PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Defining New Materials for the 1980s

W. Allen

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Defining new materials for the 1980s

By W. Allen

Bickerdike, Allen, Rich and Partners, 16 *New End, London, N.W.* 3

The author's point of departure is that building today is the early architecture of the age of science. It increasingly uses scientific methods and technologies of science.

Consequently there are many pressures and necessities to innovate, but resistances exist in the form of inertia of the industry, the educational deficiencies of the professions and constructors, the demanding conditions for trouble-free design and construction, and the penalties now consequent upon trouble.

In order to open the way for safe innovation there has been a shift towards regulation by performance criteria in place of the former definition by specific requirements; and in order to assess performance in advance of experience, a systematic evaluation is now available.

The existence of these two developments has been made possible by the growth of building science, and they in turn define the monitoring and feed-back of experience as important functions of building research for the future.

There is a need and capability developing to analyse building problems with increasing precision in several directions, and the process often defines new needs for materials and techniques. This is a centre-to-periphery process, and the reverse also takes place, where product makers thrust into the market innovations which result from some matching of fresh ideas to apparent needs. In all cases the needs are defined consciously or unconsciously from the context of the subsystem within which the product or component will function. Buildings are always systems comprising many subsystems.

Examples are then given of directions in which the author foresees needs for new developments being defined.

Architecture in the age of science

Architecture today is the early architecture of the age of science. The problems with which it has to deal are those of societies affected in various ways and degrees by science and its engendered technology. The ways in which the professions and industry respond to these problems are increasingly assisted by analytical methodologies which are scientific in their origin and nature; and the materials and techniques employed for building are now constantly under pressures of innovation called forth by the problems of change or thrust forward from the creative potential of laboratories.

Through this mêlée the professions and industry attempt to thread their way and seek in various balances economy, reliability and rapidity. They face certain constraints:

The industry is massive and has great inertia. Partly this is due to its being labour-intensive.

It is not well-prepared educationally either to innovate or to handle innovation in technology. This contributes to its inertia.

Any innovation expected to have significant benefits has to meet many difficult and constraining demands of buildability and reliability, often not clearly foreseeable.

The increasing penalties attached to failures induce caution about innovation.

The learning and control processes

Collectively the industry has attempted to open the way to safe innovation by changes in its modes of control and learning.

We have had building research for 50 years, and control systems have existed from time immemorial. An essential change in control systems to permit innovation was a shift from regulation by specific statements about materials and methods to the formulation of performance requirements. This was the key to open the door and, so far as I know, it was first conceived in dialogue between the Building Research Station and the U.K. Ministry dealing with housing and local government in the early 1930s. The process began slowly and hesitantly because it depended largely on building research, which was then still young and insufficiently comprehensive or experienced to move with strength or accuracy in more than a few areas. A great shift of education had also to take place before such a basis could become generally workable. Movement is now fairly rapid.

As long as innovations were not too frequent or extreme in character, their evaluation was allowed to remain a mixture of informality and fragmentary testing. Eventually, in the late 1950s, it became evident that a performance concept of regulation called for a counterpart arrangement for comprehensive evaluation of innovations in advance of experience or standard tests, and the Agrément mechanism was brought into being, at first in Europe, and later here. It attempts to be systematically comprehensive by test and skilled judgement.

This completed a three-part learning and control system which, as we can now see, is a necessary form of mechanism for building in the age of science. There is a research capability, and its modern functions are to monitor the design and construction operations of the professions and industry, and to provide the knowledge-base necessary for the two other elements, the control system and the advance evaluation technique. The control system is performance-based with the intent that innovation can take place freely when it can justify itself, and the evaluation process has developed to provide the justification when it appears to be merited in advance of experience.

My description, it will be appreciated, is one of principle only. The actuality is less tidy and more pragmatic than the outline I have given. For example, evaluation of isolated products and subsystems takes place under the Agrément Board while whole systems are evaluated and in some senses promoted by the National Building Agency. There was no symmetrical contrivance of the three mechanisms, and it is only in retrospect that we can see the rationale of their mutual development. However, now that it is apparent, I think that the whole arrangement should be examined afresh to ensure that it is as well adjusted for these purposes as we can manage, and in close enough contact with real-world activity to monitor it accurately and feed back to it relevantly.

These matters are of prime importance. Three misfortunes in recent years in Britain alone remind us of this. No one foresaw the results of the conjunction of trends, all individually apparently beneficial, which led eventually to the tragic scale of condensation experienced in the past four years. We were apparently unable to foresee the structural risks inherent in some forms of industrialized high-rise construction. And we did not get the measure in time of the social rejection of high-rise living by some sections of society. These are three very different kinds of problem, all involving forecasts of needs in which economic, social, and technological forces were interacting. Yet I think we have in Britain the most comprehensive and best-developed combination of research, control and evaluation mechanism in the world at present. It may be, as Professor Dietz asserted in London last year, that some building problems are actually too complex to be evaluated in advance by the human mind.

Defining new needs by formal processes

I have omitted thus far any mention of a formal mechanism for defining needs, either for materials, technologies or functions. I think that no central mechanism comparable to these others would be appropriate. Research, performance statements, and advance evaluation can all contribute to accuracy and perception for definition, but the origins of change and consequent needs are too various to be centralized. Many belong in the area of free response between designers and the art and society they serve, or are the consequences of systems-shifts in building processes, or are the creative output of industry sensing potentialities in technology or in the market.

Yet some centralized thrusts have been made and are important direction-pointers. The prefabricated school movement which received its principal impulse in Hertfordshire in 1947 stated performance needs for education functions, indoor environments, and construction. The movement eventually took on the character of directed development from several centres each having its own line of this activity. It was truly developmental in character in that it had cyclic arrangements to respond to feed-back from experience.

It produced an American spin-off in the 1960s in the work of Ehrenkrantz in California, who took the ideas in a different direction by writing more elaborate performance specifications for open tendering by component or product developers, and by setting up the interface arrangements to which developers had to conform so that a full building system would result. This was an elaborate statement of needs; and just as the British schools teams used centralized purchasing power to induce desired responses from industry, he also used the bait of large initial orders to evoke the necessary private development work. He also required his tenderers to submit a single price covering both supply and maintenance for a specified period of years. This gave an astutely judged incentive to balance first cost and reliability. I think this particular lesson is significant and thought-provoking. It amounts to having parts of your building on hire.

Each of these actions has spread, though somewhat unevenly and with less obviously successful results, into areas such as public authority housing and hospitals. I think that Operation Breakthrough in the U.S. lies in a line of descent in this family of activities.

Defining needs from situations

In the area of free response between designers and their conscience, probably the best example is the now somewhat passé curtain wall. It arose from a compulsive architectural feeling that if walls were not load-bearing, it was out of character and therefore wrong to make them look as if they were. Hence the non-loadbearing term 'curtain' and the character of the construction. But once the industry had embarked on satisfaction of this demand, new needs for materials and techniques largely defined themselves, for many difficulties had to be surmounted. Now that the endeavour to master this type of wall is largely behind us, it has acquired a recognized place among modern architectural resources and no longer attracts much development interest.

I mention this not merely as an example of architectural compulsions leading to the definition of new needs. It has another purpose for me, because it is a good example of a building subsystem, and I want to emphasize that one fundamentally important way of seeing buildings is to recognize that they are and always have been created as systems, and these systems comprise numerous and varied subsystems. It is not a terminology which architects often use, but it is their instinctive and necessary process of design, as it is for their numerous collaborators in structural, mechanical, electrical and other fields.

Probably this will be readily apparent, as will be the obvious importance of harmonizing the subsystems to work together. If demountable partitions are to be used, for example, this implies certain requirements in the ceiling system, the main structural system for floors, the window arrangements, and so on.

That is a very simple example. We can get a deeper insight by lifting into consciousness how the energy balance in a building relates its lighting, its heating and cooling, the thermal mass of the building fabric, the energy flow through it, the glazing, the depth of the interior, the numbers of occupants, their cycles of usage, the internal air dynamics, and so on. Each of these is, in my imagery of building, a subsystem of some kind, and this is verified by the fact that each of these is the subject of study by researchers and product-developers of different kinds who implicitly recognize that they are dealing with things that can never be adequately studied in isolation. You must be a systems thinker to be a good designer, product-developer, or researcher in building.

I emphasize this because I think that in the future the definition of a large proportion of needs for new materials – and indeed for new technologies, because the two must generally go together – will emerge largely by themselves out of systems situations, and will be observed in contemplation of the ways in which these are developing and settling down from time to time into larger patterns or trends which are groups of subsystems. These are for designers what formulae are to mathematicians, and they enable us to comprehend and handle more complex situations more skilfully in design than would otherwise be possible.

It will now be obvious that I have been trying to identify specific ways by which I think new needs will mainly be defined by designers and the industry as we move towards the 1980s, out of development studies to improve building types, often via detailed performance requirements, and increasingly assisted by a systems approach to design and construction. We also have the free creativity in industry and laboratories.

Examples of trends and situations that define needs

Much of this will operate within a framework of trends and general situations which themselves will lead to definitions for new needs. I offer a few examples.

Easy adaptability is an essential attribute to develop if national stocks of certain types of buildings are to give a necessary economic return on the original investment they represent. No country can afford rapid replacement of these durables, yet they must be able to be efficiently used throughout their natural lifetime, and must accommodate adaptation and updating. Laboratories, factories, hospitals and education buildings are examples.

I believe there will be increasingly clear distinctions made between the life-expectancies of the main fabric (upwards of 60 years), the main service systems (20 to 30 years) and the motor mechanisms (10 to 15 years). The service and motor systems might virtually be on hire.

I go along with the current thinking of some others that, in Britain at least, we will see less of the big public housing projects at densities calling for high-rise flats than in recent years. It is getting too hard and too slow to get large blocks of land together; but without this, certain forms of industrialized housing will not have the markets they need for economic production runs.

Presumably development will be diverted towards component systems more suitable for shorter runs on smaller sites, and towards systems capable of use for a broadened range of building types.

It seems too easy a cliché to point to problems of the potential exhaustion of natural resources, but I believe we take inadequate care about this. Timber, gravels (in parts of Britain), and metals are vulnerable. Perhaps petrochemicals as well before very long, but that is part of a larger issue, since they are used also for energy.

The latter of course is another conservation problem. We have to a large extent moved into a design attitude in which we rather exult in an ability to use energy to maintain internal climates rather than to use our building fabric, but energy conservation is rapidly becoming critical. It is made more pressing as our outdoor noise rises to levels where we prefer to be sealed off and use artificial indoor climates. A shift of design attitudes is already apparent.

We have generally fallen into the habit of improving thermal insulation in walls by special interior materials. It seems to me that in most forms of wall this exaggerates the stresses introduced in the solid fabric by its exposure to external extremes and the screening off of the moderating influence of the indoor climate. Do not logic and some recent trials suggest that we should now develop materials and techniques for exterior insulation of walls? By this means the structural system would be protected against major thermal stress and the need for expansion joints minimized; the thermal mass of the structure would become a valuable temperature stabilizer indoors, adding thereby to comfort and the reduction of energy consumption. Cold bridging and condensation would be minimized. It might even be useful to have sound absorbent thermal insulations and reduce street noise reverberation.

Tension structures can be seen now to offer practical and remarkably beautiful big-span enclosures. The permanent buildings for the Tokyo Olympics represent one thrust, and the recent German developments of cable roof systems associated with translucent, withdrawable flexible sheet roofs are another.

Inflatables have made rapid progress in recent years. Some have covered as much as 4 hectares (10 acres). They have been used for activities as varied as sports grounds and university residences. The materials are becoming more durable, but other characteristics need development. A sound-absorbent surface is a necessity inside for example. Inflatables involve a whole new design technology.

We can heat the indoors readily, but we need heating now for outdoor situations also.

The appearance of external concrete in wet weather often disappoints architects, and perhaps the public. Britain has a damp climate, and prolonged dampness holds dirt. There has been a great development of surface finishes for concrete, but I have a feeling that the wet appearance still leaves scope for development.

Gypsum is a marvellous material, so white, so beautifully responsive to casting. The recent development work on fibre-reinforced plaster seems to open new prospects of delight. If it can eventually be made satisfactory for external use, we would have an excellent addition to our range of outside finishes.

Glass-reinforced plastics, like the plasters, look like being very valuable. Among their useful attributes is good bonding to bitumens and asphalts, for it adds to our inadequate vernacular to deal with rain-protection.

Among the metals, the controlled-rusting steels, with their luxurious brown finish, are exceptionally interesting and attractive. I anticipate a more general use if more design-development work is done.

We urgently need in the UK external woven blinds to screen solar heat and reduce sky glare without entirely cutting off our view.

Among broader trends that seem to me likely to generate new needs for materials are clip-together construction, by which I mean largely dry assembly systems, and semi-systems, which is my term for half-industrialized traditional construction. I am apprehensive about the latter because they are attempts to create systems for individual projects and I do not see a prospect of the necessary development work being done to get the risks out of them before commitment to their use.

These are only examples of directions in which I see new materials and technologies being identified for development, but a catalogue is impracticable and I hope this group at least illustrates the richness of the opportunities.

Summary

I do not think anyone can be very specific about defining needs either for new materials or technologies 10 or 20 years ahead, except by understanding the systems character of buildings and concentrating on particular subsystem areas where both needs and potentialities can be identified. Needs will be created mainly by changes in attitudes to design or construction, by shifts in building economics, or to provide uses for new inventions of value.

Some of the changes in design or construction will be deliberately induced by formal studies of building types, which in turn give rise to whole programmes of needs. I referred to notable examples of this. I think this will be a recurring form of activity, buttressed by cycles of development work.

All this would not have seemed as deeply significant to me as it does had I not also seen it as part of the developing process of making architecture today, tomorrow, and all tomorrows for a long time to come. In my view, building research, regulation by performance requirements, and systematic evaluation of innovations are an interdependent set of activities, upon which architecture will depend in this age of science for much of its rightness, strength and relevance.

Our greatest difficulty, as I now see it, is in education, at the middle levels in professional offices and industry. The handling of innovations in materials and techniques is very unsatisfactory, and it is difficult and fraught with danger to get innovations through to the work-face. Education has not provided the knowledge and skills needed at middle levels for successful innovation, and until this is rectified, wise caution will inhibit change, and genuine advances will be frustrated.

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