase the number of slabs in Fig. 7, for instance, as shown in Fig. 12, we reduce the transverse moments in each slab element, but we complicate the calculation and are still more dependent on the shape of the cross-section, to avoid distortion. If we go the whole hog and change the section into a smooth curve, as in Fig. 13, we can reduce the bending moments to a minimum.

This form of construction, a barrel vault shell of approximately elliptic cross-section, spanning 'the wrong way' was first developed in the 1920s by the firm of Dyckerhoff and Widmann in Germany, in conjunction with the Zeiss optical concern, and patented under the name of 'Zeiss Dywydag Gewoelbe.' The patents covered the method of calculation as well as the practical application. An explanation, with calculations, is given in *Handbuch des Eisenbetonbau* by Dr. Franz Dischinger of Dyckerhoff and Widmann. In the beginning, great care was taken to give the shells the correct mathematical shape and to make them very thin, so as to correspond to the theory, which assumed that all forces acted in the plane of the shell and were evenly distributed over the thickness, but later analytical and practical research showed that other forms were possible. Now these shells are mostly given the shape shown in Fig. 14.

This has the advantage that the slope of the curved section is such that no top shuttering is required, only the straight vertical ribs requiring double shuttering. Top lighting can be provided, as shown in Fig. 15.

While it is easy to see that sections such as Figs. 7, 10, 12, 13 and 14, must be able to span some distances, the actual calculations are rather involved, and some simplifying assumptions must be made. One method is to treat the structure according to the usual beam theory, assuming that plane cross-sections remain plane after loading. This is not very exact, and the method used by Dischinger is the so-called membrane theory, which makes the assumption that the membrane is infinitely thin (mathematically speaking), and that all stresses must be parallel to the surface.

The difficulty is to balance the system of forces with the existing boundary conditions, and in any case the assumptions are not correct, as the shells must be given certain thickness and the moments cannot legitimately be disregarded, however thin the shell. This throws us back on the general theory of elasticity, applied to a spatial structure, and to an isotropic material with a certain stress-strain relationship and a certain value for Poisson's ratio. We must consider the equilibrium of each small element and of the system as a whole, and make the boundary conditions conform to the physical facts. In short cylinders of large radius it may be necessary to introduce stiffening ring beams to deal with the bending moments.

When we come to doubly curved shells, it is actually easier and more correct to apply the membrane theory with a correction in regions near the edges. The construction of domes and double-barrelled vaults is possible even in a material which will not resist tension, as has been known for hundreds or thousands of years. Sometimes, the dome was prevented from spreading out by a tension ring or chain at the springing (Fig. 16). Actually, the whole lower zone of the dome is subject to circular tension, and we may, therefore, have cracks in the lower part, as in Fig. 17. In a reinforced concrete shell, the reinforcement can be placed where it is needed, and the dome can be made much flatter and thinner, as we are not dependent on gravity to bring the thrust line down.

We can also make use of many other double-curved or single-curved surfaces. Figs. 18 to 23 illustrate some of the possibilities. Any kind of corrugation can be used to increase the stiffness of a slab — which does not mean that they are all equally effective. In the new bus terminus, now being built at Store Street, Dublin, a canopy made of corrugated reinforced concrete has been designed, cantilevering 20 ft., although the thickness is only 2½ in. (Fig. 22). If a corrugated section is arched at the same time, as in Fig. 21, the effect is further increased.

Shell construction is the most important development in reinforced concrete in recent years and will undoubtedly contribute to the character of the coming architecture. It places at the architect's disposal a new form of construction, which serves the dual role of cladding and structure, and gives him greater freedom of planning and elevational treatment to meet both functional and architectural requirements.

At the same time, it should be noted that its proper design calls for more intricate calculations on the part of the engineer, to deal with a statically indeterminate three-dimensional structure. Early collaboration between architect and engineer becomes very necessary.

Conclusion

Perhaps the future development of shell construction will depend largely on the way in which the contractor approaches the constructional problems involved, as these differ considerably from those encountered in normal construction. Standardization of shuttering and a large number of uses are essential for economy, and this is a point which should be borne in mind when general layouts are being considered. Methods of depositing concrete in large areas of thin slab, while still improving the quality of work, require consideration, and the general planning of sequence of construction, stage by stage, is essential. As these and other problems are mastered, there is little reason to doubt that shell construction will compare favourably with more orthodox forms of construction for covering large uninterrupted spaces.

Modern architecture: the structural fallacy

This article was published in The Listener, *7 July 1955.*

I want to discuss here the rather complicated relationship between the structure of buildings and their architecture. There is now a wide range of new structural possibilities through the use of structural steel, of reinforced concrete, prestressed concrete, of aluminium alloys, and other materials in all their varying forms. This, together with the advance in engineering knowledge, has enabled us to create structures of an incredible lightness and strength, compared with the old gravity structures. We can soar into the sky and span if not the oceans at least long distances with the greatest of ease; in fact, we can do most things we want to do, if we want them badly enough.

Side by side with this extension of the range of structural possibilities, a gradual change in the processes of production has taken place. Work on the site has been largely mechanized, and more and more building components are being mass-produced in factories. The former aspect of modern building technique has given the architect greater freedom to do what he likes, the latter tends to restrict this freedom in the interests of standardization. How are architects responding to this twofold new situation? And how does it affect architecture?

Maxwell Fry, in a talk entitled 'The Architect's Dilemma' printed in *The Listener* of February 17, went back to the beginnings of modern architecture. It set out, he said, to be

> 'entirely freed from subjection to any style; its only criteria being: carefully analyzed function, honestly expressed structure and the demands of applied sociology'.

It is significant that this definition contained no mention of aesthetic principles, or of architecture as an art. Indeed the pioneers of the movement, or some of them, thought that if only they attended to the function of a building, and — to quote again from Maxwell Fry — 'adopted a structure arising from engineering, and clearly expressing, instead of hiding, its structural function', then beauty would automatically arise, and the result would be architecture.

The aesthetic programme of the modern movement is hidden away in an excessive admiration for all things technical, for new structural forms and materials, for making full use of all the latest technical innovations long before they are economically justified, and for the 'honest expression' — whatever that may mean — of the structure. So much enthusiasm for the means of building is suspicious. It shows that there is more in it than meets the eye. And so there is. There has been a revolution — we all know it — in aesthetic sensibility. It started 50 years ago in painting and thereafter permeated all the visual arts; it derived inspiration from primitive art, from the new patterns and images brought to light by scientific investigation and made accessible by modern photography and reproduction techniques; it derived a further impetus from the new structural forms developed by engineers. Through the opening up of these new worlds, we have learnt to see beauty where it did not occur to us to look before.

But modern architecture has still not produced a new architectural language which is universally accepted by our time. Aesthetically we are still in a state of flux, and that is perhaps not a bad thing. We see the romanticism of a Frank Lloyd Wright side by side with the classicism of a Mies van der Rohe. We see the beginnings of a great many different fashions, with *clichés* originated by the great going their round in architectural magazines, and being copied with glee all over the world; but they do not seem to stick, they have not congealed into a new academicism. The nearest approach I can find to a common ideology is the frequently expressed conviction that a regeneration of architecture in our new technical age must come through the truthful expression of structure. This sounds attractive enough — especially to an engineer — but what in fact does it mean?

In an ordinary brick building, the walls have a number of things to do — they enclose space, and keep out the weather, they retain heat, insulate against cold and sound, and they also carry the loads from the floors and roof. But in this latter capacity they are only partially employed, and without opening up the floors and finding out which way the timber joists are spanning it is difficult to see which of the walls or parts of them are structurally active. Expression of structure hardly comes into the picture, and yet some very good architecture — Georgian, for instance — has been produced with brick. When the walls are pierced by large window openings, and when they also have to act as buttresses for vaulting or to ensure stability, as in the case of the Gothic cathedrals, we can begin to talk about structural forms and possibly also of the expression of structure: if structural economy is to be achieved, the enlarged scale and the magnitude of the gravitational forces impose a certain discipline of their own.

Carried to its logical conclusion, Gothic architecture does represent a structural idea: the gravity structure soaring upwards, but

pared down to the minimum thickness that will ensure stability. Its forms may approach what I have called the 'organic structure'; in a structure of this type the material is disposed so as to take care of the flow of forces in the most advantageous way. The ideal Gothic forms flow solidly from the ground, where the heaviest loads occur and are attenuated towards the top. The rounded arch, vault, or dome, of masonry or brick, represents a slightly different structural idea, with the emphasis on spanning horizontally rather than soaring upwards. But here we can distinguish between two different approaches. The 'organic structure' of this type would be given the structurally correct form — somewhat approaching a parabola — which would reduce the bending moments and therefore the mass to a minimum, and the thickness of material would at every point be adjusted to the force. Architects have, however, often preferred a simple geometric form; they have turned the arch into a half circle — in former times this was partly due to ignorance, but also because in classical architecture, and in modern architecture with a classical flavour, it is considered an aesthetically more satisfactory form. This kind of disciplined structure we might call 'geometric structure', to indicate that it is modified or purified to fit into a geometric pattern.

Modern structural materials, such as steel and reinforced concrete, have given architects the possibility, with the help of engineers, of creating a number of *new* structural ideas or archetypes, so to speak. There is, for instance, the three-dimensional structural steel grid or frame. Steel, being a purely structural material, cannot be used economically to form floors or walls; in a building it provides only the framework on which the other materials are hung. Being produced by rolling it is available in uniform sections; for this and other reasons it does not lend itself to the creation of an organic structural pattern in the way of a tree, with tapering branches, but it is very suited to the imposition of geometric discipline. Modern architects have seized this opportunity to create the idea of the ideal structural grid — a three-dimensional rectangular system of lines evenly disposed, of even and as small as possible section throughout, and with no disturbing excrescences at the joints, a conception of pure geometry.

Mies van der Rohe especially has struggled hard to give effect to this idea, and that implies of course expressing or showing the structure, otherwise there would be no point in the attempt. In his Lake Shore Apartments in Chicago and some private houses the walls are therefore made of glass, so that the grid itself can be clearly perceived and nothing shall mar the purity of the conception. Then there is reinforced concrete, which can enclose space and — with a little help — keep out the weather, besides providing structural support. The structural carcass of a building in this material may be thought of as a series of horizontal slabs — the floors supported by a regular grid of columns. The box-frame or egg-crate is another very simple geometric idea characteristic of reinforced concrete construction; it consists of a regular system of vertical and horizontal slabs. Reinforced concrete has also given birth to other structural forms — the cantilever, for instance — like a branch of a tree, strong at its base and tapering outwards; and thin concrete shells, which can take on a great number of shapes and now replace gravity vaulting. Then there are all the various forms of frames, arches, trusses, and girders and there are tent-like constructions based on suspension cables, and the so-called space-frames: three-dimensional triangulated grids, which at present have a vogue in architectural schools far in excess of their importance.

These structural forms are mostly developed by engineers for utilitarian or economic reasons, but they exert a strong fascination on architects, who are apt to react to them in an emotional or intuitive way, seeing them as spacial forms or patterns which are capable of being organized artistically. This can be done either with a bias towards organic, so to speak romantic, forms, or on strictly controlled geometrical and classical lines.

Sometimes architects seize on a characteristic structural feature and use it for purely aesthetic ends where it is neither economically nor structurally justified. This has happened throughout the history of architecture, and there is nothing wrong in that, as long as the aesthetic purpose is acknowledged and achieved. Take, for instance, the hinge, which impels all the forces to meet in a single point. In nature, hinges or joints are used to allow movement, as in the case of an elbow joint. Plants which are stationary have no joints; it would mean an unnecessary weakening of the structure. In structural engineering hinges are introduced for two reasons: to facilitate calculations by making the structural system statically determined, as in the three-hinged arch, and, as in nature, to allow movement — for instance, a settlement of foundations or temperature expansion of a bridge.

But architects love hinges for their own sake.

In the new Coventry Cathedral, Basil Spence makes the columns carrying the internal canopy taper downwards ending in a kind of ball-bearing; and Saarinen's spectacular, triangular, concrete shell at the Massachusetts Institute of Technology rests on three points, formed as steel hinges. There is no structural or economic reason for this — it is a purely aesthetic device conveying a feeling of crispness and also of a purified structural idea, which may be aesthetically justified in spite of being slightly bogus. Incidentally, the appeal of the hinge or focal point is strikingly revealed in the architectural drawings of Steinberg, when he shows enormous arches and suspension bridges ultimately supported on needle points. As an artist he catches the essence, the aesthetic spirit of engineering structures, and architects have often a similar approach.

The engineer, in accordance with his training and purpose in life, is trying to find the most economical structure. I mean economical in the means of production. He takes into account available resources and the characteristic manner in which each structural material is produced. This does not necessarily imply the most economical use of material as in the concept of an 'organic structure', although in large-scale structures that concept may be approached. It is not always the aesthetically most satisfactory approach either. Nevertheless it is in the quest for economic ways of solving difficult structural problems that the new and exciting structural forms have been evolved. They generally need a little trimming, a deviation from the strictly most economical solution, to bring out their inherent beauty, which may be of an organic or geometric type in accordance with the materials and methods used. But the point is, that whereas in large-scale and difficult engineering structures, such as bridges, dams, and long spanning roofs, economy and beauty often coincide — or nearly so — if a clear and simple structural idea is logically pursued; it is not at all easy to cash in on this fact in architecture, as architects would dearly love to do.

Above: Hallfield Estate, Paddington (1949-53)
Architects: Drake and Lasdun
(Photo: de Burgh Galwey;
copyright *Architectural Review*)

Right: Coventry Cathedral (1955-62)
Architect: Sir Basil Spence
(Photo: Copyright John Laing & Sons Ltd.)

Below: Lake Shore Drive Apartments (1948-51)
Architect: Mies van der Rohe
(Photo: Courtesy Architectural Press Ltd.)

In our normal multicellular buildings the structure, besides being of an elementary and unexciting kind, is cluttered up with walls, stairs, flues, service-ducts, lift-shafts, and so on, and to submit it to a strict aesthetic discipline and then to expose it sufficiently for it to be understood as a whole, would in most cases require great sacrifices in money and the disregard of other necessary functions. In our climate buildings must have an overcoat and a raincoat, and there is no particular reason why the structure should be left out in the cold. And, internally, we do not want to be reminded of it; it only gets in the way.

Recently, on a tour in the United States of America, I had occasion to show some slides of the new Hallfield Estate in Paddington, by Drake and Lasdun. In this scheme the access balconies and other elements of the facade are used to make a formal pattern; this pattern, however, bears no relation — or at least does not truthfully express — the structure behind, which is a simple box-frame of reinforced concrete. At Harvard, Chermayeff thought that this was by far the best piece of architecture which had come out of England after the war. But others, at the University of Pennsylvania, and especially at the Illinois Institute of Technology where Mies van der Rohe is in charge, were very scathing in their condemnation of this aimless doodling, which they considered dishonest, fortuitous, and futile. They insisted that the box-frame behind the facade should have been expressed on the outside.

It is difficult to analyze this attitude — it is a mixture of sense and nonsense. As so often happens, means become aims; the expression of the structure, which may admittedly be a means of creating architectural unity (although sometimes an expensive and unnatural way of doing it), becomes an end in itself. This moral streak, which was certainly present in Victorian architecture before it pervaded functionalism, leads to the naive assumption that straightforward, unadorned, economic building will somehow display the quality which is so admired in engineering structures. The fact is, of course, that it requires a major *tour de force* to impose this quality on ordinary buildings, as Mies' Lake Shore Apartments show. Ordinary buildings are much more influenced by building technique proper: by standardization, mass-production of building elements, and so on.

The expression of structure makes more sense in buildings providing large spaces — factories, exhibitions halls, and so on. Here the structural members are often bound to be prominent and have to be organized.

But there should be no moral compulsion about it. Acoustic ceilings, water-proofing insulation and service ducts may make it impractical to reveal the structure, especially if it is of the economical but ordinary, rather than the inspiring, variety. The engineer is probably as keen as the architect to evolve an exciting structural solution but it is his duty to point out to the architect that the beautiful structure is rarely the same as the economical structure, although in some inspired solutions the two may almost coincide. Yet, in spite of all this, I would count that there is something valuable and right in this architectural approach to structure, and many engineers might do with a dose of it.

Architecture is concerned with 'organizing the functional elements so as to create something aesthetically coherent and with a personality of its own', as J.M. Richards put it in a talk entitled 'Architecture Dehumanised' printed in *The Listener* of January 6. It is a matter of giving the proper weight to various conflicting claims and creating harmony and order out of chaos. Organizing the available material in space means imposing on it some easily recognizable pattern or main motif, creating a simple, if subtle, balance of masses and spaces, tying it together with lines and planes, creating unity by consistency, by limiting the means of expression to a chosen few. Subordinate to the main pattern there may be other patterns, elaboration of detail, but they must not obscure the clarity of the main conception, which acts as a frame of reference, making the whole thing intelligible and obvious at a glance. A certain simplicity, a sense of the unavoidable, of essential rightness is, I think, common to all great art.

A clear, simple and well-proportioned structural system can be eminently suited to the role of providing this general pattern, this orderly frame of reference. The wish to express it is therefore a very natural one, as long as ethics are not mixed up with it and as long as it is realized that this 'organization of the functional elements' can just as well, or just as legitimately, be achieved by other means.

The importance of having a simple guiding idea to help in the solution of an architectural problem was brought home to me when in 1946 Clive Entwhistle was working on his scheme for the Crystal Palace competition in my office. It contained, as a central feature, a very large pyramid covered entirely in glass-bricks. Le Corbusier, who took a friendly interest in the work of his pupil and worked on the scheme for several days, suggested that the inside of the pyramid should be treated in an organic manner, so to speak, with ceiling heights getting smaller towards the top, and everything else in proportion. He was at the time very full of his modular system of proportions, and he drew a kind of tapering Christmas tree to indicate his conception. Clive disagreed with this: for him this building was a crystal, where every part was like every other part, and floors equidistant throughout, and he stuck, I think rightly, to his conception. The problem could have been approached from a purely functional and structural angle, but both architects felt the need to subordinate this approach to a general principle. This has a bearing on ideologies and theories in general; although it could be argued, as I have done, that they matter less than the amount of artistic effort expended, or the degree of synthesis achieved, they may nevertheless be a help to the creative artist. If so, well and good, but it is the result that matters.

Coventry Cathedral: how the plan took shape

This appeared in The Times *Supplement on Coventry Cathedral, 25 May 1962.*

Photo: John Laing

Architectural and structural design are really two aspects of the same thing, but because our knowledge of ways and means of building has been so vastly increased, one designer can rarely cope with both, hence the design of an important building must result from a collaboration between architect and engineer.

The latter looks after the structure — which could be defined as that part of the building which ensures its stability and permanence — but as this forms an integral part of the building fabric and may embrace the major part of it, it inevitably impinges on the province of the architect. In fact the merit of the structure is not judged by its fulfilment of its main purpose — which is taken for granted — but by its economy and by its contribution to the solution of the architect's own functional and aesthetic problems.

Special problems

In Coventry Cathedral the emphasis is very much on aesthetic quality, and this has posed rather special problems for the engineer. There have been, of course, many quite ordinary matters to attend to: the foundations — which in the end were designed to consist of 671 bored piles, 17 in. in diameter and of varying length, to carry the loads down to the sandstone — the loadbearing walls, the floors, the crypt, the ducts, the thermal insulation and waterproofing and other such mundane matters. But when we come to the parts where the structure is visible, the roofs, the canopy, the screen or the flèche, then the structure cannot be considered separately from the architecture; it must be subservient to it. This must not be misunderstood: were the architect to make complete nonsense of the structure, the architecture itself would suffer. A certain structural clarity and crispness is desirable, and therefore a very intimate collaboration between architect and engineer is necessary.

Abstract sculpture

But the problem is not just to design an efficient and economical roof spanning 80 ft. It is to create a visual impact, to create abstract sculpture, if you like. If it were not for the demands imposed by aesthetic or symbolic requirements, there would hardly be any structural problems at all. To span a roof 80 ft. can be done in a hundred different ways. If an acoustic false ceiling is needed under the roof, it can be slung from it. The columns, which in the old cathedrals used to support the roof, are not at all necessary in this case. But that is not a fault in the design. It would be absurd to contend, as some architectural critics are apt to do, that the design of a cathedral should grow out of structural necessity. The structure of the canopy, for instance, should be crisp and elegant and articulated, the details should be controlled, but whether the canopy with its columns should be there at all, or some other way found to create the atmosphere the architect is striving for, is not a matter to be settled by criteria of structural economy.

The design of the canopy has gone through many stages as the architect — aided and abetted by the engineers — worked untiringly for some years to find the form that would satisfy him. To begin with, there were four rows of columns supporting a kind of concrete vault. Then the two rows near the walls were left out and the positions of the two rows of centre columns which converge towards the altar were determined by a system of diagonal gridlines based on a mathematical relationship which also determined the whole plan of the cathedral and fixed the position of a series of ribs in the canopy. For aesthetic effect and for acoustic reasons the spaces between the ribs were filled with concrete panels forming shallow pyramids, which effectively concealed the ribs from underneath, making the whole appear as a kind of concrete shell. Later, the pyramids were pierced then the ribs were partly shown underneath the canopy in the interest of structural honesty and finally the concrete panels were replaced by timber slats, spaced apart to admit light. The canopy now appears as what it was all the time: a free-standing spatial framework of ribs and columns, complicated by the fact that the ribs pursue a somewhat angular course up and down, which never goes from column to column, but, proceeding diagonally from a column, always ends up on the other side between two columns. However, statically the structural system is clear enough in spite of its complication.

The columns were precast, in three pieces, glued together on the floor and prestressed, then lifted into position. Later, when the ribs were cast, the prestressing in the columns was reduced on the inside and increased on the outside to improve the moment distribution between columns and ribs, thus making it possible to increase the slenderness of both.

Design of roof

The most interesting structure from an engineering point of view is probably the roof above the canopy, and especially the roof over the baptistry. The latter covers an area of 100 by 90 ft. and consists of a 4 in. reinforced concrete slab slightly folded, but with a very low pitch, strengthened by ribs and held together by strong prestressed concrete ties concealed in the walls. This roof supports the 78 ft. flèche — a manganese bronze space frame — and also part of the large bronze and glass screen. The latter is hung from the roof in ten ¾ in. inclined rods, prestressed to give the required stability against wind. By this arrangement the screen could be made much lighter, which improved its appearance and saved a lot of money at the same time, which is exactly the sort of thing the engineer is always trying — and sometimes managing — to achieve, especially if the architect and engineer pull together as they have done in this case.

The problem of producing quality in building

This talk was given to Westminster Chamber of Commerce on 27 April 1965.

I thank you for the honour you show me in inviting me to speak to you today. I can only hope that your confidence will not prove to be entirely misplaced. The title of my talk, *The problem of producing quality in building*, sounds pretty formidable, obviously you do not expect me to solve this problem in 20 minutes. All I can do is to talk round the subject and to make one or two observations based on personal experience, observations which I am sure you are perfectly aware of already, old stuff which I have been bringing to market for the last 20 years or more, but which still has got some wear left in it.

Building

I need not tell you that building is a very important activity in our society, because it provides the shell which houses most of our activities and makes our kind of life possible.

We are in dire need of buildings — throughout the world. We cannot get enough of them fast enough, our resources are overstrained. This imposes an obligation on us to use our limited resources wisely, to get the most out of them, but in discussing this problem we must not forget that all this building activity is constantly changing our environment, for better or worse, but much too often for worse, in spite of the fact that we have it in our power to make our environment better, if only we would use that power. I think that our environment has an enormous influence on us, it is a constant source of happiness or misery, and to get the environment we would like to have instead of one which is forced on us by expediency, or by economic forces which we fail to control, is surely a very worthy object to which we all subscribe, even if we do not always agree on what we would like to have. But that is just part of the challenge, we do not want uniformity but variety, variety to express different personalities, different modes of life.

This complicates the matter. It would be so much easier if we could just get on with organizing our building activity efficiently for maximum output and minimum cost, without bothering about artistic effects, the psychological impact of space, colours, textures, light and shade — all these matters which long-haired artists spend all their energies talking about without ever agreeing about what they really want, and which would drive sober and practical men of affairs up the pole if they were ever to take any notice of it. It *is* a complication, but it is a complication we must face, and to which I think we ought to give very high priority. There is no need to stress functional and technological efficiency; needs are needs, and will assert themselves, and money we know, talks; but beauty, character, poetry or environment — what shall I call it — is something which has to be fought for. It is highly prized where it exists, especially when people have got used to it — then they will pay fantastic sums for a house in a favoured locality — but they are not so eager to make any sacrifice or to exert themselves unduly to create it, if it should happen to conflict with maximum letting space, for instance, or with the convenience of the almighty car.

There is a fourth and confusing issue which raises its ugly head in a discussion of building activity. All those people who move stuff about with their hands or with the help of machines, those who tell them what to move, those who think out what the second lot should tell the first lot, and those who tell the last lot what to think out, and so on, in an intricate maze of activity — all these people are not really collaborating in a spontaneous desire to create new and better buildings, what they are doing is to make their living according to some complicated rules which have been evolved and fought over for centuries. What they are thinking of, what drives them on, is probably how to improve their status and their share of the common cake. Anybody who would try to eliminate want by organizing the necessary collaboration of many people on a more rational basis is at once up against old customs, established trades and professions and vested interests, and the whole thing moves into a sphere of social organization and politics. I cannot even attempt to deal with all that here. I must confine my remarks to the *design* of buildings, to the problem of getting the best possible design — which happens to be the way *I* make my living. This leaves out the important questions of politics, how to initiate or instigate action, town and county planning and how to organize the execution of the design, once it is established. It leaves all this out, I say but it can't quite leave it out, because everything is intertwined. Design must take account of purpose — and purpose is politics if you like. And design must most certainly take account of execution — in fact it is nothing else than indicating a sensible way of building. So both client and contractor are involved in the design. As I use this word here, it is a vital link in the chain that leads to the realization of a project, in fact it is the key to the building. It includes all drawings, specifications, descriptions and detailed instructions about what should be built *and how it should be built*. Some of these instructions may emanate from the client or the contractor — but they must be absorbed by the designer and made part of the design. If we get the right design therefore we will get the right building — provided the design is executed as intended.

What we want, then, is designs of quality — to produce buildings of quality. Perhaps quality is not the right word — I have used it because the word quality implies something of value, something we prize. It is also related to a purpose, it is the result of a discipline imposed by man, the result of something well done or well organized, as opposed to shoddy work and lack of organization.

Architecture

In architecture — and architecture in this connection covers every kind of man-made structure which forms part of our environment — it is useful to distinguish between three kinds of quality, according to the three things we require of a building or structure, namely:

(1) That it should fulfil its function in the best possible way.

(2) That it should not tax our resources more than necessary.

(3) That it should enhance our environment rather than spoil it.

This means that the designer must organize the design from three different points of view — that of the client, the builder, and the artist, and, reversing the order, we can call them the A, B, and C discipline of design. Each is important, but in varying degrees, according to the kind of job we are dealing with. The ideal is to combine all three kinds of quality, but unfortunately they nearly always clash — how often do we not see function sacrificed for some aesthetic preference, or cost soaring for the same reason, or because the ideal functional arrangement poses difficult structural problems? Every design is therefore a compromise between the three kinds of excellence, and the problem is to strike the right balance, the balance appropriate to the task in hand.

How we get it is another matter.

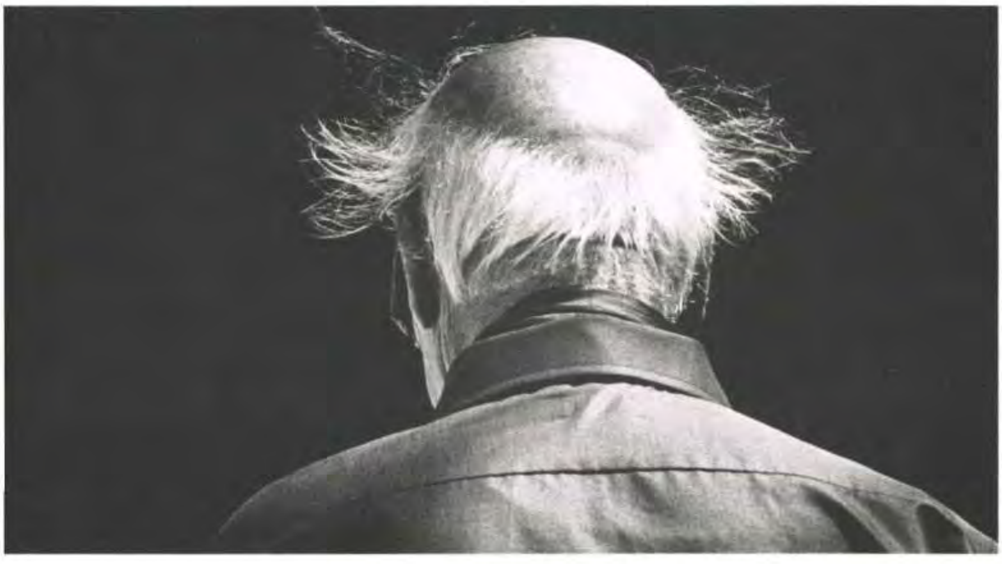
I am afraid there is no general solution to this problem but I should like to illustrate it by reference to the design of engineering structures, where I feel most at home.

The problem here is the same: the same threefold design discipline is needed, but the artistic organization does not play such a big role here — in fact it is generally neglected altogether — and the function, although it determines the form of the structure, is generally pretty clear and uncontroversial. One knows exactly what is required of a grain silo, retaining wall, jetty or bridge. The designer therefore starts with a clear idea of what the purpose of the whole undertaking is — which is the first requisite for producing a design. The second is that the designer has certain facts at his command. I am thinking of the engineering knowledge and experience which make him a qualified engineer, augmented for the occasion by reference to books or papers or by asking other people's advice. And this knowledge must of course include awareness of all the available constructional techniques and their cost. And then there are all the data peculiar to the particular job: the site, and subsoil, local resources, in short everything which may have a bearing on the design and the method of construction.

Design

The design then emerges as a result of a mental process, a kind of synthesis of (1) and (2). The engineer, knowing his stuff, knowing what has to be achieved and having gathered the local information, sets to work on the problem.....

I am of course talking about creative design, not about ordinary routine design where not much effort is applied. Excellence follows from intelligent application, you don't get it for nothing. And progress in engineering has always depended on ingenuity and invention, it is a creative thing which cannot be arrived at by statistical methods or any of the latest rational design techniques. This is a fact which is often forgotten by some people: clients, public servants, financiers, lawyers and others who have no knowledge of design. And there is another thing I would like to stress. Nearly all this invention is concerned with how to do things, finding new, simpler



and better ways of carrying out the work. And therefore, as I have said so often, design cannot flourish without knowledge about methods of construction. Designing is indicating a sensible way of building. Any contractor who has suffered from impractical consulting engineers' designs knows this.

I have not said anything about the artistic organization of the design — except that it is generally neglected, and I am afraid that is only too true. In industrial design — coal bunkers, gantries, purifiers and that kind of thing, any attempt at artistic control would be laughed out of court. And where it *is* considered desirable to add some artistic touch at the end this probably makes matters worse. This is simply because engineers as a rule lack that artistic sensibility which is necessary to produce a work of art. You can't blame them, but the result is that the work suffers from a deficiency of A-vitamins.

Now this is bad. And, in fairness I must say that it is being recognized more and more that this is a bad thing, and engineers are increasingly concerned about adding some kind of artistic education to their curriculum. This is not easy. Artistic discipline is a very personal thing. Art can only be judged by acquiring understanding of artistic culture in general and of the personality of the artist in particular. Art can be criticized, perhaps, but it cannot really be taught. There are no rules — the artist makes his own rules. In this respect it differs from technological or functional quality. The first can be measured in L.s.d. The second can perhaps only be proved in the same way as a pudding — in the eating — which may apply to artistic quality too, but it does yield to research and scientific analysis which artistic quality, or 'delight', does not.

'Delight' can be compared to a coy maiden who will shrink from direct pursuit but pretend to ignore her and get on with your work and she may come running after you. My advice to engineers is to be good engineers first of all. A brilliant engineering solution is quite likely to be praised for artistic qualities where an attempt to force the design into a preconceived artistic form would fail miserably.

If we now turn to architectural design — with an architect in charge of the design team, we will find that it correspondingly suffers from a lack of B discipline or to put it another way, it does not realize the technological potential. This is naturally because the architect-designer, who has to effect the synthesis between the relevant facts is himself less of a technician; he must therefore rely on technical advisers. Many of the technical and constructional considerations which rightly ought to influence the design are never given the attention they deserve because they never surface in the brain of the designer. He thinks it is better to concentrate on A and C — C because that is his main duty, the purpose of the whole undertaking, *which he is the only one to take care of*, and A, because he is or fancies himself as an artist and his whole ambition is bound up with the wish to make an architectural — which in this connection means an artistic — statement.

There is a good excuse for this and there is also a great danger.

Buildings cater for people

The excuse is that architectural design — and I can only talk about the average in both cases, because there are all kinds of architecture — is generally much more complicated than structural design — or at least there are many more facts to consider. This is mainly because engineering structures cater for the force of gravity and other natural phenomena, whereas buildings cater for people. And people *are* complicated. The engineer need not bother about the purpose of the design — he is told what is required. The architect bothers very much, he must study human needs, human reactions to environment, human ways of life, humans at work and play, their need for privacy and social contacts. This is both a complicated and controversial subject. And because he caters for human beings, the artistic organization also becomes so much more important. And the technical data which have to be considered tend to be more numerous and varied. So naturally the synthesis of aims and means is more complicated. One mind simply cannot absorb all the relevant data. The synthesis then becomes a synthesis of only those facts which are uppermost in the architect's mind — it is incomplete. Or if all relevant facts should be brought to the designer's notice, he is unable to effect a true synthesis — the result is patchwork, which is worse. The situation is sometimes aggravated by an attitude of mind which is frequently found amongst architects. He is a superior being, his main concern is to keep alive the flame of true art, and the objects of his attention receive a kind of reflected glory and are raised to a higher category, that of works of art. He is in charge of function or commodity, as well, of course — but as arbiter of taste he really thinks that he should dictate to the client what he is allowed to have. And as for technology — well, there are people who can work that out, and thank God for the quantity surveyor who can keep him at a suitable distance from such mundane matters. His attitude to technology is that of a husband when it comes to sewing on buttons.

Arrogance will not do

Such arrogance may well produce works of art which are praised in the technical papers and excite architectural students all over the world. One may even contend that a certain amount of arrogance is necessary for an artist, although some seem to make do with humility instead. But it will not do for the great bulk of building which is so urgently required. If the architect does not knuckle down to trying to understand and guide technical development, the system-boys will take over. There is nothing wrong with industrial building and systems of building for mass production, it is our kind of technique, and the renewal of architecture must come from a study of man's needs and from invention and organization of building technique. But building technique has its own economic logic. It imposes its own discipline which, left to itself, will take no account of art or true amenity. That is the danger. This discipline must be guided, it must be fused with artistic and functional discipline. This can only be done if the designer or the leader of the design team understands all three forms of discipline, and if he is supported by the powers that be in insisting on certain standards of excellence. It is too much to hope, however, that such support will extend to providing much extra finance. You can only put across delight if it doesn't cost anything. Therefore you have to study building methods and see whether you cannot work with your material rather than against it. Those who are on the side of the angels must join the battle where it is fought: on the economic front. The architects must stop shielding behind quantity surveyors to avoid contact with the mundane world of building, building costs and building invention. Their spatial imagination must be put to use in the service of practical building.

That is all very well, you may say, but how can the architect possibly manage more than he is doing already. His curriculum is full. It cannot be increased — perhaps it can be changed?

Yes, perhaps. I think it is absolutely necessary that architects, if they aspire to be the leaders of a design team, should think more about how things are put together. Delight is produced by imposing some kind of organization on the building structure, and you cannot organize something you don't know anything about. A sculptor must know his material. Bricks and mortar are the stuff that dreams are made on. You cannot produce delight in a vacuum.

But generally speaking the answer is teamwork. The data, the knowledge required, can be found not in one person, but in a number of persons. But how do we then contrive to produce the synthesis, the artistic or human unity which alone will ensure quality. That is the question, and it is much more difficult than most people realize.

I have spoken to you about the threefold discipline which has to be imposed on a design to get what we ought to have.

Let us imagine that we accordingly chose a team consisting of a sociologist to define the human requirements, a builder cum engineer to design the body of the building, and an artist, a sculptor for instance, to impose artistic control. It would be hopeless. They would not speak each other's language, and the builder would prevail in the end because it is he who puts up the building.

Teamwork

No. Successful teamwork requires that each member of the team understands what the others are doing and respects them, and that they are united in a common purpose: to produce good architecture. Two heads are better than one, but too may cooks spoil the broth.

And, as it would be next to impossible that they should all agree on relative priorities, they must have a leader who gathers all the threads together and makes the decisions. In fact, I don't mind his being a 'prima donna' architect in the best sense, being a true leader, shaping the design annd giving orders, but on the basis of acquaintance with and understanding of the fundamental principles of the various disciplines, so that they can understand the advice given, and can assess its relevance to the design.

How difficult it is to realize these conditions. I could spend hours in telling you about the various frustrations occasioned by the present organization of the building industry, about the impossibility — almost — of ensuring proper integration of the various technical disciplines — let alone the artistic and functional. And that is perhaps where my talk ought to have started.

I have not begun to suggest a solution to the problem — but I am afraid that would take another 20 minutes.

Advances in engineering

This article appeared in a special Financial Times *supplement on cement and concrete on 11 July 1967.*

Assuming that we are talking about advances inside the last 10 years or so, or at any rate since the war, there is nothing radically new to report. Concrete is still the same old material produced by mixing cement with sand, stone or other aggregates, adding water and stirring the mixture into a porridge and pouring it into forms. It will then harden into a stone-like material of a shape determined by the formwork. This has been known since Roman times. And the two main inventions which have laid the foundations for the use of concrete as a modern structural material by overcoming its weakness in tension, reinforced concrete and prestressed concrete, were both made before the war.

But this does not mean that there has been no progress since then. On the contrary — one may even call the progress spectacular if one compares it with the slow progress before the war, and if one accepts the fact that progress is always much slower than it theoretically need be.

This especially applies to a material like concrete, which depends on so many factors for its success, and which for that reason can be a very primitive or a highly sophisticated material. It is like the girl with the curl — when it's good it's very very good, and when it's bad it's horrid. Improving concrete construction is in a way like improving agriculture — it is not enough to improve the quality of grain or the milk yield of cattle — you have to pay attention to soil, weather, pests, weeds and especially to the whole complicated economic proposition of increasing yields with limited and expensive man-power necessitating mechanization, rationalization, larger units, etc., and you have to square this need with human factors, with ingrained habits and existing social organizations.

Fickle material

It is the same with concrete. It is not enough to show theoretically how various combinations of steel and concrete can result in a building material of excellent properties, it is necessary to create the technology which can transform a primitive and fickle material like the original handmade mass-concrete into a precise, controlled product with predictable qualities, dimensional stability and acceptable appearance, worthy to enter into union with steel, the structural material par excellence, on which the whole of our industrial revolution is based.

It has long been clear that if this could be achieved, if the valuable properties of steel and concrete could be combined and the shortcomings eliminated, we would be on to a very good thing, because the two materials complement each other. The main weakness of concrete is its unreliability in tension, the second, its dependence on good workmanship. The first can be completely cured by adding steel in one form or another, the second by strict control and mechanization.

Steel on the other hand is liable to rust and to weaken under fire, and these faults can be eliminated by encasing in concrete.

The composite material has great strength which can be varied and concentrated exactly where needed. It has the necessary body to form walls, floors, ducts, containers and any other desired shape, and its raw materials are readily available in bulk. This makes it an exceedingly versatile material.

Before the war all this was known; it was also known how to make high quality concrete where required, and with experience stretching back over 40 years there had been an impressive development in the design and construction of reinforced concrete structures by engineers, specialist firms and engineering contractors, whereas the ordinary builders were hardly involved. But unsightly cracks, rusting reinforcement due to insufficient cover, an unpleasant surface, etc., were so common that it brought the material into disrepute. It didn't pay to make really good concrete, because in ordinary reinforced concrete it was not possible to make use of the greater crushing strength which could be obtained by improved cements and more scientific mix-design, or of the greater tensile strength of the latest high tension steels. The ordinary run-of-the-mill concrete was quite adequate for its purpose even if it didn't look so good.

New development

The invention of prestressed concrete changed all that. Now every additional ounce of strength in the constituent materials could be exploited, and when after the war the traditional building methods could no longer meet our needs, engineers and contractors rushed over to Paris or Brussels to learn about this new development. It was quite amazing to see how strongly contractors were represented at the various congresses. Many of them equipped themselves to meet this new challenge even before the economic implications were known, a welcome change from the cautious attitude to new ideas shown by contractors before the war.

This interest in prestressed concrete set off a chain reaction which far exceeded the importance of the new material itself — at least in its first stages. Because now it became necessary and profitable to study and to practise the making of high quality concrete, and to develop still stronger high tension steels, cables and strands and improved anchorages.

Monolithic character

The new invention also stimulated the practice of precasting concrete elements away from the site under more favourable conditions. This had often been advocated, especially by architects, as a means of improving the quality or appearance of concrete, but it had generally foundered on the hard fact that the method could not compete with in situ concrete, and because it destroyed the monolithic character or continuity which was one of the valuable features of r.c. structures cast in situ. However, prestressing can overcome this latter deficiency, in fact, with a continuous structure formed by stressing together a number of precast units, the designer has a much greater control over the stresses induced in the structure. The two processes, precasting and prestressing, complement each other, and they also fit in with the general trend towards replacing quantity by quality, labour by machinery, craftsmanship by automatic control — in short: rationalization, or the rational use of our resources.

In fact, advances in concrete construction form only a part of a general technological advance and they are dependent on and greatly helped by advances on other fronts.

That is why it is so difficult to discuss concrete in isolation. The advances could not have happened without, for instance, the digital computer which allows more accurate analysis of structures, statistical analysis of concrete strength leading to economies in cement, and makes the use of limit state design a practical proposition. Improvements in cements, the development of special cements for special purposes (phosphor-resistant, water-repelling, expanding, etc.), new and more reliable lightweight aggregates and the methodical study of the nature of concrete and its behaviour during curing and maturing are, of course, directly relevant to this development, but so is the development of special steels, of epoxy resins and other jointing and waterproofing materials, of phosphor bronze for sliding joints and especially of all the different kinds of machinery for use on the building site and in the factory, from the largest tower crane and complete industrial plants to the hundreds of small gadgets which contribute to the economy of the various processes.

Economic methods

It would be hopeless to enumerate all these advances here. It is of course not primarily a question of producing better quality concrete — that can be done if we pay for it — it is really a search for economic methods of building, which incidentally, through mechanization and control, lead to better quality, at least on the technical level. The most spectacular advances are therefore the new construction methods or production techniques — I am thinking of the diaphragm wall cast in a bentonite-filled trench which has supplanted steel sheet piling for basement excavations down to 75 ft. and more in city centres where noise and vibration are problems; or the improved sliding formwork for tower block cores with door openings, etc., or the many other forms of moving formwork — the free cantilever construction for bridges and the development, already mentioned, of precasting larger and larger units and of the factory production of complete housing sections such as bathrooms and kitchens with all fittings and finishings done in the factory.

Most of these methods have been used even before the war on a smaller scale and in a more primitive form. What brings them to the fore now is not only advances in technology, but the different economic circumstances — the higher cost of labour, the greater demands for housing and all kinds of engineering structures, the greater emphasis on large-scale planning, leading to bigger jobs and to bigger design offices and contracting firms to deal with them, and the fact that these bigger units make it possible to introduce a greater amount of repetitive processes or units, which again is the basis for any rationalization of building.

What has hindered this development and what is still one of the principal obstacles in the way of rational building, is the fragmentation of the building and construction industry, which has its roots in history, but which ill accords with modern technology. In no other industry is design completely divorced from production, or are design decisions taken by so many different authorities, professions or firms, who are each a law unto themselves. In times of traditional building — when building methods remain stationary over a period and are known to everybody — this is a possible way of dealing with things, but it is totally unsuited to a state of flux, where new materials, new inventions, new methods of building tumble over each other.

Best use

The design must then be firmly anchored to the method of construction, and the implications of a given choice must be understood by the legal, financial and political authorities if the best use is to be made of our technological potential. There is no easy way to achieve this, but the progress which has been achieved lately, is I believe, largely due to the fact that the interdependence of the different professions and institutions dealing with building is better understood.

The slipformed core of Barclays Bank Chief Foreign Branch, London EC3 (1969-72) Architect: City of London Real Property Co. Ltd. (Photo: W.H.R. Goodman)

Architects, engineers and builders

This paper was the Alfred Bossom Lecture of the Royal Society of Arts and was delivered on 11 March 1970.

The title of my talk doesn't sound promising. 'What, again!' would be a natural reaction. It was suggested in order to make the title suitable for a Bossom Lecture, it being implied that as long as the title was correct, what followed didn't matter. But somehow this way out doesn't appeal to me, so we are stuck with the title and I had better consider what can usefully be said about this much-laboured theme.

The trouble is that the terms Architect, Engineer and Builder are beset with associations, from a bygone age, when building was something very much more primitive than it is now; and they are inadequate to describe or discuss the contemporary scene. The building and construction industry, to which they all belong, is in a state of flux. If I delve into this chaotic conglomeration, I will find myself overwhelmed by its complexity, and can certainly do very little justice to the theme in one lecture.

What then is useful? The word only has a meaning in relation to an aim, and the aim in this case would naturally be to suggest ways in which the building industry, which term I shall use this evening to include the construction industry, could do whatever it has to do more effectively than at present.

To do this one would have to define *what* the building industry should do, *how* this could best be done, and *what* reforms this suggests — indeed a tough proposition.

If you look at the building industry in a global sort of way it embraces all the activities which shape our physical environment. But the environment is the product of our way of life, and it again influences our way of life. In the past the environment, the landscape in all its natural and urban forms just happened, it was never before deliberately created by man, except in small patches. The technological revolution is changing all that. Man's battle with nature has been won. Whether we like it or not, we are now burdened with the administration of the conquered territory. Nature reserves, landscape, townscape; they will all be wantonly destroyed, to the ultimate ruin of man, or they must be deliberately planned to serve his need. Much has been destroyed already and more will be destroyed, but the alarm has sounded. Pollution, population explosion, etc., are news. The battle is on, and it is a crucial battle for mankind. Those who long to return to the good old days must be told firmly that that road is now closed.

Logically, we would now have to define man's needs to enable us to discuss the means to provide them.

This, I am afraid, is beyond the wit of man. How we want to live is a matter of values, and values are under debate. Even if a vague ideal way of life could be agreed on — and it could only be vague — the way to achieve it would be equally debatable. Any hope of defining the task of the building industry on the basis of some such ultimate aim must, I am afraid, be abandoned, at least as far as this lecture is concerned.

The purpose of life is like that of a work of art, it emerges only during the making.

This doesn't mean that we can do nothing. I think we can give a push in the right direction, and if enough join in, it may even have some effect.

We could start from one of the entities or structures produced by the building industry, as for instance a bridge, a water reservoir, a harbour, or a factory, school, town hall or other building, and consider how such an entity is planned, designed and finally built. We know it can be done in many ways, some good, some bad, and some indifferent, measured by the result. If we can find out what is needed to produce a good result, the best possible result, an entity of quality we might say, then what aplies to one entity might well apply to most, and might also give us a clue as to how the organization of the building industry could be improved to facilitate the production of such entities of quality. We have to realize, of course, that we don't necessarily get the best total environment, the best town, for instance, by ensuring that each of its constituent parts is a perfect example of its kind. These parts must also be integrated and priorities assessed, to produce the right environment. But it would certainly be an improvement if the parts taken separately were satisfactory. And as the need for proper integration of parts is a feature of all design — whatever sized entity we are dealing with — the experience we gain on a smaller scale may help us to tackle the larger.

To treat such an entity as an independent whole is of course a device to limit the area of attention, it is the only way by which the human mind can deal with the chaotic material presented to it. The danger is, that we forget to switch the mind back to the connections which we have so ruthlessly severed.

Everything in nature hangs together in various ways, and the same applies to the artificial world of human creation. The connection may be a matter of proximity in space, of generations supplanting one another or of different species that feed on one another.

Relationships

In our building activity we are mainly interested in three such relationships:

(1) The relation of part and whole

(2) That of means and ends

(3) What I might call the spiritual relationship between inanimate objects, usually thought of as aesthetic, though I don't think this word covers it entirely.

This last is a very difficult relationship or quality to define, describe or manipulate — but is of the greatest importance. The words 'art' or 'artistic' are vague enough to cover it, perhaps. I will return to it later.

In the total building activity relating to an entity or a job, it is usual and indeed useful to distinguish between two stages, design and execution.

Design can be simply defined as 'constructive forethought'. *Designing* is a mental activity devoted to 'figuring out' and *deciding* how to make or build a thing or an entity, what it should be made of, what it should look like, how it should be made, etc.

A *design* is the sum of all these decisions recorded in the form of drawings, sketches, models, prototypes, instructions, specifications, etc., covering all the facts which must be known and the processes which must be gone through to realize the project.

Defined in this way, the design is obviously the key to what is built. The actual building or execution is equally important, or more important if you like, but it does not add anything to the concept of the thing, if it is carried out as visualized in the design.

What I will call *'the total design'* defines the entity completely.

I use the words 'total design' to distinguish it from what usually goes under the name of design, or is called a sketch, scheme, blueprint or plan — which are generally only partial designs, ranging from a mere recording of a tentative idea to what almost amounts to a total design which only needs to be supplemented by the dealing of certain parts or site arrangements carried out by manufacturers, contractors or specialists. Such definitions are always somewhat arbitrary or blurred at the edges, but the idea of total design implies that sufficient decisions have been made and recorded to enable others skilled in organizing such work to carry it out.

As mentioned, most things are parts of other larger things and consist in turn of many smaller things, and their designs are therefore also organized in a kind of *chain or hierarchy of part and whole*. The designs of part and whole are always interdependent, but in varying degrees. Some entities are fairly self-contained, and are thought of mainly as wholes — for instance a building or water-tower. Others have only meaning as parts — a concrete beam, for instance. But the designer or designers of one thing can't also design all the other wholes or parts in the chain, he must stop somewhere; the stopping is done by giving him a brief. The designer of a bridge need not bother about the larger context, the road-net etc., if he is given a brief telling him where the bridge is to be built, what traffic it will carry, etc. The design is then a *closed* design — upwards. Downwards he must know all *relevant* details — for instance he may have to know the quality of cement — but not necessarily how that quality is obtained in the factory. He must simply know everything which would or could affect his design, including of course the cost of different possible methods of construction.

The *hierarchy of ends and means* sometimes coincides with that of whole and part — for instance the foundation is part of a building and also a means of enabling it to be built on that spot; but generally the path diverges: a crane is a means of building a tower, but not part of it, a building is a part of a village but a means of educating children or manufacturing shoes. Obviously the ends and means relationship affects the design very much, and if this is closed upwards it too must be defined by the brief, which must specify exactly what the entity is going to be used for.

The chain of means and ends generally ends up in some spiritual sphere implying value judgements. We build a school for the education of children — for what? Value judgements, whether in the sphere of art, ethics, religion or politics tend to be controversial. Therefore the further we go along the line to search for the ultimate ends, the more difficult it is to reach agreement on what these ends are.

Paradox

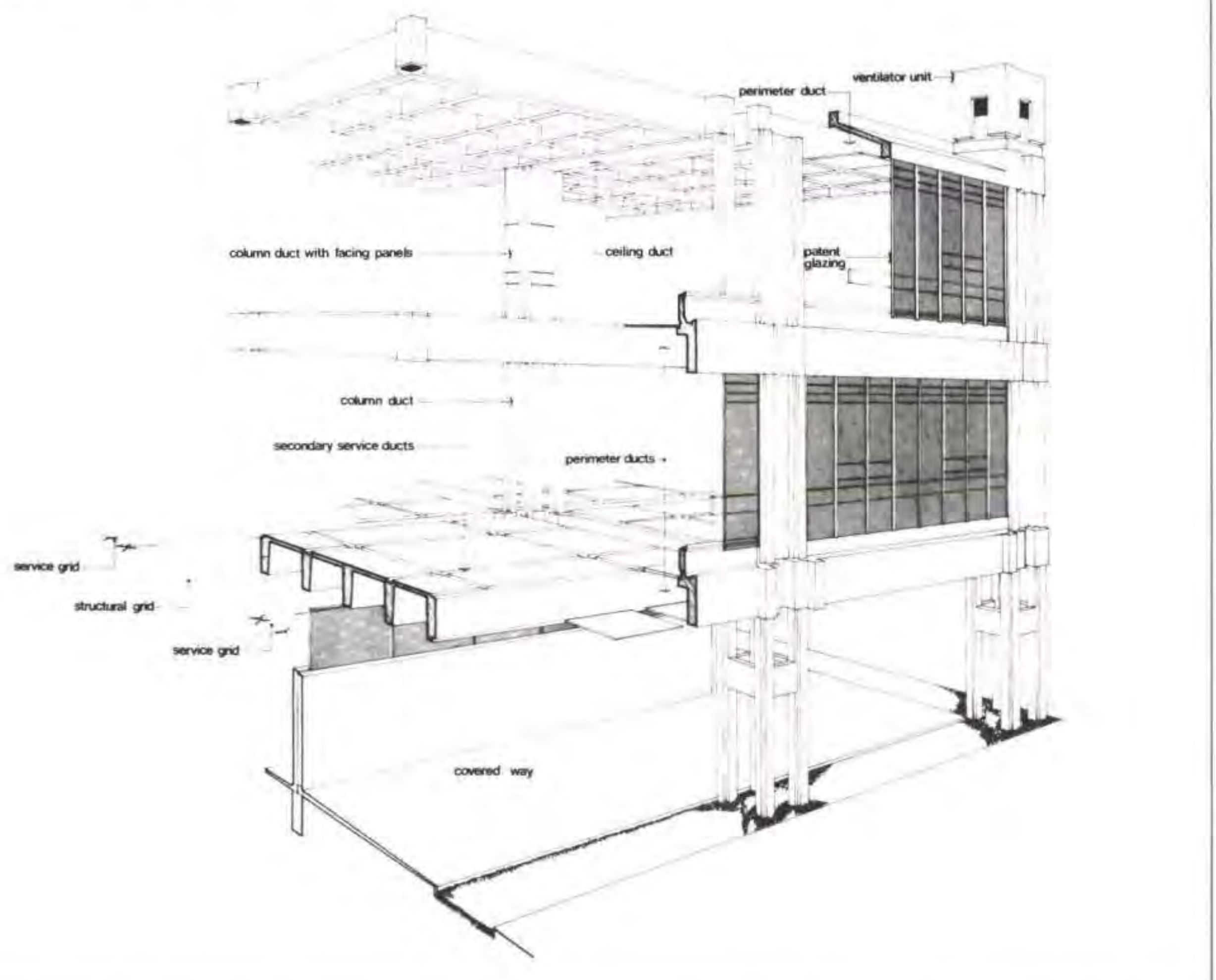
We are faced with the paradox that the pursuit of value of some kind or other is undoubtedly the mainspring of action, and yet if people really went about thinking about the ultimate purpose of all they did nothing would ever get done, there would only be a glorious fight about what ought to be done.

This kind of thing is not unknown in human affairs, but fortunately it is not what people normally do. In most cases they don't think at all — and that is perhaps going a bit far in the other direction. They are quite happy to pursue means without bothering about the end — let alone anything so remote as an ultimate end. In fact means have a habit of becoming ends in themselves. This saves thinking, and encourages action. But, seen in a wider context, it could be the wrong action.

The *artistic relationship* of things may also affect the design — the whole in relation to its surroundings and its parts — but is of course also often controversial.

A *part design* is either a part of a total design or a total design of a part, in relation to a given entity.

Mining and Metallurgy Laboratories, Birmingham 1966
Arup Associates



In theory the total design includes all its part designs, but in practice the obligation to define all its constituent parts is mostly discharged by making use of already designed and mass produced parts and partly processed materials readily available. We are moving strongly in that direction; it simplifies design, encourages mass-production of standard components, thereby lowering cost, and if coupled with such practices as using standard computer programs for statistical calculations it can speed up everything — but it also reduces the freedom of the designer and the possibility of matching the parts to the whole — so necessary for artistic excellence. A proper integration may therefore require a needed part like a window or partition to be specially designed by the design team in collaboration with the producers of the article. As manufacturers are often backward in applying rigorous functional or aesthetic criteria to their products, the result can be a great improvement in the design of this part, thus both lowering costs and raising standards. But it can only be done for large repetitive jobs.

Since the start of the Modern Movement architects have toyed with the idea of a standard, prefabricated kit of parts which could be assembled into different types of building: strangely enough, for it would kill what is generally understood by architecture, and anyhow it is, and has always been, nonsense.

You can design a system of limited flexibility with a limited number of standard parts, but the parts can then only be used for that system.

We started this inquiry by considering a particular entity, its position in the chain of things, and its design, by which it is defined.

How then is a design of excellence or quality produced?

I described designing as a mental activity. It is set in motion by the challenge of a particular practical problem, that of satisfying a brief with means which are available, or can be made available.

To meet this challenge the designer's mind must be stocked with a great deal of knowledge about available materials, their behaviour under various conditions, their cost, their durability and the manner in which they can be used, about processes and construction techniques and a host of other things which are far too numerous to mention here. He must have the ability to supplement this knowledge and experience with new data relevant to the particular problem — for instance site conditions, local resources, etc. — and if his own resources are insufficient, he must get advice elsewhere. Lack of expert knowledge is not conducive to excellence. He must have a thorough look at the brief, absorb it in his mind, question it and criticize it and have it supplemented if necessary. Having marshalled sufficient data to start with, he sets to work on the problem. His imagination juggles with the data, hauls out for inspection various combinations and possibilities, discards them, tries again — intuition, invention, ingenuity spring into action, tentative solutions emerge, are developed, analyzed, adopted as working hypotheses, new relevant data collected, partial decisions made, etc. It is difficult to describe this process in detail, and I think it is quite impossible to replace it with some computerized technique, as has been suggested. The result will depend on three things:

(1) The completeness of the data on which the design is based

(2) The quality of the brain in which the design process takes place

(3) The effort, devotion and enthusiasm applied to the problem.

This is not exactly surprising. It means that the *best designs* are produced by good designers with plenty of knowledge and experience and plenty of imagination, ingenuity and inventive capacity, who take the trouble to gather all the relevant information and keep on worrying about the design until they are completely satisfied with the result. And perhaps we should throw in a bit of luck and an interesting problem to solve.

What the designer is trying to do is to produce a structure of building which

(1) Functions well

(2) Looks well

(3) Lasts well

(4) Costs little,

but if we survey the whole field of possible structures, the emphasis placed on these four demands differs widely.

All structures must fulfil their particular function, for that is the reason for building them.

But the functions vary, from those which are easily defined but difficult to fulfil (such as bridging a gorge), to others which would be easy enough to fulfil if only we could manage to define them (such as those of teaching hospitals, involving several authorities and a large number of doctors all with their different and often conflicting demands which are, moreover, likely to change before the building is finished).

All structures should also look right — they create our man-made environment which is of concern to us all. But the importance of this varies widely — between, for instance, a jetty and a cathedral.

All structures must also last well — that is, they must be stable and able to withstand

Factory, IBM Havant 1970
Arup Associates

wear and tear by natural forces or imposed loads. This again may be a simple matter, or in the case of daring engineering structures, a very complicated one.

And finally, all structures should cost as little as possible, but again, the need for economy varies. Economy is a matter of devising a sensible way of building the structure. It therefore depends on engineering design and construction — not on costing, which is a means of guessing more or less accurately what the cost will be. Even the richest client doesn't want to spend more than necessary.

Corresponding to this difference in emphasis we are wont to divide structures into two categories, architectural and engineering structures.

Roughly speaking, engineering structures are those which have an easily defined and undisputed function but which present structural problems of some intricacy, whereas architectural structures are those where aesthetic and functional problems dominate.

And of course architectural structures are supposed to be designed by architects and engineering structures by engineers.

This division has done a great deal of harm, because it has diverted attention from the fact that *all structures* must be submitted to the threefold discipline of functional, aesthetic and structural or technological organization. But it has its roots deep in history. Architecture, building as a 'fine' art, can trace its origin back to antiquity. It concerned itself with the design of mansions and important public buildings according to varying principles or theories which had more to do with forms, spaces and proportions than with strains and stresses. Engineering structures — bridges, tunnels, harbours, etc., — were classed as utility structures. They were built on quite different principles and did not have anything to do with architecture. Ordinary houses were, and are still to some extent, the province of builders.

The traditional differences persist in the differences in background, training and outlook of the two professions. 50 years ago they didn't even speak the same language. Each profession lacked understanding of the values the other profession stood for, which naturally led to a neglect of those values in their own designs. The natural tendency of a designer to care for the appearance of what he creates was actually thwarted rather than encouraged in the education of engineers, with predictable results. And the emphasis on the spiritual quality and preoccupation with architectural theories in architectural schools sometimes made pupils forget about how their beautiful drawings were to be transformed into real buildings.

Even the firms which carried out the work — the split between designers and constructors having occurred centuries before — were divided into builders, working for architects, and engineering contractors, working for engineers.

Architecture

The Modern Movement changed all that in theory. It was discovered that the work of bygone engineers was in fact architecture. It is now accepted that bridges and factories and all that are architecture. So is housing, in fact everything built is architecture. And the same spirit which is supposed to be moving architects is behind town-planning and landscaping as well as interior design and furnishing. Everything made by man for man's use now has to be designed. And in all these spheres dedicated engineers are trying to conjure forth that mystical spiritual quality which is the essence of art.

The difference between builders and civil engineering contractors is also disappearing. Buildings are just as much constructed as are bridges or radio-masts. If we add to this that technological advance has produced a host of new experts and specialists, and computerized techniques for dealing with all this bewildering detail, it is clear that in large complex jobs we cannot manage with one designer on each job, we need dozens.

This brings us to the very topical subject of teamwork.

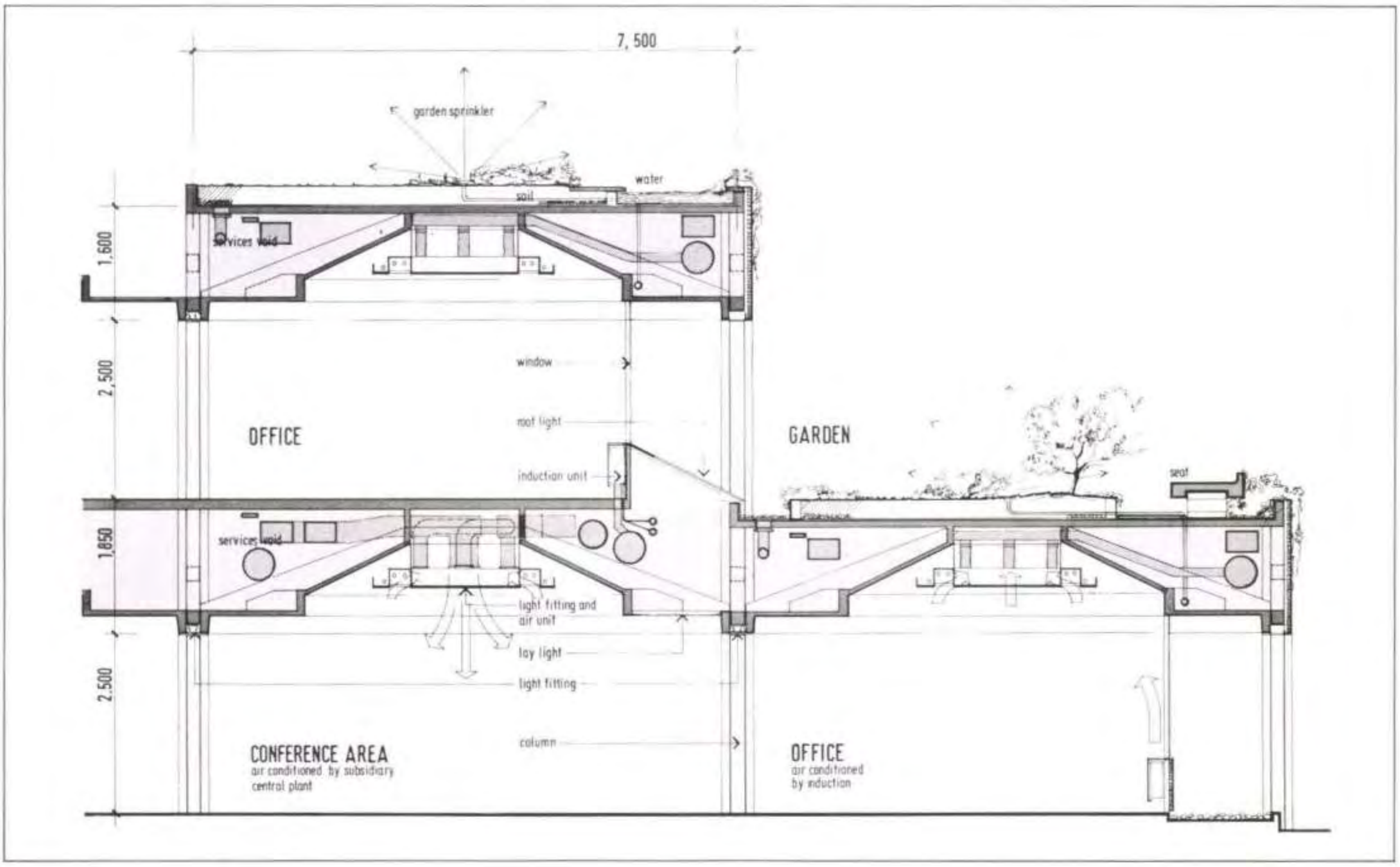
I have earlier emphasized the need to integrate all design decisions relating to a job. The growing specialization makes that very difficult, but it also makes it *more necessary than ever* if we are to produce the perfect job — or let us say a job which is as good as we can make it. I am quite convinced that lack of proper integration of design decisions is largely responsible for the mediocrity of much of what is built today. What we build should always be a whole, an entity, and the job of designing it is very much the job of giving it the wholeness of a work of art, and the inevitability of the perfect tool. If you split the design up amongst a number of specialist designers each acting more or less independently, plus various clients and authorities who do not even realize that they are making design decisions which may affect the design adversely, you won't get a whole but a hotchpotch. You don't get quality that way, anyhow.

I come back to what I said before, that the quality of a design depends on three things:

(1) The completeness of the relevant data

(2) The quality of the brain of the designer

(3) The effort, devotion and enthusiasm applied, except that now we are not dealing with one brain but with many.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column
CONFERENCE AREA
air conditioned by subsidiary
central plant
OFFICE
air conditioned
by induction

The idea of a composite mind is useful. To be effective, the participating minds must collectively span over an area of knowledge and experience which covers all the knowledge needed to produce the best possible design. Each should preferably be an expert in his own field — or at least have easy access to supplement his knowledge if required — and the fields should overlap so as to leave no gaps, and to facilitate communication. But equally, or even more important, they should share a common aim, that of creating 'total architecture'. This is not an aim which can be defined — anything which has to do with art is emotionally charged and therefore *personal*. But there must at least be agreement about one thing: that total architecture is not just a matter of creating a sculptural monument which enhances our visual environment, or a matter of fulfilling certain functional requirements or satisfying the need for 'firmness'. It is all these things together, and moreover they have to be achieved at a cost the client or the community can afford, and must therefore embrace the art of building in a practical, sensible way. As I said before, the relative importance of these claims varies, but they cannot be neglected on any job.

I would define architecture as: 'A way of building which delights the heart', because this emphasizes the two essentials, that it is a way of building, and must therefore be judged by the standards of competent building, and that it must touch the heart — it must give us a shock of delight.

But delight is not only aesthetic delight. There is delight in economy of means, in the recognition of inventive simplicity, of directness and clarity of structure, in the appropriateness of the spiritual quality expressed in the combination of forms and spaces. Architecture can transmit to us the human emotions which inspired it — perhaps unconsciously, perhaps even accidentally — it can appear as forceful, bombastic, exuberant or modest, restrained, controlled, it can be serene or exciting, cool or giving warm welcome — or it is just right — why, you cannot say. And this spiritual quality, which can neither be defined nor created according to a formula or recipe, but which can contribute so much to our happiness, this quality is the result of personal involvement, of enthusiasm. And of many other things as well, but enthusiasm must be the impelling force.

It is clear, then, that even agreement on the ideal of Total Architecture leaves plenty of room for disagreement on what kind of architecture and which claims should receive preference, for that they frequently clash is obvious. It is therefore also necessary that the members of the team are on the same wavelength, that they are excited by the same things. If two people come together who recognize that they share the same enthusiasm, then there is great joy, then a bond is created, then they can collaborate and fructify each other's minds.

Perhaps not necessarily, if they are on the same level. I am sorry, but I can hardly begin to make a statement without thinking that the opposite may be equally true. It is not my fault, really, for that's how things are. After all, two sculptors, or two architects, on the same job is really not so hot — or should I say too hot? They have to be very intimately attuned to make a success of it. But there are all sorts of fruitful relationships. If, for instance, one acknowledges the other's pre-eminence, and the relationship is that of master and admiring disciple — and it need not go to that extreme. If there are several members who cover the same field of expertise, it is desirable that there is an acknowledged line of command, but it is equally desirable that it should hardly be noticeable. If each member of the team is encouraged to contribute his share to the total solution and is not just told to shut up and do as he is told, ideas will trigger off other ideas and there *will* in creative moments come into being a kind of composite mind, superior to the sum of its components.

Respect is necessary

It is not so difficult for members of different professions to collaborate, because their pride is not affected by having to accept the expertise of another profession. But what is absolutely necessary is that they should respect each other, and each other's point of view. They should recognize that each has a valid contribution to make, that the goal is not yet reached if the solution of one part or one aspect is second rate. Great architecture can be created from a tortuous structure or at inordinate cost, but it would be greater still if structural clarity and ease of construction could be added to its virtues. And who knows that this might not be achieved by further effort? Complete perfection is unattainable, but if we are satisfied too early we are not even attaining what is possible.

To reach this state of understanding between members reared in different establishments where no thought is given to other than their own disciplines, takes time. *Ad hoc* teams, hurriedly thrown together for the duration of one job, are useless for the production of quality, unless the coordination of the work takes place at a higher level between principals who agree on the total aim. They have to get acquainted with each other's territory, to understand at least the principles followed and the aims pursued. They have to approve of these aims, and they must come to like each other, or at least accept with tolerance and humour each other's idiosyncrasies. They must to a large extent be prepared to sink their own personalities in that of the group, forgetting status, position, and personal or professional pride. In a choir a member will enjoy making his or her own contribution, but it is the performance of the ensemble which matters and which all members are proud of — even the one who moves the chairs about. This sharing of enthusiasm and pride in the work of the team is the best seed-bed for nurturing a work of quality.

Of course, enthusiasm is not enough. It must be tempered with realism, with the ability to

Facing page:
Offices, Basingstoke,
Gateway House 1 1976
Below:
Offices
Finsbury Avenue 1984

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apply critical analysis. It is an advantage of team work that where enthusiasm is leading one astray, as it easily can do, other members of the team may be able to supply the antidote. For my whole argument rests on the fact that if you want Art in building you cannot afford to neglect mundane, practical matters.

There must of course also be some organization and leadership, so that the whole thing doesn't degenerate into a talking shop.

The fundamental design decisions will nearly always be taken by a small nucleus of people representing the disciplines primarily involved. You have to start with an idea, a tentative proposal and then investigate the implications. The important thing is not to freeze any decision until its consequences for the detailing can be assessed. If new factors emerge — the client changing his mind, for instance — the whole position should be reviewed afresh.

Impossible to generalize

To generalize about the organization of the team is, however, quite impossible and to attempt a survey of the many forms it can take would take too long. It depends on the nature and size of the job, the personalities involved and the whole social setting.

The ideal would be a relatively small closely knit team, working in the same place and having a continuity of work on a few jobs at a time, so that the members could really learn to appreciate each other's qualities, or if necessary shed those members who didn't fit. In such a team the question of leadership need hardly arise, each member taking the lead in his own subject. Even the professional demarcations may fall away — at least in the discussion of the main design decisions. But generally there will be a natural leader, an architect for architectural jobs, an engineer for structural jobs, or a manager type understanding what it is all about and almost representing the client inside the team.

But such a small team has its limitations. Jobs are getting bigger and bigger and more like machines to work in, full of installations of different sorts. Or large engineering jobs may call for scientific research, the invention of construction techniques, extensive computer services, etc. Top level men in all these fields cannot give their full time to work on a small team — yet their advice may be crucial to the problem in hand. So unless such a small team, or several such, can be embedded in a very large multi-disciplinary engineering firm with free access to all kinds of advice, it will have some difficulty in obtaining this special help.

Large, technically complicated jobs may therefore require a different organization — the design will have to be organized on different levels and be split up in parts to be designed by well coordinated teams. To paraphrase the well-known tag:

Large parts have small parts,
The art is to unite them,
And small parts have smaller parts,
And so *ad infinitum*.

But the important thing is the human element in whatever organization adopted, the determination to succeed, the agreement about aims, at least among the leaders of the design team, *and the powers that direct their work*.

This brings me to my last task, for which unfortunately hardly any time is left, to see how these conditions for producing excellence can be realized in the rough and tumble of the real world.

For it is not enough to have the will to produce a work of quality, and the insight and ability to know how to do so, you must also have the power to get it done.

Unfortunately the three are seldom combined.

The power to initiate action rests mainly with a small minority wielding political or financial power. Their main preoccupation is, however, with the maintenance and extension of this power. Improving the quality of our environment is not likely to come high on their list of priorities unless it can be made to serve their primary objective. And with the best will in the world, their power to act depends on their voters or shareholders, and *their* support can only be won by appealing to their pocket. And even where idealists among them are prepared to use their power to the utmost for a good cause, their ability to choose the right advisers and the best cause is questionable.

This is not surprising, for even those who are concerned, with building, with planning and design, those who have both the insight and ability, and often the will, do not agree on their objectives. Apart from the fact that they differ in their likes and dislikes, each can only have a limited and varying knowledge of *all* the factors — local, national and worldwide — which have a bearing on, or would be affected by, a planning decision. As regards large-scale planning they must to a large extent be guided by intuition, by a kind of Utopian vision. Where their views carry weight is in relation to a limited objective which they have made a special study of, a design of a neighbourhood, for instance. It is heartbreaking for them and for others who share their values to see their hard-won success in reaching a good solution brushed aside by those in power for reasons which have nothing to do with and completely ignore their own objectives, as happens frequently. The advisers may of course not be wholly disinterested, and the powers may possibly be right, or may have no choice in the matter — but one feels that they so often are wrong because their priorities are wrong, at least seen from the point of view of long-term benefits.

But this, I am afraid, does not only apply to those in power — it applies to everybody. The will — or rather the wish — to see our environment improved is fairly widespread in so far as the matter is given any thought at all. But it is not very strong. At least there are a number of other things we want still more. First of all, we must make a living — we have to, otherwise we can't make anything. Just as the Government first of all must try to stay in power — otherwise it can't influence matters for good. Making a living is quite a job in itself, and while you're at it, you had better lay something aside for your old age, and look after your family. And whilst you yourself may be content with only a modest place in the sun, you see no reason why your wife and children should be worse off than your neighbours. And so on.

Sphere of ideas

And if it isn't money we are after, it is recognition, prestige, status — we want our fellow-beings to love us, if possible, but at least to respect us. And if we are more discerning, we may realize that the applause of the uninformed is worth less than the respect of those who share our values. And that the values themselves are more important even than the respect of others, that what matters is that we can respect ourselves. And we move into the sphere of other motives which generally would be classified as less selfish, but which perhaps are even more selfish, because they satisfy a part of ourselves which we would like to see win. We move into the sphere of ideas, and their motive power, of compassion for suffering humanity, of allegiance to a cause, of identification with a larger unit, town, country — mankind. And we come to the pleasure of exercising our faculties, the satisfaction of the creative urge — which is bound up with the quest for quality. Self-fulfilment, if you like. As Maria Callas said in an interview recently: 'How can you exist if you do not do things, and how can you exist with self-respect if you do not do things as well as lies in you? And how can you achieve that if you do not work at it?'

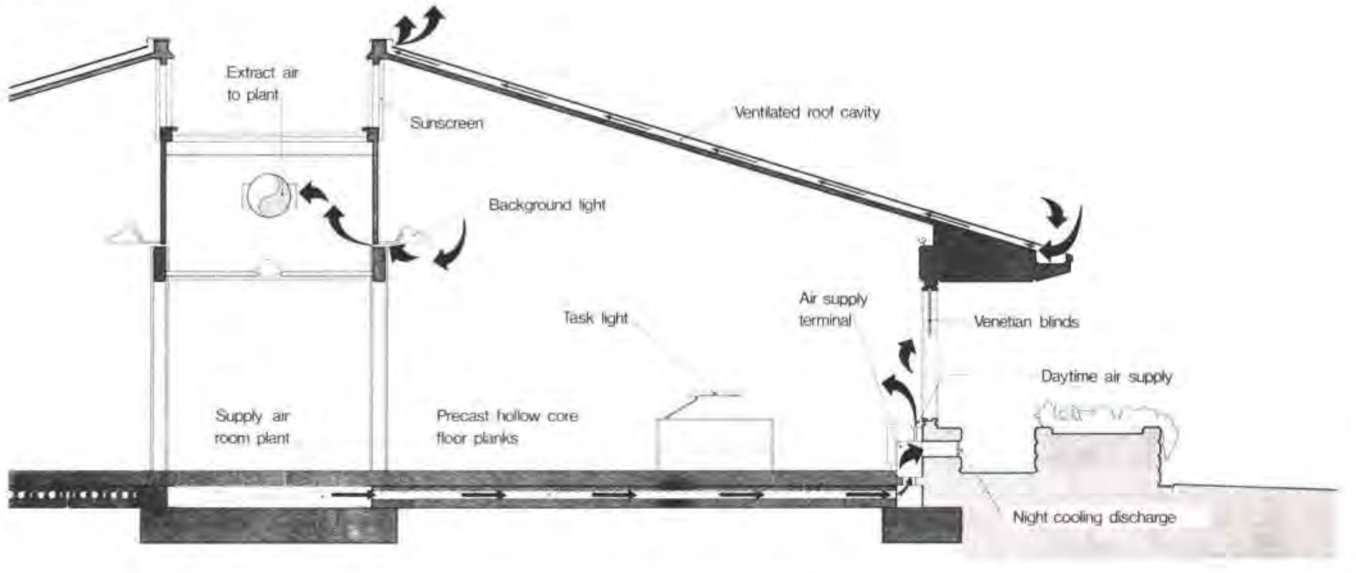
That, as I have already pointed out, is the attitude of those creative people who could make a contribution if allowed to. But occasionally you see this attitude allied to a thirst for fame which can lead astray. That is the trouble with all these motives — they are hardly ever pure, they are mixed with all the other motives, and taken in all, it is the grosser, simpler motives which are strongest. We have to accept this fact, and use it. To realize a 'higher' aim, we must attach it to a 'lower' one, and it must at least not go against the business of making money. That is why ambition, a striving for recognition and status, can be so useful for begetting the right kind of action. And that is why if we want quality, at least of a spiritual kind, we must master the economy of construction.

This digression into the tangled complex of motives is not irrelevant to our theme, for it is motives which beget action, and it is action guided by deliberate choice we are seeking. But you will agree that it is hopeless for me to attempt a review of this tangle. I would only say this, that in the discussion of world affairs, attention tends to be focused on measurable things, gross national product and the rest. The importance of 'imponderabilia', of the dreams of mankind, are neglected in the interest of 'realism'. Which is very unrealistic. For it is the power of these dreams which will decide our fate. And it is the unfortunately fragmented fraternity of people with imagination and a perhaps irrational concern for humanity which is our hope for a better world.

Divisions

The divisions within the building industry do not help matters. All the many economic units, professional firms, builders' manufacturers, etc., of which it consists are in business to make money. Prestige, status, etc., comes next — but also mainly as an aid to profit. Collaboration therefore collides with competition. The same rat-race is repeated inside the firms themselves. The business of designing is split up among a number of autonomous units concerned with safeguarding their interests, and clients and government agencies knowing little about the business of building. The gap between design and execution is almost unbridgeable, preventing the designers from obtaining first-hand knowledge of the cost of various means of construction, an essential requisite for original, inventive design. The prevailing system of quantity surveying only makes matters worse. It erects a barrier between the architect and the builder, thus widening the gap between design and construction. It enables construction to start before the design is completed, a very bad habit leading to confusion, delay and extra expense. It encourages architects in their besetting sin, the delusion that they can create original masterpieces without soiling their hands with such mundane matters as how the pieces are put together. And it lulls the client into the delusion that his affairs are in safe practical hands, wont to deal with money and real estate and such solid realities. Whereas the fact is, that these over-elaborate bills of quantities are a clumsy method of defining the contractor's obligations, which can be better done by drawings and specifications; that costs should not be based on what other contractors have quoted on other occasions for various fictitious items taken out of their context, but on the operations, plant, materials and manpower needed to carry out the job in hand; and that it is too late to find out that the job costs too much after the design is finished, and then proceed to muck around with the design.

Cross-section showing energy-saving designs
CEGB Bedminster Down 1978
Arup Associates



As it is the design which, apart from fluctuating factors, determines the cost of the job, costing, which of course is very necessary, must be an integral part of designing, and the quantity surveyor — and that incidentally is a bad name, for the taking out of quantities is in itself a very simple job if it is not unnecessarily complicated to impress the layman — must immerse himself in the prime cost of various site and factory operations, etc., to become a useful member of the design team.

That individual quantity surveyors can be very useful indeed in the present situation is another matter altogether. I have always maintained that character and intelligence are more important than letters after the name.

It is quite impossible for me to deal with all the other factors which inhibit integrated design — private property rights, the fragmentation of public authority, the restrictions too freely imposed in the form of bye-laws and regulations, etc. I will just say a few words about the dichotomies between design and building, and between professional and commercial.

Design

Over a large area of the building industry design is undertaken by professional firms for a fee, and building by commercial firms for what they can get in the market. This difference in remuneration widens the gulf between them and inhibits collaboration, because a free and frank discussion about design and construction methods and costs is bedevilled by the reluctance of the builder to put the cards on the table for fear of the financial implications. In any case both methods of remuneration are highly unsatisfactory — but it is not easy to suggest any better. To award the contract to the lowest tenderer in open competition is a very risky undertaking for the client, as has been shown over and over again. It is the quality and efficiency of the firm that matters to him.

And *vis-à-vis* the professional designer, the architect or consulting engineer, the client is in some respects helpless; he must take him or his firm on trust, as you must your doctor, dentist or solicitor. The choice of consultant is obviously very important for the client, yet is often undertaken very lightly. This method of remuneration does not call for competition in design, which could be stimulating, but is at the same time fraught with danger. In fact, the less the consultant spends on the design, the more money he makes, and the worse the design will be, probably without the client being any the wiser. This is perhaps not quite so serious as may appear, because firms depend for their commissions on their reputation and standing in the profession, which is built up gradually through their performance. But the client, as an outsider, can easily be taken in by experienced client-charmers.

The professional institutions exist to:

(1) Protect the public by ensuring that everybody entitled to practise has the necessary qualifications and obeys certain rules of conduct

(2) Advance the disciplines and skills on which the profession is based and enhance the reputation and social status of the profession

(3) Prevent competition by unscrupulous or undignified means likely to mislead the public, or by unqualified persons, and one could perhaps add

(4) Thus fix a scale of fees and conditions of employment from a position of strength.

As you see, this is a mixture of public and private benefits — the only way a thing like that can be made to work at all — and it has on the whole worked well. It encourages professional pride — which is both good and bad. It is good because it embraces pride in your work, the essential quest for quality. But when the pride leads to pomposity and sectarianism it is bad. Specialization is necessary, the practice of 'apartheid' between professions is absurd and harmful.

I should like to see the various institutions pulling together more to fufil their rôle as *guardians of quality*. And it seems to me that the organization of construction or building ought to be a profession, and should gradually be merged with the activity of designing. Then nothing would hinder the free exchange of information. This would in my opinion be a better way than making design a commercial activity and merging it with building, as in the contractor's package deal. The latter gives the public no protection — and the quest for quality, for artistic wholeness, would suffer a serious setback, in competition with soulless efficiency. After all, the professional man has his standards of excellence, his pride in his work, for which he is usually prepared to make a great effort, even if it does not pay. I expect most professional firms lose on those jobs they are most proud of. A commercial firm's first duty on the other hand is to pay a dividend to its shareholders.

That the public as a whole does not understand that design is a creative activity which determines the quality of the job is shown by the attitude of clients and government departments, of lawyers and administrators. Of course there is a good deal of routine design, which is just a repetition of previous designs, according to given rules. But quality can only be produced by personal effort, and that takes time. That time is seldom available. The difference between a good and a bad design can be tremendous — but the client pays the same for both, and as cash is the only acknowledged yardstick for value, they are assumed to be equally acceptable. A great mistake. The cost of the fee is actually insignificant compared with the cost of the job and the effect of the design on the job. But unfortunately one cannot be sure of getting a better job by paying a higher fee — as might be the case with sculptors or opera singers. The effort must be given freely from an inner compulsion. But the extra cost involved for the designers may of course be inhibiting. In fact, fee scales are much too low to allow for the effort to produce a masterpiece; it's a luxury one indulges in for one's own pleasure. They are too high for the far too frequently mediocre design; they are too low for small jobs, too high for large. They are too low for service engineers to do their job as they should, which they as a consequence seldom do — they get the contractor to do the detailing. And they are too high for quantity surveyors. But as you can't measure quality or the real value of the service to the client, there is not much you can do about it. All this is of course my personal opinion, and I have said enough already to get my neck wrung.

Conclusion

I have dealt rather perfunctorily with the obstacles to a good design — I have no time to look at the other side of the coin. It would present a picture of great endeavour by many designers to improve the quality of design. The best architectural and engineering design is getting better all the time, and is setting an example which will have a greater effect than mere talk. And powerful corporations and firms who seek to increase their prestige by the way they build are realizing that vulgar display is less convincing than all-round excellence. In the end it will be the general level of understanding of what good building could do for us, which will decide what we get.

'Key speech'

This talk was given on 9 July 1970 at Winchester during one of the meetings of the Arup Organization.

In its pre-natal stage, this talk has been honoured with the name of 'key-speech'. It is doubtful whether it can live up to this name. What is it supposed to be the key to? The future of the firm? The philosophy? The aims? At the moment, sitting in my garden and waiting for inspiration, I would be more inclined to call it: 'Musings of an old gentleman in a garden' — and leave it at that.

I have written before a piece called *Aims and Means* for a conference of Senior and Executive Partners in London on 7 July 1969. It did not manage to deal much with means, however, and it is of course difficult to generalize about means, for they must vary with circumstances. The first part of this paper was published in *Newsletter 37*, November '69. This you may have read — but I will shortly summarize the aims of the firm as I see them.

There are two ways of looking at the work you do to earn a living:

One is the way propounded by the late Henry Ford: Work is a necessary evil, but modern technology will reduce it to a minimum. Your life is your leisure lived in your 'free' time.

The other is:

To make your work interesting and rewarding. You enjoy both your work and your leisure.

We opt uncompromisingly for the second way. There are also two ways of looking at the pursuit of happiness:

One is to go straight for the things you fancy without restraints, that is, without considering anybody else besides yourself.

The other is to recognize that no man is an island, that our lives are inextricably mixed up with those of our fellow human beings, and that there can be no real happiness in isolation. Which leads to an attitude which would accord to others the rights claimed for oneself, which would accept certain moral or humanitarian restraints.

We, again, opt for the second way.

These two general principles are not in dispute. I will elaborate them a little further:

The first means that our work should be interesting and rewarding. Only a job done well, as well as we can do it — and as well as it can be done — is that. We must therefore strive for quality in what we do, and never be satisfied with the second-rate. There are many kinds of quality. In our work as structural engineers we had — and have — to satisfy the criteria for a sound, lasting and economical structure. We add to that the claim that it should be pleasing aesthetically, for without that quality it doesn't really give satisfaction to us or to others. And then we come up against the fact that a structure is generally a part of a larger unit, and we are frustrated because to strive for quality in only a part is almost useless if the whole is undistinguished, unless the structure is large enough to make an impact on its own. We are led to seek overall quality, fitness for purpose, as well as satisfying or significant forms and economy of construction. To this must be added harmony with the surroundings and the overall plan. We are then led to the ideal of 'Total Architecture', in collaboration with other likeminded firms or, still better, on our own. This means expanding our field of activity into adjoining fields — architecture, planning, ground engineering, environmental engineering, computer programming, etc. and the planning and organization of the work on site.

It is not the wish to expand, but the quest for quality which has brought us to this position, for we have realized that only intimate integration of the various parts or the various disciplines will produce the desired result.

The term 'Total Architecture' implies that all relevant design decisions have been considered together and have been integrated into a whole by a well-organized team empowered to fix priorities. This is an ideal which can never — or only very rarely — be fully realized in practice, but which is well worth striving for, for artistic wholeness or excellence depends on it, and for our own sake we need the stimulation produced by excellence.

The humanitarian attitude

The other general principle, the humanitarian attitude, leads to the creation of an organization which is human and friendly in spite of being large and efficient. Where every member is treated not only as a link in a chain of command, not only as a wheel in a bureaucratic machine, but as a human being whose happiness is the concern of all, who is treated not only as a means but as an end.

Of course it is always sound business to keep your collaborators happy — just as any farmer must keep his cattle in good health. But there is — or should be — more in it than that. (We know what happens to cattle.) If we want our work to be interesting and rewarding, then we must try to make it so for all our people — and that is obviously much more difficult, not to say impossible. It is again an ideal, unattainable in full, but worth striving for. It leads to the wish to make everybody aware of, and interested in, our aims and to make the environment and working conditions as pleasant as possible within the available means.

This attitude also dictates that we should act honourably in our dealings with our own and other people. We should justify the trust of our clients by giving their interest first priority in the work we do for them. Internally, we should eschew nepotism or discrimination on the basis of nationality, religion, race, colour or sex — basing such discrimination as there must be on ability and character.

Humanitarianism also implies a social conscience, a wish to do socially useful work, and to join hands with others fighting for the same values. Our pursuit of quality should in itself be useful. If we in isolated cases can shown how our environment can be improved, this is likely to have a much greater effect than mere propaganda.

There is a third aim besides the search for quality of work and the right human relationships, namely prosperity for all our members. Most people would say that this is our main aim, this is why we are in business. But it would be wrong to look at it as our main aim. We should rather look at it as an essential pre-requisite for even the partial fulfilment of any of our aims. For it is an aim which, if overemphasized, easily gets out of hand and becomes very dangerous for our harmony, unity and very existence.

It costs money to produce quality, especially when we expand into fields where we have no contractual obligations and can expect no pay for our efforts. We may even antagonize people by poaching on their domain or by upsetting and criticizing traditional procedures.

It also costs money to 'coddle' the staff with generosity and welfare, or to lose lucrative commissions by refusing to bribe a minister in a developing country, or to take our duty too seriously if nobody is looking.

Money spent on these 'aims' may be wisely spent in the long term, and may cause the leaders of the firm a certain satisfaction — but if so spent it is not available for immediate distribution among the members, whether partners or staff. So aim No. 3 conflicts to that extent with aims 1 and 2. Moreover, if money is made the main aim — if we are more greedy than is reasonable — it will accentuate the natural conflict about how the profit should be distributed between our members — the partners and staff or the different grades of staff.

The trouble with money is that it is a dividing force, not a uniting force, as is the quest for quality or a humanitarian outlook. If we let it divide us, we are sunk as an organization — at least as a force for good.

So much for our aims. As aims, they are not in dispute. What is debatable, is how vigorously each shall be pursued — which is the most important; how to balance long term against short term aims. Let us first see what these aims imply.

Obviously, to do work of quality, we must have people of quality. We must be experts at what we undertake to do. Again, there are many kinds of quality, and there are many kinds of job to do, so we must have many kinds of people, each of which can do their own job well. And they must be able to work well together. This presupposes that they agree with our aims, and that they are not only technically capable but acceptable to us from a human point of view, so that they fit into our kind of organization; and that they are effectively organized, so that the responsibility of each is clearly defined and accepted. In short, we must be efficient — individually, in all our sub-divisions, and as a world organization.

I have tried to summarize the foregoing in a number of points. Like all classification, it is arbitrary and rough — but may nevertheless be useful as a help to understanding and discussion, if its imperfections and its incompleteness are borne in mind.

The main aims of the firm are:

Group A

(1) Quality of work
(2) Total architecture
(3) Humane organization
(4) Straight and honourable dealings
(5) Social usefulness
(6) Reasonable prosperity of members.

If these aims could be realized to a considerable degree, they should result in:

Group B

(7) Satisfied members
(8) Satisfied clients
(9) Good reputation and influence.

But this will need:

Group C

(10) A membership of quality
(11) Efficient organization
(12) Solvency
(13) Unity and enthusiasm.

Of course there is not really any strict demarcation between aims (Group A) and means (Group C) and the results (Group B) flowing from the whole or partial fulfilment of the aims in A. And it is not absolutely certain that these results are obtained. For instance, A3 and 4 (a humane organization and straight dealings) can as well be considered as a means, and in fact all the points are to some extent both aims and means, because they reinforce each other. And there will be members who are dissatisfied no matter how good the firm is, and the same may apply to clients, who may not appreciate quality at all. But on the whole, what I said is true. We should keep the six aims in A in view all the time, and concentrate on the means to bring them about.

But before I do this, I will try to explain why I am going on about aims, ideals and moral principles and all that and don't get down to brass tacks. I do this simply because I think these aims are very important. I can't see the point in having such a large firm with offices all over the world unless there is something which binds us together. If we were just ordinary consulting engineers carrying on business just as business to make a comfortable living, I can't see why each office couldn't carry on, on its own. The idea of somebody in London 'owning' all these businesses and hiring people to bring in the dough doesn't seem very inspiring. Unless we have a 'mission' — although I don't like the word — but something 'higher' to strive for — and I don't particularly like that expression either — but unless we feel that we have a special contribution to make which our very size and diversity and our whole outlook can help to achieve, I for one am not interested. I suppose that you feel the same, and therefore my words to you may seem superfluous; but it is not enough that *you* feel it, everybody in the firm should as far as possible be made to feel it, and to believe that we, the leaders of the firm, really believe in it and mean to work for it and not just use it as a flag to put out on Sundays. And they won't believe that unless we do.

On the other hand, who am I to tell you and the firm what you should think and feel in the future when I am gone — or before that, for that matter. It wouldn't be any good my trying to lay down the law, and I haven't the slightest inclination to do so. That is my difficulty. I dislike hard principles, ideologies and the like. They can do more harm than good, they can lead to wholesale murder, as we have seen. And yet we cannot live life entirely without principles. But they have in some way to be flexible, to be adaptable to changing circumstances. 'Thou shalt not lie', 'Thou shalt not kill', are all very well, generally, but do not apply if for instance you are tortured by fanatical Nazis or Communists to reveal the whereabouts of their innocent victims. Then it is your duty to mislead. What these commandments should define is an attitude. To be truthful always, wherever it does no harm to other ideals more important in the context, to respect the sanctity of human life and not to destroy life wantonly. But where to draw the line in border cases depends on who you are, what life has taught you, how strong you are.

In the following 13 points, which I must have jotted down some time ago — I found them in an old file — I am grappling with this question, perhaps not very successfully. I give them to you now:

Principles

(1) Some people have moral principles.

(2) The essence of moral principles is that they should be 'lived'.

(3) But only saints and fanatics do follow moral principles always.

(4) Which is fortunate.

(5) Are then moral principles no good?

(6) It appears we can't do without them.

(7) It also appears we can't live up to them.

(8) So what?

(9) A practical solution is what I call the *star system*.

(10) The star — or ideal — indicates the course. Obstacles in the way are *circumnavigated but one gets back on the course* after the deviation.

(11) The system is adopted by the Catholic church. Sins can be forgiven if repented — it doesn't affect the definition of good or evil.

(12) That this system can degenerate into permanent deviation is obvious.

(13) One needs a sense of proportion.

Incidentally, they should not be taken as an encouragement to join the Catholic church!

I found also another tag:

'The way out is not the way round but the way through.' That's rather more uncompromising, more heroic. It springs from a different temperament. It's equally useful in the right place. But the man that bangs his head against a wall may learn a thing or two from the reed than bends in the wind.

The trouble with the last maxim is that it says something about the way, but not about the goal. The way must be adapted to the circumstances — the goal is much more dependent on what sort of person you are. I admit that the last maxim also says a good deal about the man who propounds it, a man of courage, of action, perhaps not given too much to reflection, perhaps not a very wise man. The wise man will consider whether this way is possible, whether it leads to the desired result. Unless of course his goal is to go through, not to arrive anywhere, like the man in the sports car. But this only shows that it is the goal which is important, whatever it is.

The *star system* is an attempt to soften the rigidity of moral principles. But it doesn't really solve this dilemma. It is a little more flexible than moral precepts as to the way, but surely the 'stars' must be fixed — for if they can be changed *ad lib* the whole thing wobbles. And that in a way is what it does — I can't do anything about that. I should have loved to present you with a strictly logical build-up, deducing the aims for the firm from unassailable first principles. Or perhaps this is an exaggeration — for I know very well that this can't be done. All I can do is to try to make the members of the firm like the aims I have mentioned. I would like to persuade them that they are good and reasonable and not too impossible aims, possessing an inner cohesion, reinforcing each other by being not only aims but means to each other's fulfilment.

'Stars' like goodness, beauty, justice have been powerful forces in the history of mankind — but they so often are obscured by a mental fog — or perhaps I should say the opposite — they are created by a mental fog, and when the fog lifts, they are seen to have been illusions. They are man-made. I do not rate them less for that reason — but they are too remote, too indefinable, to be of much practical use as guide-lines. They sustain or are born of the longings of mankind, and belong to the ideal world of Plato — which is fixed for ever. Rigid ideologies feed on them. Not so practical politics.

Our aims on the other hand are not nearly so remote. We will never succeed in fulfilling them *in toto*, but they can be fulfilled more or less, and the more the better. And they are not grasped arbitrarily out of the sky or wilfully imposed, they are natural and obvious and will, I am sure, be recognized as desirable by all of you: so much so, in fact, that the thing to be explained is not why they are desirable, but why I should waste any words on them.

I do, as I pointed out at the beginning of this argument, because our aims are the only thing which holds us together, and because it is not enough to approve them, we must work for them — and the leaders must be prepared to make sacrifices for them. Temporary diversions there must be, we have to make do with the second best if the best is not within reach, we have to accept expediencies — and from a strict point of view all our activities can be considered as expediencies, for in theory they could all be better still — but the important thing is that we always get back on the course, that we never lose sight of the aims. Hence the name *star system* derived from comparison with old-fashioned navigation. But I propose to abandon this expression, partly because its meaning in the film industry may confuse, especially as it is very opposed to our point of view, which is in favour of teamwork rather than stardom: and also because it suggests *star-gazing*, which I find uncomfortably near the bone because I might with some justification be accused of it. So I am afraid we have to fall back on 'philosophy'. Having dabbled in this subject in my youth I have been averse to seeing the term degraded by talk about the philosophy of pile-driving or hair-dressing, but it is of course useless to fight against the tide. The word has come to stay — and in 'the philosophy of the firm', it is not used quite so badly. So that's what I have been giving you a dose of.

I will now discuss what we have to do in order to live up to our philosophy. And I will do it under the four headings 10 to 13 in my list of aims and means:

(10) Quality staff

(11) Efficiency

(12) Solvency

(13) Unity and enthusiasm

but it will of course be necessary to mix them up to some extent.

Quality of staff

How do we ensure that our staff is of the right quality, or the best possible quality?

We all realize, of course, that there is a key question. The whole success of our venture depends on our staff. But what can we do about it? We have the staff we have — we must make do with them, of course (and I think we have a larger proportion of really good people than any other firm of our kind). And when we take on new people — the choice is limited. Again we have to take the best we can get. We cannot pay them a much higher salary than our average scale, because that would upset our solvency and sink the boat. Naturally our method of selection is important, and what we can do to educate our staff and give them opportunities to develop is important, but I can't go into details here. All I can say is that staff getting and staff 'treating' must not degenerate into a bureaucratic routine matter, but must be on a personal level. When we come across a really good man, grab him, even if we have no immediate use for him, and then see to it that he stays with us.

The last is the really important point, which in the long run will be decisive. Why should a really good man, a man — or woman — who can get a job anywhere or who could possibly start out on his own, why should he or she choose to stay with us? If there is a convincing and positive answer to that, then we are on the right way.

Presumably a good man comes to us in the first instance because he likes the work we do, and shares or is converted to our philosophy. If he doesn't, he is not much good to us anyhow. He is not mainly attracted by the salary we can offer, although that is of course an important point — but by the opportunity to do interesting and rewarding work, where he can use his creative ability, be fully extended, can grow and be given responsibility. If he finds after a while that he is frustrated by red tape or by having someone breathing down his neck, someone for whom he has scant respect, if he has little influence on decisions which affect his work and which he may not agree with, then he will pack up and go. And so he should. It is up to us, therefore, to create an organization which will allow gifted individuals to unfold. This is not easy, because there appears to be a fundamental contradiction between organization and freedom. Strong-willed individuals may not take easily to directions from above. But our work is teamwork and teamwork — except possibly in very small teams — needs to be organized, otherwise we have chaos. And the greater the unit, the more it needs to be organized. Most strong men, if they are also wise, will accept that. Somebody must have authority to take decisions, the responsibility of each member must be clearly defined, understood and accepted by all. The authority should also be spread downwards as far as possible, and the whole pattern should be flexible and open to revision.

We know all this, and we have such an organization: we have both macro, micro and infra-structure. It has been developed, been improved, and it could undoubtedly be improved still further. We are of course trying to do that all the time. The organization will naturally be related to some sort of hierarchy, which should as far as possible be based on function, and there must be some way of fixing remuneration, for to share the available profit equally between all from senior partner to office-boy would not be reasonable, nor would it work. And all this is very tricky, as you know, because, as soon as money and status come into the picture, greed and envy and intrigue are not far behind. One difficulty is particularly knotty, the question of ownership, which is connected with 'partnership'. There is dissatisfaction amongst some of those who in fact carry out the functions of a partner — dealing with clients, taking decisions binding on the firm, etc. — because they cannot legally call themselves partners but are 'executive' partners — or have some other title. I have discussed this problem in my paper, *Aims and Means*. If some viable way could be found to make 100 partners, I wouldn't mind, but I can't think of any.

In the Ove Arup Partnership we have all but eliminated ownership — the senior partners only act as owners during their tenure of office — because someone has to, according to the laws of the country. And I wish that system could be extended to all our partnerships. It no doubt irks some people that the money invested in the firm may one day (with some contriving) fall into the turban of people who have done nothing to earn it — but what can we do? The money is needed for the stability of the firm, it makes it possible for us to earn our living and to work for a good cause, so why worry?

It may be possible to devise a different and better arrangement than the one we have now, more 'democratic', more fair: it may be possible to build in some defences against the leaders misbehaving and developing boss-complexes and pomposity — and forgetting that they are just as much servants in a good cause as everybody else — only more so. This is partly a legal question depending on the laws of the country. But I have neither the ability nor the time to deal with all that here. What I want to stress is the obvious fact that no matter how wonderful an organization we can devise, its success depends on the people working in it — and for it. And *if* all our members really and sincerely believed in the aims which I have enumerated, if they felt some enthusiasm for them, the battle would be nearly won. For they imply a humanitarian attitude, respect and consideration for persons, fair dealings, and the rest, which all tend to smooth human relationships. And anyone having the same attitude who comes into an atmosphere like that, is at least more likely to feel at home in it. And if the right kind of people feel at home with us, they will bring in other people of their kind, and this again will attract a good type of client and this will make our work more interesting and rewarding and we will turn out better work, our reputation and influence will grow, and the enthusiasm of our members will grow — it is this enthusiasm which must start the process in the first place.

And they all lived happily ever after?

Yes, it sounds like a fairy tale, and perhaps it is. But there *is* something in it. It is a kind of vicious circle — except that it isn't vicious, but benevolent, a lucky circle. And I believe that we have made a beginning in getting onto this lucky circle. I believe that our fantastic growth has something to do with our philosophy. And I believe our philosophy is forward-looking, that it is what is needed today, is in tune with the new spirit stirring in our time. But of course there are many other and dangerous spirits about and too much growth may awaken them. Too much growth may also mean too little fruit.

My advice would be:

'Stadig over de klipper', or if you prefer:

Take it easy!

More haste less speed!

Hâtez-vous lentement!

Eile mit weile!

Hastværk er lastværk!

It's the fruit that matters. I have a lingering doubt about trying to gain a foothold in various exotic places. Might we not say instead: Thank God that we have not been invited to do a job in Timbuctoo — think of all the trouble we are avoiding. It's different with the work we do in Saudi Arabia, Tehran and Kuwait. There we are invited in at the top, working with good architects, doing exciting work. We are not hammering at the door from outside. But as a rule, grab and run jobs are not so useful for our purpose. I think the Overseas Department agrees with this in principle, if not in practice.

It's also different with civil engineering work, provided we have control — complete control — over the design and are not 'sharing' the job or having a quantity surveyor or 'agent', etc., imposed on it preventing us from doing the job our way. The general rule should be: if we can do a job we will be proud of afterwards, well and good — but we will do it our way. In the long run this attitude pays, as it has already done in the case of Arup Associates. And incidentally, the control of such jobs should be where our expertise resides.

To export Arup Associates' jobs is much more difficult, for whilst we may be able to build a bridge or radio tower in a foreign locality, good architecture presupposes a much more intimate knowledge of the country. Long distance architecture generally fails. But that does not mean that the ideal of Total Architecture is irrelevant to our purely engineering partnerships or divisions. In fact they have been founded on the idea of integrating structure with architecture *and* construction, and in Scotland for instance they are trying to give architects a service which will unite these domains.

Coming back to my main theme, I realize that when I have been talking about quality, about interesting and rewarding work, about Total Architecture, and attracting people of calibre, you may accuse me of leaving reality behind. 'As you said yourself', you may say, 'our work is teamwork. And most of this work is pretty dull. It is designing endless reinforced concrete floors, taking down tedious letters about the missing bolts, changing some details for the nth time, attending site meetings dealing with trivialities, taking messages, making tea — what is exciting about that? You are discriminating in favour of an élite, it's undemocratic. What about the people who have to do the dull work?'

Equality of opportunity

You have certainly a point there. Of course I am discriminating in favour of quality, and I would do anything to enable our bright people to use their talents. You cannot equate excellence with mediocrity, you cannot pretend they are the same. We would be sunk if we did that. We need to produce works of quality, and we need those who can produce them. One perfect job is more important for the morale of the firm, for our reputation for producing enthusiasm, than 10 ordinary jobs, and enthusiasm is like the fire that keeps the steam-engine going. Likewise one outstanding man is worth 10 men who are only half good. This is a fact of life we cannot change. It is no good pretending that all are equal — they aren't. There should be equality before the law, and as far as possible equality of opportunity, of course. But the fact that you are good at something is something you should be grateful for, not something to be conceited about. It doesn't mean that you are better as a human being. And there are probably many other things you are hopeless at.

No man should be despised or feel ashamed because of the work he does, as long as he does it as well as he can. What we should aim at, naturally, is to put each man on to the work he *can* do. And, fortunately, there is nearly always something he can do well. We will have square pegs in round holes, we shall have frustrated people, unfortunately — those who are not frustrated one way or another are in the minority. But fortunately people vary, as jobs vary, and few would want to do the job another calls interesting if they are no good at it.

If we can reach a stage where each man or women is respected for the job they do, and is doing his or her best because the atmosphere is right, because they are proud of what we are and do, and share in the general enthusiasm, then we are home. And each job is important. Secretaries, for instance. They could have a tremendously civilizing influence on our staff. They could teach them to write English, for instance, a most important and necessary job. But secretaries who can do that are of course at a premium. We must try to find them. It is even more important than that they are good-looking — and nobody could accuse me of being indifferent to that.

Our messengers and cleaners — how important it is that they are reliable and likeable, human, with a sense of humour. A cheerful remark can brighten the day. All our people are part or us, part of our 'image', create the atmosphere we live in.

But it doesn't alter the fact that the services of a messenger are less valuable to the firm than those of a gifted designer or an imaginative mechanical engineer, a fact that even the messenger will understand.

But there are of course people we cannot employ usefully. Masses of them, in fact.

Those we should not take on, obviously, except on a strictly temporary basis. But sometimes they are found inside the firm. They may have been good once, but are on the way down. I am a case in point myself. But their loyal service, their place in the hierarchy, makes it difficult to de-grade them. To deal with them requires much tact, and is embarrassing. But they should not be allowed to pretend to do jobs they are no good at. They must not prevent the good ones from functioning.

It's a problem all firms have, it's one of the cases where humanity and efficiency clash. To resolve it tactfully may be expensive, not to resolve it is fatal.

So far I haven't said much about solvency. Stuart Irons can tell you something about that. I compare it to stability in engineering structures — without it the whole thing collapses but if you have much more money than you need the usefulness of it declines until it becomes distracting and dangerous. That danger need not worry us for the time being.

At the moment the need for solvency is restricting, and is the most frequent cause of having to compromise. That we may have to do — but let's not do it unnecessarily, and let's get back on course.

And Unity and Enthusiasm, the last item, is in a way what my talk has been about. It is a question of giving the firm an identity. What do we mean, when we speak about the firm, about 'we' or 'us'? Is it the whole collection of people in dozens of offices in different places? Are 'we' all of them or some of them, and which?

I think it is unavoidable that 'we' should mean different things in different contexts. Sometimes what is said is only relevant to the upper layers of management, sometimes it is meant to include everybody. What we must aim at is to make 'we' include as many as possible as often as possible. To increase the number of those who have a contribution to make, however small, who agree wholeheartedly with our aims and want to throw in their lot with us. We might think about them as members of our community; the others, who come and go, might be called staff. Of course there can never be any clear line of demarcation — it is not a question of signing a form or bestowing a title — it is a matter of how each feels and what we feel about them. For it is a two-way business.

But what binds our membership together must be loyalty to our aims. And only as long as the leaders of the firm are loyal to these can they expect and demand loyalty from the members. This speech is too long already, and I have not even touched on what you perhaps expected to be the main subject of my talk, the relationship between the Ove Arup Partnership and the Overseas Partnerships. But from the foregoing my point of view should be clear.

The fact that we have these outposts all over the world is of course an enormous source of strength to us and to you, it helps to establish our reputation and power for good, and opens up opportunities for all our members. This is however only because the leaders in these places are our own people, bound to us by common aims and friendships. But as the old leaders retire and growth takes place mainly locally, the ties that bind us together may weaken. We should prevent this by forging more ties, forming new friendships, and always being true to our principles. Improve communications — the universal injunction nowadays. Absence does not make the heart grow fonder, unfortunately. There will always be a need for a strong coordinating body — which is at the moment formed by the senior partners — which has the power to interfere if our principles are seriously betrayed. For should that happen, it would be better to cut off the offending limb, less the poison should spread. Our name must not be allowed to cover practices which conflict with our philosophy. But at the moment there is no danger of that, and we can take comfort from what has been achieved. Perhaps that should have been the gist of my talk? But you are seeing it for yourself. I could also have dwelt on how far we have still to go; it would perhaps have accorded more with my star-gazing habits. But my time is up — my speech should have been condensed to one-third — but it is too late now. I hope at any rate that I haven't deserved the warning which the Duke of Albany addressed to Goneril in *King Lear*:

How far your eyes may pierce I cannot tell.
Striving to better, oft we mar what's well.

The built environment

This paper was given as the Building Services Engineering Society inaugural speech, at the Institution of Civil Engineers on 26 October 1972.

When I was asked to speak at this inaugural meeting of the BSES I little knew what I would be letting myself in for. I was told that the Society was formed by 10 sponsoring bodies and seven affiliated bodies to advance and disseminate knowledge in the field of building services engineering and to foster co-operation between all those involved with the total 'built environment'. But when I found that neither the RIBA, the Institution of Structural Engineers, the Institution of Heating and Ventilating Engineers, the Institute of Builders, nor the Royal Institute of Chartered Surveyors were to be found among the sponsors, I was puzzled. It was explained to me that the RIBA was on the original Organizing Committee of the Society, but was, in the event, unable to become a sponsoring body but that it was hoped that they would come in before long.

This explanation still left me puzzled, and I said I would have to investigate this matter further and discuss the result of my investigation in my speech. I confirmed this in a letter to Garth Watson which I will read to you:

Following our telephone conversation today I think I ought to put on paper the conclusions we reached, so that there is no misunderstanding.

I said that I could only speak at the Inaugural Meeting of the BSES if I could voice any conclusions I might reach after thinking about the whole matter of the Building Services, and discussing it with members of the various bodies connected with the building industry as a whole.

Whilst I concede the need for close integration of the work of all those concerned with the production of buildings, I have doubts about the value of a society which does not embrace the key professions represented by the RIBA, the Institution of Structural Engineers and the IHVE. As you say, discussions can do no harm unless they are a substitute for action, but what seems to be needed is an institution which can map out a better training for those concerned with building services of all kinds. It could most naturally be based on the IHVE, and it might be wrong to deny them a Charter, provided their standards are raised and provided only those taking the new degrees can call themselves Chartered Engineers.

I understand that you would want me to speak at the Inaugural Meeting even if I should reach some such conclusion. But if you are doubtful about this I am very willing to withdraw.

I received a reply to this letter saying that the Chairman and Garth Watson were in no doubt whatever that they wanted me to speak at the meeting as the Society was a forum for discussion and was not in itself taking any particular point of view on what were certainly controversial matters. Which I must say is a laudable attitude.

I also received a statement of 925 words on the origins of the BSES and the actions taken by the CEI in regard to the learned society and the qualifying role, ending up with an announcement that I had accepted an invitation to speak at this meeting on a subject of my own choosing *within the theme — the built environment*.

This last qualification is not exactly what I agreed to, but let that pass.

In the meantime I had had other letters and messages, and I had talked with various people concerned with the matter, and it was obvious that there was a large number of people who thought that the forming of this new society was not only useless but directly harmful. They regard it as a clever device by the big three, the Civil, Mechanical and Electrical Engineering Institutions, to divert attention from what was really needed and what they wanted to prevent: the granting of a charter to the IHVE. Opinions differed about what should be done instead, but whatever it was it would be very difficult to achieve because the other fellows wouldn't play ball.

The whole situation is extremely confused, to put it mildly, with institutions, charters, societies and other bodies proliferating, but never dying. Unity is extolled, apartheid practised.

I am telling you all this to enlist your sympathy for the difficult situation I find myself in.

I could, of course, confine myself to talking about the need for collaboration between all those concerned with the built environment. I seem to have done that all my working life, stretching over half a century or so, and I suppose I could so some more of it. But isn't it a bit unkind to trot out this old war-horse? After all, we all agree on that. In all my years of campaigning I have never found anybody who disagreed with it. But *talking* about it doesn't seem to have much effect. One must somehow create the conditions which will *allow* such collaboration to take place, and one must educate members of the building team to see their own contribution *not* as an end in itself, but as a part of a common endeavour to create comprehensive, total architecture. That is what we have been trying to do inside our own firm. And therefore we know how difficult it is. And yet we are particularly fortunate in being able to foster such experiments — and they have gone far beyond that experimental stage now — inside a large engineering firm able to supply the necessary engineering experience and finance. But we are, of course, all the time up against the reluctance of clients and government departments to change established rules and procedures. Especially our insistence that our quantity surveyors must be part of the design team causes uneasiness. And yet it is so obvious that accountancy cannot create anything unless it guides what is being designed and therefore what is built. The system of over-elaborate bills of quantities produced after the design is made, or worse still, before the design is made, is directly harmful in many ways, among others because it erects a barrier between the designer and the builder.

One thing we ought to be able to agree on is, that the designer must know how his design can be executed, and the approximate cost of it. If, instead, priced bills of quantities are treated as secret documents which must not be shown to the designer, as happens sometimes, the whole thing becomes absurd. Designing is indicating a sensible way of building, among other things.

All this is by the way, but it reinforces my opinion that more talking is not what is needed. There are enough societies and journals where people can and do talk and write. The Joint Building Group and the Junior Liaison Organization have more or less the same aims. And if the institutions most intimately concerned with building oppose this venture, it indicates that the most pressing need is not the forming of this society, but to bring some order into the chaotic state of separate institutions, chartered or otherwise, which have been created in a very accidental way in response to technological development and specialization, or else because groups of engineers have been dissatisfied with the conservatism of old institutions.

Now, it is obviously not very pleasant for me, having been invited to speak at the inauguration of a new society sponsored by so many worthy people, to come and tell you that the whole venture is worthless, to put it much too bluntly. It is, to say the least, an odd way to inaugurate a new society.

It would make it easier, of course, if I could also tell you what you *should* do. But I am not as clever as that. When it comes to the unravelling of the tangled network of institutions I am singularly inept, in fact, I know only a few of them, most of the letters behind names are meaningless to me. I am a bad institution man. I could, perhaps successfully, put forward excuses or rationalizations for this, but it would be a waste of time, it wouldn't alter the fact.

The Royal Charter

When I look at the list of 15 chartered engineering institutions forming the membership of the CEI I feel tempted to scrap the lot and begin afresh. Divide the whole field of engineering into sections according to the nature of the work they have to do or the knowledge they have to have, and then perhaps group neighbouring sections into a number of institutions which together would cover the whole field of engineering, united by the CEI at the top. Inside each institution you would then have different grades, Chartered Engineers, Technician Engineers and Technicians, if you like. The Chartered Engineer would have a more broadly-based knowledge of mathematics, physical sciences and of all the various branch disciplines inside his particular institution, specializing in one of them, but able to represent them all on the conceptive stage of original design. And so on. New techniques or fields of operation would then originate inside one of the institutional territories and might ultimately warrant the creation of separate institutions. And some old workings might be closed down.

That is what I would be tempted to do, I said. But I am totally unequipped to do it and in any case it can't be done, and it is very doubtful if it would be desirable to do it. For when it comes to dealing with human beings logic breaks down. To force them to do what they don't want to do is counter-productive. To destroy their traditional links with the past would be wrong too. But to build on the present haphazardly disposed foundations is a very complicated business. The creation of the CEI was, however, a very significant step in the right direction. Let us hope that it can gradually sort things out. But if it is intended to limit the number of charters to 15 for all eternity, as some people believe, it can only make sense if there is a re-shuffling of existing charters or if it is a step on the way to total elimination of charters.

All this is of little help. But let me try to establish what we, I hope, can agree on, and what we are up against.

The trouble appears to be this: The Institution of Heating and Ventilating Engineers want a Royal Charter and membership of the CEI. On the one hand they feel they deserve it. They are on the way up, their importance in the building team is growing and generally recognized, they are expanding over a wider field and want to embrace all the building services, and they are doing all they can to improve their service. On the other hand, they feel they need it, they find it difficult to attract the right kind of student unless they can dangle a charter in front of him. If the building services engineer — or more ambitious still — the environmental design engineer — has to study another two years to join a member institution of the CEI to get charter status, however irrelevant those studies may be to his chosen career, it will have a most disastrous effect on recruitment, to quote Mr Pullinger.

But unfortunately it is getting more and more difficult to get a Royal Charter. When the CEI was created in 1965 they were given eight years in which to raise the standard of the Chartered Engineer. By 1973 they will have to satisfy the Privy Council that the corporate members of all the chartered engineering institutions in the CEI have reached the required standard, otherwise *their* charter may be withdrawn. And they have had a look at the qualifications of the present corporate members of the IHVE to find out whether they meet the criteria for constituent membership of the CEI.

Unfortunately an *ad hoc* committee decided that less than the required 75% did so, so they could not recommend the IHVE for membership of the CEI. And as a result they could not get a Royal Charter either. It seems to be the case that no engineering institution will in future be able to obtain a charter without satisfying the CEI criteria.

Whether the BSES was launched by the Civils as a sop to the wounded IHVE I don't know. It has really nothing to do with the charter business, because the BSES is supposed to be only a talking shop, or perhaps I should say a learned society, and not a qualifying body. And it was meant to include the architects, structural engineers, heating and ventilating engineers and builders, of course.

But now these last four have withdrawn from sponsorship and any form of participation. They all feel that the IHVE should have a charter, that it is absurd that such a vital section of the building team should, so to speak, have a lower status than the other members of the team. And they believe that the formation of the BSES is distracting attention from the much more important question of improving the status and performance of the heating and ventilating engineer.

This seems to me to be a fatal blow to the BSES. For it would, I think, make sense to have a society which embraced architects, heating and ventilating engineers, structural engineers and builders, for they are the four *main* members of the building team. But a BSES without them is nonsense.

I am not claiming any great accuracy for this rough outline of the problem, and I should not be surprised if both the contending parties were dissatisfied with my exposé. But it wouldn't do any good losing myself in all the pros and cons — the fact is, that *this fraternal dispute is a setback to the much needed mutual understanding and collaboration between the various professions engaged in building*. And the whole thing is rather silly when you consider that everybody agrees that:

First: There *is* a great need for a professional building services engineer with a wider education, who, as a member of the design team alongside the architect, structural engineer, etc., can make a creative contribution to the design at the conceptual stage, before the options are frozen, and that such an engineer, by studying on a scientific basis those subjects which would be most useful to him in his work, should be able to become a Chartered Engineer, and have his professional home in a chartered institution adapted to his needs.

Secondly: It would be a very good thing to have a forum, in the form of a learned society, where all the professions and trades who work together to shape our environment could come together and exchange views.

The difficulty in the first case is, of course, that the IHVE seems to put the cart before the horse when it demands a charter *before* the majority of its corporate members have reached the required standard — if that is in fact the case. But they can certainly claim that there is a precedent for such a procedure — in the case of the structural engineers, for instance, and probably in the case of most of the other CEI members too. So why should the IHVE be penalized? And they *need* a charter *now* to boost morale — and on balance it would, I think, be better to let them have it even if some of them were elevated beyond their proper station — after all, it is not the presence of bad but the scarcity of good engineers which is the trouble, the bad will be found out in time, and the supply of good engineers would be stimulated. But the CEI is, on the other hand, right in upholding the calibre of Chartered Engineers, it is their job to do so, and it would be wrong to devaluate the *designation* C. Eng. in the eyes of other nations. And the alternative of elevating only some of the IHVE corporate members to the blessed state is politically unacceptable. So that's where we are stuck.

When we turn to the question of the BSES, I must admit that I cannot understand why its launching should actually *delay* the granting of a charter to the IHVE. On the other hand there are, as mentioned, other societies and institutions who are already now engaged in such multi-disciplinary discussions, so why should the Civils, Mechanical and Electrical Engineers suddenly presume to lead in a domain in which until recently they have not shown much interest? Other bodies, especially the RIBA and the IHVE, would consider themselves more entitled to take the lead in this sphere. And, of course, if it really is only a Building Services Engineering Society, then the IHVE would have a strong claim. But that is another thing I don't understand:

Why should it have this name? I thought it was to 'foster co-operation between engineers and others in all the disciplines concerned with the design, operation and equipping of buildings' — or in another version 'with the total built environment'. So why not call it the Society for the Built Environment?

To sum up this part of my talk: The quarrel is not about what is needed, but about who should do what, and what labels to put on people. And that is really a sorry state of affairs.

Motivation

It stems, of course, from the schism in the motivation of a professional man.

On the one hand he wants to do a good and useful job.

On the other hand he wants to — and must — make a living. These two aims tend to conflict, and that gives rise to no end of trouble.

In any situation where many people possessing different skills have to produce an artefact — and that practically covers the whole of human endeavour in the building field — their work must be integrated if it is to produce a whole which possesses any kind of quality. This requires unselfish collaboration, and this means collaboration aimed at producing a good job and not hampered by considerations of personal glory, status or reward. But the quest for status, profit and the rest is a fact we have to live with, and it *does* interfere with the quality of practically every job, and with the quality of the whole of our environment in fact as our pollution problems testify.

Of course the two aims *need* not conflict. Quality of environment is being produced in patches without endangering the livelihood of those taking part in its production, indeed the opposite is just as likely to result. But only if the natural acquisitiveness, greed and personal ambition of man is kept under control and the quest for quality is given first priority.

Our real problems begin, however, when we realise that it is not enough to create quality in a few favoured locations, that our survival depends on our ability to create tolerable conditions for the whole of mankind without upsetting the balance of nature. But this is by the way, although it is of course this danger ahead which ought to bring us to our senses.

Through a long evolutionary process, civilized man has to a large extent learnt to keep his natural aggressiveness under control, at least in his personal relationships. We associate quite amicably with our potential rivals for jobs or promotion in our professional institutions. In fact the common interests form a bond between us, we feel friendly even towards unknown colleagues. We become a kind of brotherhood pursuing common interests, a mutual benefit society. And then the devil crops up again, our aggressiveness is transferred to the institution, internal unity is stimulated by cultivating a feeling of superiority towards lesser breeds in other institutions. Personal ambition is camouflaged as concern for the status and public image of our profession, our officers are unashamedly pursuing a policy of extending the size, the influence and the field of operations of our particular institution. It is their duty, they feel proud to do battle for what they have no doubt is a righteous cause. We move into the sphere of politics, decisions are reached through a tug-of-war between rival lobbies, not by disinterested reason.

Power struggle

This is a well-known phenomenon which applies to all kinds of groups able to exact loyalty from their members, whether tribes, nations, corporations, companies, religions or political factions or what have you, and it applies in a mild and comparatively innocuous form to professional institutions. This is what lies at the root of the present impasse, and this is how the affairs of the world are generally conducted — by a struggle for power of conflicting interests — and it appears to be the only way. But we know also that it can be a dangerous way, it can even lead to the destruction of mankind. Vietnam represents the ultimate in de-personalized aggression.

One could perhaps imagine a Utopia where affairs were managed more wisely. Loyalty to a narrow circle of friends, compatriots or confrères, which is a good thing in itself, would then not be allowed to detract from our loyalty to a wider entity, that of this whole planet of ours and the life it supports. We are not living in Utopia, however. But perhaps it is not too fanciful to suggest that architects, engineers and the producers of our artefacts could forget their interprofessional rivalries and concentrate on how to improve our habitat.

They all profess to do so — why not do it? It entails in some cases a widening of their horizon and a sacrifice of cherished inessentials.

Titles, letters behind your name, are these decorative features so important? Status, what does it mean? Let's get this thing in perspective. Can we not agree that it is the reality behind the facade which matters? Of course we need some labels. It's no good taking your shoes to the butcher to get them repaired — one must know or must be able to find out whom to go to. Modern society depends on advertising, and its usefulness is immensely enhanced if it is truthful. But how much of it is? In most cases a label tells you very little about what you really want to know. That so and so is a doctor, yes. But is he a good doctor? Will he kill you or cure you? Someone else is an architect. But is he a good architect? Of all those with the same qualifications some are good and some bad — or shall we say not so good. It can make an enormous difference to the job you get. And when you employ somebody or consult somebody you want to know not only his technical qualifications but what sort of person he is. Can you rely on him? does he mean what he says, is he truthful, reliable, honest, bright, friendly, easy to get on with? Titles and labels are not much use as a guide in this respect. The Honourable So-and-so could well be dishonourable, and the engineer who is a Doctor of Science may well be useless as a designer. We all know that, so why take these letters so seriously?

I know the answer, of course. Many employers take them seriously, institutions and Government departments take them seriously, your family take them seriously, so they can really mean something, even in hard cash, at least at the beginning of a career. And patience is in short supply nowadays.

I grant all that. But then we should try to make them really mean something. Make them truthful advertising.

And another thing. What is even more important than a C.Eng. is the reputation of an engineer among those who know him personally and know his work. If I wanted some really useful information about a man, I would try to find somebody whose opinion I valued and who knew the man. But that may not be easy. Then the only reliable way is to try him out. The proof of the pudding is in the eating. Of course reputations, status, fame can also be misleading. The only status worth bothering about is your standing among those who know you and whose opinion you value. And not least, your opinion of yourself — although even that could be the opinion of a fool!

These reflections are, of course, intended as a plea to concentrate on the essential thing: *to improve the value of our work to society, and that means without a shadow of doubt, learning to collaborate.* And improving the value of our work is not a bad way to improve our status, either. This may sound smug and banal — but nobody can deny that it is true.

To those bright boys who are supposed to hesitate before studying to become building service engineers because there is no Chartered Engineer status in sight at the end of their studies, I would say that they need have no fear that they can't get a good job at the end of it all. There is, and will be for a long time, a crying need for them.

So relax, and concentrate on your studies. For I hope that you haven't interpreted my words as a disparagement of what the title C.Eng. *should* stand for. To learn what the title demands you should learn is very important, in fact I think the standard should be raised, and that we should demand of Chartered Engineers both more basic science and more knowledge of adjoining fields. But long experience has told me that it is possible to pass an examination without deriving much benefit from it. Your ability to learn while you are working is more important. That an examination you passed as a young man or boy should mark you for life and put you in a certain category is a rather absurd over-simplification.

The architect and the engineer

The same can be said about the sharp division between the image of an architect and an engineer. The terms were coined in an earlier age, but they don't fit any more, and this leads to misunderstandings. I am not suggesting that we should abandon them but that we should now realize what they mean or should mean *now*.

We are in the midst of a transformation of the building industry. Arts and crafts are being replaced by science and technology — or should I say science-guided design and mechanized production. The process was in its early stages when I joined the fray, but now the rate of what we like to call progress has increased to such an extent that we must change our old ways of thinking.

Science-guided design and mechanized production — technology for short — is the domain of engineers.

It is advanced through engineering design. As the art and craft of building is being swamped by technology, the engineer muscles in on the building field. This is as it may look from an architect's point of view. He was once a master-builder. After he had ceased to be a builder himself, he was still master, he knew the art and craft of building, and he could design competently and tell the builder how the work should be done. But submerged by technology he had to learn new tricks, he was bewildered, insecure. He had to listen to advice. He was still master, but he did not master the technique of building any more. And a general who doesn't know his army, an artist who doesn't know his medium, and a designer who has to choose among unfamiliar materials and processes is in an insecure position. He cannot design with confidence. And he is in danger of losing the respect of those he commands.

But the architect wanted to remain master at all costs. For he had a sacred duty to perform. He represented the client, the user, the public. It was his responsibility to see that the building served its purpose, fitted into the neighbourhood, was a joy to behold and live or work in, did not cost more than his client could afford. All this, and more, as expectations of comfort rose, all the multiplying claims of the perfect architectural solution, including his own dreams of artistic wholeness and integrity — all this had to be achieved with the ever-increasing technical aids at his disposal.

But the engineer didn't see it this way. He could see where the architect blundered, his technical inadequacies, his squandering money on architectural or aesthetic aims which the engineer did not understand. He suspected that what the architect was doing was simply pandering to his own ego at his client's expense. And he didn't see why he, the engineer, couldn't go it alone, with the aid of the contractor, of course. He could get the foundations, the walls and the roof constructed, all sound and solid and waterproof, he could put in the required services, enclose the required number of rooms with access and exit — the lot. Why should he need a long-haired architect to tart it up and add to the expense — he knew what he liked, and if necessary he could always hire a tame architectural assistant to make a nice perspective for the client.

Artistic values

The client and the quantity surveyor, being concerned with value for money, were often inclined to share this view. Artistic values change, what one generation cherishes the next despises. To decide in the surge of new isms what is *'timeless'* art is difficult. Although this adjective is not infequently bestowed by critics, it is often doubtful whether it will stick. The average client cannot be expected to share contemporary artistic sensitivity, he likes what he is used to, so quite apart from technical and economic considerations, he dislikes modern architecture. He expects the architect to provide cosy old-world cottages with all modern conveniences, access by car, etc., and available for millions of new customers. Or so one would think if one read some of his complaints.

One could not expect the architect to accept this valuation. He still believed in his mission and struggled to keep aloft the banner of Architecture with a capital A.

This, I know, is a travesty of the present complex state of the engineer-architect confrontation. Like the image of Uncle Sam and John Bull, such caricatures have, however, a long life, and I wonder whether in the depths of the engineering jungle there are not tribes who still see reality in this way. And would this, I wonder again, be at the root of the idea that a successful integration of all the building services, or even a meaningful discussion of such integration, could be achieved without the participation of the architects, or the heating and ventilating and structural engineers, for that matter? Of course one must grant that there is a great deal of truth in this caricature, otherwise there would be no problem. But I believe in the architect's mission. All the same, some, or many architects, if you like, may not be good enough, cling to outworn ideas. *But architecture is important. It is about time engineers realized that engineering is useful, necessary indeed, but not enough.*

Specialization and the environment

I suppose I will have to try to explain and support this statement. But it should not be necessary for me to go into the whole question of pollution, squandering of scarce resources, overpopulation and the rest. That mankind is in a precarious situation we all realize by now. And, as Barry Commoner so convincingly argued at the recent RIBA annual conference on 'Designing for survival', the root cause of the trouble is the massive introduction of new technologies, impelled by greed and fear.

The environment created by natural forces acting in compliance with their own laws, by fauna and flora in equilibrium or by the dwelling or tilling patterns of a pre-industrial era, all speak to us in some way — it can be awe-inspiring or sinister, squalid or pathetic, it can lift up our heart or welcome us. But the environment created by uncontrolled industrial processes, the ravishing of our countryside, the pollution, the insensitive building for profit, simply disgust us. To feel at home we must feel the impact of the human mind on our environment, not the mind of the rapist but the lover.

What could save us is also technology, but wisely guided to serve humanity. But how do we, and can we, guide technology wisely? That is the question. Technology is guided by design, and designing is decision making. These decisions are made by people. And if only these people would make the right decisions we would be home and dry.

What are the right decisions? A designer, to make the right decisions, must know:

(1) What he should try to achieve, and

(2) How to go about achieving it.

Aims and means, for short. The engineer is not used to worrying his head very much about the first of these problems. His task is set for him — to span a river, invent a machine to make buttons, produce an insecticide to kill certain pests. He throws himself enthusiastically into the problem and comes up with an answer. The best answer he can think of. Until recently, at least, it didn't occur to him to doubt the value of his work. In fact he saw himself as a benefactor, liberating man from drudgery and fear of want. Did he not harness the forces of nature for his benefit? Did he not increase man's power, force the earth to yield its riches?

These achievements were based on specialization. And the more the engineer specialized, the narrower was his aim, the more he shut himself off from any global view of things.

Recently I attended the Fourth Fluid Science Lecture at the Royal Institution. The speaker was Mr Braikevitch, one of the world's foremost water turbine engineers, one of those who need no introduction, but whose name I had never heard of, typically enough. He talked about the development of the water turbine. He had apparently devoted his life to the improvement of this very important tool, continuing the work of previous generations. And a very full life it was, too. According to the speaker, there is more to this machine than meets the eye. Water is a fickle mistress, it has to be coaxed, but like a human being it works better when given a little freedom. As every part of a turbine is inter-connected hydraulically with its neighbour, fluid engineering has to be applied right the way through so that a harmonious whole is obtained, and the efficiency is at the maximum. The research field is therefore much wider than the lecturer was able to indicate.

Obviously, trial and error, science, and feeling for the totality, the soul of the machine, all this and more went into it. Obviously he was an artist in his domain.

The aim of all that effort was to increase the output of electricity which could be obtained from a given variation in water levels.

Who could possibly object to this aim?

I remember as a child staying with my maternal grandparents in Norway and hearing people discuss a proposal to harness the largest and most spectacular Norwegian waterfall, the Rjukan, to provide electric power. I remember the sorrow and dismay they felt at the possible loss of this awe-inspiring national monument. I was sad, too, for I would for ever by deprived of the possibility of seeing this sight. It was, I suppose, the first time I had an inkling of the ecological consequences of technology, although I didn't exactly put it that way.

A trivial matter? Perhaps. But have you ever been spell-bound by the majesty of such a display in a setting of great natural beauty? It does something to you. It teaches you humility. Have we a right to deprive mankind of such an experience forever, everywhere?

One could mention hundreds of such specialized disciplines or technologies exacting complete devotion from their acolytes, with their institutions, congresses, trade journals and their heroes who need no introduction but are unknown outside the charmed circle. And all have impeccable aims. Aims which obviously benefit mankind.

And yet, when you add it all up, there seems to be something wrong. The undoubted progress seems to be somewhat patchy. It is good in parts, like the curate's egg — but taken as a whole, the curate's was a bad egg. What went wrong? Obviously, in pursuing their aims, engineers also achieved a great number of other things. Some of them perhaps relatively harmless on a small scale, but catastrophic if large-scale interference upset the balance of nature. Like the medicine that cured the fever and killed the patient. We must understand that everything we do affects everything else, and that we must consider the consequences of our actions. Efficiency in achieving our narrow aim at the lowest cost to us or our client cannot remain our only yardstick. Systems engineering and value engineering attempt to take into account the effects of a given technological decision when assessing its merit. But merit is still equated with cost-efficiency. This is something entirely different from human welfare. Engineers have been very successful in solving the problems they are faced with. Almost too successful, for we cannot resist the temptation to show off, to do things just because we are able to do them, without considering whether we really need them. During the war we were told to ask ourselves whether our journey was really necessary in view of the need to save resources for the war effort. We have a war on now, and we would do well to ask the same question. In other words, we must pay more attention to the first problem.

What should our designs try to achieve?

We must take a critical look at the brief, make it more comprehensive. We must look beyond the narrow object and ask ourselves: What will be the ecological consequences? What about the working conditions for those who carry out the work, including their spiritual well-being; will the work provide useful employment or cause unemployment — perhaps in other countries? What effect has it on other industries? What is the cost in scarce resources? We must ask ourselves what would happen if everybody else did what we do. Would that serve humanity? The Kantian criteria for ethical conduct.

Taking this global view is a daunting task. Engineers have a big role to play in this discussion about aims, for just as it is no good doing things which serve no useful purpose or are harmful to humanity, so it is no good aiming at things which can't be done. You cannot alter the law of gravity, for instance.

I am afraid I have spent too much time in proving the obvious: that the failure of our civilization is not a failure to increase our power, but a failure to use it wisely. We must bring technology under the control of man for the benefit of man. This has been said a thousand times, of course. Both architects and engineers see themselves as fulfilling this role. Both are right, to a certain degree, but to understand their respective roles better, we must study them in the milieu in which they cannot avoid the necessity of collaborating, the urban environment.

Design

Architects and engineers both see themselves as designers. And although the majority of engineers and a great number of architects can hardly be called that. It's the designers I am concerned with here. For the design, as I use the word, is the key to what is built; it is the record of all the decisions which have a bearing on the shape and all other aspects of the object constructed. These decisions are unfortunately not all taken by the designer but they must be known to him and integrated into a total design.

We must distinguish between routine design, which does not require any creative thinking, and what may be labelled original, innovative, conceptual or creative design. Creative design must, of course, build on previous experience and contains and employs predesigned parts, and it may even consist almost entirely in assembling such parts to create an entity. But building is always tied to locality and to the people one builds for, and they vary from case to case. The synthesis required to create an entity, a whole which economizes in means yet fulfils the aims, is an artistic process.

Art, as the Danish author Piet Hein has stressed, is solving problems which cannot be formulated before they have been solved. The search goes on, until a solution is found, which is deemed to be satisfactory. There are always many possible solutions, *the search is for the best* — but there is no best — just more or less good. *Quality is produced if the search doesn't stop at a second-rate solution but continues until no better solution can be found.*

The artist who knows his stuff — literally — knows when it clicks. Then he knows: this is the best I can do. He has his own artistic yardstick — and if he is satisfied there is a good chance that his work will make other people happy — for he should be his own most severe critic. But this statement carries no guarantee with it, for sometimes he isn't.

This extra exertion is not dependent on monetary reward, and frequently goes without, but it is indispensable if the result is to possess any quality.

All this applies to engineering design as well as architectural design — in areas where both act as prime agents. In both cases the designer is responsible for a structural entity, and in both cases he is trying to make it function well, last well, look well and cost little, or to put it differently: make it fulfil all the requirements of the brief including the aforementioned social and ecological aims, at the least cost to the community.

An engineer who doesn't care a damn what his design looks like as long as it works and is cheap, who doesn't care for elegance, neatness, order and simplicity for its own sake, is not a good engineer. This needs to be stressed.

The distinctive features of engineering are mainly matters of content — the nature of the parts and the aims.

Engineering structures are mainly concerned with the forces of nature, overcoming difficult soil conditions, retaining earth and water, containing grain and liquids, spanning rivers, creating terra firma in deep water, moving mountains and taming rivers. All very difficult but with easily defined aims.

Architects, on the other hand, have to deal with people. Cater for them, cosset them. Would you like a little more heat, or light? Do you like your living room facing west? Or would you prefer the view on the golf course? And as the people can't reply, they have to choose for them, and get the brick-bats later.

People are fickle. They differ. They quarrel. They flock together. They want privacy. They want to drive their cars everywhere. They hate other people's cars. It is quite a difficult problem. Compared to that, the actual physical obstacles to overcome are generally trivial.

But enough of that. Besides this kind of difference there is the difference in background and education and the resulting values of criteria. What the engineer sees as a structure, the architect sees as a sculpture. Actually, of course, it is both.

In building, the entity we want to perfect is not the structure or the air-conditioning as such — although that as well — it is the sum of all these parts. The engineer only designs a part of the total. His ideal structure may occupy space which is required for other purposes, it is also part of the architectural composition and therefore subject to other criteria. The ideal air-conditioning system cannot be installed because there is not enough money or because it is deemed more desirable to enable the windows to be opened, etc. The search in this case is for a comprehensive quality which is a sum of particular qualities, each measured with its own particular yardstick, but modified to fit into a general pattern.

The success of the whole undertaking depends on the right allocation of priorities and whether the resulting entity has this quality of wholeness and obvious rightness which is the mark of a work of art.

And as this sounds a bit high-falutin I will try to show you some slides which may throw some light on what I mean, or at least will relieve the tedium.

1 Cafe and shelter: Canvey Island

2 Model of spiral tower for Clacton Pier

Examples

I recently found some prewar photographs and press-cuttngs in an old folder, and I will show you a few of these.

(1) The first example is, I think, the first building I had anything to do with. It is a small cafe and shelter built just behind the river wall in Canvey Island in 1932 or '33, by Christiani and Nielsen, specialists in the design and construction of reinforced concrete structures.

I was employed by them as their chief engineer in the London office. I functioned both as architect, engineer and contractor — but was severely restricted by lack of funds and lack of architectural training. But as you can see, I had an architectural 'image' derived from the Modern Movement — a kind of mock Mendelsohn, or perhaps Tecton. The steel columns supporting the canopy of the shelter roof, introduced here to restrict the view as little as possible, definitely remind me of the Penguin Pool at the Zoo — and other Zoo jobs. Although I think these came later — so perhaps I went to the fountain head, le Corbusier. Anyhow, the circular café with windows all round, everything supported on a concrete cylinder on piles, and its extension upwards through the café in the form of six columns supporting the roof, all this couldn't be simpler, and was certainly cheap — and, I am afraid, also rather nasty. Anway the one time I was allowed to visit the job — my place was in the office — I was depressed by the shoddiness of the cheap standard metal windows, the concrete which had received only the normal contractor's rubbing down with cement grout and cement wash or perhaps a coat of *Stic B*, the bare columns supporting the concrete drum at the back, the cheap lino and desk, the bad detailing. But I couldn't do anything about that.

The moral of it all? That architecture on the cheap by an amateur architect employed by a contractor, and a client with no money to spend, is not a good way in which to achieve perfection.

(2) The next slide shows a model of an ambitious scheme to build a spiral tower at the end of Clacton Pier. Visitors would enter through a central lift and then gently meander down a spiral concrete ramp, passing the shops, stalls, etc. (including peeps at what the butler saw) which were arranged on the inside. Much the same idea was later adopted by Frank Lloyd Wright for his Guggenheim Museum in New York but I am not suggesting he got the idea from me! The construction was very simple, a cone of inclined columns supported on pile groups or cylinders, and supporting the double cantilevered concrete ramp, which in turn contributed to the stability. It was much cheaper than making a long pier deck to house the stalls. I took the model to Mr Kingsman, the owner, who resided on the Riviera in the winter. He and his family were enthusiastic, but later saner consel prevailed. The scheme was never built.

Moral? That bright ideas too much removed from the ordinary run of the mill hardly ever get adopted. Certainly not in prewar Britain.

3 Water tower

(3) The next is a sad story, for this monster *was* actually built. The client wanted a water tower with the tank divided into five compartments, four of equal size and one larger. As his architect was unfamiliar with water tanks or reinforced concrete, he asked my firm — J.L. Kier and Company — to give him a price for design and construction.

I came up with a scheme with four circular tanks on slender circular columns, flaring at the top to support the tank walls. The fifth tank was formed by the space between the interconnected tanks. It was a monument beautiful to behold. But then the architect got the bright idea of using the space in beween the columns for an office, adding some decorative features, rims at the top and bottom of the tanks, etc., which considerably complicated the formwork.

Moral? The intervention of an architect, even if he succeeds in pleasing the client, is not always helpful.

(4) Highpoint by Tecton, is quite a different story. Here was an architect, who knew what he wanted, and how to get it. An architect, I say — there were seven young architects, all equal, trading under this name, but one was more equal than the others. His name was Lubetkin, and from him I learnt among other things that architecture involves taking infinite care over every detail, including services, fittings, and other installations. Every tile was placed in an orderly pattern of unbroken squares, floor tiles lined up with wall tiles.

Lubetkin detailed the liftcage and shaft in tubular steel and netting, light and elegant, and between us we dealt with waterproofing, insulation, surface treatment of concrete, etc., in a very dilettantish way, I am afraid. It had to be cheap, and shoddiness gradually resulted, as with all these modern Corb-inspired buildings.

I dealt with the structural design, suggesting doing away with columns and beams inside the concrete box — which pleased Lubetkin — and organizing the construction, devising a special moving platform raised by jacks from which the formwork was suspended.

And I had to fight the authorities about the bye-laws and concrete regulations. So between us it was complete integration of design and construction. The heating was done by Hadens, hot water tubes being embedded in the concrete floors, a new development at the time.

Moral? Taking pains gets results.

4 Construction and right: interior of Highpoint 1

(5) The fifth is Brynmawr Rubber Factory, designed by four young architects, the nucleus of the later ACP, or Architects Co-Partnership. It bubbles over with shells, as Jane Drew described it at that time. What I would like to point out is the way the heating and ventilation were integrated with the roof structure of the main hall. The two main ducts blowing hot air into this area were housed inside two edge beams of adjoining square domes and the point is that the whole form of construction was especially chosen to make this possible, so avoiding the usual ugly ducting. That among other things, is what integrated design means, and I can't see how that can be achieved without the architect and the structural engineer coming into the picture beside the heating consultant.

And that is the moral.

(6) Lastly I show a few slides of Sydney Opera House. Utzon believed in the architect having control of every visible detail, like Lubetkin, and he undoubtedly was an architectural genius. But the organization he built up was not capable of dealing that way with a job of this complexity and magnitude. All went well as long as he was only dealing with the structure — the architecture in this case is the structure, he used to say — but integrating the unbelievably complex installations and furnishings with the structure in his exacting way could only have been done by a much more expert integrating team. The thing had to be completed without him, but it could not be done by anybody — or by Utzon himself, for that matter — to Utzon's standards. But Utzon's brilliant spatial conception has secured him a place in the architectural firmament.

The design team

Lubetkin and Utzon are what are generally referred to as *prima donna* architects, and this is meant as an insult, the image being associated with egocentric soloists throwing tantrums. Their contribution, however, is more that of a conductor — to choose another metaphor from music, so I will use the term architect-conductors. A conductor must know the score, obviously, and he must achieve a balance of sound which is faithful to the score but adds his own artistic touch to the whole. This must be hammered out in rehearsals. The conductor who only strikes attitudes and lets the orchestra get on as best it can does not deserve the name.

What does happen when the architect-conductor is mainly a visual artist, which is generally the case, is that he will allot too

5 Brynmawr Rubber Factory aerial view and, left: interior

6 Sydney Opera House

high a priority to sculptural or aesthetic quality. On the other hand his critics in most cases have also the wrong priorities, for they underrate visual or spatial quality for lack of visual training or sensitivity. You can't make a deaf man appreciate music. Yet spatial music *is* important. For we must build in space and in light, we appreciate the relationships of things in space and move in space and we create our own space. So a visual artist is not a bad conductor in this case, provided he has humanity and builds for people.

Leaving it to the architect-conductor to solve all his problems with the aid of his own team of architectural assistants and the specialists he consults, and the manufacturers he guides, can therefore give excellent results, depending on the master mind. But it breaks down in the case of large, technically sophisticated jobs. He must then at least have advisers and collaborators who are constantly at hand, also at the conceptual stage, for the whole way of tackling the job may depend on their advice — he cannot any more impose a visual pattern, it is the parameters, to use Lionel Brett's phrase, which govern the conception.

But as long as the various disciplines and trades involved are represented by different firms, it is difficult to involve them all at the conceptual stage. And in any case you can only involve a few key men at that stage, otherwise the whole affair develops into a design by committee. And most important, those key men must share the conductor's view of what the aim is, and must try to achieve 'the complete integration of structure and services which will best serve that aim'.

This can as a rule be best achieved if they are independent consultants and not representatives of commercial firms. But they must not be specialists in a narrow field only — otherwise there will be too many of them. They must represent a broader section of the total technological knowledge required, able to produce — from inside their own firms, or by calling in from outside — *ad hoc* specialists as needed. They will in fact be assistant architects. Not on paper but in action. For not only should they understand the conductor's architectural ideas and approve of them, but like the architect they each represent a team covering a multiplicity of detailed knowledge and experience in a particular area of related subjects. They are also synthesizers, like the architect. It would not be a bad idea to recognize this and call them structural architects, building services architects, etc., etc., if they really are capable of fitting that role.

In the past, there have always been large lacunae in the combined knowledge of architects and consultants, which were covered by hunches and rules of thumb. That's why the fabric deteriorates, and the services don't work. This must stop; responsibility must be squarely placed in one camp or another.

The integration will then be effected from the top, so to speak, by the architect-conductor in conclave with his chief assistants and specialist co-architects, who then each will see to it that his particular team, including the *ad hoc* advisers needed, carries out the leader's agreed intentions.

Such a system can work very well, it is the parallel working which in a more or less incomplete form is generally practised.

The question has often been raised whether another profession could not fill the role of the leader. Of course, but it is not a profession but a person (with his team) which is the leader — and it depends on that person. He must then have the necessary qualifications for such leadership. He must be able to assess the priorities and effect the synthesis, be in effect an architect-conductor — in my sense.

I have not time now to discuss which technical co-architects will be required and what their role should be. There will obviously be a structural architect, for the structure and fabric of the whole building is the physical expression of the architecture. And there will equally certainly be a building services architect. As the name implies, he should cover all services, but should also understand the architectural and structural implications of their spatial requirements and the psychological and physiological effect on human beings of light and glare, of humidity, heat and radiation, noise vibration, acoustics — as well as the economic and ecological aspects of different sources of power. It is a very wide field and is largely dealt with by architectural hunches — which are very important, but can hardly deal with modern technological sophistication. One man cannot deal with all these aspects — but he should be able to call on the needed expertise as required. He would be of immense help to the building team, in fact without him expensive blunders are inevitable. And, of course, he should be able to achieve chartered status, but his status would be assured, anyway, if he could fill the role.

And may I say again that encouraging high calibre people to fill this role is much more important than any inter-institutional rivalries. If giving them chartered status furthers this aim, ways should be found to give it to them. If no more charters are available, they should combine with the Structurals, who also provide a building service, or with the Mechanicals, or some of the other institutions should combine — Structural with Civil for instance, which would be sensible — or what about Mining with Mining and Metallurgy, Marine Engineers with Naval Architects — leaving a space open, so to speak. This may be utterly naive, but those who know the ins and outs should find a way.

I wonder, are institutions created to prevent us from doing what we want to, or to give us an excuse for *not* doing what we ought? Surely not, so let bygones be bygones, kiss and be friends and let Fred have his lollipop. And if you think I am not serious you are wrong.

There is a third chief adviser who I think is needed, especially when the design stretches into untrodden territory. It is a production engineer, or operational costing expert. But this is a chapter in itself, and highly controversial to boot. I have probably offended enough people for one evening, and I have no time, either.

There are, of course, many ways of working other than the way I have just described, in fact the possible permutations are legion. There is, for instance, the contractor's package deal, and there is the multidisciplinary team working as we practise it in Arup Associates.

The latter is probably the best way to eliminate professional rivalries and create the right enthusiasm straight down the line, but it takes time. The quality of people plus enthusiasm is what matters, much more so than the type of organization. But the latter should be of a kind to encourage and not thwart enthusiasm.

The comprehensive view

Just one thing more — to set up an organization which is able to effect the integration of diverse elements of the environmental fabric is one thing. But its usefulness is severely restricted by existing bureaucratic boundaries.

Every time a major surgical operation disturbs established environmental patterns it sparks off side effects which may even make the proposed operation obsolete before it can fulfil its function. Where people live and work determines the transport network that establishes routes for underground services that feed the buildings with light, heat, water and tele-communications. These in turn generate new and inter-related problems and so on almost *ad infinitum*. A comprehensive is essential. But departments keep on dealing with one aspect at a time.

The establishment of the Department of the Environment is the Central Government's answer to this problem. But will this enormous conglomeration of civil servants and professional gentlemen be able to cope with it? It seems almost too much to expect.

We must hope that they will learn by experience, it is obviously a step in the right direction. But we are beginning to witness the emergence of pressure groups of laymen who no longer are satisfied to trust the collective wisdom of the professionals to supervise our environment. The task is to restore trust in our ability to tackle comprehensive problems comprehensively.

Our aims must be comprehensive.

Our building competent.

But priorities must be fixed by men, not by machines.

I have said both too much and too little. I have tried to place the problem in its global or overall setting and therefore courted and, I am afraid, not avoided the dangers of superficiality. But I have made it clear, I think, where I stand.

I honestly cannot see how the BSES can achieve what it set out to achieve as long as the principal institutions concerned with building oppose it. It would become a bone of contention instead of a unifying influence.

And we very much need a unifying influence. I am all for a society of this kind, but the name should be something like the Society for the Built Environment. And it should not be the property of any institution. I cannot see the architects flocking to a meeting at the Civils or the engineers coming to the RIBA.

The venue could be changed from time to time, meetings could be arranged also in other cities. It should, of course, be supported by all those institutions who are now sulking — no disrespect intended — and it should collaborate with or absorb the Junior Liaison Organization and perhaps other groups who have the same aim. And the governing body, or at least the body that takes the initiative, should not consist of a representative from each of the sponsoring institutions or anything of that kind. It is not their job to represent anything except common sense. To run the show we should have people who understand the problems, who are convinced of the need for collaboration and have the enthusiasm, drive and *tact* to further the aims of the society. (The last is inserted to leave me out).

And finally I suggest that the matter should be taken to the Presidents' Committee for the Urban Environment to initiate the formation of such a reformed society. This was Alex Gordon's suggestion, and it is obviously a sensible one, as you would expect. I hope the present sponsors would generously agree to that.

It remains to thank my hosts for affording me the liberty to express my views. If I should have caused offence I regret it — but I can only say what I think is right. If I am not right, then I can only ask you to forgive me. If I should have been able to convince you that my views are sound, you will be generous enough to act on them.

But I cannot help thinking of Orwell's words in the recently discovered foreword to Animal Farm:

'Liberty means the right to tell people what they do not want to hear'.

To which my secretary cynically added:

'Stupidity is expecting that they will listen'.

Institution of Structural Engineers Gold Medal Speech

This speech was given when Ove Arup received the 12th Gold Medal of the Institution on 11 October 1973.

First of all I want to thank the President and Council and all of you for honouring me in this way. I am naturally very pleased, and I don't think this statement needs supporting evidence or argument. I was also very surprised, at least in the sense that I didn't expect it. Whether I think I *deserve* it is yet another question, and one to which I am not prepared to give a straight answer – sometimes I do and sometimes I don't.

In your very generous citation you honour me for my rare ability to influence the thoughts of my colleagues. If you say so, I suppose I must have influenced them – it is not for me to judge. It must obviously be left to those who have been so influenced to bear witness; which presumably they have done – and that it is a good influence is obvious from the whole context, so that is very gratifying. In fact it is quite marvellous what you say, I couldn't ask for more. But – I ask myself – what does this influence all amount to?

Perhaps that is a naughty question to ask, and perhaps I am fundamentally naughty, although I try to conceal it. But obviously everyone must put his own valuation on whatever praise or blame comes his way, so as not to get swollen-headed or unnecessarily dejected. As I have said before, to be fooled by praise or praised by fools profits no one. And it could be said that all the things I have spent my life trying to say and do and teach are simple, commonplace, and obvious, things that every moderately sensible person would know. For instance:

that design and construction are interdependent and must be adjusted to one another

that simplicity of design makes economic and aesthetic sense

that two parallel brick walls covered with a reinforced concrete slab don't provide a good shelter against blast

that when we build we don't want a good structure, but a good house

that when many cooks make a dish, they had better agree amongst themselves about the recipe

that to start thinking about the cost of what you are designing after you have designed it, is a bit late

that it is a waste of time to base exact calculations on rough assumptions, or a strong building on weak foundations, or in general to pursue the means without defining the ends

All that, and more, – it hardly seems to merit a Gold Medal, exactly. At least, if it does, it isn't because it is particularly clever. It must be because it needed saying just the same.

And as for influence – my persuasive powers may have worked with my colleagues, and with my collaborators especially. But I don't always seem to have made much headway with government departments or with official bodies. During the war, for instance, I remember I struggled hard to save steel for the war effort, and to knock some sense into official shelter policy – with scant success.

Institution of Structural Engineers Gold Medal

So you see, it isn't just a matter of what you say. It also depends on whom you say it to and when. You have to be fortunate enough to find people who will listen to you, so that concerted action can result. Ideas are powerful: that's why totalitarian states are afraid of them. But it's a delayed action.

They take time to sink in, and still more time to produce practical results – and the latter depends on other people.

Mind you, I am not trying to argue that I don't deserve the medal. It would be very sad if my rare ability to influence others persuaded you to take it back again. It may be that my ideas are not explosive, that they are very simple; they are just common sense. But it is unfortunately also true that most of the mistakes made by engineers – and I suppose it applies to other people too – are elementary, are in fact due to lack of common sense. It is not so much that the involved calculations go wrong. It is more often that the structural system to which they are applied is basically unstable, or acts as a mechanism. Or that some forces are simply forgotten.

Or that people think and draw in two dimensions, forgetting the third which may contain some awkward forces. Or they forget that the design has to be built, and must therefore be possible and preferably not too difficult to build and should be stable during all stages of the construction. Or that they put things in the wrong place altogether, because the whole purpose of what they are doing is barely considered.

I could tell you many frightening stories of failures of common sense. There was one glaring and almost incredible case. I know I shouldn't tell you about it, because it casts a not too favourable light on the *Journal of the Institution of Structural Engineers*. But it was in 1929, and the Journal now is not what it was then, it has improved beyond all measure, and what happened then certainly couldn't happen now. So perhaps I may be forgiven.

An article by a past President of the Institution appeared in the Journal under the heading: 'Notes on a failure due to subsidence under tidal pressures'. He had been called in to apportion blame in a case where a retaining wall or wharf had collapsed as soon as the backfilling was placed. The wall was L-shaped, some 20 ft. high, with counterforts about every 10 ft., each supported on two, almost vertical, piles. There was absolutely nothing there that would prevent the wall from being pushed forward by the filling, one could see that at a glance by looking at the cross-section. No anchors, no raking piles. And isn't it remarkable that in those days a design like that could be adopted, the contractor could build it without protest, and a learned and respected engineer could undertake completely unnecessary measurements of minute vertical and horizontal movements of the mud in front of the wall under the influence of the tides, and his report could be published in an engineering journal, without anybody raising an eyebrow so far as I know. So I piped up. I sent an article to the Journal gently pointing out the facts of life – only to be told that it was controversial and couldn't be published under the umbrella of the editor. I could only be allowed to send in a private letter, which could go in at the back of the journal on my own responsibility. So that's what I did and waited for the explosion. And I never heard another word about it.

That was long ago, and times have changed. But wasn't Ronan Point a similar case? Isn't it clear as daylight that when you have an end wall, which is not tied back, supporting a portion of the building, and when an explosion takes place behind it, then what must happen is exactly what did happen? The important difference is, of course, that a backfilling is bound to exert a pressure, whereas explosions are not bound to take place, and were in any case not officially anticipated in the regulations. So perhaps the remedy is official anticipation; in other words more regulations. Or perhaps what is needed is the kind of common sense that would reject a structure which only needed a hard push to come tumbling down. And if once it is generally accepted that designs may be successfully produced simply by applying a host of detailed regulations, common sense does tend to get left out.

So perhaps after all it is useful to repeat obvious things again and again. When I was young and innocent I would have hesitated to do so – but now that I am old and cynical, I have learned better; and so I fully intend to continue to utter platitudes for the rest of my life.

And that, surely must be the perfect lead-in to allow me to trot out again some of my old hobby horses. To say again, for instance, that a structure exists for a purpose and as part of an entity that also has its purpose; and that the efficiency of a structure can only be judged in the light of these various purposes great and small. To insist again on the need to integrate the work of the various disciplines in the building industry, in order to achieve greater efficiency, and greater artistic control. All right – old hat it may be; but the hat still fits. The plain facts are that architecture will die if it is not efficient; and that we *need* an environment where we can feel at home – which is what architecture stands for. Such facts are no less true now that we are undertaking tasks of ever-increasing size and complexity, with ever more complex technical resources at our command. And when I say that design should aim at a practical fulfilment of purpose, this is the purpose I have in mind.

But it is not the purpose that is forced upon us. For totally integrated comprehensive architecture will result in efficiency of execution, but will also require much effort and dedicated involvement on the part of the directing team. And the onslaught of mechanization and standardization, the compulsion to minimize human efforts, to reduce cost at whatever cost, all this may spell – I am afraid – the end of design as an art. And of course many people realize now that our economic thinking is faulty, that the cost in human happiness is too high, that we are frantically busy building on sinking foundations. We can afford, if need be, a lowering of material standards. What we can't afford is to lose our humanity.

But there is no agreement on what we can do about it; the radical measures required for reversing the trend seem impossible to realize. Perhaps I can put it this way: that unless we cultivate an art of the impossible, we may well be doomed.

This is a gloomy note to end on, I am afraid. But receiving a Gold Medal should be, not an impediment, but an encouragement to speak one's mind. It is in my mind that the time ahead is going to call for common sense to a quite uncommon degree.

Finally, I thank you again for my Gold Medal. I am aware that to get a Gold Medal one also has to be lucky. One must firstly have collaborators who follow up ideas with actions and one must live long enough for such actions to bear fruit. I have been lucky in both respects. One of my partners, a very distinguished member of your institution, happens to have been with me for 30 years this very day, and I honestly don't know what the firm or I would have done without him. I think you can guess his name.

I conclude therefore by thanking my partners and collaborators who should really be sharing my medal with me and also last but not least, my wife, who *will* share the medal with me.

The Building Centre

A talk given at The Building Centre, 18 May 1978.

Origins

The Building Centre came into being because a number of public spirited people concerned with building in some way or other felt that something like that was needed to take advantage of the many new materials and inventions which had come on the market lately, and they decided to *do* something about it. They were not so very clear about what exactly was needed and how to finance the venture, but in the typical British way they started on a small scale with something obviously useful, a samples room at the Architectural Association perhaps, roped in like-minded people who gave of their time and money, and off they were. Where to? — that could be and was discussed on the way, as the nature of the country dictated.

That this developed into the present Building Centre is a tribute to the devotion and tenacity of the founders. But that is not what I want to dwell on tonight. Instead I will try to tackle the problem from the other end: why do we need a Building Centre? What is it for, and what should it provide, ideally speaking, if money were no problem?

My point of view will be that of a designer who is trying to find the best possible solution to design problems occurring in buildings, and I am suggesting that to help designers in this task should be the main aim of the Building Centre.

Total design

This is not such a one-sided view as it may seem to be. For it can be argued — as I have done for 40 years — that what I call the Total Design is the key to what is built. If the design is right, and, if it is executed as intended, then the job will be right. And the aim of the designer of buildings or parts of buildings, and that of the building industry as a whole, as well as that of the general public, must of course be to get the best possible buildings at the right cost, which as I have argued, means ensuring that the design is right. The execution must be right as well, of course, but that is another matter; the design must be tackled first.

The word design can mean so many things, however, and it is necessary to emphasize that here I am talking about the Total Design, by which I understand the sum of *all* the design decisions made by many people with different functions and which collectively define the finished job. The decision may be recorded in specifications, on drawings or sketches, in by-laws and regulations, or it may be contained in the client's brief, or consist of verbal instructions by clients or foremen or others; the test is whether the decision affects what is being built or constructed.

It will be readily seen that there is practically no limit to the number of Total Designs which could be made for an artefact consisting of parts which can be varied and combined in an almost infinite number of ways — good, bad or indifferent. But how do we know which is which? How do we recognize the 'goodness' of a building, or of any human artefact, for that matter? Which of all the possible designs is the best one?

Quality

A quantity surveyor can't help us, for he can only sum up the quantities and transform them into costs, but he will miss what is most important — what we may call the quality of the building. But quality — what is it?

We come up against the fact that quality can't be measured. We may recognize quality when we see it, but we can't define it. And the worst is, that it means something different to different people. 'One man's meat is another man's poison' as they say.

But it would be wrong to conclude from this that quality only exists in the eye of the beholder. When it comes to works of art we have plenty of 'Quality Surveyors' — critics, historians, practising artists, or students of art, who are very willing to tell us what is good and what is bad, and they would strongly deny that they only spoke for themselves. They consider themselves as experts on a particular art form, at least inside a cultural frame of reference. It is true that they often disagree. There are factions and fashions in the world of art. But inside each of these factions or fashions it is possible to distinguish works of character and quality from what is just immature rubbish, more or less. And unless an artist has this veneration for art, and believes in the mission of the artist, he is unlikely to produce anything outstanding. The highest accolade which can be bestowed on a work of art is to call it timeless art. But how timeless? If humanity perishes — 'timeless art' has no meaning.

When we come to building, the situation is somewhat different, for a building is more than a work of art. It has work of its own to do, it should satisfy a great many different requirements, which might, with some contrivance, be summarized under the headings: commodity, firmness and delight. Unfortunately they often clash with each other and money is mostly short.

We therefore have to fix our priorities to make a judgement and these priorities are bound to vary, for instance according to whether we judge the building as users, owners or just onlookers.

The quality of a building thus appears as a conglomeration of different qualities which, however, cannot be added up to produce a sum which would be an index of the total quality, for they have no common denominator. Some qualities, like stability, are essential up to a point and useless thereafter — others are marginally desirable, some make for comfort, some for beauty and some of economy — it is a question of what you want most.

The functions and what we might call the engineering qualities of rival schemes can, to some extent, be measured and compared. It may take some time before their true worth is revealed, however. In contrast, we are immediately aware of the visual aspects of a scheme as represented by perspectives or models, and it is on this basis that its place in the architectural hierarchy is determined. This can often be very misleading.

Many people suffer through having to live or work in architectural masterpieces and many highly praised designs in architectural competitions couldn't be built as depicted or would fall down if they were built.

In line with this, it is nearly always the architect who is blamed if a building project happens to displease, or praised if it pleases, for whatever reason. This is often unjust — but on the whole it makes sense, for it is the architectural direction which determines what we get — the technique is only the means of getting it.

Any good design must strive both to create internal harmony between its parts and outward harmony with its surroundings. As the Total Design is not often the creation of one man, as the public is led to believe by the media, but is affected by the design decisions of numerous people largely motivated by their own aims, this internal and external harmony or integration can only be achieved if the designers themselves work in harmony.

Choosing

Designing is choosing: the materials, the structure, the spatial layout, the services, all of it. Without choice there can be no perfection — perfection is choosing rightly all the time. But we don't invent everything from scratch. More and more designing is becoming the judicious assembling of pre-manufactured parts. The right parts, assembled the right way.

The choosing must therefore be guided by a vision of the whole. If this vision is accepted by the whole design team, and has the enthusiastic backing of the clients, then there is the best possible chance of a happy ending. Unfortunately this does not happen too often.

To choose the right materials and parts, we must, of course, also know that they exist, where they can be got, their properties and price, so that we can compare them and choose those that best serve our purpose. If I may quote from an address which I gave to the British Association for the Advancement of Science during the War in January 1942 '... a wealth of new knowledge, new materials, new processes has so widened the field of possibilities, that it cannot be adequately surveyed by a single mind...and the usual problem arises — how to create the organization, the "composite mind" so to speak, which can achieve a well-balanced synthesis from the wealth of available detail. This is, I suppose, one of the central problems of our time.'

My answer was at that time, briefly:

(1) 'One is to have the planning carried out by a team of experts whose combined knowledge covers a substantial part of the relevant technical information.

(2) Another is to have all the technical information which may have a bearing on the problem checked up, classified, standardized and made easily available.'

If this was needed then, it is 10 times as much needed now, and what the Building Centre is trying to do is really to help with the second requirement, that of knowing which materials and resources are available. They are doing a very useful job in that line, but there is still a considerable gap between what the sponsors would have liked to do and what they in the nature of things can do.

The user

The user would like the exhibition to include anything which could be useful to him. For obvious reasons it would be impossible to include everything being manufactured or imported for use in building so a selection must be made to reduce it to a manageable dimension. But on what basis? The present policy of allotting space to those that pay for it may be unavoidable, but is obviously unsatisfactory. What could replace it? Selection according to quality?

We have already discussed the difficulties inherent in that. Besides, cost is so important that we cannot make quality the overriding condition. The exhibition is also meant for housewives and 'do-it-yourself'-ers, who have every right to decide what they want their kitchen to look like, but who do not necessarily care for the opinion of well-wishing quality surveyors. And think of the consequences. The cry of 'Why weren't we included?' The very idea of selection bristles with difficulties.

But there are two ways of selling:

(1) By producing goods which are good, durable and yet cheap — which are easy to sell

(2) Or, to rely on advertising, packaging and salesmanship to seduce people to buy.

It would be a good idea to favour the first kind — but they are not always easy to distinguish — there are many grades between the two. But that there ought to be some kind of selection cannot be gain-said, also because the whole purpose of the Building Centre was to further *better* building. I am afraid this is a matter I will have to leave to the management to solve — it calls for tact and diplomacy, which is not my country, but it could become easier as the prestige of the Building Centre grows, as I am sure it will.

If space is scarce and sought after, it might be possible to impose certain restrictions and conditions.

But there is another need which is still more important, and also more difficult. The Building Centre provides information mainly by referring to the trade literature of the exhibiting firms. This naturally praises their wares, more or less truthfully, but doesn't say anything about the snags, except perhaps in a few cases of truth in advertising. But it's the snags we are interested in. We want to know how long the thing will last, what can go wrong, what are the maintenance costs, how does it compare with a rival article? These things the Building Centre cannot disclose — it would upset its customers. And if one turns to the various research stations we have the same trouble. They will issue a report of their research to the firm that pays for it, and the firm will use its discretion about what to publish. The law of libel is probably too strict. If you tell a truth which damages somebody's economic interest, truth is no excuse — if I am not mistaken.

It somehow reminds me of an old German couplet which I was taught when, as a child, I went to school in Hamburg and which in my childish innocence I embraced with enthusiasm. It was this:

> *'Wer die Wahrheit kennet*
> *und saget sie nicht,*
> *der ist für wahr*
> *ein erbärmlicher Wicht.'*

As there may be some of you who don't understand German, I will attempt a translation:

> *'He who knowest the truth and doesn't speak out,*
> *he is indeed a contemptible lout!'*

The last word should have been 'knave' — but what rhymes with knave?

A more up-to-date version might be:

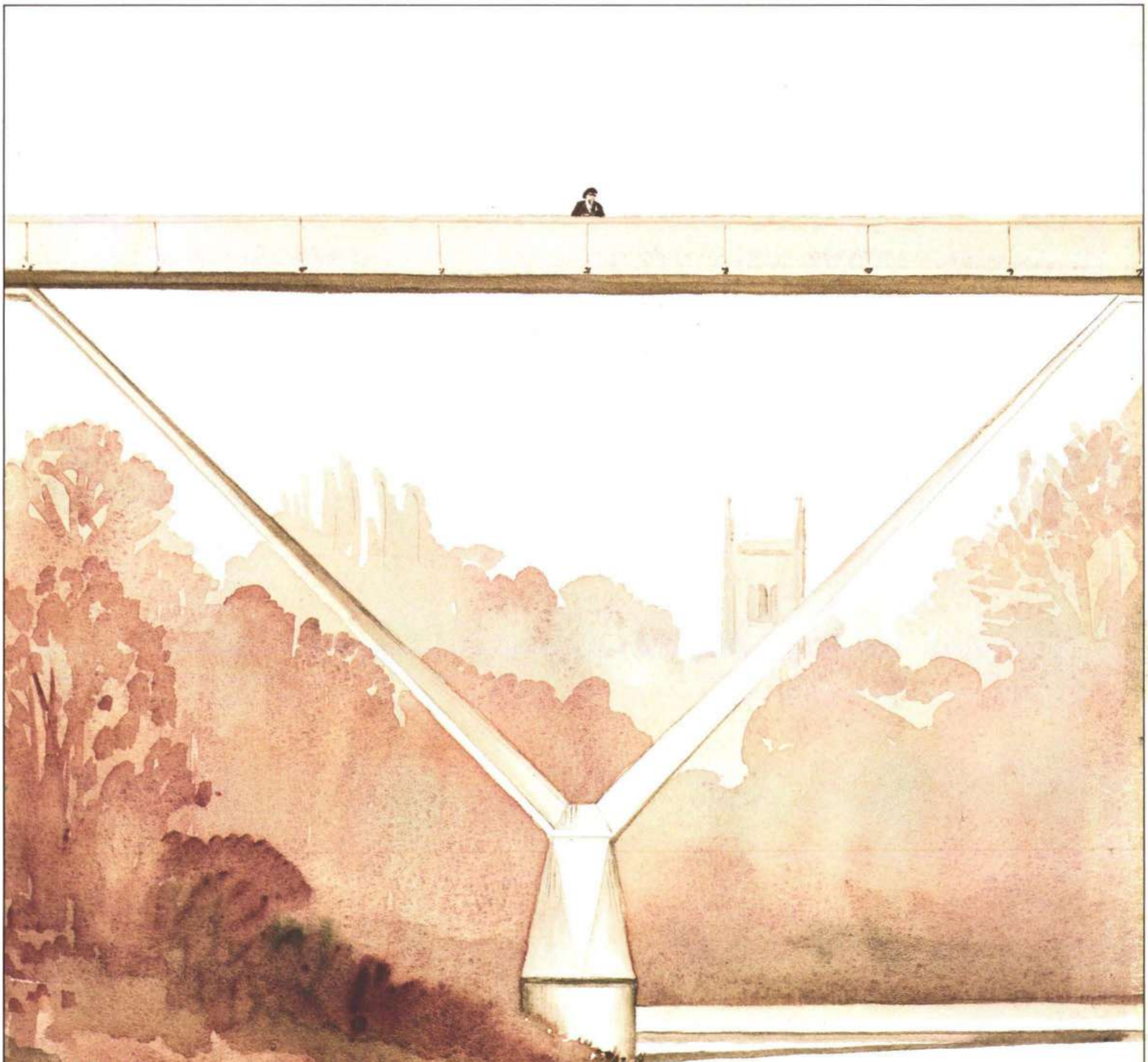
> *'He who knowest the truth,*
> *had better forget it,*
> *Lest otherwise,*
> *He should live to regret it.'*

So what can be done about that?

The Building Centre wants to be a force for good; but it must pay for itself, it must be solvent to exist, as it gets no grant from the Government.

The solution has been to run the Centre on strictly commercial lines, and with the profit it makes it endows a trust which hands out money to socially useful activities. This is probably an excellent policy — for it is difficult to mix business with charity. But I do think they should not forget their primary business of giving the public an overall view of what industry and commerce can do for building, by making their exhibition selective and yet inclusive and their information a model of truth in advertising. It is a formidable task and I know it is what the present leaders would want to do. Ought it to have Government consideration, particularly at this time when Agrément activities are under review?

Chess set designed by Ove Arup



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