ON STRUCTURAL DESIGN AND ITS RESEARCH

by

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1. Notion of structural design

Structural design and structural designer are new notions, the meanings of which lack a uniform interpretation. In this country the term "structural engineer" has been frequently replaced by "structural designer", just as at the beginning of this century the term "architect" had often been replaced by "architect artist", suggesting a special degree of knowledge. Thus, structural designer and structural design cannot be spoken of without exacting their meanings, i.e. that of the one, since the other originates from that. It is more proper to define the notion of structural design, it being a distinctible part of the overall design notion, while its performer may also be either the designer architect or the structural engineer.

Structural design is a component of the overall (non-particular) design pertaining to structures. It is the structural design in the course of which the overall system, shape, material, building method and principal dimensions of the structure are established. It is not concerned with details of the building method and of the particular dimensions. Results of the structural design are realized in structural sketches rather than in work drawings.

The above definition of the structural design began by stating it to be the component of the overall design concerning the structures. This, however, would not mean that it is not concerned with anything else than structures. On the contrary, there are involved several aspects such as function of the building, desired appearance, etc., that seem rather independent of the structure itself at first sight, and that are decisive for the selection among possible economical structures. Thus, the structural designer must be familiar with general design and aesthetical aspects, in addition to the structural and constructional ones. This would not mean, however, that he is to be considered a specialist knowing more than do structural engineers or architects, or else, to consider his activity of structural designing superior to other activities. Such

a ranking would be just as erroneous as that between compositor, conductor and performer of a violin concerto. In either case the rank depends on how the task is solved, rather than what the task is. Just as for the solution of most problems, this also requires a lot of special theoretical and practical knowledge: the solution itself may range from just acceptable to artistic.

To divide the activity of overall design into architectural design and structural design is far from being artificial, on the contrary, it is accessory to technical development and largely facilitates success of the general design. This is also reflected in the profusion of the related books and papers ([1] to [11]), rather scarce before.

On January 12th, 1967, an interesting and rather arduous discussion took place in the Institution of Structural Engineers (London), concerned with the problem of whom to consider a structural designer [12]. On the point, however, that the structural design is an independent operation, and on its definition, the views were largely in agreement, even if formulated differently, and if pointing out different aspects.

Let me quote for instance:

Mr. A. J. Harris: ... Some of you think that structural design is working out how many bars go in the beam. Others know perfectly well that most of the structural decisions of any significance have been taken long before the point is reached when that particular calculation is made. To start with there is the decision to have a beam; then the decision to make it out of concrete, then to make it in reinforced concrete and indeed, long before that, there is the decision to have a building at all. There is at least one consulting engineer who has achieved fame, although perhaps not fortune, by advising his Central African client that what he wanted was not a 3,000 ft span suspension bridge, but a small helicopter!...

Mr. Ove Arup: ... We are often building the wrong things the right way...

Mr. Jan Bobrowski: ... "hear music" before it is played and see things before they are built...

Mr. Peter Dunican: ... I think everybody will agree... that structural engineering is an art and a science and the practitioners can be either scientific artists or artistic scientists...

Mr. S. B. Tietz: ... We must be clear that we are talking about design and not detailing. A lot of processes are involved which take up much time long before a design crystallises, and even longer before anything ever happens on a site...

Mr. B. K. Bardhan-Roy: A good structural design is one which satisfies the functional requirements in the most economic way. The economy cannot be achieved merely by proportioning the sections and saving materials.

All these are to demonstrate that it is a rather common requirement to have better structures and better structural design and that there is a trend towards a closer indication of tasks, to particularize and systematize.

At first, let us outline possible tasks of structural design.

2. Problems and means of structural research

2.1 Problems of structural research

There are several branches of research that may contribute to the improvement of structural design. These may start from any field of sciences, technique, aesthetics or other likely to be related to structural design. Of course, technical domains are of primary concern.

For instance, structural research may be directed towards new types of structure, new structural development. By other words, structures likely to be of interest from some aspect and not yet applied may be investigated. No matter if these structures are too abstract to attribute them a possibility of practical application. Even the investigation of such structures may lead to conclusions likely to be applied in practice. In general, such investigations follow the pattern:

Assume the load affecting the structure and the supports to be given. Assuming the structure to possess some favourable characteristic, find the form by which the assumed advantage can be obtained. This kind of structural design problems is termed that of *form determination*. Formerly, such problems were rather scarce, disregarded from the classical problem of "beams of uniform strength" (or are being rediscovered now [13], [14]), recently, however, they tend to multiply.

A related problem arises when overall outlines of the structure are given, only particular dimensions are undefined which should be determined so as to provide for some advantageous characteristic of the structure. These are termed problems of *proportioning*.

Both previous problems are related to or better involved as special cases into the problem of *optimation*. This problem is of a more general character than the previous one in that it suits also to determine sizes irrelevant to the shape or proportions of the structure. These sizes are function of the requirement to optimize some characteristic of the structure (e.g. its weight), pertaining to economy ([15], [16]).

A special category is devoted to the so-called *variational problems*. These pertain to the economical, constructional, deformational, formal or other improvement of structures with given overall shape and proportions, by omitting, adding or altering some elements. If a sufficiently exact scale is found to define this improvement then the variational problem can be formulated as an optimational one. But even in lack of such a scale, it can be decided which alternative is the most advantageous one.

Also *combinational problems* may be of use. These examine combinations of different types of structure likely to be of advantage from some aspect.

The enumerated structural design problems were all of the *general* kind, inasmuch as they might arise for any building material, method or type, while could also be treated independently, with a general validity.

There are, however, *special* problems of structural design, to determine most convenient structural systems for the given conditions, for predetermined building materials, building method, special kind of building or part of it.

Special problems may be of outstanding importance or of extreme difficulty. A special importance is due e.g. to the structural design problems related with panel buildings. On the other hand, structural design problems related to monument preservation, reconstruction or integration may be extremely problematic.

One difficulty is pertingent to the impossibility or nearly to follow the force distribution in ancient structures (of no tensile strength or of the timbered type). By that time they had not been calculated, so that effects had been involved empirically, rather hard to reckon with at due accuracy, even at the actual state of knowledge. This may explain why a simple checking of ancient structures shows them to be completely deteriorated while in fact they are perfectly sound.

Another difficulty is that ancient structures may be very useful from different aspects (for instance, a round bastion adjacent to a castle wall may be an efficient counterfort, an ingenuous bulwark and at the same time a beautiful formation), but it would be quite erroneous to construct a similar one adjacent to existing structures, leading to a poor, tenuous solution.

2.2 Means of structural research

There are several varieties of structural research. Though structural design is not concerned with actual dimensioning, in some form or other it has recourse to all means of applied and theoretical mechanics, and even to quite novel means. A major difference between calculations for structural design and for dimensioning is that the former are less involved in details (namely at the stage of preliminary design most details are still unknown), they are often more of a large scale, and attempt to seize the primordial features.

Or the structural research may not have recourse to mathematical means and though it seeks to decide between possible structures reasonably, explicitly and reliably weighing intervening factors. The papers below are illustrating some examples.

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