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# Influence of size, function and design on the standardisation of components

By N. B. Hutcheon and S. R. Kent (Canada)

The principal objective of industrialisation of building is to increase productivity, or in other words to reduce the cost of building. Since almost all the materials and components assembled on the building site under present methods are already produced in factories of one kind or another, it becomes necessary in justifying an extension of industrialisation to assume that a further transfer of operations from the site to the factory will result in overall savings. This must mean in general that larger and more complex assemblies must be made in factories and transported and erected on the building site. The ideal of complete factory assembly such as is achieved in the case of automobiles will seldom be achieved except in the case of very small buildings.

Since components and sub-assemblies must always be fitted together they must inevitably be made to controlled dimensions. Clearly, if these dimensions are standardised, and if designs of buildings are carried out so as to employ components of these standard dimensions there exists the possibility of establishing requirements for larger numbers of identical units. Conversely, since successful industrialisation of building depends upon just such a demand, the greatest possible degree of standardisation would appear to be essential. Some system of modular coordination becomes highly desirable in order to provide a firm basis for the coordination of dimensions both in design and manufacture.

Modular coordination is in the first instance a discipline in the establishment of dimensions. Thus it provides a rational basis for standardising and coordinating them. But standardisation of external or overall dimensions is only a part of the standardisation of a component or assembly for purposes of facilitating either mass production or subsequent use. Repetitive production results in identical products, having identical functional capabilities as well as dimensions. From a manufacturing point of view it may be just as costly to provide a range of functional capabilities within a fixed set of dimensions as to provide some choice of dimensions within a given number of units.

The development of industrialisation in building will depend very largely on the extent to which it is possible to develop and extend repetitive production and to employ this production economically in the construction of buildings. Thus, the role of standardisation, of which dimensional standardisation is only a part, can only be assessed realistically in terms of the effects it will have upon the design and economics of buildings constructed from standardised components.

## Size of units

Transfer of more of the building operation to the factory inevitably means making larger units or sub-assemblies to be transported and assembled at the building site. This increase in the size of units, coupled with the need for standardisation and reduction in the variety of units offered in the interests of economical factory production inevitably introduces a certain rigidity in design. As an example the selection of a wall panel 20 ft (6 m) by 10 ft (3 m) may predetermine certain basic dimensions, and thus influence the division of space into rooms for various purposes. Alternatively, a requirement for variation in the width of rooms or in the spacing and width of windows may indicate the appropriateness of panels of different widths. The forcing of dimensions to conform to the minimum number of standard sizes may be wasteful in the matching of the space provided to the requirements, while an increase in the variations in sizes of components may increase the cost. This problem is not peculiar to buildings constructed of large factory-made units, but is likely to be more acute as units and sub-assemblies become larger under the pressure of exploiting the economies of factory production. A gain in one direction may be offset in part by a loss in another.

The increase in size of units will reduce the number required for any one building, and will tend to reduce the number of applications which can be found for them through reduced flexibility in application. Increased size and weight will require changed transportation and handling facilities, while the requirement to develop a use for the largest possible number of units from any one factory will make it desirable to ship units as far as possible. All of the added costs involved will have to be offset by the reduced cost of factory production.

## Function and design

An increase in size and complexity of components and sub-assemblies tends to make them less versatile, so that fewer uses for them can be found. This might be offset in part by over-designing as to functional capability in order to maintain the widest possible range of application for them. Structural elements such as beams and columns provide the more obvious but by no means the only cases. Attempts to encompass a wide range of structural capabilities in identical units can only mean that such units will always be overdesigned for any specific application. The added cost of materials inevitably involved will have to be offset by savings resulting from increased production.

Exterior wall panels represent an extreme case of multiplicity of functions. Walls may be constructed in situ from a variety of materials selected to satisfy the various functional requirements to the degrees required by the particular application. A "standard" exterior wall panel may have to be overdesigned in respect of structure, fire and acoustics as well as for the control of heat, moisture, air and rain in order to encompass a wider range of applications. To these functional complications there may be added those of size, fenestration and aesthetic flexibility, all of which are in opposition to a high degree of standardisation.

## Open versus closed systems

Industrialised building systems which envisage the construction of various kinds and sizes of buildings from selected factory-made components conforming to the system are commonly referred to as "open". Those which are based on a particular set of components, complete and coordinated within themselves, not necessarily interchangeable but often capable of some rearrangement to offer some variation in size and shape of building are referred to as closed systems.

It is the open systems, obviously, which offer the greatest scope, in principle, for the extensive development of industrialisation. The requirement for complete standardisation and interchangeability as between components from different sources is a very demanding one and one which has seldom if ever yet been achieved in the case of any other manufactured products consisting of closely assembled units and of appreciable size and complexity. This slow development of standardisation on an "open system" basis for other manufactured goods is most significant and deserves the most serious consideration. It may be argued that buildings, because of size, must always be assembled from parts on site and this favours standardisation. On the other hand the parts must always be assembled in close physical association and often become highly integrated functionally as well. Further, the margin of possible cost saving by mass production of buildings will never be large because of the high proportion of final cost already represented by materials and components. A hand-made automobile engine costs 100 or more times that of a mass-produced one, while buildings at present seldom have more than a 60% on-site labour cost.

The development of mass production of other manufactured goods has rarely proceeded on an open system basis. The initial stages have always been on a closed system basis which exhibits reproducibility of the products made by the one manufacturer but no standardisation in the sense of interchangeability of parts as between manufacturers. Standardisation has developed slowly, beginning with the smallest or most elemental components such as screws and bolts which are both physically and functionally simple and can be put to diverse uses in large numbers. The larger and more complex sub-assemblies become standardised at a much later stage, if at all, beginning first with physical or dimensional and later with functional standardisation.

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It is difficult to find justification for the assumption that industrialised building will be developed effectively by concentration on the development of open systems. The more natural and logical sequence would appear to be first to anticipate the development of closed systems for specific types of buildings similar in size and function. These buildings may be identical but not necessarily standardised in the sense that components are interchangeable with those of other manufacturers. Standardisation of the smaller, more repetitive units, which has already begun, can be extended to include larger components such as doors and windows. Standardisation can be extended logically and naturally, up to the stage of complete open systems, as and when the net advantage of such extension becomes clearly established.

## Standardisation and coordination of dimensions

Several significant points arise from the previous discussion. Standardisation is not essential in the first instance for mass production. Correspondingly, closed building systems need not be standardised. There need only be a requirement for a sufficient number of identical units so that an economically satisfactory production can be established. Standardisation may, however, contribute to the success of closed systems in several ways. Closed system components and sub-assemblies may themselves be made in part from standard units or sub-components which are less costly than non-standard parts. Also, it may be desirable to offer some freedom of choice of finish materials such as floor and ceiling tiles and panelling obtained from other sources and offered in standard sizes. This may impose a measure of standard dimensioning upon the assemblies. Further, it may be possible to extend the use of selected components of closed systems in other applications if they are standardised, and thus reduce their cost through increased production.

The gradual evolution of standardised parts and of closed systems has been proposed in this paper as a natural and logical approach to the development of open systems. It may be noted that closed systems need not be standardised even though they employ standardised parts. They have the virtue of assuring that all the components necessary for the construction of a building are provided and that they will fit and work together. They accomplish this with a minimum of the overdesign which is required when components have to be adaptable to a wide range of uses in various kinds of buildings. It may be more economical at times to design on a non-standard basis. Nevertheless, taking a long view, the greatest facility will be provided in overall development toward industrialisation if as much coordinated standardisation as is economically justifiable can be introduced at all levels.

Fully developed open systems require that all the components required for a complete building be available preferably from various sources, and that they be standardised so that they will fit and work together. The degree of standardisation must go far beyond that of dimension alone, as already pointed out. This poses the very great problem of functional as well as dimensional integration of all the components selected. In addition, it will probably be necessary to limit the sizes of components to a much smaller range of choice than is offered by steps of one module.

The integration of standard units or components becomes progressively difficult as the components are increased in size and complexity. The functional complexity will in general increase in proportion, and the jointing or connecting of components, which is always a major problem, becomes progressively more difficult, since the joint must provide for functional as well as dimensional integration. The progress of development of modular coordination and of industrialisation can only progress as quickly as adequate solutions are found to the various jointing problems which are created. It seems fitting, therefore, to conclude this paper with a discussion of this topic.

## Joints and standardisation

Modular coordination arose from the logic of arranging the larger dimensions of buildings so that repetitive units, notably bricks, could be used to form these dimensions without cutting. The methods of joining bricks, by the use of mortars, had already been well established. This was fortunate for it made the application of modular coordination possible. Such application does not create any particular problem with joints, on the other hand it can contribute nothing to the solution of any joint problem. The point being made is elementary but it is well worth emphasizing since an enthusiasm for modular coordination in particular and standardisation of components in general may make one forget the importance of joints.

It may be noted in the case of brick masonry that the mortar joint accommodates the functional as well as the dimensional requirements. Both types of requirements are likely to exist for any joint. The extent to which they can be met, rather than the properties of the components being joined will often be the limiting factor in the final performance of the combination.

The kinds of solutions to the joint problems which are commonly used in current on-site construction will not be adequate for industrialised building. New techniques and designs will have to be devised which are appropriate to the particular situations created.

The joint problems posed by open systems of standardised building will be more difficult than for closed systems. More versatile types of joints will be required since they will be called upon to serve for a range of selected component combinations as well as for a wider range in functional capability. It is certainly not beyond the capacity of human ingenuity to devise such solutions but whether they will be accomplished at a sufficiently low cost to make a marked advance in industrialised building possible remains to be seen.