The Utility of Building Science

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Journal of Building Physics 1998; 22; 4
DOI: 10.1177/109719639802200102

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THE BUILDING RESEARCH station at Garston in the UK has recently celebrated its Golden Jubilee. The Central Building Research Institute in India is celebrating the twenty-fifth anniversary of its founding, having been established, like most of the national building research institutes in the world, at about the time that BRS had completed its first twenty-five years. Such special anniversaries are often used as BRS has done, and as CBRI is doing, for a stock-taking of accomplishments and a reappraisal of objectives. Regardless of anniversaries, research institutes everywhere are increasingly under pressure to reconsider what they ought to be doing.

There is a growing disenchantment with science in the world. Science for the sake of science is being criticised and there is a popular cry that scientific research should be closely related to social and economic goals. Building research directed to the development of knowledge for application in building does not avoid the possibility of criticism as to its relevance. There is a tendency to ignore even basic aspects of knowledge and its use that building research institutes should reexamine at this time.

Knowledge about building, called, for convenience, *building science,* is valuable largely because it is useful in predicting the outcome of the result of some building situation. The prediction may involve the thermal pattern resulting from a particular wall construction in a given climate or the service to be expected from a particular kind of brick used in a given way in a particular location. The situation may be real, if the building already exists, or it may be posed in a hypothetical way in the normal course of building design. Rational design is possible only when there is the capability to establish, each time a choice is made, the probability of a particular result.

It is widely acknowledged that building has been strongly based on tradition. This does not mean that it has proceeded without predictability, for tradition embodies prediction, embracing those things which have been shown by experience to produce a predictable result. Such experience very often has

1097-1963/98/01 0004-05 $10.00/0

arisen from unintended, costly, full-scale experiments associated with failure of part or all of a building either during or after construction.

Trial-by-use, although it was the basis for much of the tradition in building, is by no means outmoded, since satisfactory service is still the real and final proof of adequate performance. There is a vast difference, however, between trial-by-use as the primary way of arriving at prediction and use as a confirmation of prediction based on other evidence.

Tradition has a great weakness in that it deals only with a way of doing something, without any contribution to an understanding of why the traditional method works. This being so, it is usually not possible to identify the important factors either in the situation being served or in the arrangement or solution provided. Thus, there can be no way of identifying the probable effect of a change in the situation or a change in the solution. In the words of Sir Frederick Lea from the Introduction to his history of the Building Research Station entitled *Science and Building,* "Tradition in itself provides no basis for change other than trial and error. Tradition places the emphasis on how something should be done; science sets out to explain why so that the experience can be carried over to different materials and circumstances."

There is the crux of the matter. The experiments must be done if predictability is to be extended. They can be done more economically and with greater return if devised and carried out in a systematic series, which is, of course, research. They may be done in the laboratory as well as the field, often on model scale. In this way an understanding of the importance and the relation of various factors to the final result is built up, thus providing a basis for prediction of the results of changes. It becomes possible also, as already indicated, to recognize relations with what is known of other situations for use in extending the capability to predict.

The elaboration of these relatively simple propositions before any technical audience would call for apology if they were not so frequently disregarded and their far-reaching implications so little appreciated even in the practical field of building. Their importance can be further illustrated by considering the ever-present building problem of evaluating some new product application. It does not matter whether it is the product or the application that is new, the problem is the same: to predict what service or performance can be expected. Let it be assumed, to begin with, that the product is new, that little is yet known about it, and that there is a general lack of knowledge about products of this kind. The ability to predict is lacking and testing of some kind is called for. The problem now is what kind of test.

The resolution of this problem is dependent entirely on the knowledge available. When much is understood about related products and situations it will be possible to make judgements about the factors which will influence the results and to identify those which may be inadequately understood. It may then be possible to identify some limited tests or series of tests which will provide needed information.

When little is known, an elaborate test representing the real situations may be considered. Some situations can be modelled relatively simply. Others such as those involving wind and rain effects, which are variable with geographical location, with position on the building and with time, pose serious problems. It will seldom be possible to consider tests under a wide range of conditions at full scale if only because of cost and time limitations. It may be necessary to consider only one set of test conditions, and this immediately raises the problem of what these should be. Judgement inevitably has to be exercised in deciding what elements or factors, what levels of intensity or severity and what combinations are to be selected. There is always the very great risk that in the absence of knowledge the choices may fail to represent the service condition in some important way. The single test, by itself, provides very limited information; it can be very effective when designed to provide some critical missing information in an otherwise adequate body of knowledge, like the final piece of a puzzle. Its value depends almost entirely on the relevant knowledge already available.

At the other extreme, when knowledge is adequate, prediction can be made without recourse to further tests. The common situation, however, is that basic properties such as dimension, density, colour and porosity, which identify the material or component, are determined by measurements and form the basis for estimates of more complex quality or performance characteristics. Some complex properties of materials like thermal conductivity can be arrived at by calculations based on measurements of structure, but they are more commonly arrived at by direct measurement. The thermal properties of a wall, however, are commonly calculated from estimated or measured thermal properties and the geometrics of the constituent materials.

Two further complications arise commonly with building materials. The manufacturer of a product has little control over its handling and use. These will usually be determined by others. He cannot, therefore, provide firm predictions of performance for all situations. He can only describe the performance that can be expected if the product is used in the manner stated or implied.

The other complication with most building products arises from the very long life they are expected to have. They must be evaluated for durability which may involve a need to estimate the outcome of cumulative degrading effects over 50 years or more. This is exceedingly difficult for new materials and must be based entirely on the knowledge of the product and of related products and situations until additional supporting evidence from significantly long periods of use becomes available. There is always great demand for accelerated durability tests, and these are very difficult to devise and to verify. Final verification must await the completion of a lifetime of service.

The critical relation between knowledge and predictability can now be seen. Reliance upon direct experience as a basis of prediction is highly restrictive. Only with knowledge is it possible to assess the relevance of experience and thus to draw upon broader and more varied experience in the development of predictability. There is always a requirement for as much relevant or related knowledge as possible at the time the prediction is being made. These relatively simple propositions have far-reaching implications for research and education as well as for the management of technology.

Research may be considered as the acquisition of carefully planned selective experience. It may be used to provide predictability about a limited situation, without regard for wider application, or it may be directed more broadly to an understanding of the functional relations involved in some more general situation. Both kinds of experience are important, since they become mutually supporting when taken together. Both are required to an increasing extent in support of modern building. The advance of new technologies is presenting new products and new situations at a faster rate than they can be evaluated in an industry in which the conversion from a traditional to a scientific base is still far from complete. There are demands for new and better test methods, performance tests, codes and standards, and these can be produced only if the knowledge of the subjects involved is adequate. The continuing development of building science is, therefore, essential to the welfare of the building industry.

But the mere existence of building science is not enough. It must be put to use throughout the building industry wherever technical decisions are made about building. It must be introduced appropriately into the education and training of all who are in a position to use it. There must be not only teachers but also teachers of teachers, for trades, technical and professional levels.

There must also be a new kind of professional who, for want of a better name, will be called a building engineer. It is not necessary that he should be a scientist, though he should be well versed in building science. He must be aware of the realities of the design office, the factory and the field and must have that judgement which is essential in professional practice to proceed beyond the limit of what is well established in arriving at what is wanted. There is need, in addition, for this new profession to be truly a learned one, in the best engineering tradition, capable of teaching and research as well as practice, and capable also of identifying and recording what has been learned, as a contribution to the store of knowledge and to the advancement of professional capability. This is the greatest need today in the building industry.

Much has been accomplished in the development of building science in twenty-five years. Increasing recognition of its potential will ensure its continuing growth over the next twenty-five. There will be a greater challenge in most countries to ensure a comparable development in its widespread use throughout the building industry. This cannot be accomplished by building research institutes alone, but must be strongly supported by both government and industry, and particularly by the design professions, universities and institutes of technology.