PLAYING WITH MECHANICAL TOY STRUCTURES AND SOLIDS

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Summary Mechanical scale models are important tools to enhance teaching of solids and structures. The models can be classified as simple (that a student can develop without special skills and equipments), complex (so that the activity of the student has to be guided in a laboratory environment), and sophisticated (where a fully equipped lab is needed and training and full-time guidance of the student are required). Teaching and research have the same basis, so the ability to develop sophisticated teaching models pave the way to the realization of structural models that can be used for quantitative experiments highlighting new phenomena in the mechanics of solids and structures.

INTRODUCTION

More than fifty years ago, not only structural mechanics was taught with scale models in the best schools of engineering [1-4], but these models were routinely used for the design and optimization of real structures [4]. The use of scale models in design goes back to an ancient time, for instance, Michelangelo Buonarroti, the painter of the Sistine chapel ceiling, wrote: "*i più benedetti denari che si spendono a chi vuol fabbricar sono i modegli* ([scale] models represent the best money that one who wants to build can spend)". The advent of the computer swept away the models, an event that for us represents a great loss for all engineers. Therefore, in the last decade we have designed, realized, and tested scale several models for teaching solid and structural mechanics. This experience has been extremely rewarding in teaching, but suggested us the establishment of the *Instabilities Lab* at the University of Trento, where experiments on scale structures are used as tools for the realization of proof-of-principle prototypes to demonstrate new theories and for the design of real mechanical and civil sturctures.

SCALE MODELS FOR TEACHING AND PROOF-OF-PRINCIPLE STRUCTURES

Simple models can be easily designed and realized to demonstrate structures that can be calculated on the basis of equilibrium. An example concerning the statics of a 4-block structure is shown in Fig. 1. More examples include vassoirs arches, funiculars of loads, and the catenary. In these structures deformation is neglected and the response of the model is tight to theoretical predictions. These experiments are so simplethat can be realized by untrained students at their home.

Complex models can be developed not only for structures, but also for solids. For instance, Fig. 2 presents a simplle model to demonstrate that a homogeneous deformation is an affinity, thus preserving lines and transforms polygons into polygons. The model requires the availability of a testing machine and a clamp system for the ends of the rubber sample (on which geometric figures are drawn), therefore a laboratory is needed, though the effort remains low.

Sophisticated models can be developed as proof-of-principle to demonstrate complicated phenomena. One example is shown in Fig. 3, where the first experimental realization of the Reut's column is preseted [8].

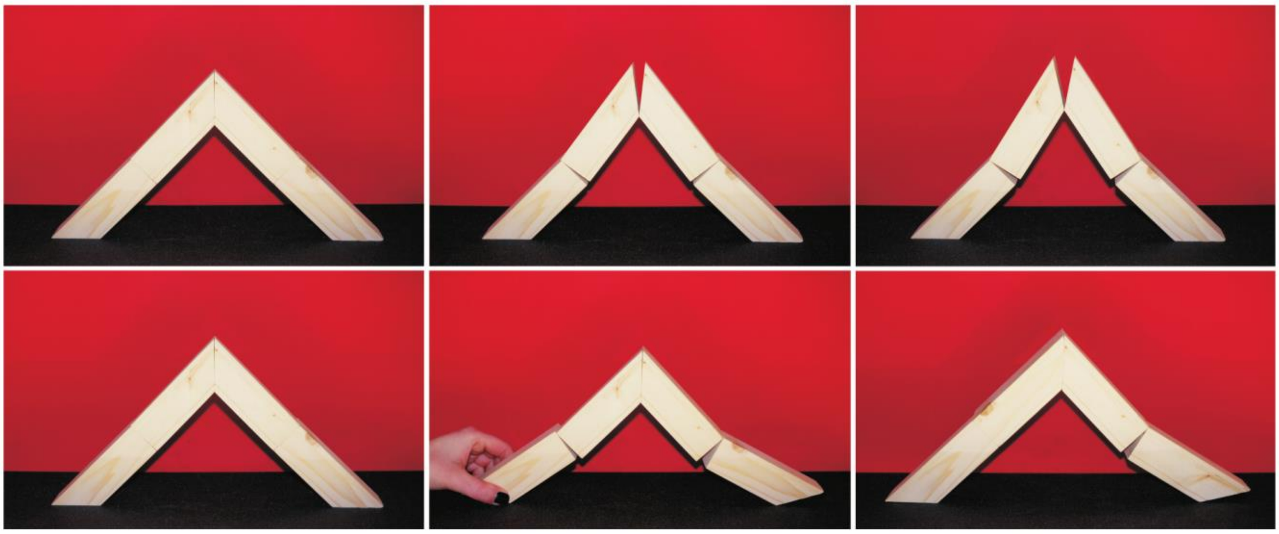

Figure 1. A wooden model of a gable made up of four rigid blocks and subject to its own weight. When the abutments move closer to each other, a symmetric solution is found in which a three-hinges symmetric system forms. When the abutments move apart, the symmetric solution realizes a four hinges system which cannot stand, so that the static solution breaks the symmetry.

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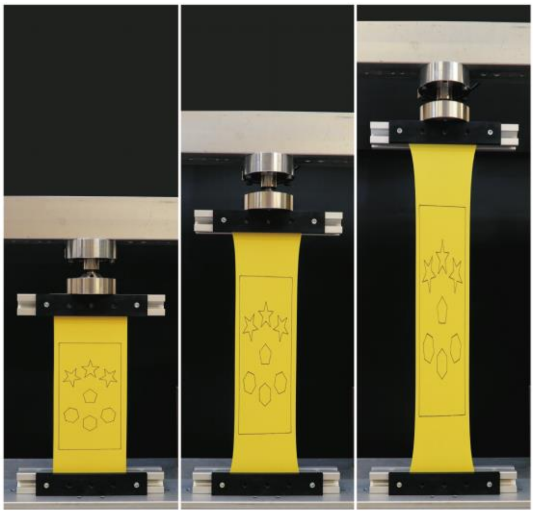

Figure 2. A stretched rubber sheet produces a central zone in the sample where a linear displacement prevails. The vertical stretch measured on the external rectangle containing the figures are from left to right equal to 1 (undeformed configuration), 1.57, and 2.14, while the horizontal stretches are equal to 1, 0.84, and 0.74. Polygons are preserved by the stretch.

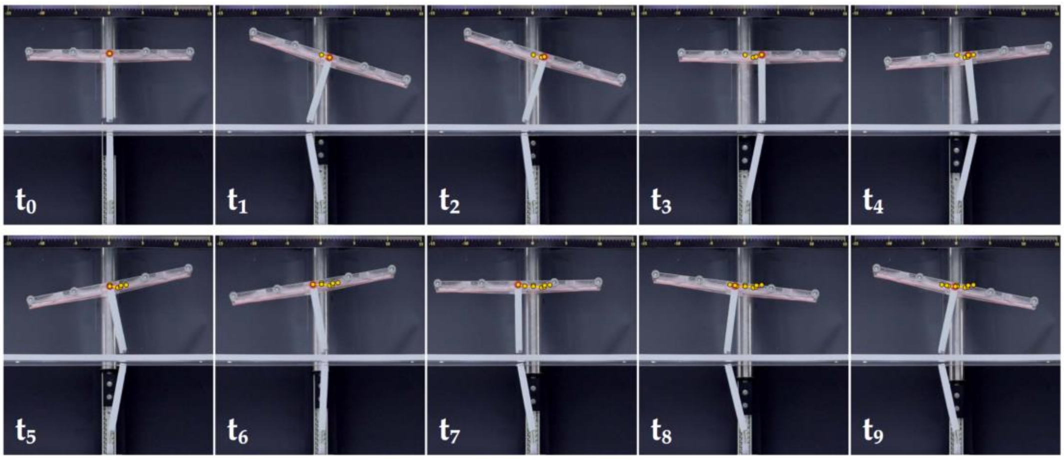

Figure 3. A sequence of photos in time documenting flutter instability in the Reut's column [8].

CONCLUSIONS

Scale models in the mechanics of solids and structures must be given much more importance than they currently receive. They can be used not only for teaching, but also to demonstrate weird or previously unknown phenomena such as flutter instability, configurational forces, dynamics of metamaterials, cloaking and shielding.

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