Using Images to Teach the Beginnings of Structural Engineering

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Abstract *- Aiming at turning theory of structures into a captivating subject to civil engineering students and at helping them understand the link between the mathematical models and the real structures, a new experience is under way at the Department of Structural and Foundation Engineering of Escola Politécnica da Universidade de São Paulo: transparencies are being used to introduce visually some of the first concepts of theory of structures. Transparencies introducing the concept of structure, transparencies presenting the historical evolution of civil engineering structures and transparencies showing the relation between the mathematical models and the real structures were produced. These transparencies were used for the first time in 1997, with great success. This paper presents the details of this experience.*

Introduction

When starting to teach theory of structures to engineering students one faces two major challenges: how to teach this subject so that it becomes appealing and captivating to the students and how to link the theory presented in the classroom and the mathematical models examined to the actual structures of the real world.

At Escola Politécnica da Universidade de São Paulo (Polytechnic School of the University of São Paulo), a new experience is under way at the Department of Structural and Foundation Engineering aiming at overcoming these difficulties.

At Escola Politécnica, civil engineering students have their first contact with theory of structures in the course PEF-124 “Introduction to mechanics of structures” and, to cope with the challenges mentioned above, a new teaching medium is being used in this fourth semester subject of the ten-semester long civil engineering course.

A series of transparencies was prepared to be presented to the students during the classes, aiming at showing them the importance and the beauty of structures and of structural engineering, the fundamental role they play in our lives and how the mathematical models are linked to the real structures.

Three groups of transparencies were prepared: (a) transparencies introducing the idea of what a structure is, (b) transparencies presenting the evolution of civil engineering structures from prehistoric times to modern days, and (c) transparencies showing the relation between the mathematical models and the real structures.

When selecting the structures to be presented, preference was given to Brazilian structures, especially those of the city of São Paulo, so that by examining constructions and objects they know well and which play an important role in their daily lives the students can feel themselves closer to structures, be more appealed by them and see more easily how significant and important structures are to mankind.

Transparencies were preferred to slides or computer images presented by means of a data projector for two reasons: (a) because overhead projectors are much more simple to have and much more easy to handle and maintain than slide projectors, computers and data projectors, and (b) because transparencies do not demand as much darkness to be projected as do slides and computer images. When projecting transparencies, some of the classroom lights may be left turned on, thus allowing the professor to simultaneously use the blackboard if he needs to do so and preventing the students from feeling the sleepiness a darker room could induce.

Most of the pictures depicted in the transparencies were taken from books, magazines and postcards; almost all of those showing structures in the city of São Paulo were photographed by Luis Alberto Tello Arévalo, one of the authors of this article.

Transparencies introducing the concept of structure

The very first concept examined in the course PEF-124 “Introduction to mechanics of structures” is that of what a structure is. It is extremely important that the students see clearly that all objects and constructions, both of Nature and made by man, have a structure.

A series of transparencies was produced so that the students can visually grasp the idea of what a structure is.

These transparencies show structures from Nature - an oak tree, a palm tree, a spider’s web, a beaver’s dam, an egg, a human skull, a rock arch bridge, etc. - , structures of everyday life objects - an umbrella, a table, a chair, a ladder, a supermarket trolley, etc. -, structures of civil engineering - skyscrapers, churches, bridges, telecommunications towers, domes, stadia, etc. -, and structures of mechanical, naval, aeronautical and aerospace engineering - a construction crane, a car, a bus, a train, a ship, an airplane, a rocket, an artificial satellite, etc.

The concept of loading is inherent to that of structure, and by showing these structures to the students and by examining how they work not only the concept of loading but also the different types of loads acting on a structure are effortlessly presented. The dead load, the wind,

rain and snow loads, the weight of people and freight being transported in a car, a bus, a train, a ship, an airplane, the weight of the vehicles crossing a bridge, the weight of the people, furniture and objects filling an apartment, the pressure of the water on a dam, the pressure of a gas on the walls of a gas tank, the effect of an earthquake on a building, etc. are effectively introduced using these transparencies.

In addition to the concepts of structure and loading, another extremely important idea can also be presented by means of these transparencies: that all structures have essentially the same behaviour. All structures, no matter whether from Nature or made by man, are acted upon by loads and under these loads they present deformations and stresses which depend on their shape and material. It is for this reason that a same theory of structures is used to study all structures, no matter whether they are from Nature or made by man, whether they are from civil, mechanical, naval or aeronautical engineering.

In Figure 1 some of these transparencies introducing the idea of what a structure is are presented.

Transparencies presenting the historical evolution of structural engineering

The presentation of a short history of civil engineering structures aims at showing the students some of the wonderful and breathtaking structures built by man over the centuries.

Transparencies showing prehistoric clapper bridges, Egyptian pyramids, Roman structures, medieval cathedrals, Renaissance buildings, iron bridges, the first skyscrapers, the tall buildings and the long span bridges of this century were produced.

The presentation of these transparencies allows for showing: (a) the sheer magnificence and beauty of the structures built by man from prehistoric to modern times, (b) that the evolution of structural engineering depends very heavily on the use of new materials and new structural systems, and (c) that based only on intuition and qualitative models man was able to produce extraordinary structures like Cheops Pyramid, the Pantheon in Rome, the Cathedral of Amiens, the dome of the Cathedral of Florence, etc.

These transparencies are presented in chronological order, the historical Brazilian structures mingled with the international ones, so that in addition to learning the evolution of civil engineering structures in Brazil the students can have an idea of its development by comparing the Brazilian structures to those built at the time in other parts of the world.

Some of the transparencies presenting the evolution of civil engineering structures are shown in Figure 2.

Transparencies showing the relation between the mathematical models and the real structures

To turn theory of structures into a captivating and appealing subject it is essential that the students see that the mathematical models they study now will be indeed behind the real structures they will design and build one day. It is fundamental that they understand clearly the role of the mathematical models and their relation to the actual structures of the real world.

To link mathematical models to actual structures, transparencies showing real structures in which simply supported beams, cantilever beams, continuous beams, plane and space trusses, two- and three-hinged frames and arches, hingeless frames and arches, Gerber beams, etc. are present were prepared.

By examining these structures and discussing the mathematical models used to represent them, it is possible to show the students that mathematical models are an approximate representation of the real structures, that a same structure can be represented with different degrees of accuracy by different mathematical models, that in engineering one does not seek to find the most perfect model of a structure but one which is good enough for design purposes.

It is also especially important to show that a same mathematical model can be used to represent adequately different real structures: a palm tree in the garden of the civil engineering building and a streetlamp nearby can be both modelled by the very same vertical cantilever beam with the bottom end fixed and acted upon by a vertical concentrated load applied to its free end and a vertical distributed load applied along its axis.

In Figure 3 some of the transparencies showing the relation between the mathematical models and the real structures are presented.

Using the transparencies

The transparencies were used for the first time in the second semester of 1997.

In all, 142 transparencies were prepared, 61 of which depict Brazilian structures, 39 photographed by Luis Alberto Tello Arévalo.

There are of course many transparencies which belong to more than one of the three groups detailed above: prehistoric clapper bridges, for example, illustrate both the history of civil engineering structures and simply supported beams; a palm tree, both the concept of structure and a cantilever beam.

Each year about 180 students enrol in the course PEF-124 “Introduction to mechanics of structures”, being divided into three classes of 60 students each. As three different professors simultaneously teach these three classes, three complete sets of the 142 transparencies were produced, so that they can be used at the same time. A fourth set was prepared as a spare one.

The transparencies were used in some of the classes of the course, in sessions in which they were presented, examined and discussed.

The use of these transparencies was very successful. Recently the students were asked to write a short comment

(a)

(b)

(c)

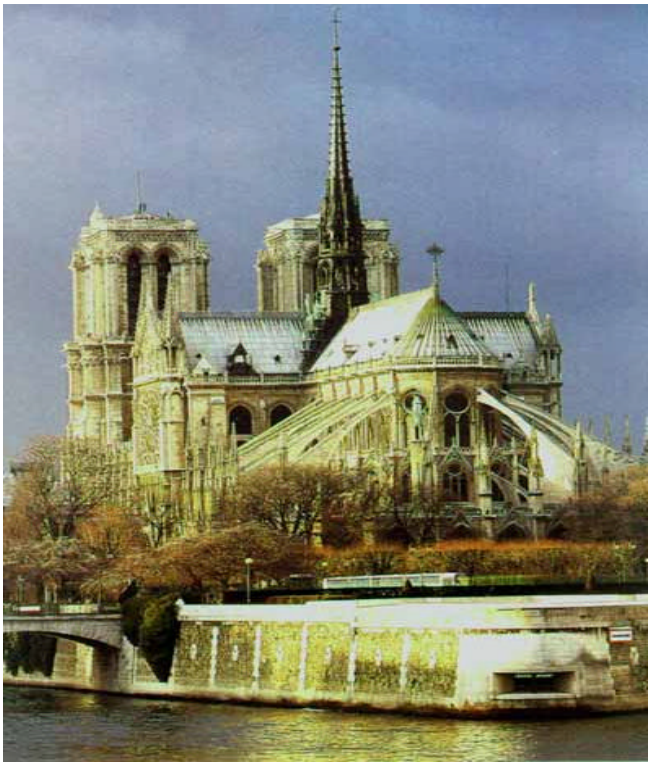
Estádio do Maracanã, Rio de Janeiro

(d)

Figure 1. Some transparencies presenting the concept of structure: (a) a spider's web [1], *(b) umbrellas* [2], *(c) a ship* [3], *and (d) a football stadium* [4].

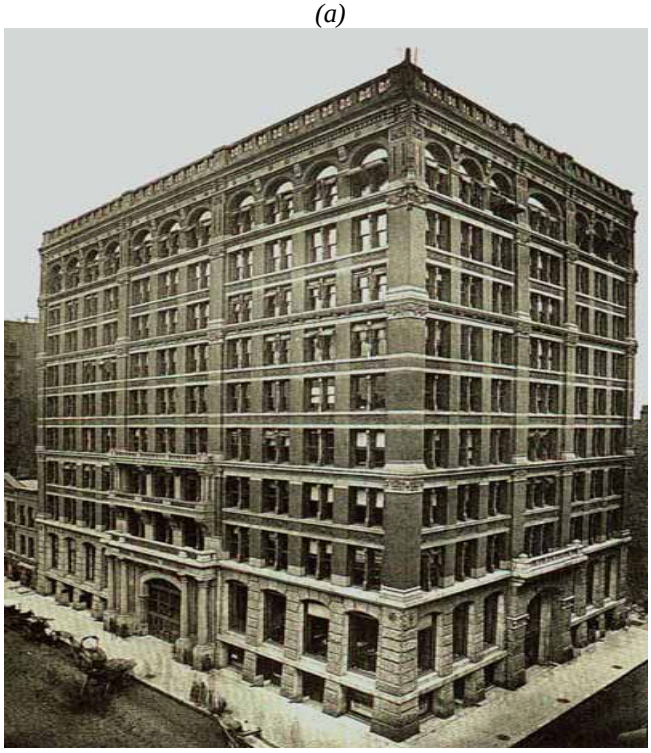
Panteon, Roma, 118 dC

(a)



Catedral de Notre-Dame, Paris, 1196-1240

(b)



Home Insurance Building, Chicago, 1885

(c)

Ponte Akashi-Kaikyo, Akashi-Kaikyo, 1998

(d)

Figure 2. Some transparencies presenting the historical evolution of civil engineering structures: (a) The interior of the Pantheon, Rome, Italy [5], *(b) Cathedral of Notre Dame, Paris, France* [6], *(c) Home Insurance Building, Chicago, USA* [7], *and (d) Akashi-Kaikyo Bridge, Akashi Strait, Japan* [8].

Ponte sobre o Rio Barle, Somerset, Inglaterra, pré-histórica

(a)

Torre da TV Globo, Av. Paulista, São Paulo

(b)

Ponte dos Veados, Paulo Afonso, Bahia, 1954

(c)

Ponte em Dudh Khosi, Nepal

(d)

Figure 3. Some transparencies presenting different types of real structures: (a) simply supported beams [8], *(b) a space truss* [9], *(c) a three-hinged arch* [10], *and (d) a Gerber beam* [8].

on this experience, and the vast majority approved it strongly, suggesting that a bigger number of transparencies covering all topics of the course should be used in the future.

Most of them pointed out that the transparencies presenting the relation between the mathematical models and the real structures were of very great importance, for having shown that the theory presented in the classroom is really used in the design of real structures and for having explained how these mathematical models are linked to the real structures.

The use of transparencies depicting structures of the city of São Paulo was also greatly approved, and the presentation of a bigger number of such structures was suggested. One of the students wrote that when she now passes by one of the structures analysed during the classes she examines it carefully and tries to see by herself all the aspects discussed by the professor.

Several students also pointed out that the use of these transparencies in the middle of a theoretical class was a welcomed and important moment of rest breaking a heavy class.

To improve this experience, some additional transparencies are now under preparation, as well as short written texts about each one of the structures presented: its location, materials used, time of construction, name of the architects and engineers involved with its design and construction, dimensions, construction details, interesting stories about it - political and economic aspects of its construction, problems and acidents during its construction, structure and foundation reinforcements, etc.

Conclusions

The use of transparencies at the Department of Structural and Foundation Engineering of Escola Politécnica da Universidade de São Paulo to present to the students of the course PEF-124 "Introduction to mechanics of structures" the concept of structure, the history of civil engineering structures and the relation between the mathematical models and the real structures has proved to be successful. This experience really increased the students' motivation for learning theory of structures.

The students were truly marvelled by several of the historical buildings presented, discovered what and how important structures are, saw what the mathematical models they study are and understood why and how the mathematical models will be behind the real structures they will one day design and build.

This experience will continue and will be improved with the addition of more transparencies and short texts about all the structures examined.

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