THE ARUP JOURNAL

DECEMBER 1970

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Vol. 5 No. 4 December 1970
Published by
Ove Arup & Partners Consulting Engineers
Arup Associates Architects and Engineers
13 Fitzroy Street, London, W1P 6BQ

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The next Arup Journal *will appear on 1 April 1971 in order to coincide with the 25th anniversary of the foundation of the firm.*

Front cover: Reproduction of a drawing by Michelangelo for the Porta Pia façade, 1568

Back cover: 19th century print showing a futuristic concept of an elevated moving walkway which appeared in the French magazine *Illustration*. Reproduced by courtesy of *The Daily Telegraph*

'Key speech'

Ove Arup

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 show 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 over-emphasized, 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, idealogies 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', is all very well, generally, but does 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 that 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 knew 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 this 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 ten ordinary jobs, and enthusiasm is like the fire that keeps the steam-engine going. Likewise one outstanding man is worth ten 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 woman 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 are likeable, human, with a sense of humour. A cheerful remark can brighten the day. All our people are part of 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, lest 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.

Post script

I only just managed to get this speech ready for the Winchester meeting and it needs pulling together and polishing. But I thought it would be best to give it here in its original form and postpone any revision until the members of the firm had had time to react to it.

I must say I was extremely pleased, grateful and not a little surprised at the reception it got at Winchester, in spite of its shortcomings. But perhaps it was not so surprising for I only expressed what the partners for years had been striving for, even if it had only been partly achieved. I feel, however, that a wider audience would very likely be more critical.

Some may actually disagree with our aims. I don't know what can be done about that, unless the disagreement arises from a misunderstanding which can be cleared up. But I expect and hope that such dissent will represent a very small minority. A more likely criticism will take the form of pointing out the gap, or even the discord, between what we in certain cases propose to aim at and what we actually do. Such complaints may be due to the fact that the difficulties with which the partners are faced are not sufficiently appreciated. But they may also highlight things which ought to be changed. In both cases it would be useful to air the matter in public – at least inside the firm.

I would therefore like you all – or as many of you as feel strongly about any point or have questions to ask or suggestions to make – to write to me personally. I will then try to reply to them singly or collectively, depending on numbers and content, in the *Newsletter*. If you don't want your name to appear anywhere, just say so. But the question and my comment are of course meant to be publicised – if they are of interest.

To avoid too many irrelevant comments, would-be key-questioners should realize that the key-speech is mainly a statement of aims and of some of the consequences and problems directly resulting from an adoption of these aims. It does not attempt to lay down the law about how these aims should be pursued in detail, and I don't think it is possible to do so. This does not preclude a discussion about these details, but it is useful to distinguish between principles and expediencies. I hope very much to hear from you and that we all can learn something from the discussion.

The inevitability of industrialization: the next decade

Peter Dunican

This paper was given at the National Congress on Concrete Industrialized Building, Johannesburg, 5-9 October 1970.

The industrialization of the building process, like all other industrialization, is primarily concerned with, and dependent on, organization and management. It is concerned with an attitude of mind and in the first place it really has nothing to do with any particular material embodiment, although it is interesting to note that some of the most successful examples of industrialized building have been essentially precast concrete structures.

But why should we industrialize? Simply to produce more with less? To integrate the processes of design, manufacture and erection? No, of course we want to produce more with less effort and we want to integrate, but there are other reasons or, perhaps to be more precise, there are a number of other problems which it is thought can be solved through industrialization; recognizing that industrialization, as we now understand it, is a stepping stone from the rationalization of conventional and traditional building to a totally automated process of design, production and assembly.

The problems to be solved vary qualitatively and quantitatively, from country to country, region to region, and continent to continent. To some extent in each place the solution depends on somewhat interdependent factors. On the one hand, social and political attitudes, and on the other hand the strength and quality of the technological and economic infrastructure. And perhaps above all, *the need.*

The significance of social and political attitudes is mainly because successful industrialization is a large scale activity which depends on continuity of demand and reduction of variety. In building terms this means continuity through organized, sizeable, standardized, rolling programmes. This in turn implies that someone, the State for instance, is required to exercise at least a leading, guiding role.

Industrialized building is directly concerned with large scale activities such as housing, schools, factories, hospitals, and so on; the sort of construction the State is very much concerned with. The construction of opera houses, for instance, can be industrialized, as has been demonstrated, but the demand for them is rather limited so there does not seem to be much point in including them in any mainstream programme.

The need for a catalyst

Someone must create the arrangements whereby all the parties concerned are brought together to produce what is required. How this should be done depends on the socio-political climate, perhaps more than on any other factor. On the one hand we have the example of what has happened in the USSR, and on the other of what is happening in the USA with the setting up, by the US Government's Housing and Urban Development Department, of the *Operation Breakthrough* programme, which relies more or less completely on private enterprise with respect to the economic and technological back-up necessary for its implementation. The particular programme is concerned mainly with housing in the sector which does not directly interest private enterprise—what is termed low-cost housing in the UK—and perhaps this is the most appropriate area of the problem to concentrate upon, mainly because of its scale and its repetitive content, and also because it is the area in which we have gained most experience. Reference has previously been made to the experience in the UK during the 60's in the Conference on Industrialization held in August 1968 in Johannesburg at the first South African Building Exhibition.

The situation in the 70's in the UK, and to a lesser extent in the USA, is dominated by this experience together with current social and political attitudes, particularly with respect to high-rise living, and the form and substance of urban development and renewal.

In general terms the main experience is quite clear. It is in the use of concrete constructions, essentially, in large precast load-bearing panel, medium and high-rise structures, either made in a central or a site-based factory. Although these first generation systems have been well developed in principle, they are still capable of being modified, extended, expanded and improved. But it has been found that these systems do have some limitations in use. To some extent these limitations arise from the pre-requisites which were necessary to enable them to be brought into being.

It is a fact that successful system building demands some purposeful discipline, which implies some constraint or inflexibility in application, but no matter how well conceived, the initially determined discipline may well be invalidated by technological, social or economic change and developing experience. To make the necessary or desirable modifications may be difficult, not only because of the natural human resistance to innovation and change, particularly when it is concerned with relatively new notions anyway, but also because of the possible redundancies in the carefully created resources, especially those which have a high capital value.

Industrialization of the building process generally implies an intensification of capital investment in what has been, until recently, a particularly labour intensive industry. It may well be therefore that any significant advance can only come about through a fundamental re-appraisal, although this does not necessarily mean that there will be any dramatic changes. No one wants change for its own sake. The inevitability of gradualness as a philosophy has much to commend it in human terms. It is pragmatic, although from time to time a good shove is not out of place—provided we know which way we are to shove—more so when there are pressing human needs which are not being satisfied; and housing in global terms certainly comes into this category.

Therefore, it might appear to be inappropriate, in such circumstances, to discuss the refinement of relatively sophisticated systems where the major need is for simple systems for universal application. However, it has been found that any critical examination of the state of the art of any technology does result in some improvement in the whole field of the technology, even if this only comes about through the increased general awareness and understanding by the technologists of their technology, without in any way effecting any fundamental, philosophical change. So, even from this limited viewpoint, re-appraisal would seem to be worthwhile.

Now, the first and main purpose for any building is that it should meet the direct needs of its users. There are other purposes, some of which are subordinate to the main purpose and others which complement it, like, for instance, contributing to the quality of the built environment—what some refer to as architecture.

So, although the design of buildings is primarily concerned with their use, design is also concerned very much with how they should be built and therefore, the means which are available to build them will affect the way in which they are designed. It follows, therefore, that systems or ways of building are important, but, if in use there is any conflict between the needs of the system and the needs of the users, the needs of the users must surely predominate.

Generally up to now it has been accepted that, in the design of any economic building system, certain rules must be observed; for instance there must be direct vertical continuity of the structure and of the servicing of the building, particularly drainage. This has resulted in the current high-rise systems virtually being a series of stacks of dwellings of similar planform, one above the other, with load supporting space dividing structures of relatively short spans. This has inhibited, if not prevented, variations in dwelling size from floor to floor, and has seriously inhibited dwelling mix—that is the creation of dwellings of different sizes in a contiguous complex—and consequently this has brought about family segregation and also—and of equal importance—under-occupation which has been shown to be one of the primary factors in the real shortage of housing in the UK.

Adaptability

If these constraining disciplines could be removed, it would be possible to make much more effective use of the new dwelling space provided. This ideal could also be achieved if it were possible to alter economically the size of the dwellings provided, in order to meet the variations in demand arising from changing family needs and social circumstances. Through the fundamental reconsideration of the structuring and servicing of dwellings and their environmental needs, it should be possible to inbuild, economically and within an acceptable price ceiling, the necessary degree of flexibility and adaptability to meet the changing needs. It must be admitted, however, that such an adaptability in use implies the sort of adaptability in application which has been the long sought, but unachieved aim of all system designers to date.

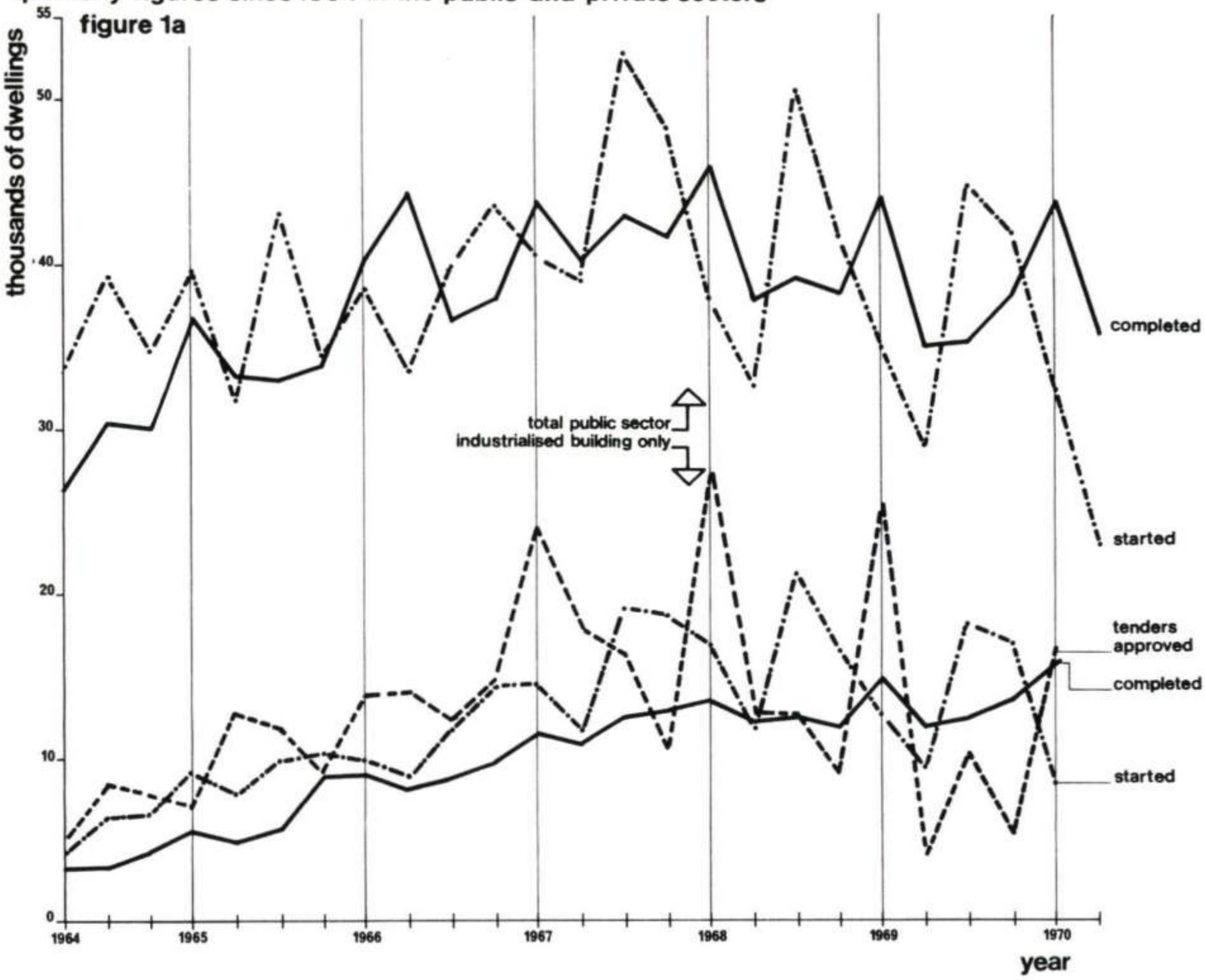
However, this notion implies the concept of the multi-size dwelling, completely co-ordinated dimensionally to allow the use of standardized sub-systems of cladding, space division and components, and which derives all of its support from a permanent serviced, minimum structured network in such a way as to allow individual dwellings to be readily modified or replaced as required by innovation, change, obsolescence or desire. This is certainly not a new idea but it might now be realizable with our present resources. But it would require a fundamental reconsideration of the problems. Ideally this should begin from three different positions. Firstly, a statistical evaluation of housing needs, in order to optimize the variables and to establish the current and future demands in detail. Secondly, a technical examination of the structural and services possibilities inherent in multi-purpose, two- and three-dimensional elements and sub-systems, and thirdly a fundamental assessment of the functional requirements of the users and their environmental and emotional needs.

All of this would require a process of analysis, synthesis and evaluation, which should converge on a limited number of potential solutions—second generation systems if you like—each of which would have an inherent consequence of some sociological, architectural and environmental significance.

But in the meantime what should be done in less sophisticated situations where the industrialization of building, and in particular of housing, has not progressed to the extent which it has done in the UK, and where the social, political and technological infrastructure may be so significantly different?

PERMANENT DWELLINGS: APPROVED, STARTED, & COMPLETED: ENGLAND & WALES

quarterly figures since 1964 in the public and private sectors



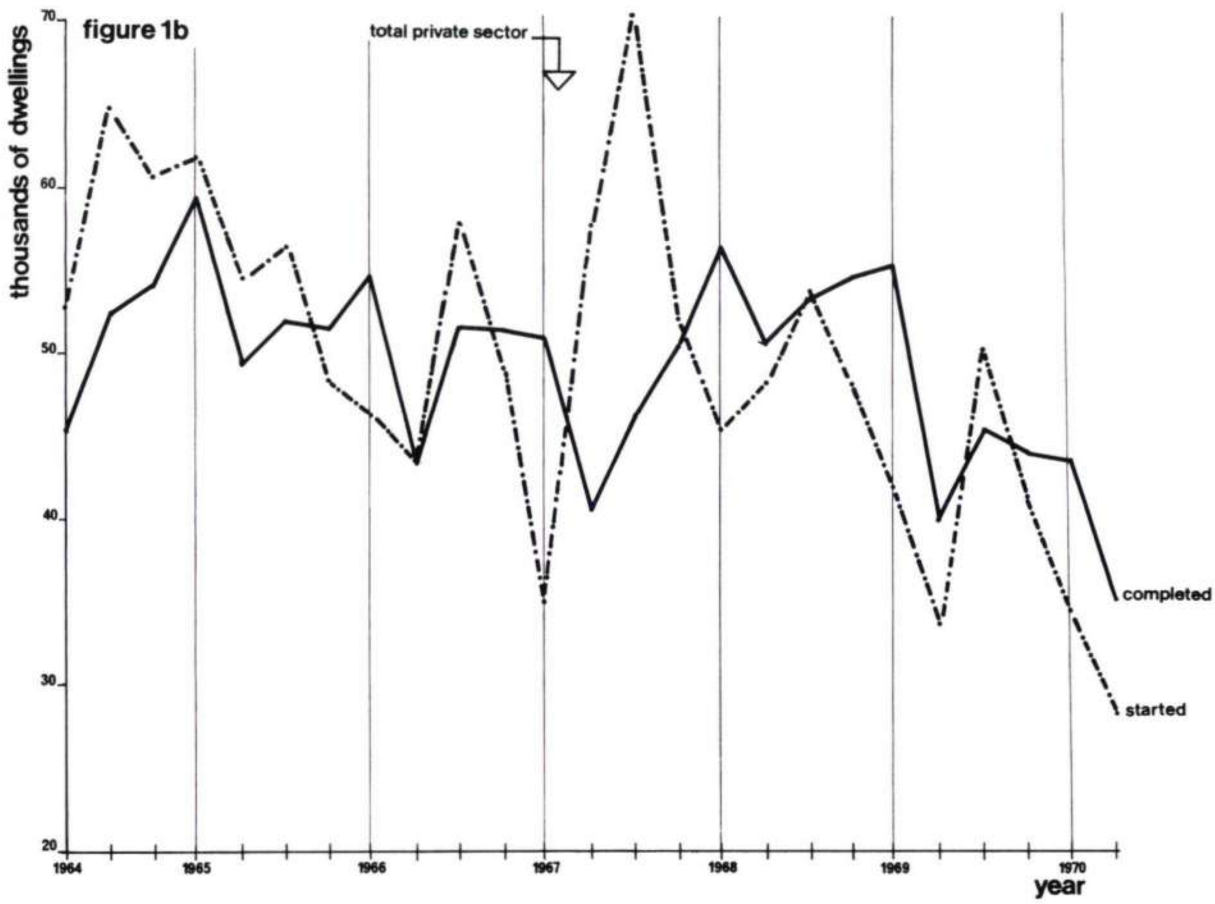
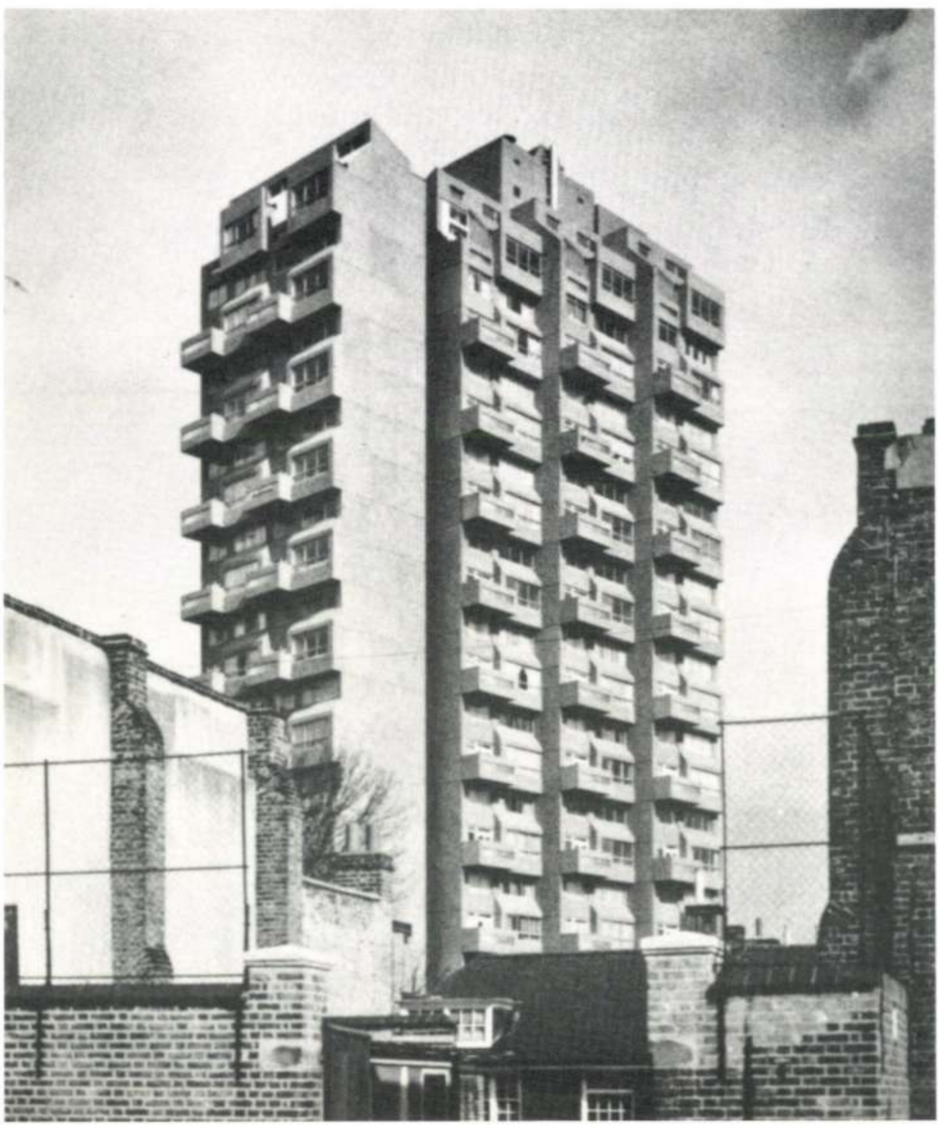


Fig. 1

Fig. 2 above
Yorkshire Development Group Mk. 1 System: The Leek Street Scheme, Leeds.
The Yorkshire Development Group, consisting of the cities of Hull, Leeds, Nottingham and Sheffield, conceived and sponsored this medium-rise, high-density, deck access system, which was intended to provide 4,500 dwellings in three years. The contract was awarded to the Shepherd Building Group, who were also responsible for the detailed design and development of the system within the geometrical concepts, based on a standard 5.5m. (18 ft.) floor span and established by the YDG architects and their consultants, Ove Arup & Partners. Policy changes within the constituent bodies of YDG, arising from external factors, have led to the programme being concluded on the completion of six schemes comprising 3,734 dwellings.



Learning from our mistakes

Here there is the opportunity to learn from our mistakes. But this is difficult, firstly because the mistakes may not be so obvious, secondly because those who know about them and who were possibly responsible for them, will not admit to them, at least in public, and thirdly because human nature seems to be against learning from the mistakes of others. However, mistakes there have been and we must try to understand them and to learn from them.

Probably the major mistake has been the way in which the technological potential has been deployed in practice, particularly by Government, through its procedures, and by the designing architects, seduced if not suborned by the technologists.

Industrialization of the building process cannot flourish unless there is a large continuous programme of demand. This demand exists but it must be organized, not only technically but politically. It is here that Government can play its major role.

In the United Kingdom it is recognized that housing is a public service and the Ministry of Housing and Local Government are responsible for setting targets and controlling financial, functional and space standards. In particular they control central government's subsidy to local government for carrying out the low-cost housing programme and, through this means, they are in a position at least to exercise guidance over the programme, within the capacity of the individual local authorities to respond to the local demand as they interpret it and as it may be affected by central government as part of their control over the national capital investment programme and the implementation of their fiscal policy.

There are a number of other factors which must also be taken into account such as the availability of land and regional planning policy, etc., but there is no doubt that Government does exercise a direct influence on the way in which the demand for new housing is made on the construction industry. Certainly they encouraged the industry to industrialize itself and to produce house building systems.

For political reasons central and local government are also concerned about how many houses are started and built during each year. This sort of decision should also take into account the ability of the construction industry to produce economically. Ideally, demand and the capacity to produce should be balanced. This balance can be achieved through the timely placing of contracts, but when the housing starts and completions over the last few years are examined we find an erratic distribution (fig. 1). As might be expected, the number of completions reflects the number of starts, but with the extreme variations reduced through the bottleneck created by the annual overloading. The consequences of this are obvious.

Fig. 3 left
Wates System: high-rise blocks for the London Borough of Lambeth.
One of eight 23-storey blocks built on four separate sites, comprising 700 dwellings. The design demonstrates the relative versatility of a site-based system. In this case, due to limitation of space, the factory for all of the structural elements was set up on one site and the cladding and façade units were made on another. This meant that some of the units had to be transported up to two miles. Architect: E. A. Hollamby, ARIBA, AMTPI, DipTP; Consulting Engineers: Ove Arup & Partners; Contractor: Wates Construction Ltd.

Fig. 4 left
12M/Jespersen System: Aylesbury Development for the London Borough of Southwark.
This is the largest industrialized building project undertaken by a London borough. It consists of 1,957 dwellings in 35 blocks, ranging from four to fourteen storeys in height. The contractor and system sponsors, John Laing Construction Ltd., were responsible in the design team for the structure and the detailed application of the system. The team was led by the Borough Architect, F. O. Hayes, OBE, FRIBA, who was advised on all structural matters by Ove Arup & Partners. All of the precast elements for this development were made in two computer-controlled factories at Andover and Princes Risborough.

Fig. 5 left
Wates System: Kingsholt Estate, King Edward's Road, Hackney, London.
This mixed development for the Greater London Council consists of 771 dwellings in two 23-storey blocks and 21 five-storey blocks. It is a further example of deck access planning, where all the five-storey blocks are linked at third floor level. The high-rise blocks are necessary to achieve the desired quality of environment within the density limitations imposed by the GLC. The system was chosen by the architects, Yorke, Rosenberg, Mardall, with the advice and assistance of their consulting engineers, Ove Arup & Partners, and the National Building Agency, because it was thought that this site-based system would provide the most flexibility in application. The contractor, Wates Construction Ltd., participated in the design development of the project.

Efficiency in construction is inhibited and so is efficiency in design.

Architects, just like builders, cannot work efficiently and effectively in such a situation of fluctuating demand. Neither can architects produce what is required of them functionally, environmentally and architecturally, if they uncritically accept all of the claims which industrialized builders make for their systems. All systems have some advantages and these are usually stressed when they are being sold. But, when selling systems, it is not usual to stress their limitations in use. You have to buy the system before you find out what these are but by then it is a bit late. But limitations apart, having bought a system you must learn how to use it. Generalizing, architects still do not appear to have sufficient regard for the environmental consequences of building with large scale, repetitive units. It is difficult to understand why this should be. Perhaps they are also inhibited by the demands for quantity at the expense of quality. Industrialized building can improve quality.

Systems appraisal

Techniques of systems evaluation have now been developed to aid the architect in the selection of systems and to help protect him against himself. The National Building Agency in the United Kingdom, created in 1964 by the Government in particular to further industrialized building, have been central to the development of these techniques, and they have demonstrated once again the value of an independent expert advisory body without commercial affiliation or connection. They have instituted appraisal certificates for specific house building systems to ensure that they meet all of the functional and statutory needs. It could be argued that the extension of the appraisal of systems to all housing would be of considerable social benefit. At least it would be another means of ensuring a minimum standard of performance. Perhaps we should have an International Building Agency to further this idea.

Despite the considerable assistance which can be obtained from the National Building Agency in the choice of system, there are other criteria. For instance competitive cost effectiveness in a given situation. This makes it particularly difficult to carry out comparative evaluations of different systems because in practice they are never being applied in precisely the same circumstances.

Here it would be interesting to critically compare a number of successfully industrialized, local authority housing schemes, each carried out by different methods. (Figs. 2, 3, 4 and 5).

There are certain simple facts which are more or less readily available, like how much each scheme cost, and how long it took to build, but any meaningful objective evaluation of the degree of success achieved in the application of industrialized building methods in any particular situation is well beyond the scope of any individual.

Individual judgements are bound to be prejudiced and subjective to a greater or lesser extent, and also a reflection of personal experience and therefore they must be assessed in this context. Post-rationalization can often give them an unexpected validity.

It is rather like intuition which with some can be reasonably described as instant logic—proof to follow later.

However, it is possible to reach some general conclusions within the context of a specific experience, particularly in the use of large precast concrete panel load-bearing structures applied to low-cost housing. Of course, the scale of the scheme is a major factor with respect to cost and the level of the lower limit of the effect of this scale depends on whether the system is site based or made in an off-site factory, which in turn has a considerable influence on the amount of capital required to be invested in the system.

There is no doubt that industrialized concrete, high-rise, low-cost housing costs less than conventional high-rise housing, but in low-rise construction the cost gap is much more difficult to bridge. This is partly because in current industrialized low-rise developments considerable efforts are now being made to embrace, within single blocks, the multiplicity of dwelling types which are so desperately needed, whereas, in general, conventional constructions are only being applied to conventional concepts and these provide the basis for cost comparison.

Nevertheless the industrialization of low-rise constructions is becoming an economic reality. Functionally it can be assumed that there is not much difference between one scheme or another, or between the systems. On the other hand client sponsored systems, dominated as they are by users' requirements, as interpreted by the architect, are more likely to produce better results architecturally and environmentally. (See footnote 1)

But architectural and environmental consequences are of total significance demanding difficult value judgements often with cost implications, and it is here that the technicians and technologists can make a major contribution by helping to save money elsewhere so that the most desirable design can be built within the funds available.

Our technological vocabulary is expanding and developing but there are still gaps—problems which could be solved more effectively and efficiently than they are at the moment. Often the major obstacle to finding optimum solutions to these problems is lack of resources, mainly brainpower. Services sub-systems are a particular example. We still have not available to us an economic serviced kitchen/bathroom unit—the so-called heart unit. Every new house needs one so the market ought to be large enough, but it needs organizing, particularly dimensionally. Perhaps the major breakthrough here depends on a nationally acceptable and mandatory solution of the problem of dimensional co-ordination. Dimensional co-ordination or control is necessary for successful industrialization and is central to the development of standard elements and sub-systems which can be used in a variety of circumstances; recognizing that the needs of the users must dominate the dimensions.

Documentation and communication

We must also further develop our system of documentation and communication. The conventional techniques of outline drawings, reinforcement details and bending schedules are no longer adequate. New techniques must be evolved and their evolution will have considerable impact on the organization of the design office. The main object of industrialization in the United Kingdom has been to reduce the site labour content of construction. We have more than halved site man hours with our present techniques but we have increased the workload in the design office. Therefore the cost of design has increased. This increase may be less evident in the application of what are called closed systems than it is in the application of open systems. Of course, this change of emphasis in the nature of the designer's work is an inevitable consequence of industrialization which must flow back from the site right through to the initiation of a project.

In this connection the use of computers and network analysis techniques should have considerable influence. It will not be long before the whole design and construction process is completely dominated by the computer as a management tool. The computer can process, methodically and rapidly, a great mass of detailed information and thereby facilitate decision making.

But, of course, as Paxton clearly demonstrated in 1851, it is not necessary to have a computer to be able to produce a successful industrialized building. All you need are ideas. It is difficult to understand why the real philosophy inherent in the Great Exhibition building and the Crystal Palace and other contemporary constructions such as Brunel's hospital at Renkioi did not flourish (See footnote 2). Perhaps this philosophy, as pragmatic as it may then have been, was obscured and confused by the developing science and technology of the industrial revolution.

Technology can confuse simple issues and simple ideas; like for instance industrialized building which is rapidly becoming a part of the terminological and technological mythology of the second half of the 20th century; but really there is no mystery.

Technically speaking industrialized building can be defined as any systematic method of building which is completely planned on paper before it starts on site, and where the construction processes are designed to achieve the maximum utilization of the available resources. It is a process which first begins in the mind and is implemented through the drawing board.

Industrialized building is just another way of building; a better way of building, which of necessity will give us the stability, and demand the foresight, which are the precursors of good design, good architecture and good environment; and this is what building—which is an art as well as a science—is all about.

Industrialization is inevitable. The only outstanding questions are, how long will it take and how well will we do it.

Footnote 1

Probably the most successful complete building system yet developed in the United Kingdom resulted from the collaborative efforts of some local education authorities and central government in the form of the Ministry of Education through the Consortium of Local Authority Special Projects—CLASP.

This client sponsored system was originally intended for school building on sites subjected to mining subsidence but the economic and other advantages obtained by large scale manufacture of a completely integrated kit of parts have resulted in the system being equally suitable for normal sites at a price more than competitive with conventional designs. The system has been used for 1,226 buildings to the value of £141 million since production began in 1956. During this time the cost of building generally has increased by at least 60% whereas the cost per place of CLASP primary schools has increased by not more than 40%.

The CLASP system, which is based on the structural use of pressed steel sections, more than justifies the claims made for user dominated designs made in total collaboration with manufacturing and other commercial interests to satisfy a need stemming mainly from social and economic pressures.

Footnote 2

The building for the Great Exhibition 1851 was the result of a design and build contract awarded to Fox, Henderson & Co. The inspiration for their tender came from Paxton and was based on a sketch he made, on a piece of blotting paper, on 11 June 1850. It was a prefabricated modular design of cast and wrought iron, timber and glass, containing nearly 90,000 m² (1,000,000 ft.²) of floor space and about 930,000 m³ (33,000,000 ft.³). The tender was accepted on 16 July, although the formal contract was not signed until 31 October. The first column was fixed on 26 September. Charles Fox, who later founded his own firm of consulting engineers in 1857, now known as Freeman, Fox & Partners, was responsible for making all the detailed design and working drawings and for the erection of the building which was finished and opened on 1 May, 1851.

Paxton received a fee of £2,500 from the contractors and both he and Fox received knighthoods.

Eventually, as intended, the building was taken down and re-erected at Sydenham during 1853-4 after some delays caused by governmental and political vacillation. Brunel designed the nearly 90 m (300 ft.) high water towers which were subsequently added at each end of what was by then called the Crystal Palace.

On the initiative of Florence Nightingale on 16 February 1855 Brunel was asked 'if he would be willing to design an improved hospital for the Crimea which could be quickly built in England and then shipped out for assembly on some predetermined spot'. He accepted the commission. All the buildings, complete with mechanical ventilation system and other services down to the toilet paper for the water closets, were shipped from England. Erection started on site at Renkioi on 21 May. By 12 July the hospital was ready to admit 300 patients and by 4 December 1855 it was equipped with its full quota of 1,000 beds, despite the fact that anticipated local labour was not available and the whole works was carried out by 18 men sent from England.

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British Embassy, Rome

Ted Happold

Job no. 1510 started in 1960 when Sir Basil Spence was appointed architect for the British Embassy in Rome and advised the Ministry of Public Building and Works that he would like us to be his structural engineers. Nervi was appointed to advise locally, Reynolds and Young were appointed as the surveyors and the Ministry carried out the services engineering themselves.

Unfortunately, the progress of the job reflected the national stop-go policy. The structural design was started in 1961 and included not only the chancery building but also a block of flats. The design went on hesitantly until the end of 1966, with the architects running it from an office in Rome for a couple of years and the brief losing the flats somewhere in the period. The project was taken right up to tendering but stopped before tenders were received. The job finally went out to tender at the beginning of 1968, devaluation made it appear likely to die again but the lowest tender received was still below the pre-devaluation estimate and so construction started in April 1968.

Building in Rome

At the start of the design Povl Ahm and myself went out to learn something of the Rome building industry. We found that there are similarities between the organization of building in Italy and in Britain, but there are also many differences. Buildings and structures are designed by architects and engineers and constructed by general contractors. Architects and engineers are trained at university and then have to pass state examinations to be professionally qualified. Heads of contracting firms usually train as engineers. Quantity surveyors do not exist as an independent profession, but the architects, engineers and contractors have trained technicians in their offices, called *geometras*, some of whom specialize in this work.

The method of working between architects, engineers and contractors is more varied than it is in Great Britain. The system adopted usually depends on the nature and complexity of the work. When the building is important, the client, as in Britain, appoints a structural engineering consultant on a percentage fee and he produces all the drawings necessary to construct the structure. For simpler schemes the client may only appoint an architect on a percentage fee, who in his turn will employ a structural engineer to size his building. The engineer's drawings are then minimal and only in cases of complexity show any reinforcement detail.

For both systems, drawings and specifications are sent out for tender and the tenderers work out their own quantities and submit them with their prices. The successful tenderer, under Italian law, then takes over a share of the responsibility for the design of the building. For this reason the contractor may have to check all the consultant's sizes and then calculate redraw and detail the structure. If the contractor has to do this work he may use his own staff, but often he employs an independent structural engineer, on occasions the one who did the original sizing for the architect.

This fragmentation of what the British would consider the structural consultant's work tends to mean very small consultants' offices and quite a few engineers work in this field on a part time basis. As half the responsibility for the design of the structure lies with the contractor, he normally has engineers in senior positions and the quality of their design and execution, especially in civil engineering structures, is very high. On the other hand, it often means that the contractor is in a strong position to change the architect's conception for his own reasons and this is not always for the good of the building. It also means that for many simple jobs the client goes direct to the contractor who can do the whole of the design

THE TIMES FRIDAY NOVEMBER 1 1946

BOMB OUTRAGE IN ROME

BRITISH EMBASSY DAMAGED

ITALIAN DISMAY

From Our Correspondent

ROME, Oct. 31

Soon after 2.30 this morning a severe explosion from two bombs seriously damaged the British Embassy. No members of the Embassy staff suffered injury in any way, but one Italian civilian, who was passing, was removed to hospital, where he is reported to be critically ill.

The main building has been badly damaged, and it was stated this morning that the whole structure might require rebuilding. The blast of the explosion has affected the main supports in the rear, which are twisted and broken. The windows are completely shattered, and jagged masonry above the front door where the explosion took place is sagging dangerously. Glass and débris litter the road, and houses in the vicinity have suffered damage.

A cordon of Italian police surrounds all approaches to the Embassy, and passes are carefully scrutinized. Comment is extremely guarded in police and Government circles as to the motives behind the explosion or the people responsible.

A few minutes before the bombs went off two suitcases which contained them were placed, one on top of the other, against the main door of the Embassy in the Via Venti Settembre. A block of wood which was intended to act as some kind of barrier stretched from the door to the edge of the pavement, and on the wood was the inscription: "Attenzione—miny" [sic]. When the explosion came it was powerful and was clearly heard over wide areas of the city.

PUBLIC INDIGNANT

The police are waiting to question the wounded man as soon as his condition permits. Meanwhile Signor Nenni, the Foreign Minister, has expressed the deepest regrets to the British Chargé d'Affaires, Mr. Ward, and signs of indignation and anxiety are manifest among the general public and the Rome Press this morning. The general feeling is that Italy's international position may be adversely affected by this incident should Italian nationals be involved. A demand for the closest inspection of foreigners now resident in Italy is already becoming apparent.

Signor de Gasperi, the Prime Minister, has cabled to Mr. Attlee: "I have learned with deep regret the news of the outrage this morning against the British Embassy. I beg to express, Mr. Prime Minister, the friendliest feelings and solidarity towards the British Government and people in face of a hateful and stupid deed which arouses the deepest and most unanimous condemnation in Italian public opinion."

Signor Nenni has cabled to the Foreign Minister, Mr. Bevin: "The hateful outrage this morning to the British Embassy meets with the unanimous condemnation of the Italian Government and public opinion. Everything will be done to bring to book those responsible."

LORD KINDERSLEY'S RESIGNATION

Fig. 1 above
Times article describing the bombing of the embassy
(Reproduced with the permission of *The Times*)

Fig. 2 left
View of the bombed entrance hall of the old embassy
(Photo: courtesy of the Keystone Press Agency)

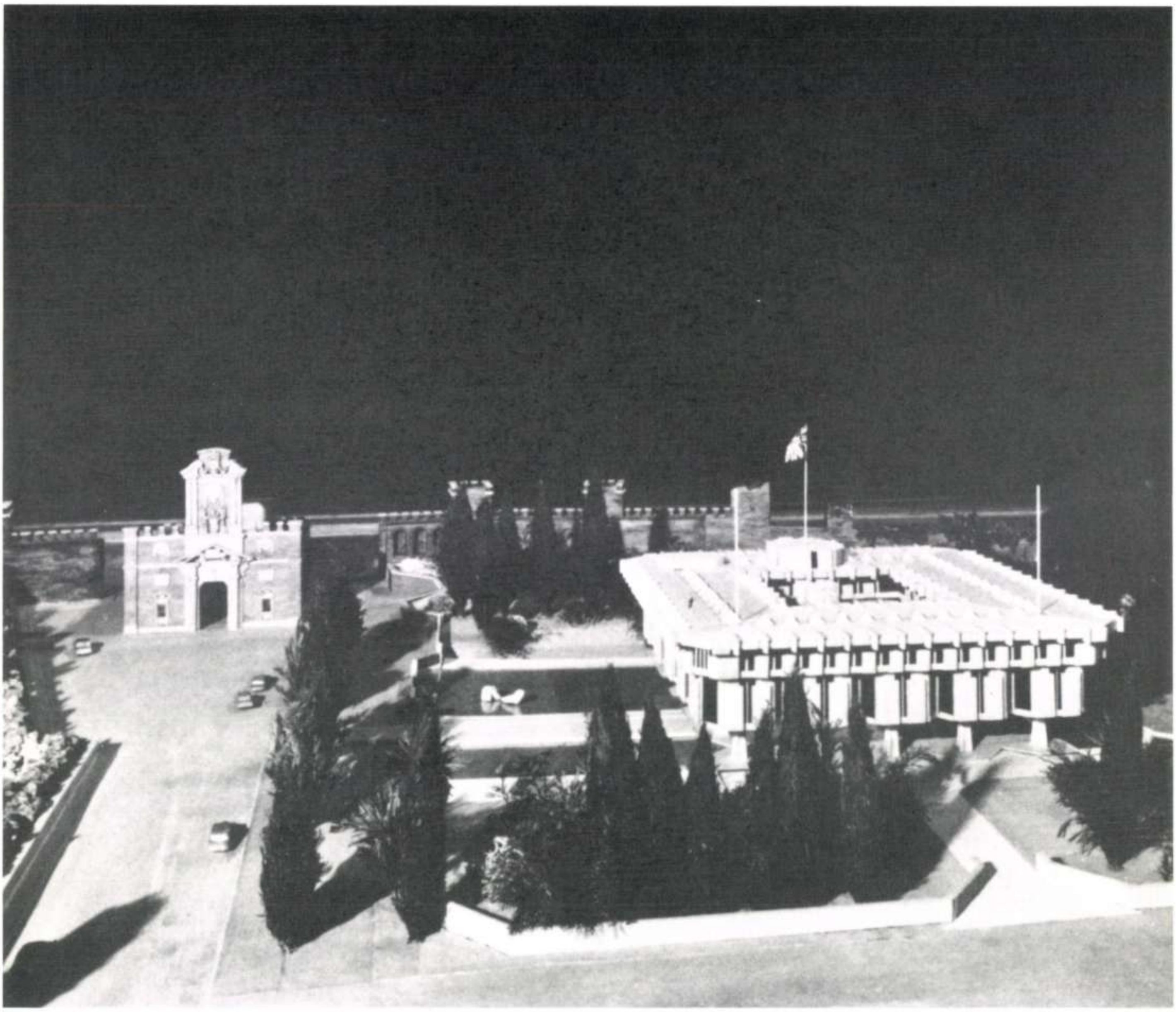
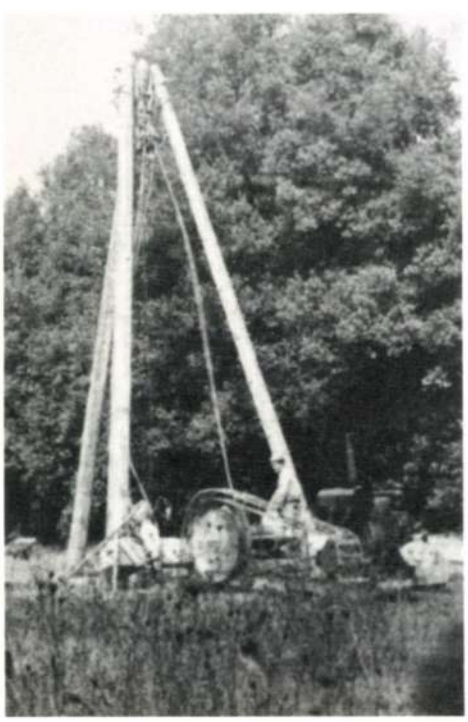


Fig. 3
Photo of model showing relationship between the Porta Pia and the British Embassy, Rome (Photo: Henk Snoek)

Fig. 4
Piling rig



in his own office. The bias is certainly towards having the structural engineer employed by the contractor rather than by the client.

The legal responsibility for the safety and standard of the work is put on two men. One, appointed by the client, is called the *Direttore dei Lavori*. If there is a structural consultant, he would be the client's nominee. The other, appointed by the contractor, is called the *Direttore del Cantiere* and he is additionally responsible for the safety of the temporary works. Both these men must be state registered engineers, one of the qualifications of which is Italian citizenship. They, jointly, take the responsibility for the contractor's design and construction and for collapse due to latent defects for a period of ten years after completion.

The use of building regulations in Italy is difficult. The current structural code for reinforced concrete, *Norme per la esecuzione delle opere in conglomerato cementizio semplice od armato*, was issued in 1939. It has been revised since then but, due to political instability, there has never been enough parliamentary time to make the revisions law. There is a prestressed concrete code, but this has not yet been made legal either, though there is a branch of the *Coaglia Superior dei Lavori Publica* (High Council of Public Works) which has to check and approve all prestressed concrete design prior to construction. This lack of legal codes is not as serious as it would be in Britain, as the design responsibility is usually subject to performance based laws rather than standards based laws and so buildings can be designed to the most recent codes even though they are not yet law. Calculations can be called for by government departments, but, if there is any discussion, sections of the buildings are often test loaded.

All this is not to say that the Italian building industry is inefficient. There is a national form of building contract, *Capitolato tipo per Appalti di Lavori Edilizi*, which is law and which covers construction extremely efficiently and sometimes poetically, e.g. Pipe work in lead: 'The watertight solderings should be carefully worked with tallow of lard and cotton cambric and when completed should have the shape of a ripe olive (English workmanship)'. The contractor's responsibility for the quantities means large prime cost sums in the contract, but for progress payments and elements such as foundations they have a simplified standard method of measurement. Cost can be controlled as drafting in architects' and contractors' offices is done by

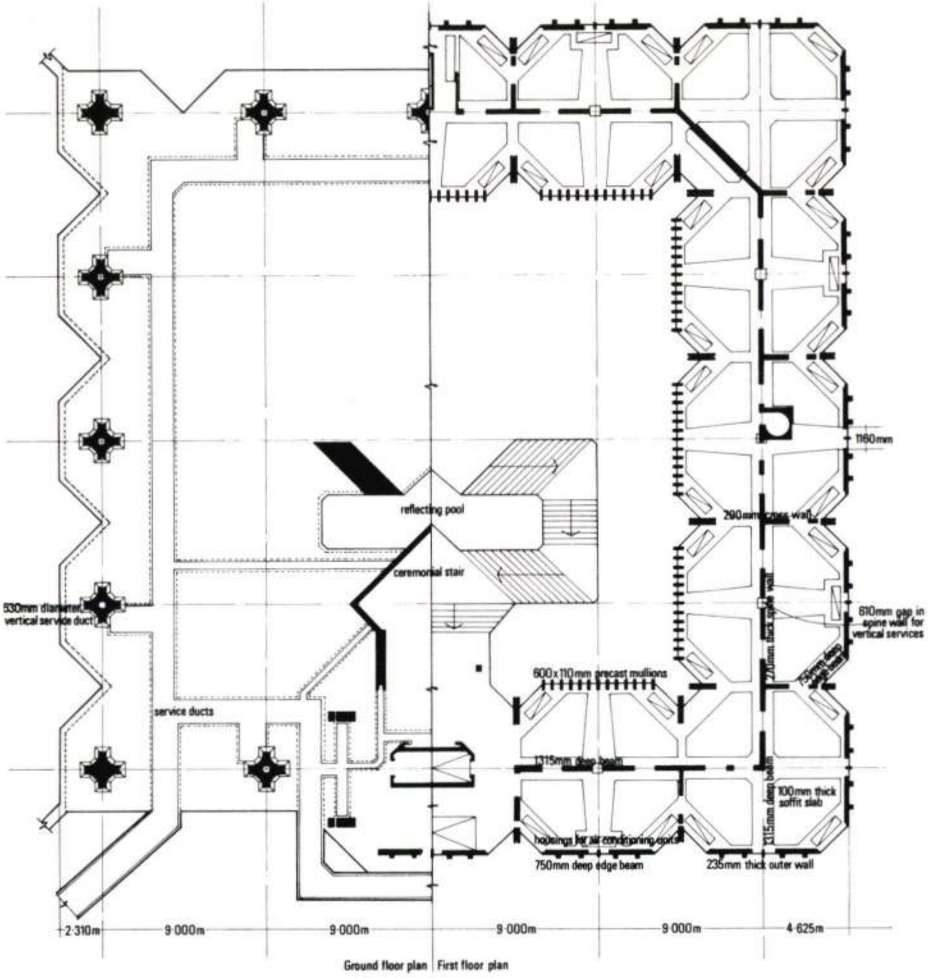


Fig. 5
Plan of
ground/first floor

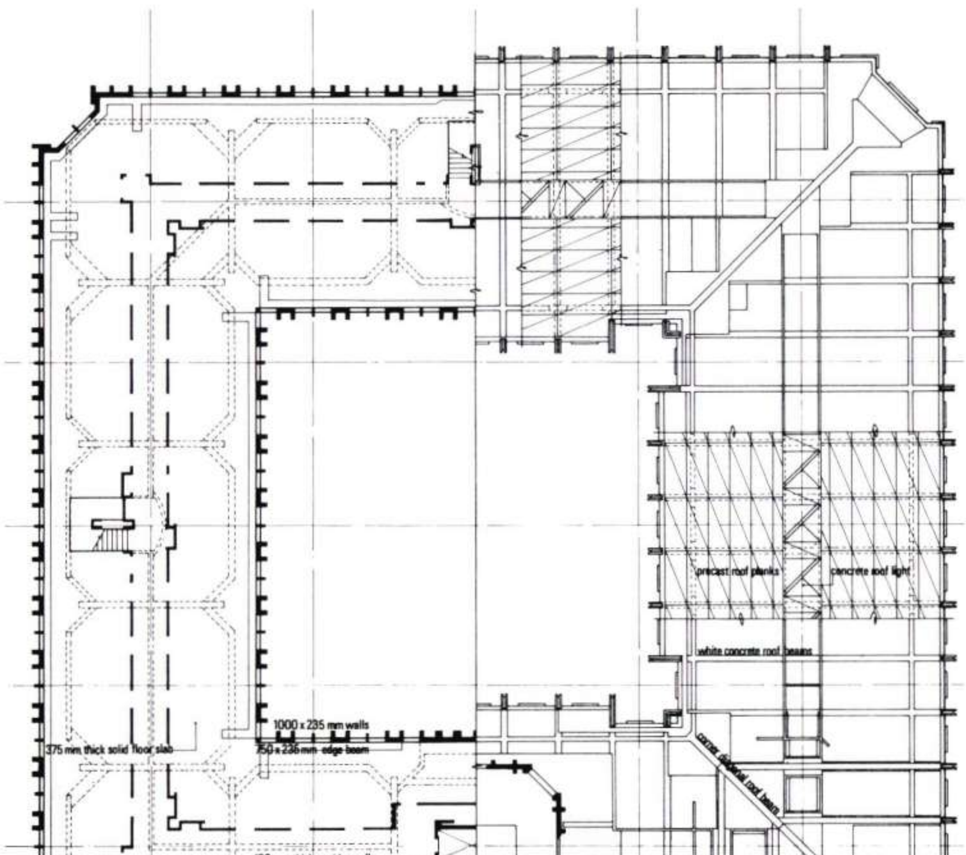


Fig. 6
Plan of
second floor/roof

geometras, who take off the quantities at the side of the drawing as it is completed. The cost can be checked from lists of typical prices which are available.

In situ concrete construction is still the predominant and the cheapest method of construction used in Italy. When non-standard precasting methods are used the precasting normally takes place on site. Even Italian contractors who use industrialized systems in other countries in Europe, tend to prefer in situ construction in Italy. The reason for this is probably that the effective cost of labour is still lower in Italy than in most other European countries and that the Italians have a deeply rooted tradition of building; it is still considered a craft.

Concrete finishes are not as developed as they are in Britain, for though the workmanship is often better, the technical know-how used is poorer. Usually the concrete is plastered; occasionally they use boarded shuttering and they also pick tool or bush hammer the surface. Inside the Aurelian Wall in Rome the equivalent of the Fine Arts Commission, the *Belle Arte*, insist that all buildings must be plastered or faced in travertine.

Perhaps the main difference between the construction of the British Embassy and the construction of most buildings in Rome lies in the finish of the structure. In Britain the finishing of a structure is determined by the architect. In Italy the contractor is in a strong position to influence it. Thus, in many Italian buildings, the lack of concern about cover to reinforcement may not perhaps be structurally important, but, after a few years, the rust staining appears unsightly by British standards.

Good concrete finish requires careful mix design, tight shutters and the correct release agents. This is now widely known and used in the British building industry, due largely to the Cement and Concrete Association. A considerable technology has been built up so that any grading of aggregates can be obtained and the literature is available to determine a suitable mix. Contractors are encouraged to experiment with mix designs by consultants using performance specifications.

In Italy most concrete specifications ask for nominal mix proportions. Because Italy is geologically varied, there are no very common aggregates. The best natural aggregates are found in the north of Italy, mostly from the Po Valley. In the south of Italy, with the lack of rivers, natural aggregates are rarer and a lot of crushed limestone is used. In the Rome area one of the main problems is the dearth of good sand. Most natural fine aggregate is river sand coming from the Tiber or pit sand coming from the Magliana area. Both sands present problems in their use. Tiber sand is variable in its grading and produces a harsh mix with a tendency to bleed. Magliana sand is more consistent but has a gap in its grading and contains a high percentage of dust.

Form of contract

Everyone at the time strongly felt that the tendering and form of contract used should be on the principle of 'When in Rome do as the Romans do'. To be certain, however, that all the tenderers were tendering for the same building and to ensure the architecture, it was decided to produce Bills of Quantities and the Works to be measured in accordance with the British Standard Method of Measurement. This was discussed with the *Associazione Nazionale Construttori Edili* and they felt it would be acceptable and not so different from the system they were used to. The contract was made under English law to protect the client and the tenderers were supplied with Bills of Quantities in English and Italian, very full drawings of the building and typical reinforcement placing drawings and schedules. The successful tenderer was asked to appoint the *Direttore dei Lavori*, as

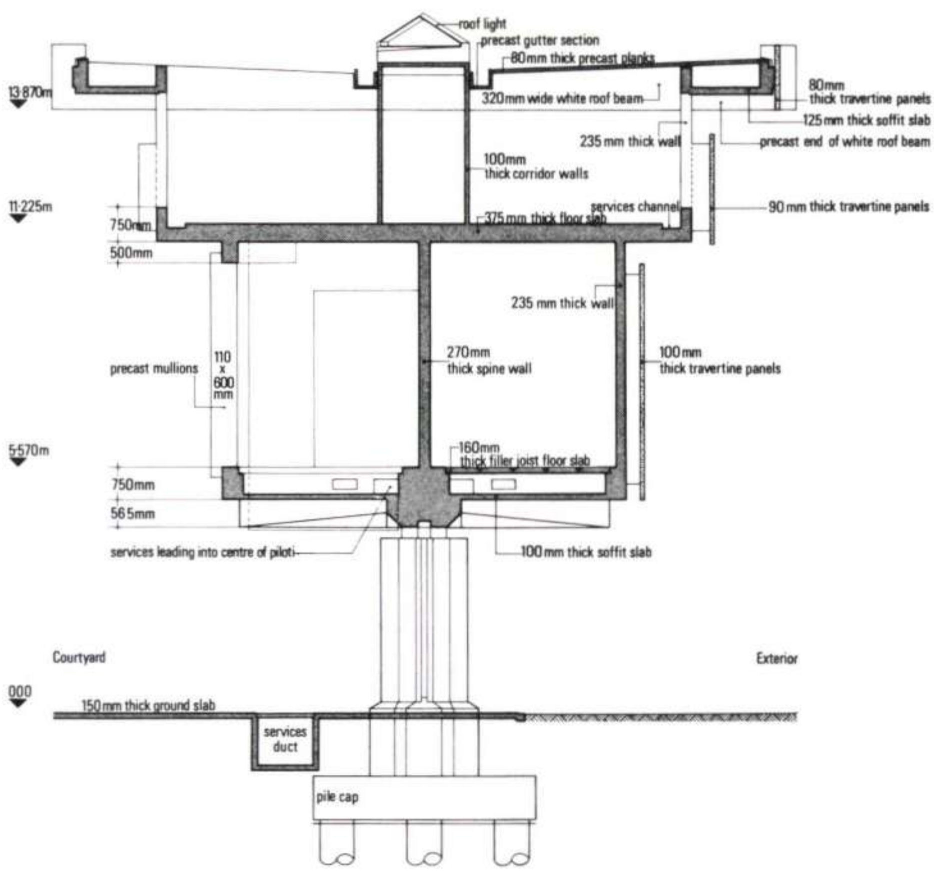


Fig. 7
Cross section through typical cell

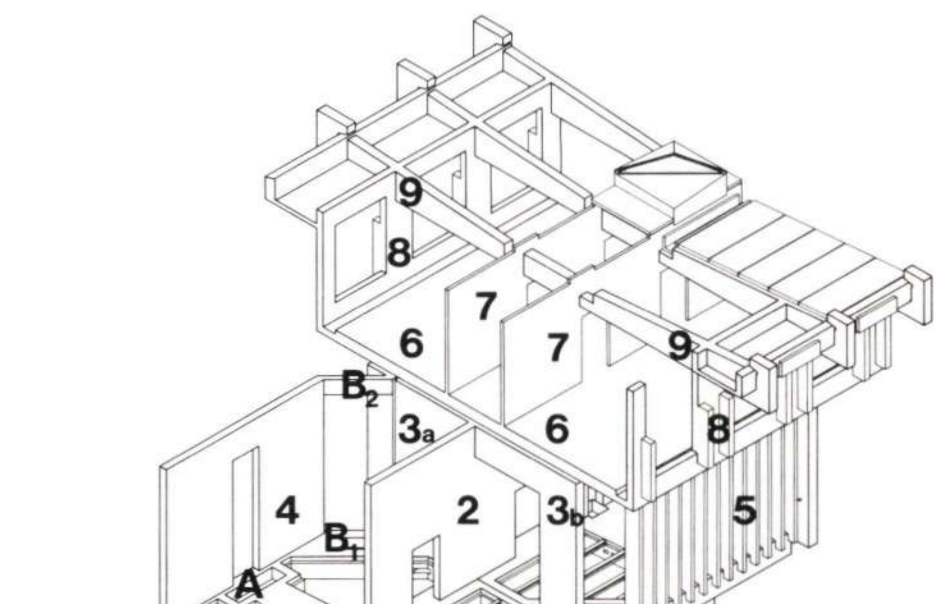


Fig. 8
Isometric showing construction of typical cells

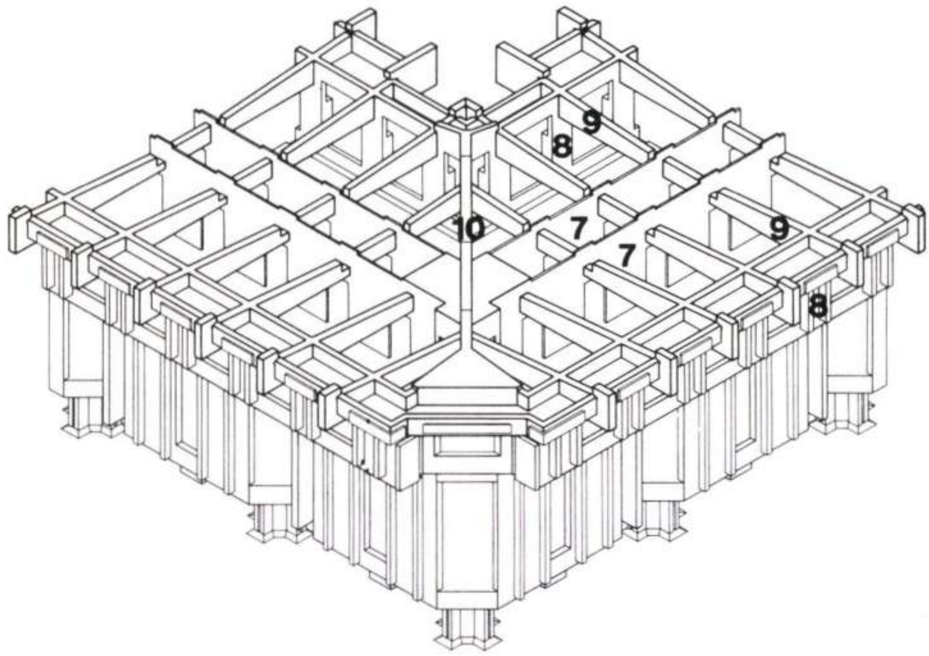


Fig. 9
Isometric of corner up to roof

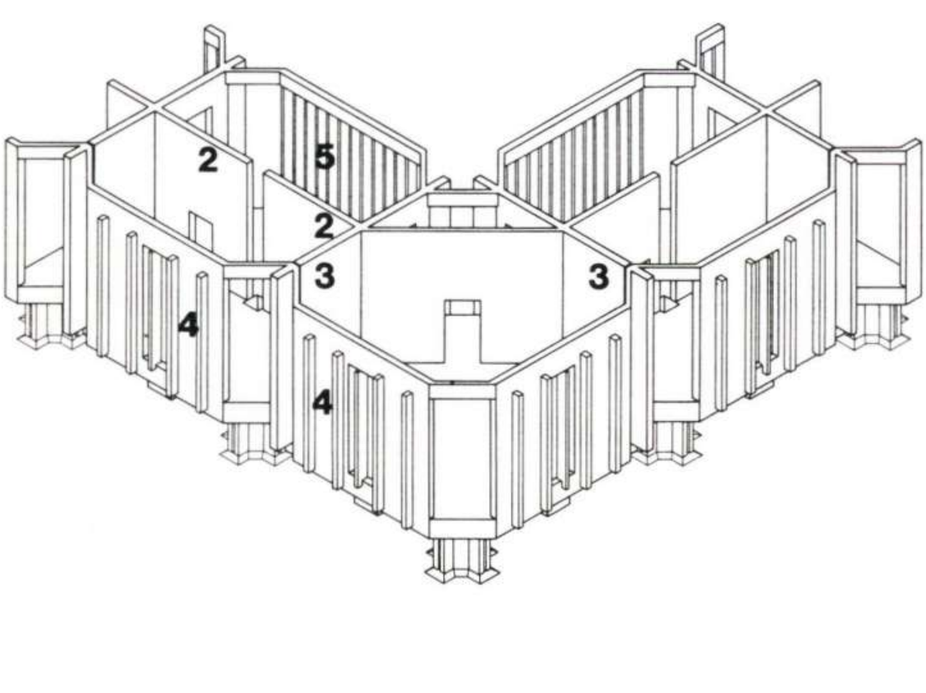


Fig. 10
Isometric of corner up to first floor

well as the *Direttore del Cantiere*, and all the structural calculations were to be handed to him to check if he felt it was necessary. No queries were received by the consultants during tendering though it is probable that the tenderers treated it as an Italian contract and worked out their own quantities. A large number of contractors in Rome were interviewed and examples of their work visited.

A soil investigation was also put on hand. When the contractor turned up he had brought a full piling rig instead of the little *Wayfarers* we were so used to having (see fig. 4).

Prior to the building of the Aurelian Wall the city wall had been closer to the city centre and along the city side of the site. It was the custom in those days to bury the dead outside the walls and we were warned that voids, due to graves, were likely to be encountered.

The test borings showed about 8 m (26 ft.) of disturbed ground and about another 20 m (66 ft.) of non-cohesive tufa* of the *pozzolana*† type. Voids up to 2.5 m (8 ft. 3 in.) deep were found between 10.3 m (34 ft.) and 12.2 m (40 ft.), confirming that end bearing piles must be used. 600 mm (2 ft.) diameter and 800 mm (2 ft. 7 in.) diameter bored piles, 18 m to 20 m (59 ft. to 66 ft.) long, carrying 100 T and 160 T respectively were selected, bearing on the tufa.

The decision was later proved right by the encounter with a large number of voids during the piling and by a subsequent discovery, when a road caved in, of an extensive tunnel system running under the site connected to an early Roman water system and also due to mining for *pozzolana*.

Site

Any description of the architecture of the embassy cannot be divorced from a description of its location, which is on the Via Venti Settembre, previously the Via Pia, and alongside the Aurelian Wall. The street is a famous one. About 1560 the Pope, Pius IV, wanted to develop a new street which would be an integral work of art and bear his name. Unfortunately the Pope encountered difficulties in building the full length because of the steepness of the grade and because compulsory purchase orders were no more popular in the 16th century than today. So the Via Pia began at the Cavalle di Tiridale and ran through the Aurelian Wall to the bridge on the Nomentana. The unity of the street was achieved by the ingenuity and variety in the designs of the façades and, most of all, by the quality of the gate, built into the Aurelian Wall. This gate, the Porta Pia, was designed by Michelangelo and was totally unlike any previous city gate. It makes no pretence to be a defence structure. It faces inwards to end the view up the city street, rather than outwards to welcome the approaching traveller. A painting rather than a sculpture, it is an enormous doorway with flanking walls whose effect is achieved by emphasizing the non-structural elements. The structural material in the façade is brick, yet the travertine decoration dominates. There is a very flat arch over the gate, achieved by a semi-circular relieving arch above, with tremendous projecting ornamentation and the scale is enhanced by the strongly modelled, but very small, windows on the flanks. The embassy site is alongside the gate and the new building is in direct relationship to it.

The embassy stands in large grounds at an historic point within the old Aurelian Wall. On 20 September 1870 General Lamarmora and his *Bersaglieri* blew a hole in the Wall, entered Rome and annexed the city to Italy.

*Porous stone, formed of powdered matter consolidated and often stratified.

†A volcanic ash, containing silica, alumina, lime, etc., originally found at Pozzuoli, near Naples.

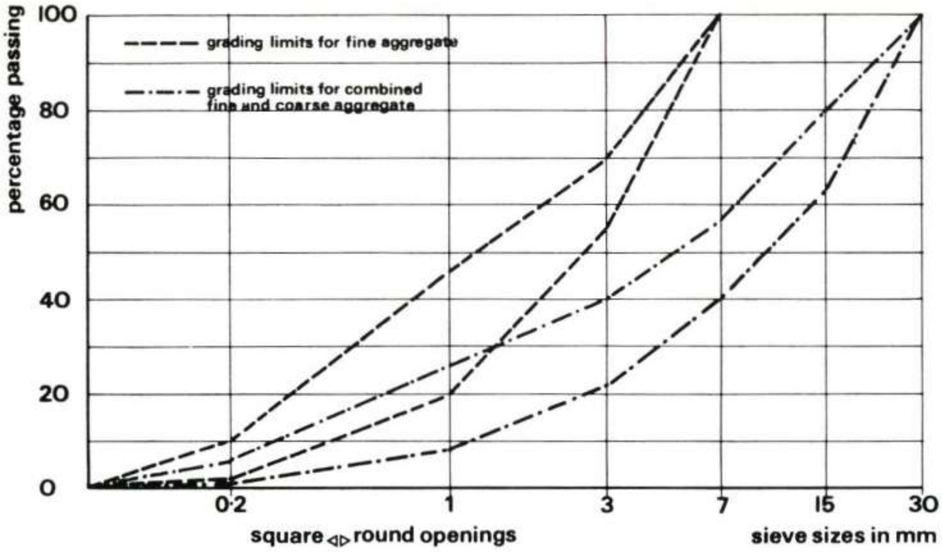


Fig. 11
Grading limits for aggregrate in Italy

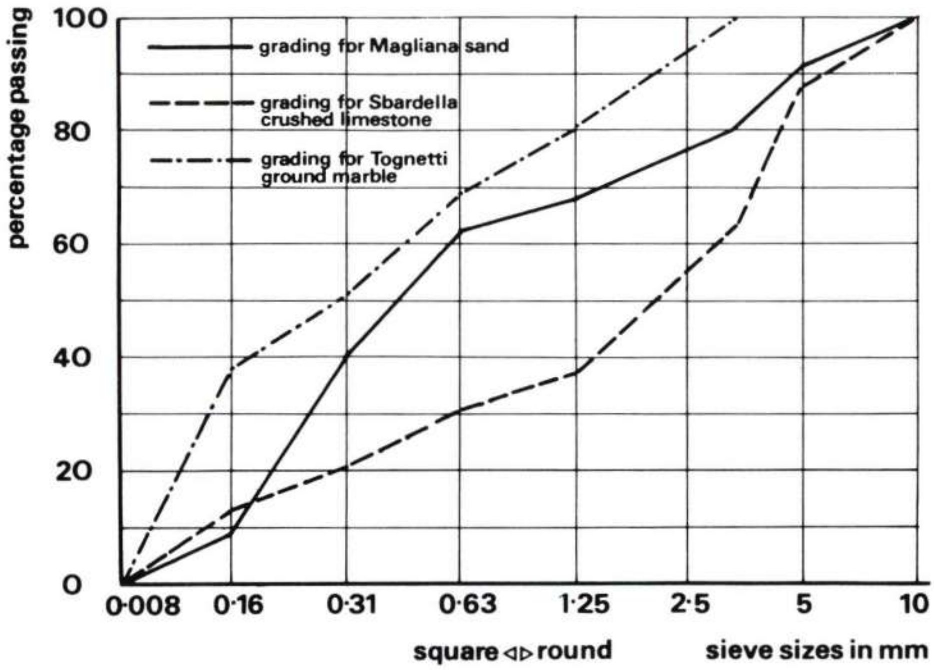


Fig. 12
Fine aggregate gradings

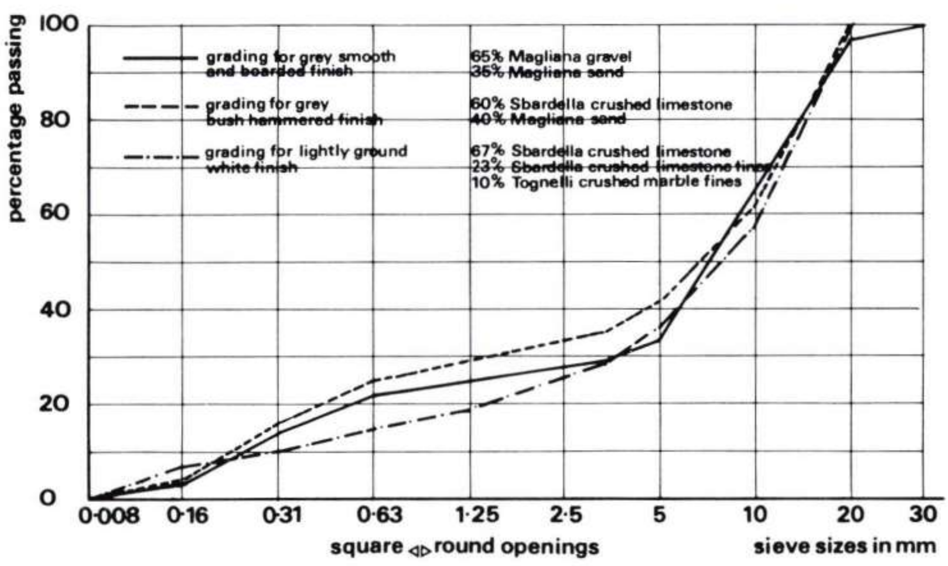


Fig. 13
Combined fine and coarse aggregate gradings

Unfortunately for the Pope's ambition the street name was changed in celebration to Via Venti Settembre.

Another explosion in 1946 irreparably damaged the previous embassy on the site. Members of the Jewish freedom organization, *Irgun Zvai Leumi*, placed two suitcases full of explosives against the main door and the damage led to the abandonment of the building. The embassy moved to the Villa Wolkonsky, the former German Embassy, but offices in deteriorating old German Nissen huts finally forced the move back to the Porta Pia site.

Description of building

The main embassy building is called the Chancery. It is a two-storey square ring on columns with an entrance and lift core area carried down to ground level. All the services are housed in a separate building by the Aurelian Wall. Roads, car parks, boundary walls and three external pools complete the works.

The foundations of the Chancery consist of bored in situ concrete piles supporting the structure on pile caps and ground beams with a system of underground ducts for services. The structural concrete frame (figs. 5, 6 and 7) consists of 15 cruciform shaped columns, from the top of which the first floor octagonal cell structures cantilever. The cell structures have fairfaced concrete cruciform beams over the heads of the columns with a double skin floor system enclosing the services. The lower skin is 100 mm (4 in.) thick in situ concrete with boarded finish and the upper skin is 160 mm (6.3 in.) thick filler joist floor slab. A central reinforced concrete spine beam runs through the building and each bay is separated from the next by a transverse concrete wall acting as a room divider and strongly expressed on both the external and internal elevations. This expression is enhanced by white precast elements cast in the first floor slab and by white concrete walls protruding through the façade on both elevations. The external elevation between these cross walls is a series of concrete walls, enclosing windows, on which large panels of travertine are hung proud of the building. On the internal courtyard elevation a succession of white precast concrete mullion units act as window dividers and reduce the scale of vertical repetition.

The second floor slab cantilevers over the first floor. The perimeter walls support travertine panels clear of the structure and, together with the central corridor walls, support a transverse roof beam system which cantilevers further over the second floor. It is expressed by making the exposed beam ends from white precast concrete elements which are cast into the beams. The infill decking is formed by precast concrete roof slabs and fairfaced concrete roof lights over the corridor.

The external cladding consists of the large independent travertine panels, which are hung proud of the general face of the building, anodised aluminium windows and large areas of exposed concrete structure. The roof is pitched to gutters on either side of the concrete roof lights and is covered in zinc. The internal partitions are either formed by the structural concrete walls or by lightweight blockwork. The building has two passenger lifts, one main staircase from ground to second floor, two secondary staircases from first to second floor, a small circular stair and an external main ceremonial staircase from ground to first floor. Services come from the separate service unit through underground ducts and are taken up into the Chancery building through the columns. The first floor is serviced within a double floor system to air-conditioning units set in the edge beams. Services for the second floor run up vertical gaps in the spine wall through the second floor slab and branch out in chases in the floor slab.

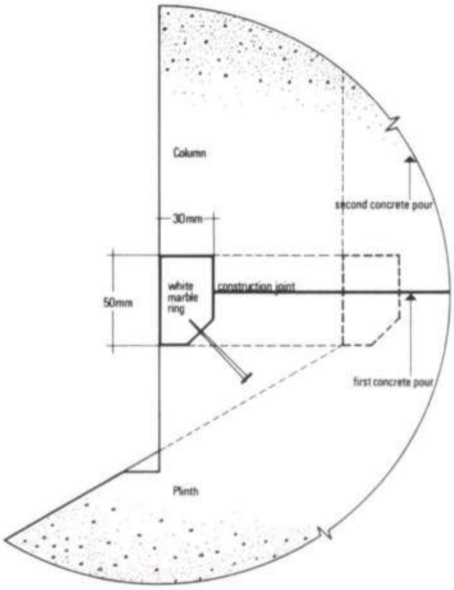


Fig. 14 above
Detail of marble masking insert cast in at column construction joint

Fig. 15 above
Reinforcement of second floor showing junction with transverse wall and 45° edge beam (Photo: Sciamanna, Rome)

Structure of Chancery

This building can be divided into typical cells along the sides, typical corner cells and the lift core cell. The lift core cell has no particular load-carrying interest except that it helps to ensure the torsional stability of the ring of the building.

The basic load-carrying system for a typical cell (fig. 8) consists of:

1 The cruciform columns and transverse cruciform beams (X beams) with in situ edge beams, soffit slabs and filler joist floor slabs.
2 The central spine wall acting as the web of an I beam with the first and second floors
3 The transverse walls acting as stiffeners to the I beam and consisting of a cross wall on the external side (3a) and a cross frame on the internal side (3b)
4 The external walls at the front between first and second floor which, together with the edge beams, B1 and B2, act as a Vierendeel truss supporting the second floor
5 The 600 x 110 mm (2 ft. x 4.3 in.) precast concrete window mullions at the interior of the building carrying the second floor
6 The 375 mm (1 ft. 3 in.) thick second floor slab which overhangs the first storey
7 The 100 mm (4 in.) thick concrete corridor walls supporting the roof beams
8 The external and internal façade walls between second floor and roof and supporting the roof beams
9 The roof beams at 3 m (10 ft.) centres supporting the precast concrete roof slabs

In the corner cell (see figs. 9 and 10) the roof grid is carried by a diagonal beam (10) which rests on the external and internal façade walls (8) and the corridor walls (7) and links with transverse beams in either direction. At the north corner the corridor walls supporting the roof beams stop short of the corner, due to the need for a large uninterrupted space which is required for a cinema on the second floor, so that the corner roof grid spans directly between external and internal walls.

Construction on site

Construction started with the piling at the beginning of April 1968. Piling was completed by the end of June 1968 and the structure was finished by the end of May 1970.

The general contractor, Impresa Castelli, SpA, is an old family firm working mainly in Rome and Milan. They have done a considerable amount of high quality work including several other embassies in Rome. The family still owns and controls the firm but the overall responsibility lies with the general manager who is a registered engineer. His son, also an engineer, was designated by the firm to be *Direttore del Cantiere* and also *Direttore dei Lavori*. These two, together with a *geometra* responsible for measurement, operated from the contractor's head office which was about 200 m (660 ft.) from the site. Control on the site was carried out by two *geometras*, one acting as agent/general foreman and responsible for reading the drawings, setting out, controlling labour, and the second acting as his assistant. A third *geometra*, employed mainly as an interpreter, helped in the site office. Three foremen were responsible to the *geometras*.

The division between the engineers and the *geometras* was clear; it does not appear that a *geometra* has any easy opportunity of becoming an engineer. Ordering was done by the general manager, usually on a more personal basis than it would be done in Britain. The general manager network in Rome is a powerful one, built up over decades. The day to day control of the site, however, lay with the senior *geometra*.

The client's supervisory team was headed by Bob Annandale, a senior Ministry clerk of works, highly experienced in working abroad. Ove Arup & Partners were fortunate in having on their London staff an Italian, Peter Cavanna, and he was appointed as resident engineer. Site inspections and meetings were held monthly and representatives of the consultants attended from London. The contractors' general manager always attended. The contractor provided an interpreter and the meetings normally lasted two or three days.

As described earlier, the quality of the embassy building depends on a higher standard of concrete finishes than is normally asked for in Italy. Five different surfaces and two different colours of concrete were required. These were:

a Grey smooth finish from *Wisaform*, a plastic faced plywood form
b Grey boarded finish from shutters lined with 40 mm (1.6 in.) wide softwood strips
c Light grey bush hammered finish
d White concrete with the surface lightly ground to expose the aggregate
e Grey rough finish

Two strengths of concrete, 30 N/mm^2 (4350 lb./in.^{2}) and 24 N/mm^2 (3480 lb./in.^{2}), were needed and the contractor was obliged by the specification to propose the mix designs. This was a difficult problem because very little advanced mix design is carried out in Italy and there is little literature on the subject. The national specification for reinforced concrete is not much help. For example, the grading limits for sand and coarse aggregate combined with fine aggregate are shown on fig. 11.

From these it can be seen that large differences in the percentages of the finer sizes of sand are acceptable and so it is extremely difficult to obtain more specific gradings from suppliers. This makes for general ignorance of the actual constitution of successful mixes.

Our ability to use British papers on the subject was limited because of the lack of knowledge of the relationship between gradings determined using round or square aperture sieves. Theoretically the difference is zero with a perfectly spherical aggregate but appreciably different with a flaky aggregate. The problems were increased by doubts on the accuracy of testing by the institute employed by the contractor to crush the cubes. Normally in Rome the university is used for testing and the accuracy is beyond question. Unfortunately there is a heavy demand on their services and the processing of results is slow. In the end the contractor set up a testing laboratory on site which included a 300 ton crushing machine, a *Speedy* moisture tester, a set of sieves, etc., and the cubes were crushed on site.

A very large number of cubes were required before strength, workability and colour were acceptable. Aggregates from five quarries were tested and, with some combination, satisfactory mixes were achieved. The gradings used are shown in figs. 12 and 13.

The casting of samples proceeded simultaneously with the mix designs. Again problems were encountered and the know-how came mainly from the consultants. The early white concrete samples had too many blow holes. The consultants believed the cause was the release agent as well as the mix design. Neither an insoluble emulsion of water in oil nor a mould cream emulsion could be found in Rome, in spite of an intense search by the resident engineer, advised by telex from London. Finally, a gallon of *Gulform 105*, for the non-absorbent shuttering, and a gallon of *Gulform 600*, for absorbent shuttering, were flown out from Britain and used on samples. The contractor was convinced and their use approved by the consultants. Changing from an impermeable plywood to a normal wood form and improving the mix design, finally reduced blowholes to a number which could be acceptably filled.

To confirm the finishes, a full scale sample column was cast with two cruciform beams and two external walls. The grey smooth finish of the cruciform beams gave trouble. Leakage occurred at the joints and the surface had ripples on it caused by blisters on the form. The contractor wished to change from *Wisaform* but sealing the edges of the boards and all screw holes with chlorinated rubber paint cured the problem.

Trouble also occurred at the construction joint between the top of the plinth and the column. Finally, a white marble ring, 50 mm (2 in.) deep by 30 mm (1.2 in.) wide was made in lengths with the joints confined to the internal angles (fig. 14). This ring was cast into the lower pour and the concrete stopped about 20 mm (0.8 in.) below the top of the ring. On the later grinding the irregularities were removed.

These experiences were harrowing for everyone. The contractor felt great uncertainty while the supervisory staff were worried about the responsibility they were taking on site. Throughout, the contractor was unfailingly helpful and, with the supervisory staff's advice, was finally convinced that it was possible to achieve the finishes required. From then on their craftsmanship took over. The finish is to the highest Arup standards.

The high quality of workmanship extended to the setting out and steel fixing. The structural drawings were labelled in Italian and the contractor seemed to have no difficulties in using them. Kickers were not used to start the walls and columns and we were asked not to detail them.

The building had to remain propped until the roof beams were cast. It was obviously desirable to re-use the cell forms and this meant re-propping. Temporary ground beams were cast below the first floor edge beams and the structure lifted off the forms with a hydraulic jacking system. Props were fixed with screw heads and used neoprene pads to protect the finish by ensuring uniformity of pressure. The entire building was finally depropped when the roof slab was cast. The maximum deflection recorded at the ends of the cruciform beams 24 hours after depropping was 4.6 mm (0.18 in.).

The problems that arose on site sprang from the building itself rather than from working in Italy. This is a building which uses Italian craftsmanship in a very British way. In the finishes required, the consultants forced techniques of concrete quality control on an industry relatively unused to them, though the results were admirable. The problems of mix design encountered will probably not exist in a few years time as the use of ready mixed concrete is growing.

Figs. 16 and 17
The embassy nearing completion
(Photos: Sciamanna, Rome)

Conclusions

Probably the structure of the embassy is a triumph of analysis over design. Certainly it was an excellent opportunity to work in another European country and to compare the skills and techniques of the Italian and British building industries. Many engineers in Arups have worked on this job. I must mention, however, Bob Silman (now in practice on his own in New York), Dave Cathro (now working in Finland), Peter Cavanna, David Whitfield and Mike Dickson.

Credits

Architect: Sir Basil Spence and Partners
Main Contractor: Impresa Castelli SpA

Golden Lane

Turlogh O'Brien
and Tony Read

Brief history

In 1952 the Corporation of the City of London organized an architectural competition for the development of a bombed area between Golden Lane and Aldersgate Street for housing. The original scheme covered 4½ acres (1.8 hectares) and comprised 315 flats, a community centre, workshops, and a central boiler house. The competition was won by Chamberlin, Powell and Bon. Work started in 1953 and phase 1 (the original scheme) was completed in 1957. During this period the site was extended by 2½ acres (1 hectare), adding a further 241 flats, 20 shops, a public house, restaurant, swimming pool and other amenity buildings. Phase II was completed in 1962. Ove Arup & Partners were consulting structural engineers for the whole development.

The overall layout of the scheme is shown in fig. 1. A view of the typical six-storey blocks in phase 1 is shown in fig. 2; the 16-storey block, Great Arthur House, is shown in fig. 3 and a general view of the landscaping is shown in fig. 4.

The scheme received much publicity both at the time of the competition in 1952, on completion of phase 1 in 1957 and phase II in 1962. Various articles on it may be found in the library. It represented an important evolutionary step in housing design.

Description of construction

Blocks 4, 5, 6, 7 and 8 are all very similar in construction. The super-structure consists of loadbearing brick cross walls with concrete floors at every other level. The intermediate floors (within the maisonettes) are of timber construction. There are private balconies on the south elevations and access galleries on the north elevations (fig. 5). These balconies and galleries have concrete parapet walls. Access staircases are situated at the ends of the blocks and have reinforced concrete frames (fig. 6).

Block 1 (Great Arthur House) has eight flats per floor. It has concrete crosswalls and floors. Fig. 3 shows that the main elevations are clad with a curtain wall and the only concrete showing is that of the balcony parapets. The flank walls are in situ pick-hammered concrete. The building is topped by a convoluted roof canopy housing water tanks and lift motor rooms.

The remaining blocks are not being repaired at present and will not be described.

The exposed concrete on the low blocks was not originally painted. However, it was already weathering badly when phase 1 was completed, and this feature received adverse comment in the reviews of the buildings in the architectural journals. The concrete on Great Arthur House was painted from the start. At a later stage (1962-63) the concrete on the low blocks was also painted.

Existing condition of exposed concrete

Within the last few years it has become apparent that severe deterioration of the exposed concrete was occurring. Superficial examination revealed that extensive spalling and cracking was taking place. More detailed examination showed that the concrete was of poor quality with numerous blowholes on the surface, which were not covered by the paint. Severe corrosion of the reinforcement was found to be occurring.

A detailed covermeter survey was carried out by the Scientific Branch of the Greater London Council on behalf of the Corporation of London. Typical results for four balcony fronts on the south elevation of Block 6 (Bowater House) are shown in fig. 7. These concrete walls are 100 mm (4 in.) thick and have one layer of mesh reinforcement designed to be placed centrally. In practice the cover to the front face is found to vary from nothing to 75 mm (3 in.). Similar variations were found on the concrete frame to the staircases, except that in several cases the steel was actually slightly proud of the concrete surface!

It will be recalled that the cover requirements at the time (CP 114:1948) which, with the exception of those for columns, are generally less than would be specified now, were as follows:

a For a longitudinal reinforcing bar in a column, not less than 40 mm (1.6 in.), nor less than the diameter of such rod or bar

b For a longitudinal reinforcing bar in a beam, not less than 25 mm (1 in.), nor less than the diameter of such rod or bar

c For all other reinforcing bars, not less than 12 mm (0.5 in.) nor less than the diameter of such reinforcement

d For all external work, for work against earth faces, and also for internal work where there are particularly corrosive conditions, the cover of the concrete should be increased by 12 mm (0.5 in.) beyond the figures given in (a) to (c) above.

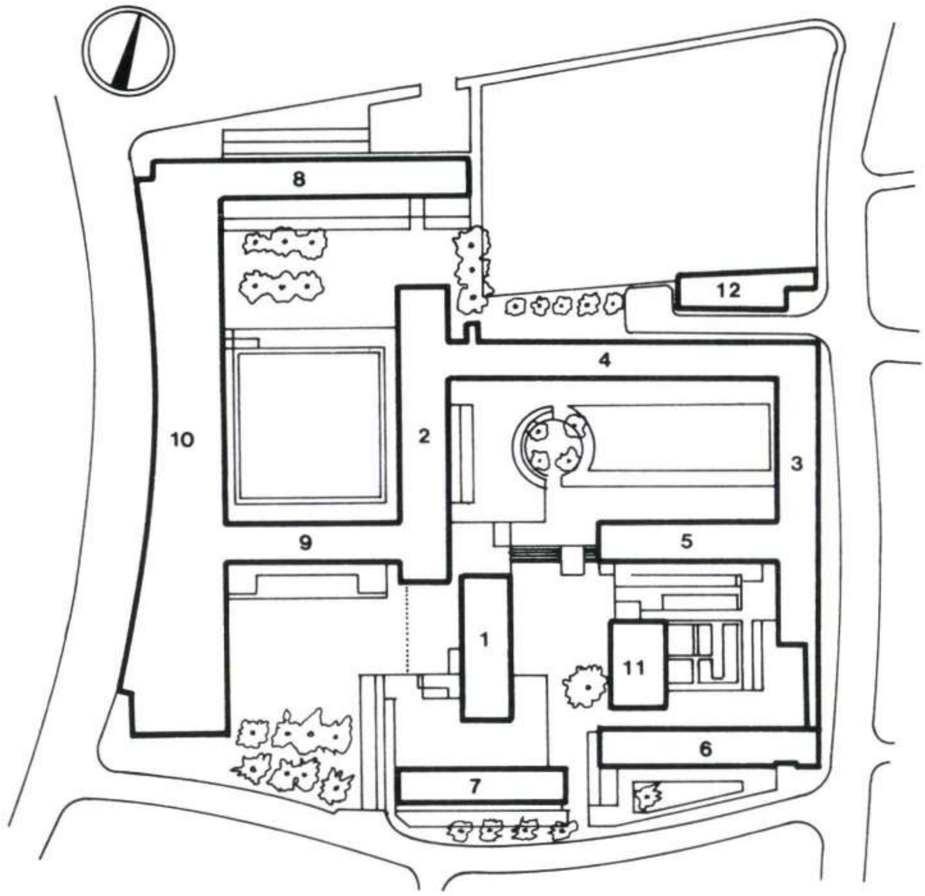
The existing paint on the concrete was generally firmly adhering and was found to be based on polyvinyl acetate resin. It had failed to protect the concrete due to the fact that it could not cover the blow holes (fig. 8).

The result of this poor cover and poor concrete is that extensive spalling has occurred. The appearance of the concrete before treatment is shown in figs. 9, 10 and 11. In addition, there are numerous shrinkage cracks which have become more pronounced with weathering.

Fig. 11 shows the spalling that has occurred on the pick-hammered walls of Great Arthur House. The deterioration has proceeded to the extent that small pieces of concrete have been falling off the block. A complete survey of the concrete surfaces has been carried out to ensure the removal of all loose concrete, and to render the building safe from falling pieces until the repair work is carried out.

A detailed survey has also been carried out of the roof canopy structure. The lower, curved concrete slab shows numerous cracks (fig. 12). The cover to main steel has been found to be generally about 20 mm (0.8 in.) but no spalling is occurring. The shape of the structure has resulted in a marked staining pattern (fig. 3), which has altered the appearance considerably from the original white concrete. The unpainted concrete on the roof (laid out as a garden, fig. 13) shows considerable acid etching by rainwater. There is a marked contrast between areas protected by the canopy and areas fully exposed to the weather.

The result of these investigations has been the decision that extensive repairs must be carried out. Originally a three phase programme was considered, but part way through the first phase, it was re-organized into only two phases. Blocks 5, 6 and 7 have been treated in 1970; blocks 1, 4 and 8 will be repaired



Key
1 Great Arthur House
2 Recreation building
3 Stanley Cohen House
4 Basterfield House
5 Bayer House
6 Bowater House
7 Cuthbert Harrowing House
8 Hatfield House
9 Cullum Welch House
10 Crescent House
11 Community building
12 Estate workshops

Fig. 1
Site plan (from *Architects Journal*)

in 1971. Blocks 2 and 3 are not included in the work, and it is not yet clear whether blocks 9 and 10 will be involved (see fig. 1).

Before the detailed specification was written, an investigation was carried out into the range of alternative treatments that could be used. This is summarized in the next section.

Alternative solutions for concrete repairs

The first choice that must be made when considering a problem involving deteriorated concrete is whether to cut out and recast or to patch up what is left. Obviously if full structural performance must be restored it may be necessary to replace members. Thin concrete cladding panels are often more easily replaced than patched. However, it is more common to adopt the principle that further deterioration must be prevented, but restoration of original properties need not be attempted. This approach is easier to apply, particularly in occupied buildings. Clearly, the deterioration must not have proceeded to the point of endangering the structure.

The operations involved in patching concrete can be summarized as follows:

1 Breaking out loose concrete
2 Cleaning exposed steel
3 Restoring original profile
4 Covering the whole surface to prevent further deterioration.

In certain cases two other operations are required:

a Removal of existing paint and/or dirt
b Filling blowholes and surface defects.

Two main categories of techniques have been developed to deal with these repairs. One uses sprayed cementitious layers (guniting), the other uses thin impermeable membranes. In the former, deficient cover is remedied by building up a thick (up to 40 mm (1.6 in.)) layer; in the latter, the concrete is cocooned in a thin membrane which excludes all air and water.

It is probable that more repair work has been done using gunite than thin membranes. Guniting is more appropriate to civil engineering structures than to buildings, and exposed concrete has been in use for longer on the former. The additional thickness applied in the gunite process often gives very difficult detailing problems on buildings, at junctions with other materials and components. In addition, reasonably large areas are required to make the process economical.

A gunited layer is more impermeable and better compacted than an equivalent thickness of trowelled cement rendering. It is normally reinforced with a mesh fixed to the substrate. Good results have usually been obtained with this method, except under marine conditions. The surface appearance is often unacceptable and decorative painting is required.

Some developments are being carried out which will enable the same results to be obtained with thinner coatings. The idea is to modify the cementitious mix with a polymer emulsion so that exclusion of air and moisture can be achieved with less bulk of material. Emulsions based on polyvinyl acetate (PVA) are unsuitable for this due to their moisture sensitivity, but newer ones using styrene butadiene (SBR) are promising.[1] Further developments may result in the inclusion of water dispersible pitch/epoxy admixtures.

The most commonly used thin membrane techniques is that developed by the Cement Marketing Company incorporating a bitumen membrane protected by *Sandtex* decorative coating. It is applied under a variety of trade names by specialist companies. A detailed description of the system may be found in *Notes on Materials—13* (December 1969). Its main advantage over other systems is its cost.

Alternative systems based on high performance resins (epoxies or similar) are newer and less tried, but are claimed to last longer. A specification for one of these was worked out for the repairs to the Chemistry Building at Exeter University. A four-coat treatment is involved, consisting of primer, thixotropic resin membrane, and two coats of a compatible decorative system. The total thickness of the system is about 0.3 mm (0.012 in.). The most satisfactory decorative systems incorporate a coarse filler to give a slightly gritty matt finish.

Before thin membranes can be applied, the surface must be prepared. Ideally it must be clean, dry, dust free and continuous (no voids). With concrete it is often difficult to get full surface continuity due to blowholes. However, the membrane system only works if it is fully continuous, and it is therefore necessary to fill all blowholes before applying the primer. In addition, it is advisable to apply the full membrane direct to concrete so that any existing decorative paints must be removed.

On unpainted, but weathered surfaces, dirt must be removed.

With gunite treatments, the filling of blowholes is not required, but the surface must be clean and dust free. A good mechanical key is advantageous. Surface preparation may be by grit-blasting, bush-hammering, spinning and chemical paint strippers or cleaners. Chemical cleaners are usually based on acids (hydrochloric or phospheric). When thin membrane treatment is to be used, bush-hammering is not normally the most desirable method of surface preparation as it is more difficult to obtain a complete film on a rough surface.

Breaking out spalling concrete can be done with hand tools, although powered tools are needed for cleaning the steel. The most effective tool is a needle gun (*Jason pistol*). After priming the steel (zinc/epoxy primer), patching must be effected to restore the original profile. The alternatives for this are

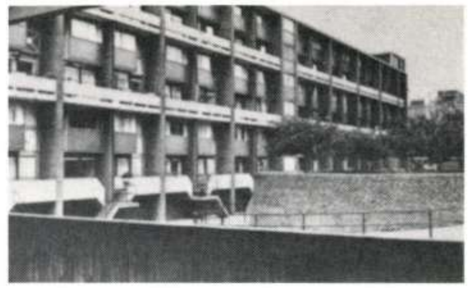


Fig. 2 right
South elevation of typical maisonette block (Basterfield House)

Fig. 3 below
Great Arthur House, showing pick-hammered flank walls and roof canopy

Fig. 4
View showing landscaping of spaces between buildings (Crescent and Hatfield Houses behind)

modified cement mortars or epoxy resin mortars. Cement mortars modified with PVA have been widely used in conjunction with the bitumen *Sandtex* membrane, but are not recommended for external use, or for use in contact with steel. It is possible that cement mortars modified with SBR emulsions will be accepted for this in the near future.

Again, with guniting, patching is not required as a separate operation. The cavities are filled as spraying proceeds.

The specification

The majority of the concrete surfaces requiring repair on the low blocks at Golden Lane had the following characteristics: they were smooth, covered with PVA emulsion paint and riddled with blowholes of varying sizes. In addition, numerous awkward details existed where the concrete abutted brickwork, asphalt flashings and floor tiles. This suggested that the thin membrane method rather than guniting would have to be used. However, before this was settled, consideration was given to replacing the balconies on the south elevations (fig. 2). It was eventually decided that the disruption to the tenants would be too great, and that the technical difficulties would be considerable in view of the way the balconies were built in to the brick crosswalls.

The use of the cheaper thin membrane treatment (bitumen/*Sandtex*) was rejected on the grounds that the protection afforded would not be sufficient, that it was too fragile for concrete in these situations (as it is easily damaged and bitumen may bleed through if the coating is leant on for long) and that the coating can be badly damaged by some attempts to overcoat it with other paints.

It was therefore decided that a resin membrane would be used, but that in order to allow some scope for contractors to use their own systems, the materials would not be specified in detail. An example was given of the type of materials expected (epoxy resin based products from one formulator) and contractors were asked to name the comparable products that they wished to use. (In the event, the successful contractor opted for materials based on chlorinated rubber resin, which, although not as hard as epoxies, were accepted as having adequate impermeability and weather resistance and better colour stability.)

The preparatory work was specified to include hammer testing all concrete surfaces to remove loose concrete, breaking out all spalling concrete cutting 20 x 20 mm (0.8 x 0.8 in.) chases along the lines of cracks, cleaning exposed steel using powered tools, priming steel with one coat of inhibitive primer, patching to the original profile using a proprietary epoxy resin mortar, removing existing paint and filling blowholes with either resin mortar or modified cement mortar.

The standards of work required were laid down in general terms, but contractors were left to select the following items:

a Type and brand of primer for steel

b Brand of epoxy resin mortar

c Method of removing existing paint

d Type of mortar for filling blowholes

The decision to leave open the method of surface preparation was taken when it was found, in discussions with possible contractors, that they had their preferred methods of working and that any one of several methods could be effective. A sample area of concrete was specified to be cleaned as the first item of work so that there would be no doubts about the standard of work required.

The specification for the treatment of the pick-hammered flank walls on Great Arthur House has not yet been compiled. It poses considerable problems as ideally the same surface roughness should be left after the work has been done. It is difficult to form a complete thin membrane over a very rough surface, so it is likely that the final treatment will involve sprayed cementitious coating, 10—20 mm (0.4—0.8 in.) thick, incorporating a polymer emulsion modifying agent. Preliminary test work is being carried out. Surface preparation will be by wet sand blasting (to control dust).

The treatment of the canopy on the top of Great Arthur House has also not yet been fully worked out. Crack filling will be required, by cutting chases and filling with soft sealant to accommodate further movement. A drip will probably be incorporated in an attempt to control the staining on the underside of the canopy, which will have to be cleaned and painted.

Treatment of the smooth concrete surfaces on this block will be by the same method as that used on the low blocks.

The specification for phase 1 of the repairs was compiled in November 1969. It was intended that work would start on site in April 1970 so that it could be done during the better weather. The specification for phase II, including Great Arthur House, will be prepared this winter so that work can start in April 1971.

Tendering

Tendering for remedial work is in some ways easier than the normal type of building work because the work to be done can plainly be seen on site. On the other hand the competitive tendering system makes it imperative that each contractor fully understands the requirements and problems of the job. It was therefore decided that, before going to tender, each contractor would be interviewed on site to familiarize him with the problem so that when tender documents were received there would be no difficulty in understanding the requirements. The interviewing also provided an opportunity to discuss various systems and assess their practicability.

Initially, eight contractors were asked to tender for the work on Bowater and Cuthbert Harrowing Houses. The tender document consisted of preambles, specification for concrete repairs and a bill of quantities. The City of London decided that the houses should also receive general maintenance work and repainting so a general maintenance specification was prepared by them and included in the document. This had to be tendered in a different way to the rest of the work. No quantities were given but the contractor had to quote a schedule of rates *and* submit a total price for the item. Tendering for concrete repairs and redecorations posed a bit of a problem since it was not known how much repair work would be necessary until the concrete had been hammer tested. At the same time an overall price was necessary in order that the various Corporation of London committees could approve the work and allocate the appropriate sum of money. (The bill of quantities covered the surface preparation, resin membrane and decorative painting of the concrete only.) It was decided that each contractor would only submit a schedule of rates for breaking out and making good spalled concrete but that in addition he should estimate for himself the amount of this work he thought would be necessary and include this in a separate letter to the City. It was emphasized however that this would not be used as a basis for the competitive tender and would be used only as a guide for the committees. Contractors also had to submit with their tender a form stating the materials and method of working they proposed using and also what reductions in price would be offered if two other houses (Bayer and Basterfield), were also included in the contract.

The tendering was disappointing, despite the efforts taken to acquaint contractors with the requirements. Of the eight contractors, only three submitted priced tenders and of these only one was tendered correctly (it was also so high as to be unacceptable on its own). The two incorrectly priced tenders had not given a total price as well as rates for the

Fig. 5 right
North elevation of typical maisonette block (Bayer House)

Fig. 6 below
Typical staircase (Bowater House after repair)

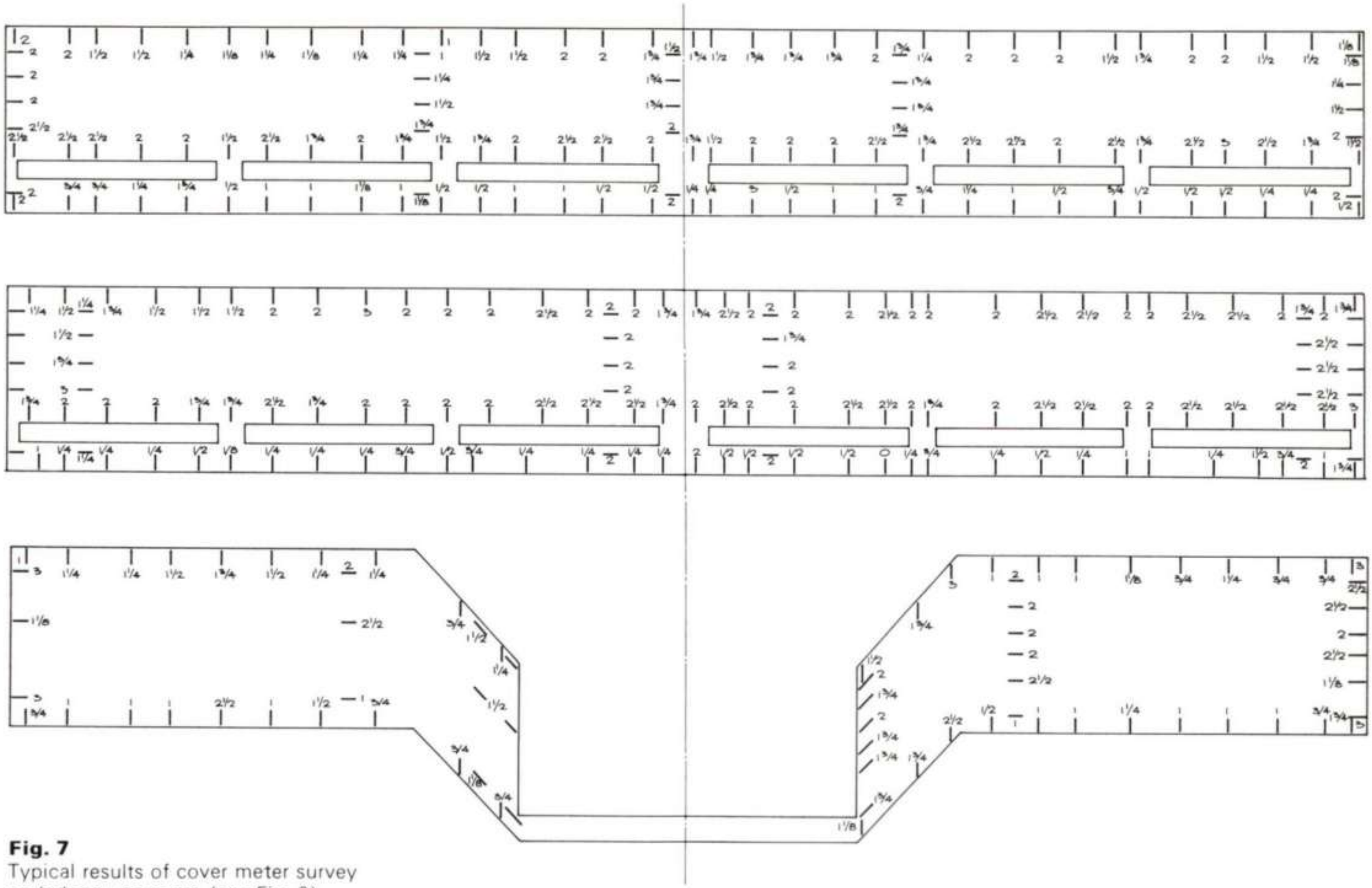


Fig. 7
Typical results of cover meter survey on balcony parapets (see Fig. 2)

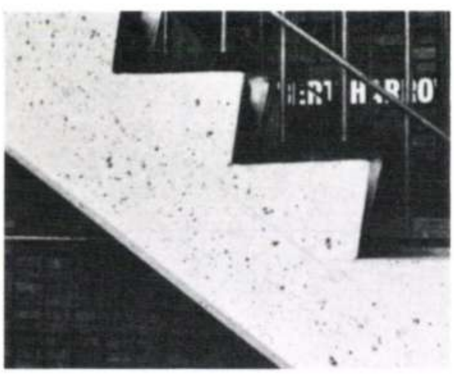


Fig. 8
The concrete surfaces are covered with blowholes as shown on the edge of a stair

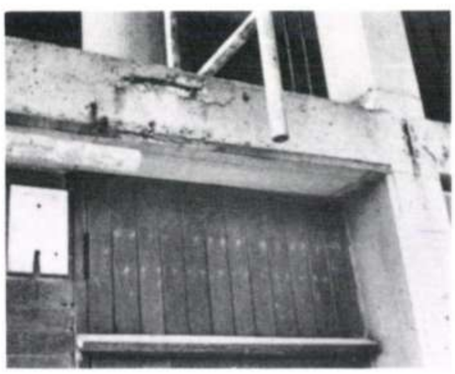


Fig. 9
Examples of spalling on the staircases (Cuthbert Harrowing House)

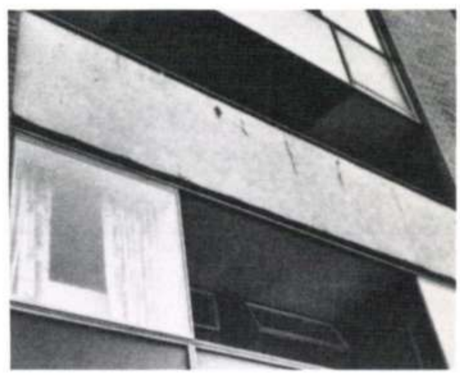


Fig. 10
Example of spalling on north facing access gallery (Bayer House)

maintenance work. Two other companies had decided not to tender because they were not used to handling general maintenance work. The three other companies did not tender because they felt that certain items in the specification precluded their repair system.

The work was retendered giving contractors the option of two types of tender. Tender A was the same as the previous one. Tender B allowed the contractor to vary certain items in the specification.

These were:

a The patching mortar for making good the concrete surfaces to the original profile

b The extent of removal of existing paint from surfaces not currently showing defects

c The junction details with other materials on the building.

No variation was allowed in the clause which required that all the specified concrete surfaces should be treated with a resin coating of equivalent performance to the one quoted in the documents. This time the response was better and eight tenders were received; four to tender A and four to tender B.

Evaluation of the tenders was not easy since they were not all technically comparable, and there was very little time in which to make a recommendation. Starting from the lowest priced, each tender was examined until a technically acceptable one was found. This was then used as a basis for contract.

An interesting point which arose from the tenders was that none of the contractors were prepared to reduce their rates for the job if the other two houses were included in the contract. Because of this it was decided that the initial contract would be for Bowater and Cuthbert Harrowing Houses only. In fact a decision was made halfway through the contract to include Bayer House as well but this was so that the programme of repairs to the whole estate could be phased over two years instead of three as originally planned.

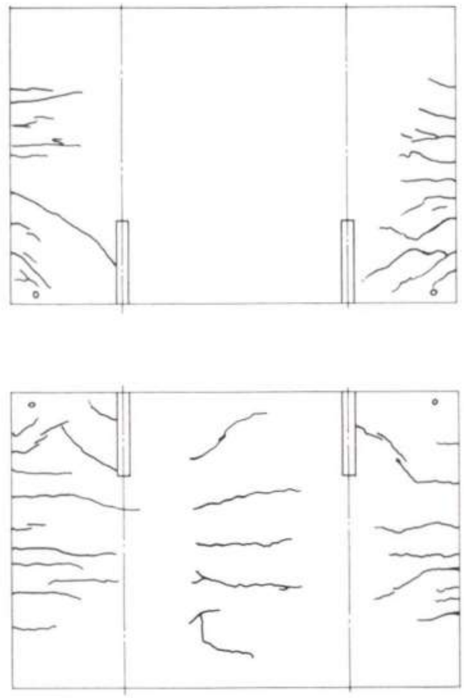
Problems on site

It is apparent from the section on alternative treatments that the success of the repairs depended on the quality of the surface preparation. This involved two operations; removing the existing paint, and filling in the blowholes. The contractor elected to carry out these operations by using a chemical stripper and a modified cement mortar. The standard of surface preparation was established by a test section prepared on one of the balcony fronts. It was stated in the specification that this would be required and used as a visual standard for the rest of the contract.

The contractor soon discovered that the chemical stripper would not remove the PVA paint and so started to use grinding discs. The grinding method would not remove paint from the hollows in the concrete so the contractor looked around for another chemical stripper and was able to find one that worked reasonably well. The surface preparation then comprised a complicated series of operations

Fig. 11
Exposed reinforcing bars on the flank walls of Great Arthur House

Fig. 12 below
Crack pattern on roof canopy soffit (survey by John Blanchard)



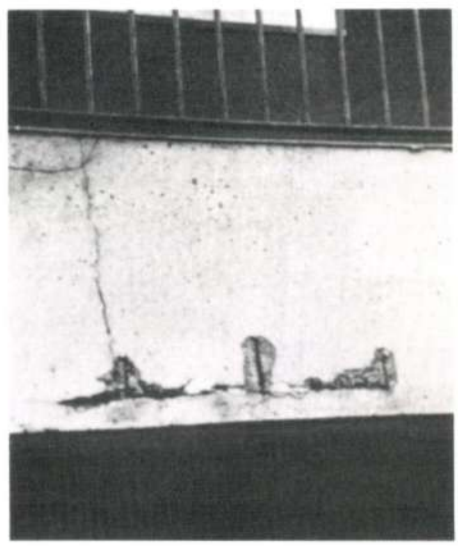
involving chemical stripping, grinding, blowhole filling and regrinding. The extra grinding operation was necessary to remove excess mortar from the blowhole filling operation. Blowhole filling had its own problems; there were so many blowholes that it was difficult to go around spot filling them without putting on a complete layer skimmed over the surface of the concrete. This produced a weak surface and so it was necessary for the concrete to be cleaned up by regrinding. The majority of these problems occurred after the sample area had been agreed and, despite the complicated cleaning operation used, the degree of surface preparation being achieved on the job was not up to this standard. The contractor finally changed the method of preparation completely and used a light bush hammering technique. This produced a rough surface and was a far more satisfactory method because it 'opened-up' the blowholes, so making them accessible for painting. There were then only a few holes left in the concrete which had to be spot-filled. The priming paint was applied to this rough surface by spray and then brushed in thoroughly. The thixotropic chlorinated rubber membrane was applied by roller and then brushed—the two textured decorative coats were sprayed on.

There was also a certain amount of trouble with bubbling and blistering of the paint at this time which the contractor and paint manufacturer finally attributed to application technique. Chlorinated rubber based paints tend to 'skin over' very quickly so that when a thick layer is applied it is possible to trap solvent within the paint which forms a bubble. One of the early detailing problems encountered was the junction between asphalt and the resin membrane. Asphalt is incompatible with most of the resins used in protective systems and so it is difficult to make a reasonable waterproof junction where the two meet. An aluminium flashing detail was originally designed to cope with the problem but was later changed after discussions with the asphalters. The detail finally adopted was to use a bitumen sealer on the asphalt and to lap the chlorinated rubber membrane on to the latter, bedding in glass fibre tape across the junction.

Generally speaking the corrosion of reinforcement had nowhere put the buildings in any

Fig. 13
Roof garden on Great Arthur House

Fig. 14
Severe spalling on downstand beam (Cuthbert Harrowing House)



structural danger but there were two instances where corrosion was so severe that it was necessary to prop members before repairing them. The north face of Cuthbert Harrowing House had large downstand beams at ground floor level which were badly cracked and spalled (fig. 14) and two large holes were found in the staircase of Bowater House. There was also a hidden void next to one of these holes which was filled by a resin grouting technique. It required five pints of resin to fill it!

Concluding notes

The repair work at Golden Lane has served to emphasize a few points which will be familiar to many people. Among the ones which have been of note are:

a Specialist concrete repair companies are not used to working with consultants. They generally deal directly with the client, offering their particular 'system'. Some of them do not like modifying their systems to suit the requirements of consultants.

b Repair work can often involve quite a wide range of specialist skills and there is the problem, on a large job, of whether to get a general builder to oversee the specialists, or whether to have the main specialist as principal contractor.

c It is absolutely essential to have detailed discussions with contractors before tenders are sent out so that the technical requirements are fully understood. Otherwise, there is the danger in competitive tendering that the one who wins is the one who makes the biggest mistake in estimating.

d Everyone involved, including operatives, requires a high level of understanding of the reasons for each operation, so that time is not wasted each time a small snag is encountered (there are usually many of these in repair work).

Credits

Client:	Corporation of London
Architect:	Dept. of Architecture & Planning, Corporation of London.
Consulting Engineer:	Ove Arup & Partners
Quantity Surveyor:	Davis, Belfield & Everest
Contractor:	Resin Applications & Linings Ltd.
Photos:	T. O'Brien & T. Read

Reference

(1) CALLEGARI, A. G. Polymer emulsion admixtures in mortars and concretes. Ove Arup & Partners. *Technical Paper no. 8*. 1969.

Dunlop Speedaway

Raymond Payne

If Nature had intended Man to walk everywhere, she would never have invented Dunlop.

(Dunlop Advertising)

Introduction

Ove Arup and Partners were asked by the Belting Division of the Dunlop Company Ltd. in 1968 to study the structural aspects and the capital cost and cost in use of the Dunlop *Speedaway* System. This initial study was for an investigation into a general structural solution for the *Speedaway* in the UK. This was followed by a commission from Dunlop requesting a translation of this work to suit conditions applicable in the USA. As the UK study progressed, it became apparent that, because the commercial success of the system depended largely on its revenue earning capacity, a general structural and economic study was not appropriate. From this point on, the structural study, to which was added our involvement in the heating and ventilating and electrical engineering aspects of the work, progressed towards a general solution for most situations. An approximate estimate of the capital cost and cost in use was also made for a typical 1 km (0.62 miles) length and a report was submitted to the Dunlop Company in July 1969. Because the revenue earning capacity of the system is dependent on capital cost, cost in use and anticipated pedestrian flows, it was decided that a study should be made of a specific area, and the Dunlop Company therefore asked us to use, and adapt as necessary, our work on the general solution to produce a specific case study for a UK provincial city which had approached Dunlop on this matter. This has now been done and the report, which included contributions and drawings from other organizations connected with the *Speedaway*, was published in October 1970. The general structural and heating and ventilation work was adapted and a fairly accurate economic analysis built around this. That our tentative general solution fitted the individual situation so well is some measure of how our approach to the design evolved a structural system capable of a large degree of adaptability.

Following on from this work we have been commissioned by Dunlop to undertake a study for a further possible application of the *Speedaway* and work has now started on this. The USA adaption of our work has now got under way and for this we have employed Farkas, Barron and Partners, New York. The information and comments which they make on the various aspects of the work for the general USA application are being collected in New York and are being processed by us in London. A report will subsequently be prepared.

For all the above work we have collaborated with, and been guided by, Brian Richards B.Arch ARIBA, consultant architect retained on the project and John Kyle C.Eng. MIMechE, Manager, Transportation Projects, Dunlop Belting Division. The economic analysis and the analysis of pedestrian flows have been done in collaboration with M. J. Thompson BSc (Econ), FSS, Rees Jeffreys Research Fellow in Transport Economics at the London School of Economics.

The system

The Dunlop Company has for some years been manufacturing pedestrian conveyor belt systems, using their patented *Starglide* belt. Movement of large numbers of pedestrians by this method is established as an efficient means of short haul transport within shopping centres and at airports. The speed of these belts is up to 3 km (1.86 miles) per hour. This speed is dictated not by any technical restraints imposed by the belt or the belt drive but by the difficulty pedestrians experience in stepping on and off a belt moving at a higher speed. The relatively low speeds of conventional belts limit this form of transport to short hauls. Distances of over 300 m (984 ft.) would take a relatively long time to cover and such journeys could be undertaken by more rapid forms of transport.

Fig. 1
View of pedestrianized street showing *Speedaway* forming covered arcade (Reproduced by courtesy of Brian Richards and the Dunlop Company Ltd.)

Fig. 2
View of pedestrianized street showing *Speedaway* station and route intersection (Reproduced by courtesy of Brian Richards and the Dunlop Company Ltd.)

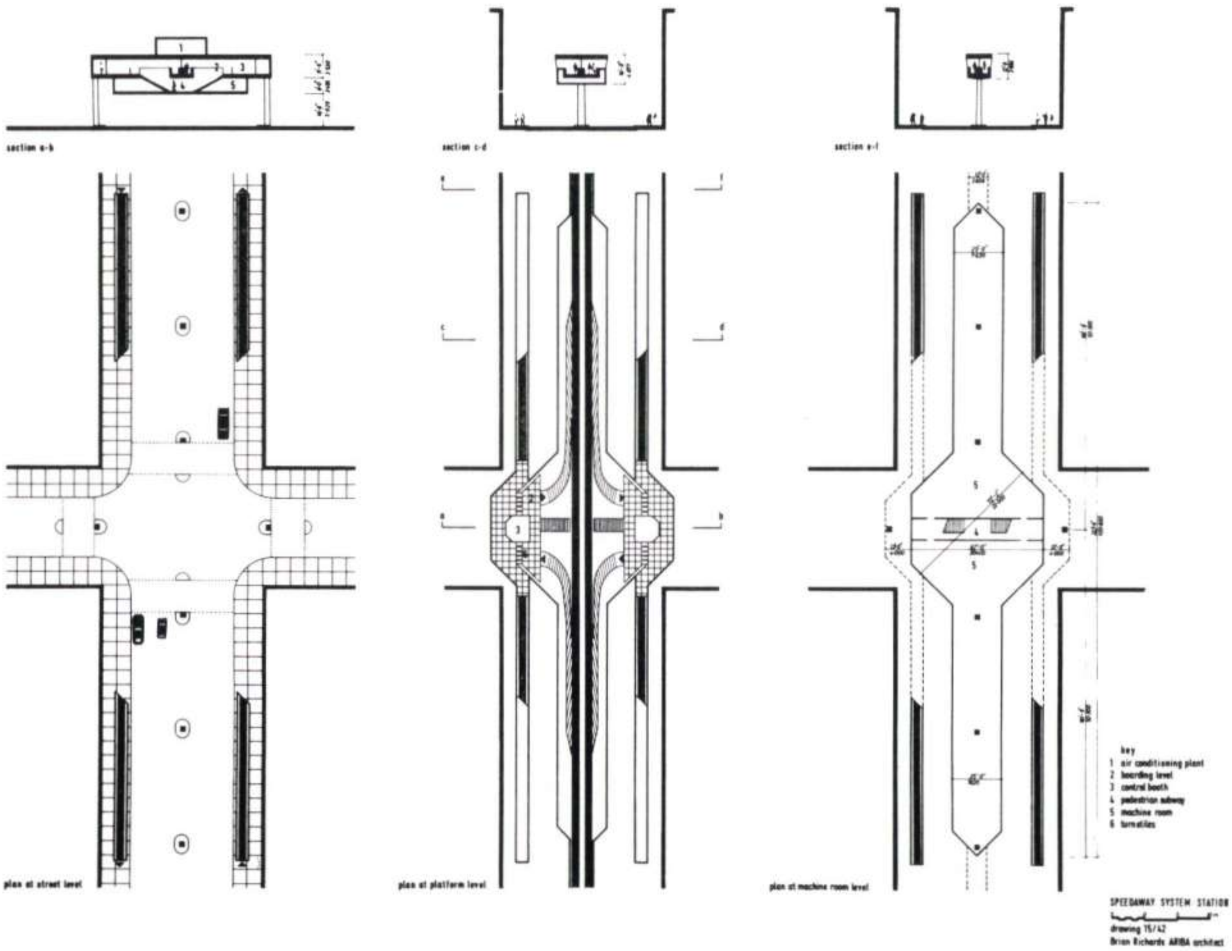


Fig. 3
Elevated intermediate station.
(Reproduced by courtesy of Brian Richards and the Dunlop Company Ltd.)

The Dunlop *Speedaway* System was evolved for medium haul distances of between 200 m and about 2000 m (660 ft.—1.24 miles) where faster travel is required. The system consists of *Starglide* belts running in each direction at about 15 km (9.3 miles) per hour separated by a balustrade supporting moving hand rails surmounted by a glazed screen. The flow of the belts may be reversed to provide for increased capacity in one direction during peak hour pedestrian flows.

The passenger space is totally enclosed and the system may be fully heated and air conditioned by means of ducts in the roof. The system can run above ground level on columns, or at ground level or in tunnels. Stations may be situated at any point along the route subject to the usual geographical restraints and the needs of the community.

The belt drive mechanism may be conveniently located at the station positions together with the heating and ventilating plant. The conventional belt and belt drive may be readily adapted for high speed running. The problem with pedestrian travelator systems has always been that of accelerating pedestrians safely from a walking speed of say 3 km (1.86 miles) per hour to a high belt speed of 15 km (9.3 miles) per hour.

This problem is the subject of sponsored development work by Dunlop which resulted in the development of an integrator which enables pedestrians to be accelerated or decelerated when getting on or off a high speed belt. The integrator is therefore essential to any high speed belt pedestrian transit system and the key to the Dunlop *Speedaway*. The capacity of *Speedaway* belts is 30,000 persons per hour in each direction; the entry and exit integrators in the present station design have a capacity of 10,000 and 12,000 persons per hour respectively.

Fig. 4
Interior view of the *Speedaway* showing glazing spine truss and twin *Starglide* belt
(Reproduced by courtesy of Brian Richards and the Dunlop Company Ltd.)

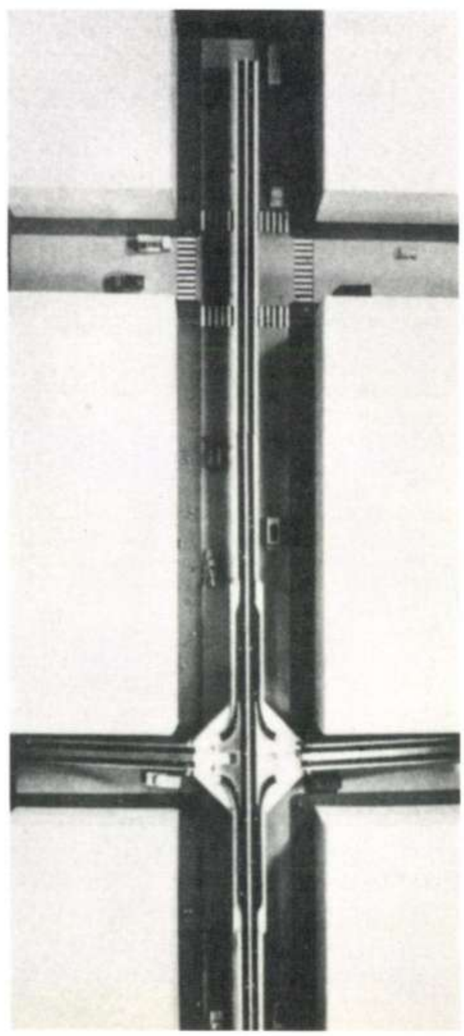


Fig. 5
Plan view of model of elevated intermediate station
(Reproduced by courtesy of Brian Richards and the Dunlop Company Ltd.)

The integrator and its operation

The integrator takes the form of equal width, metal ribbed, platforms which, at the commencement of an acceleration run, pass slowly through an entrance comb. This movement is similar to that at the entrance of a conventional escalator, but much wider. The entry velocity is about 3 km (1.86 miles) per hour. Platforms in advance of the one at the entry comb slide progressively to the left as progress along the curved accelerating length takes place. The following platforms will also slide relative to each other. This gives the platforms a two directional movement, both forward and sideways. Any point on an integrator platform follows a parabolic path throughout the acceleration zone. The acceleration on the curved part of the integrator track is constant and, on reaching the straight section, maintains a constant speed equal to the terminal velocity after acceleration. This velocity is also equal to the speed of the belt and a period of about five seconds is allowed for pedestrians to transfer from the integrator to the high speed belt. A parallelogram shape has been developed for the platforms to eliminate gaps which would otherwise occur over the acceleration section if rectangular platforms were used.

On completing the straight high speed run, the integrator platforms dip down and return under the previous run to emerge again at the entry point to form the acceleration run.

The work of Ove Arup & Partners

The supporting structure

In order to obtain a high degree of standardization, and ease of erection in city environments, we chose a steel supporting structure for the general study. The specific case study and report made use of this work and adopted this design solution. The factors affecting the general design solution were the support conditions, the choice of either site or shop assembly and erection, and the horizontal and vertical alignment.

The main requirements of the structure to support the belt, glazing and ventilation and heating ducts were:

1 Supports for the belt roller sub frames at approximately 3 m (10 ft.) centres

2 That there should be no mullions in the inclined glazed sides of the structure

3 Preferably no load bearing structure above the level of the belt roller supports and below the line of the top of the windows so that a section of the elevated structure could be adapted to accommodate a station

4 The greatest possible area of glazing in the partition between the two belts

The structural system proposed for the specific case study report had a spine girder as the main supporting member. Single columns at about 30 m (100 ft.) centres carry this girder. The spine girder consisted of a deep I-beam between the central pair of balustrades and a shallow box beam in the roof. Both of these beams extended from one column to the next. Posts spaced at 6 m (20 ft.) centres connected the upper box beam to the lower I-beam forming a Vierendeel girder.

At the bottom of the girder, cantilever beams extended on both sides of the girder to carry the belt and rollers. An edge beam connected the ends of these beams and diagonal members formed the bottom members into a horizontal truss. Similarly, at roof level, cantilever beams were proposed to support the roof, together with edge beams and diagonal members forming a truss in the plane of the roof.

The columns supporting these members were steel box sections tapered from ground level to just below the elevated structure. At the top of the column a cross head was provided to carry the outer bearings supporting the

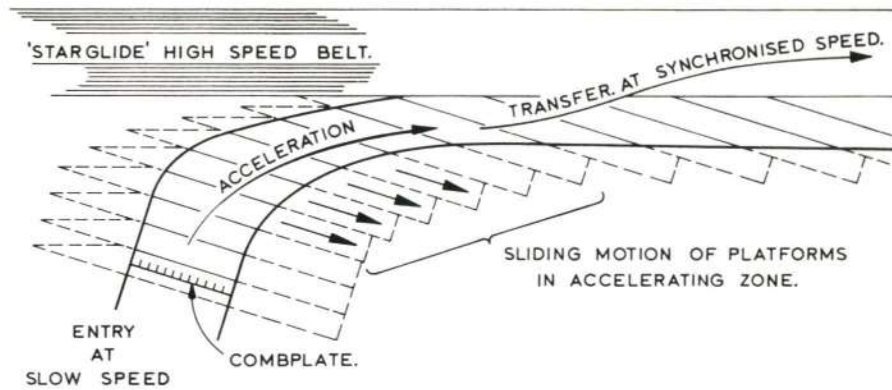


Fig. 6
Motion of integrator Platforms at entry point
(Reproduced by courtesy of the Dunlop Company Ltd.)

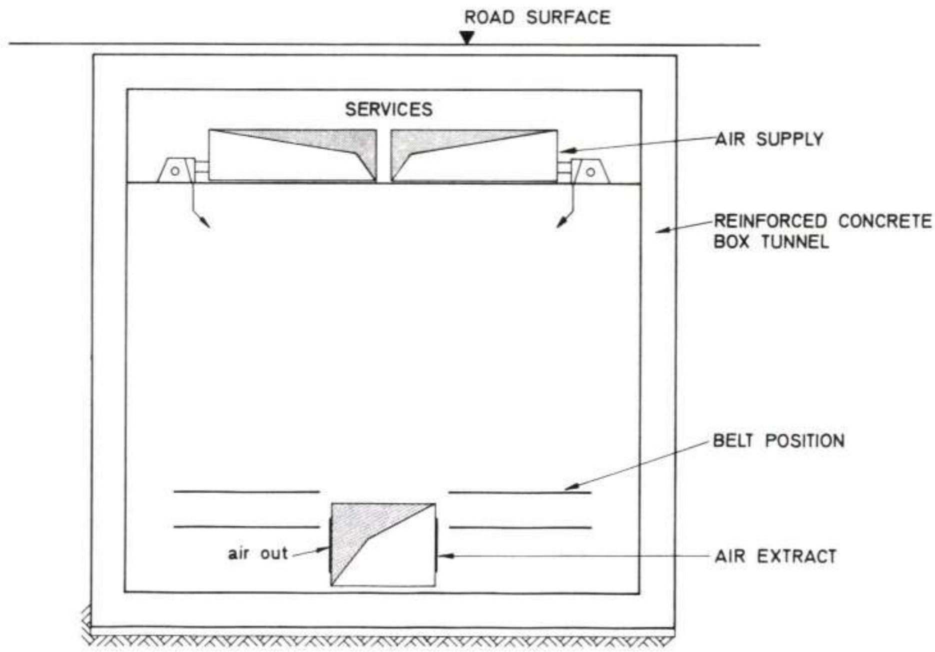


Fig. 7
Tunnel cross-section
(Reproduced by courtesy of the Dunlop Company Ltd.)

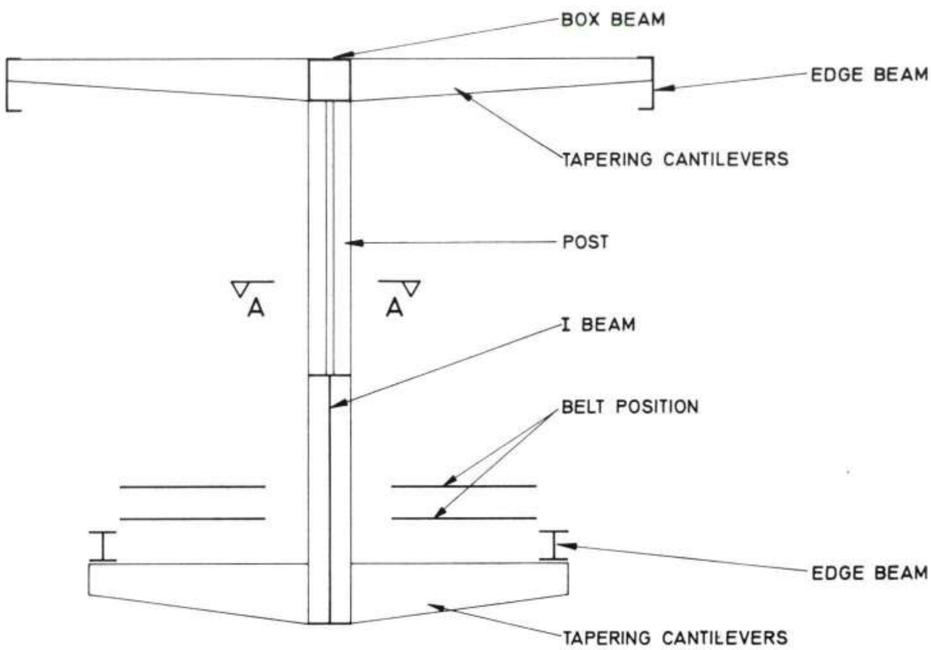


Fig. 8
Elevated belt cross-section showing structural members (column omitted)
(Reproduced by courtesy of the Dunlop Company Ltd.)

elevated structure. The main support for the latter was on the centre line under the spine beam with two secondary supports at either end of the crosshead to provide the reactions to prevent the units overturning.

The layout of an intermediate station is diamond shaped in plan and accommodates the pedestrian access and circulation areas, the integrator drive mechanism and ventilation and heating plant areas. In addition there are two wings on each side to accommodate the straight high speed section of the integrator. The main structural members for the central portion were at machine floor level and consisted of lattice girders. The pedestrian circulation and access areas and the roof were supported on columns rising off these members.

The design of the structure was such that the manufacture of the units making up the elevated sections could either be in small sub units which would be assembled on site or in very large sub units, preferably a complete span unit, which would be fabricated at the works.

For underground sections, the belt and machinery would be housed in a concrete tunnel of rectangular cross section.

Heating and ventilation

Alternative methods of ventilation were considered and the best practical method was thought to be cross-ventilation. Air would be supplied at the outer edge of the ceiling and would exhaust through slots in the balustrade, and thence through the underside of the structure to the outside air. The air supply rate would be about 0.75 m^3 (26.5 ft.^{3})/metre run of belt/side. This solution would generally apply, with the exception that the discharge air would be extracted mechanically and ducted to the ends of the system or at stations. Air would be supplied through the ceiling near the perimeter of the station, and would be extracted through the centre of the station roof. The extract quantity would exceed the supply quantity to provide continuous make-up from outside at a rate which would give an air velocity of about 5 km (3.1miles) per hour across the entrances to the station.

In the winter the air would be heated to maintain a temperature of about 10°C (50°F) in the *Speedaway*, with −1°C (30.2°F) outside, assuming no heat gains from lights or occupants. In summer, all sections and stations would be supplied with filtered fresh air. No attempt would be made at cooling as the self-induced air movement which will be evident when travelling at 15 km (9.3 miles) per hour will provide a cooling effect. All air would be fresh and filtered and would not be recirculated. The water handling plant would comprise a gas-fired hot water boiler. The plant would be sized to serve one half of the distance between two stations and would be located above the station section within the ventilation plant room.

The air handling plant would be located on station roofs in a plant room with louvred wall panels. Air would be drawn through the louvred panels, by a packaged air handling unit, comprising filter, heater and fan and discharged into a low velocity distribution duct which would be located in the roof space of the *Speedaway*.

From this duct, air would be taken to a distribution duct and would be supplied through continuous linear diffusers made integral with the lighting fittings. The ductwork would incorporate suitable expansion devices to accommodate thermal movement. Two plants would be employed, each to cover half the distance between stations in both directions. The station section would be served from the same plant and the air allowed to exfiltrate naturally.

Air would be supplied to the *Speedaway* at a nominally constant 18°C (64.4°F), regulated by a supply air thermostat controlling a valve on the water supply to the coil. The air supplied would be at ambient temperatures. An outside thermometer would bring the heating into operation should the outside temperature fall below 10°C (50°F). The controls would all be located within the station areas.

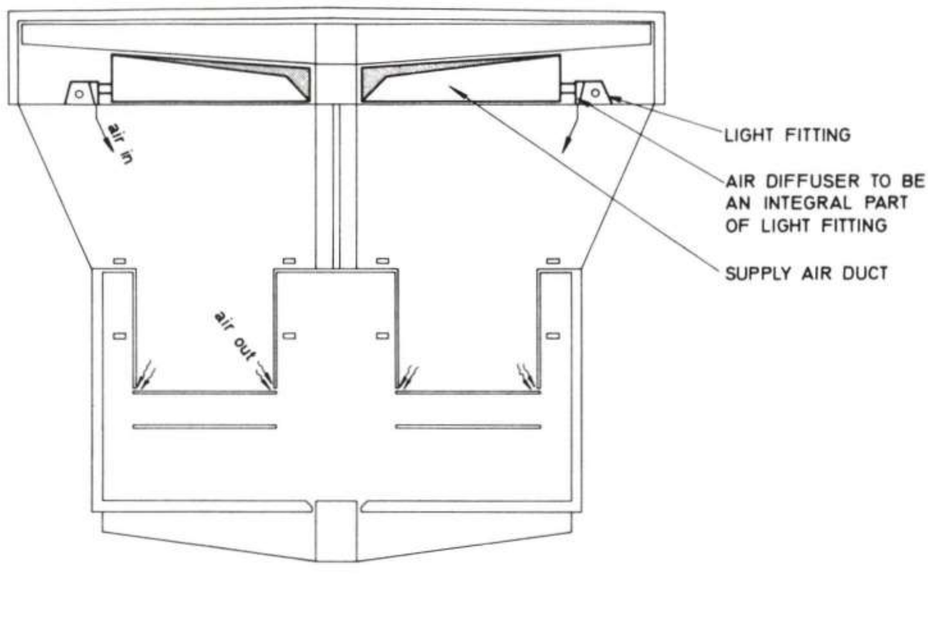


Fig. 9
Elevated belt cross-section showing integrated light/air diffuser arrangement
(Reproduced by courtesy of the Dunlop Company Ltd.)

Electrical services

Electrical services would be provided to supply the necessary lighting and mechanical plant located within the station complex, including the belt drive and integrators. All electricity boards' mains could be brought to the *Speedaway* system at stations, and, from any station, could serve as far as midway between that station and the stations on either side.

Cost study and economic analysis

We do not have the permission of the Dunlop Company Ltd. to publish details of the results of this extensive study and analysis. The general nature of our report and our approach to the work may however be given in outline.

The cost study was carried out in two stages. Initially the study was for a typical 1 km (0.62) section of elevated running length and for a typical station. The object of this exercise was to develop a method of assessing the costs involved and to establish the relative proportions of the various elements making up the civil, mechanical and electrical engineering. The second stage concerned the adaption of Stage 1 for the individual case study. The cost study for each of these stages was divided into two parts: Capital Cost and Annual Maintenance and Operating Cost.

The capital cost report set out the various elements but excluded the cost of land acquisition, obtaining construction or permanent easements and of providing maintenance facilities. Costs were calculated at the then present day costs and a contingency allowance was included. The running length between stations was shown in the form of the cost per meter of a two-way system, cost per kilometre of a two-way system and total cost. In addition a comparative cost per meter for a two-way system was shown where more than one material for a particular element had been considered. Certain elements such as the mechanical and electrical engineering work in providing the starting and running load to the belt have a non linear relationship with the running length. Elements such as this therefore only appeared in the total cost column. The percentage which each element contributed towards the total cost was also shown. All elements making up a station cost have a non linear relationship with the running length, and therefore only the total cost and the comparative cost as applicable, were shown.

The annual maintenance and operating cost report was set out in a similar fashion. An assessment was made of suitable operating times together with the charge for electrical energy. Shift working was assumed in costing the manpower requirements. The capital cost was converted to an equivalent annual cost using the capital recovery factor method (sinking fund amortization plus interest on first cost). The interest rate was taken as 5% and the probable life expectancy for the various elements being considered was assumed.

The economic analysis made use of the above information in conjunction with revenue earned from various fare structures.

Pedestrian flows were measured at various times of the day and the effect of various fare structures on this flow was examined. Capital savings accruing as a result of building the *Speedaway*, such as buses, road maintenance, etc., were evaluated. These savings were assumed to materialize at the same time as the possible construction of the *Speedaway* System.

The future

We are at present engaged on another study of a possible application of the system. In addition we are refining the original structural solution and considering different materials for certain sections and applications.

All those connected with the system in the Dunlop Company Ltd., the architect and Ove Arup & Partners, are eagerly awaiting the first real live system to design and commission. A full sized unit, with entry and exit integrators, will be commissioned early in 1971.

Note

The starglide belt, the integrator, and other features of the *Speedaway* system, are the subject of world wide patents and patent applications. *Starglide* and *Speedaway* are trade names of The Dunlop Company Ltd.