Experiences from Engineering Education in Conceptual Design of Structures

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Summary

Structural engineers should contribute to the development of structural concepts and form finding. This can even begin at the level of education. Therefore, some five years ago, a course on conceptual design was started. The course tends to give a definition of conceptual development and preliminary assessment of basic ideas. Three stages are introduced, namely the concept definition, numerical assessment and building of scale models for testing. The course also is an invitation to think about meaningful, intelligently thought structures, by asking various questions about resistance, simplification, appearance and effectiveness.

Experience has shown that enthusiasm and creativity sometimes overrules structural thinking. In addition, this activity requires intensive experienced input about loads and structural functioning. Building and testing of scale models is a large help for better understanding how some of the original concepts actually work.

Keywords: conceptual design, scale models, engineering education, form finding, .

Abstract

The need to give attention to a more conceptual approach to structural engineering is felt widespread. Modern design practice is most accurately able to make refined analysis of complicated structures and predict their behaviour in various conditions. However, a basic structure is needed before all of these tools can be used successfully. In addition, time consumption before reaching good structural solutions may be overwhelming if the process is started blindly. High-performing tools are of no practical use if the basic idea does not prove to actually stand.

On the other hand, many regret the fact that structural engineers limit their contribution in building, to checking of compliance with codes and regulations. Because of this, the engineering part is strictly reduced to verification of strength and stability, without further development of structural form and purpose. This would mean that the engineering profession has no intention to contribute to the basic design of shape and functions of structures. This appears as simply unthinkable, as many interesting structures are first carefully thought of and society is expecting this contribution from civil engineers.

Conceptual design is the part of structural engineering where imaginative processes and considering of alternatives are worked out. Obviously, it is the creative part of engineering and it should precede any other initiative during the design of a structure. Many feel the need to demonstrate this already during the education of young people even at early stage.

The notion of a concept is used often and in various ways. It may be interpreted as a vague but general idea of a principle, an object or in the present case a structure. In any case, a concept should include all properties of a structure, including strength, function, quality, economy and aesthetics.

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Conceptual design of structures is to comprise all of these qualities to a high standard in a single idea or vision of what is an adequate structure for a given problem. Obviously at some times this may be evident, whereas mostly, developing such a concept requires much effort and imagination.

Finally, the best way to proceed seems to allow for unrestricted thinking and producing as much ideas as possible, without immediate evaluation. Several ideas may generate new ones and are inspiring during the process. The design of large structures is now often determined after competitions. Unfortunately the number of proposals of each group is limited and there is no opportunity to discuss alternative designs or to combine interesting elements from several proposals. In addition, competition jury's are inclined to simply select among proposals, without further discussion.

A holistic approach to conceptual design supposes the designer tries to develop a concept which encompasses all types of qualities and requirements. The latter do not need to be defined at a preliminary design stage, since the global concept is being checked after its definition. This method is particularly useful if the concept can be determined by analogy or if it appears clearly from the start which idea is simply the better choice. It becomes more difficult if many concepts must be compared, since some may prove to be inadequate on a limited number of functional requirements. However, with this method, the alternatives are not rejected immediately and may be considered for further improvement. In addition, and as aesthetics is generally not included in requirements lists, since this quality has a subjective character and does not allow to apply hard functional data, the holistic approach should generate more aesthetic proposals. Hence, the holistic approach looses fewer alternatives and increases the chance of obtaining better looking ideas.

During the course, a progression is made from very simple to more complicated structures. Linear structures, such as frames or beam grillages may seem to be evident, although improvements to the width and construction depth of these elements may learn that alternatives can actually be generated. Obviously, another advantage of beginning with linear structures lies in the capability to use simple formulas to analyse their behaviour. Radical modification of the dimensions or spans can be easily allowed and does not require a particular effort.

In addition to accurate preliminary modeling, the assessment of loads may be a problem. At the early stage of design approximate values have to be adopted both for dead and live loads. For this, some experience is needed and especially students have to be supported. Again, wind loads are the most difficult to estimate, since their value may depend on the fundamental vibration modes and several other parameters, which can be found only during detailed design.

Building scale models of a structural concept with adequate material highly contributes to understanding the structural behaviour. Together with numerical modelling, this understanding comes by the principle of 'see and feel – touch and feel'. Materialising of the structural concept also confronts designers with practical building, albeit at a lesser complexity level. The assembling of nodes, the precision of scale model building and especially the difficulty in realizing clamping of columns and members in a substructure can be experimented. In addition, scale models allow appreciating the stiffness of a structure in various directions.

Conclusions

After 5 years of experimenting with a course on conceptual design of structures, it has become clear that students can be motivated for this activity and learn a great deal about structural behaviour. The output certainly confirms the need for designers to participate in the debate and contribute to form finding and aesthetics. In general, the enthusiasm to imagine original concepts must be tempered, since many ideas are unstable or too complicated.

In addition, students consider numerical modeling the most tedious part, and unfortunately they do not tend to use simple theory to assess the validity of concepts. Software programs have taken over most of the classical formulas and assumptions. However, since these tools are available there is no harm in using them, provided the user has sufficient insight in the behaviour of the concept. For this, the assembling of scale models and testing them is highly useful. The latter also demonstrates the gap that exists between real structures and calculation.