RAISING AWARENESS ABOUT INHERENT RESPONSIBILITY TO STRUCTURAL DESIGN THROUGH MULTIMEDIA ANALYSIS OF STRUCTURAL COLLAPSE

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Abstract
The professional activity related to the design, calculation and execution of structures involves an important responsibility, due to the considerable human and material damages that can be caused if, for any reason, a collapse occurs. The complexity of the subject is so great as to make the students to immerse themselves in the calculations so that the overall perspective is lost and students fail to recall the importance of conducting a safe structure.

The use of real cases of collapses translates into a way of understanding the scope of this responsibility, and allows the student to know and contextualize the role of the engineer in these situations. The use of multimedia resources (videos, images, simulations, ...) allows to identify and observe with greater clarity the origin of the problem, which is not easy.

The main objectives of this work are (i) to use real cases of structural collapses to help the students of these subjects in order to understand the importance of the professional work they are preparing to exercise, (ii) to use multimedia elements for a detailed analysis of each case, relating them to concepts taught in the subjects (instability, fatigue, resonance, constructive processes, ...), and (iii) to learn the role of the engineer in these cases. The aim is for students to internalize the inherent responsibility of structural calculation and to understand that it is demanding subject, since errors can lead to total failure and catastrophes.

To this end, multimedia material has been collected from more than 30 cases of collapses, which is being used by teachers to analyse them and link it with contents of the subjects, in class sessions supported by virtual teaching tools. The sessions are especially open to the participation of the students, who usually shows curiosity about what happened and interest in participating in the analysis.

The project covers 3 different courses (2nd, 3rd and 4th) of the Bachelor degree in Mechanical Engineering, and also 2nd year of the Master degree, in order to observe the evolution of interest throughout their academic career. 6 different subjects participate in the project, so it concerns more than 300 students. As a first step, this academic year it was tested with a small group of students, from 2nd and 3rd course of the Bachelor Degree. Surveys are used to quantify this interest before and after the activities. The preliminary results of this project show that these activities are appropriate to improve motivation and interest in professional ethics in the field.

Keywords: Structures, collapse, failure, strength of materials.

1 INTRODUCTION
The professional practice as structural engineer means a high level of responsibility, due to the high human a material costs which can be caused by mistakes made in the design of a structure, its calculation, verification and/or execution. It is important to educate engineering students about this responsibility, and to train professionals who are demanding and self-critics.

The use of real examples of structural collapses is nothing more than learning from past mistakes, something that is always positive in the teaching-learning process. Using multimedia elements (mainly videos and simulations) does not only allow to observe real contents that the student has to imagine or infer from photographs and diagrams, but also to work with transversal contents, skills and professional attitudes that are first discovered in a Bachelor level. All of these make these activities arouse the interest of students, resulting into an efficient way to learn.
Unfortunately, in our recent history there are many cases of structural collapses that should serve as an example to improve our professional practice and prevent it to happen again, as far as possible.

The factors that influence the safety of a structure are those that influence the design [1] plus those that appear in the construction process, and can be summarized in 6 large batches:

- **Structural theories:** The calculation of structures is not an old science but mainly developed over the past century, there are aspects in which there are still uncertainties, such as wind or seismic loads. The analysis of some collapses has served to develop theories and new calculation methods that make our structures more secure today.

- **Calculation techniques:** No calculation is free of mistakes, even though much is done automatically by computers, they are always under human control. A rigorous calculation of the structures is a valuable and habitual skill among structural engineers, and therefore, students must be taught to proceed this way. In many occasions the error was not in the calculation itself, but in the absence of it.

- **Material properties:** The resistance of materials is not an exact science either, because it is difficult to foresee with accuracy. Some structural collapses [2] led to the inclusion in the standards of safety coefficients in the calculation and on-site quality controls, which has minimized the uncertainty caused by it.

- **Construction procedures:** Sometimes the materials are adequate and the calculations correct, but the construction does not fit perfectly to the original design, either by changes required by the property, or by an incorrect execution of the work. These situations must be solved by the construction management, so the responsible engineer must have the skills to do so.

- **Communication procedures:** Failures in communication between the property, the drafters of the project, the construction management, the construction company and other agents have led to some significant collapses [3] [4]. In this field, much progress has also been made, with the BIM methodology currently in full expansion, which ensures the right communication between the different participants in a project.

- **Economic factors:** The structures are expensive and therefore the economic aspect cannot be ignored, in fact it has been behind some collapses, not so much as a direct cause but as a circumstantial factor.

Facts related with these six batches appears in the most significant structural collapses, which has led the authors to think that its use as an example, and through novel channels, can be positive for the teaching-learning process in structural engineering.

### 2 METHODOLOGY

This project is being developed in two University programs of the Higher Polytechnic School of Jaén, Bachelor and Master Degrees in Mechanical Engineering, involving 6 different subjects and a total of 300 students. This text presents the results of the first phase of the project, in which the activity was carried out in 2 subjects of the Degree (Elasticity and strength of materials, in 2nd year, and Theory of structures, in 3rd), affecting some 60 students.

To set out the activities of the project, an initial survey was carried out to the students, with the aim of knowing the cases of structural collapses they previously know, if they have assimilated the responsibility inherent to the exercise of the profession, as well as the use of multimedia material as a teaching tool that is carried out in the degree, and their opinion about it. Once surveys were evaluated, the project's teachers established a first phase of the project to begin to carry out these activities and observe their results.

To carry it out, 32 cases of documented structural collapses were initially selected, among which 5 cases have been chosen for the first phase of the project, of which multimedia material has been available, and in which examples of errors of each batch appear.

The analysis of the collapses is done through the selection of appropriate multimedia material to present the technical details of each case, the presentation itself in specific sessions in the classroom of the material and the availability to students (including material for the extension of knowledge) through the virtual teaching platform. Among the material used are documentary videos, informative videos of entities and scientific websites, videos with simulations of collapses, images and diagrams,
research articles, official government reports, and articles on different websites. Selected cases, related batches and main collected material are shown at Table 1.

<table>
<thead>
<tr>
<th>Case</th>
<th>Batches</th>
<th>Collected material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1860 Pemberton Mills factory Massachusetts, USA</td>
<td>Structural theories, Calculation techniques &amp; Material properties</td>
<td>- Report at the University of Massachusetts website [2]. - Report at “Patologías y construcción” website [5].</td>
</tr>
</tbody>
</table>

In addition to the listed material, they were made available to the student other reports and articles at different websites, YouTube videos and also some journalist article related to the role of engineers and builders at these cases [15] [16]. Some presentations were also prepared by teachers as a resume of each case.

Two sessions of one hour were used to explain the cases and show part of the material. Participation at sessions was voluntary. The evaluation of this experience has been done through a final survey.

3 RESULTS

The results of these teaching activities have been quantified through anonymous surveys to the participating students, belonging to the 2nd and 3rd year of the Mechanical Engineering Bachelor Degree. First, an initial survey is carried out, prior to the completion of the activities, and a final or subsequent one, with questions aimed at quantifying the opinion of the students on the suitability of these teaching activities. The number of participants in each survey is different due to the totally voluntary nature of the surveys.

3.1 Initial survey

Sample size was 40 students, its distribution about age and sex is shown at Fig. 1.
The results (Fig. 2 and 3) show how students are, in general, aware of professional responsibility and the impact that a collapse can have. They also claim to know some cases of collapses and the role an engineer can play, and they agree that the analysis of these cases can be positive for their learning. On the use of multimedia material, they have not yet experienced it in many subjects, but expectations are high, considering it a fundamental tool, if not indispensable.

**Figure 1. Sample distribution about age and sex of initial survey.**

**Figure 2. Results of initial survey 1.**
3.2 Final survey

Sample size was 34 students, its distribution about age and sex is shown at Fig. 4.

The results (Fig. 5) show that the activity helped them to understand different concepts related with the subject, with an important influence in each of the issues discussed. They think this activity is positive and recommend it.
How many cases of structural collapses have you analyzed (with multimedia material) in this course as a teaching activity?

- 0 cases: 2.9%
- 1 case: 17.6%
- 2 cases: 14.7%
- 3 cases: 11.8%
- 4 cases: 14.7%
- 5 cases: 35.3%
- 6 cases: 2.9%

What percentage do these collapse videos represent about the total of videos used as teaching tools in the degree?

- 0 to 20%: 2.9%
- 20 to 40%: 35.3%
- 40 to 60%: 3.5%
- 60 to 80%: 17.6%
- 80 to 100%: 35.3%

Indicate your compliance with the next statement: "The multimedia analysis of structural collapses helped me to understand certain contents of the subject".

- Quite agree: 32.4%
- Agree: 64.7%
- Undecided: 2.9%
- Disagree: 0.0%
- Quite disagree: 0.0%

Rate how much influence the analysis of structural collapses and videos in your learning about ...

<table>
<thead>
<tr>
<th>Effect of wind on structures</th>
<th>Proper execution of concrete structures</th>
<th>Professional ethics</th>
<th>Responsibilities of the structural engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of overloads and undersized</td>
<td>Proper execution of joints</td>
<td>Failure analysis and forensic engineering</td>
<td></td>
</tr>
</tbody>
</table>

Generally, would you recommend to the faculty to use more videos related to collapses and engineering errors that we can learn from as a teaching tool?

- Yes: 94.1%
- Undecided: 5.9%
- No: 0.0%

Generally, do you think that this activity can be useful when developing your professional work?

- Yes: 97.1%
- Undecided: 0.0%
- No: 2.9%
4 CONCLUSIONS

The results obtained demonstrate that the analysis of structural collapses is a good teaching tool, because it helps the student to understand concepts, observe skills and attitudes that they will have to develop in their professional future. Also, it is important to learn how to assess the repercussions of a poor work, whatever the aspect missed by the structural engineer.

For the authors, the experience has also been positive, since the interest of the students has been awakened, who has actively participated in the sessions held.

The results encourage us to continue planning and developing these activities. Further tasks will be undertaken next academic year, within the framework of the teaching innovation project in which the authors participate.

REFERENCES


