AC 2009-613: FAILURE CASE STUDIES IN THE CIVIL ENGINEERING AND ENGINEERING MECHANICS CURRICULUM: A NEW TEXTBOOK

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Failure Case Studies in the Civil Engineering and Engineering Mechanics Curriculum: A New Textbook

Abstract

Over the past three years research has evaluated the impact of including failure case studies in specific civil engineering and engineering mechanics courses. Failure case studies developed under two NSF-funded projects have resulted in a book published by the American Society for Civil Engineers (ASCE) Press, *Beyond Failure: Forensic Case Studies for Civil Engineers.* This paper presents a discussion of the organization and the presentation of the individual cases, as well as some suggestions for use of the work in the curriculum and elsewhere.

Introduction

Over the past three years research has evaluated the impact of including failure case studies in specific civil engineering and engineering mechanics courses[1, 2, 3, 4]. Failure case studies developed under two NSF-funded projects have resulted in a book published by the American Society for Civil Engineers (ASCE) Press, *Beyond Failure: Forensic Case Studies for Civil Engineers*[5]. The book cover is shown in figure 1. This book breaks down failure case studies into chapters arranged by engineering courses and topics.

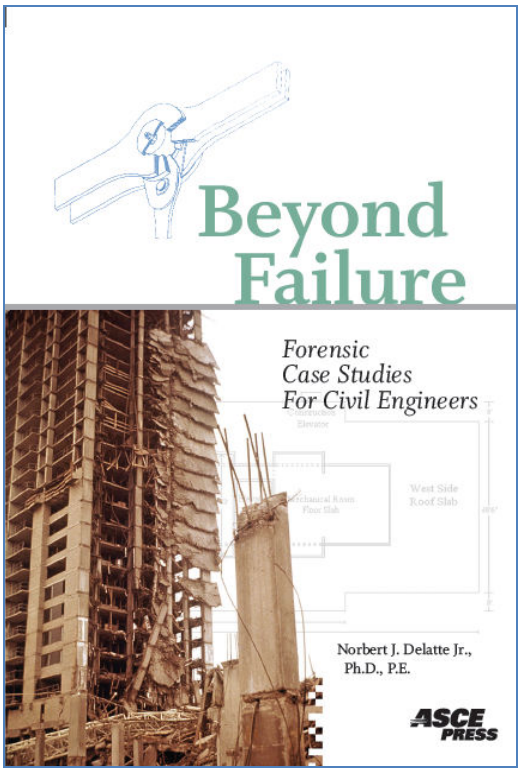

Figure 1: Book Cover

Organization of the Book

The short introductory chapter discusses the overall organization of the book, notes to the student, and sources for case study materials. After the introductory chapter, the other nine chapters address statics and dynamics, mechanics of materials, structural analysis, reinforced concrete structures, steel structures, soil mechanics/ geotechnical engineering/ foundations, fluid mechanics and hydraulics, construction materials, and management/ ethics/ professional issues. The chapters were written to parallel courses and topics typically taught in civil engineering, as well as engineering mechanics courses that may be taught by civil engineering faculty at some institutions. A list of chapters is provided in table 1.

Table 1: List of Chapters

Chapter	Title
1	Why Case Studies?
2	Statics and Dynamics
3	Mechanics of Materials
4	Structural Analysis
5	Reinforced Concrete Structures
6	Steel Structures
7	Soil Mechanics, Geotechnical Engineering, and Foundations
8	Fluid Mechanics and Hydraulics
9	Construction Materials
10	Management, Ethics, and Professional Issues

Three appendices are provided. Appendix A is Notes to the Professor, based on results from the two NSF-funded projects on teaching failure case studies in the classroom. Appendix B is the ASCE Code of Ethics, and Appendix C lists some failure case studies available on DVD and Video. These are from the History Channel's *Engineering Disasters* series.

Each chapter has between three and six main case studies, as well as a list of "other cases" with cases in other chapters that could also be considered under the topic. For example, the Quebec Bridge 1907 collapse case study is listed under mechanics of materials, but also applies to statics and dynamics, structural analysis, steel structures, and management/ ethics/ professional issues. In fact, pretty much all of the cases include a management/ ethics/ professional issues focus. Therefore, chapter 10 does not include a list of "other cases" since nearly all of the cases in the book fall under that area.

As an example, the chapter on reinforced concrete structures has fully developed case studies on Air Force Warehouse Shear Failures, 2000 Commonwealth Avenue, Skyline Plaza in Bailey's Crossroads, Harbour Cay Condominium, Bombing of Oklahoma City Murrah Federal Building, and The Pentagon Attack (9/11/2001). Most of the "other cases" cross reference to other chapters. The complete list is shown in table 2. Some of the case studies have been previously published as technical papers, including Ronan Point[6], L'Ambiance Plaza[7], and Schoharie Creek Bridge[8].

Table 2: List of Cases in Chapter 5, Reinforced Concrete Structures

Chapter	Complete Case Studies
5	Air Force Warehouse Shear Failures
5	2000 Commonwealth Avenue
5	Skyline Plaza in Bailey's Crossroads,
5	Harbour Cay Condominium
5	Bombing of Oklahoma City Murrah Federal Building
5	The Pentagon Attack (9/11/2001).
	Other Cases
4	Ronan Point
4	L'Ambiance Plaza Collapse
9	Willow Island Cooling Tower Collapse
8	Schoharie Creek Bridge
10	Sampoong Superstore
5	Autoroute 19 de la Concorde Overpass

Elements of a typical case are illustrated through the example of the 2000 Commonwealth Avenue Collapse case. This case study was based on a previously published paper[9] and illustrates the technical topic of punching shear, as well as problems with concrete construction. This section of the chapter has the following sub-sections:

- Design and Construction
- Collapse (broken down into phases, since the building collapsed in sections)
- The Commission Investigation (based on the report by a commission appointed by the mayor of Boston)
- The Punching Shear Mechanism
- Review of Causes of Failure
- Design and Detailing Concerns
- Procedural Concerns
- Conclusions
- Essential Reading (other references of interest)

Although the technical causes of failures are of considerable interest, non-technical causes are also important. These include procedural concerns, ethical concerns, legal implications, failures of communication, and others. These are important elements of case studies, because these topics are otherwise sometimes neglected in the curriculum.

Parallel Efforts

Since 2003, faculty workshops on integrating failure case studies in the curriculum have been offered with support from ASCE and NSF[10]. These one-day workshops included a binder of materials on various failure case studies, as well as a CD-ROM of PowerPoint files for presenting the case studies. In future workshops, the book will be provided in place of the binder.

A project web site was prepared along with the book. The home page is shown in figure 2. Some of the web site's sections are shown in figure 3. The web site includes a master bibliography, a discussion of the faculty case study workshops, a chronological listing of case studies, a list of course pages, and information for faculty. Further details of the project web site are presented elsewhere[11].

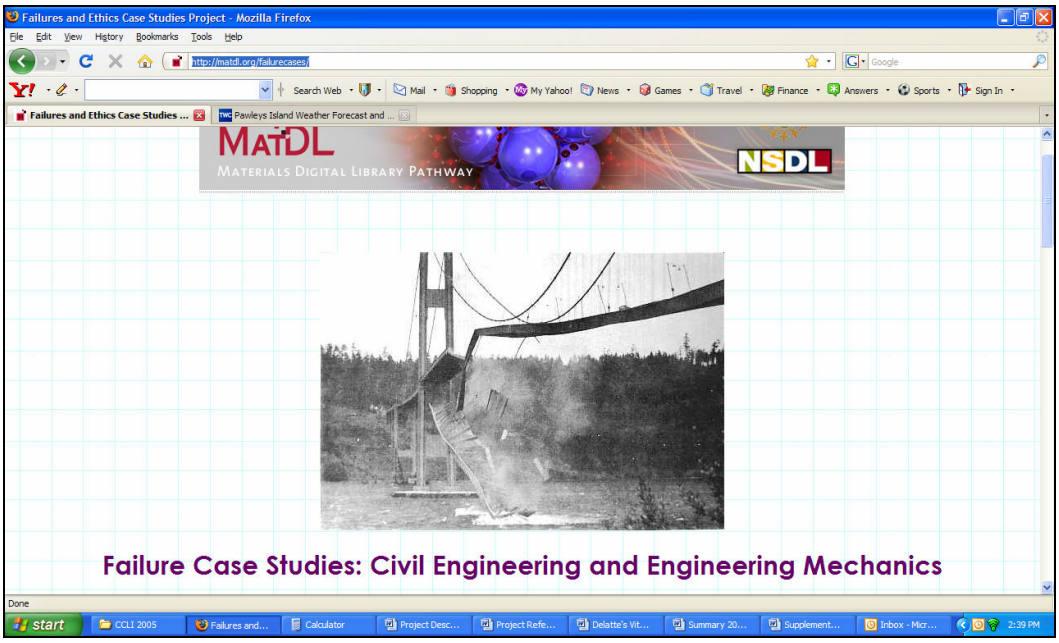

Figure 2: The Failure Case Studies web site home page, http://matdl.org/failurecases/

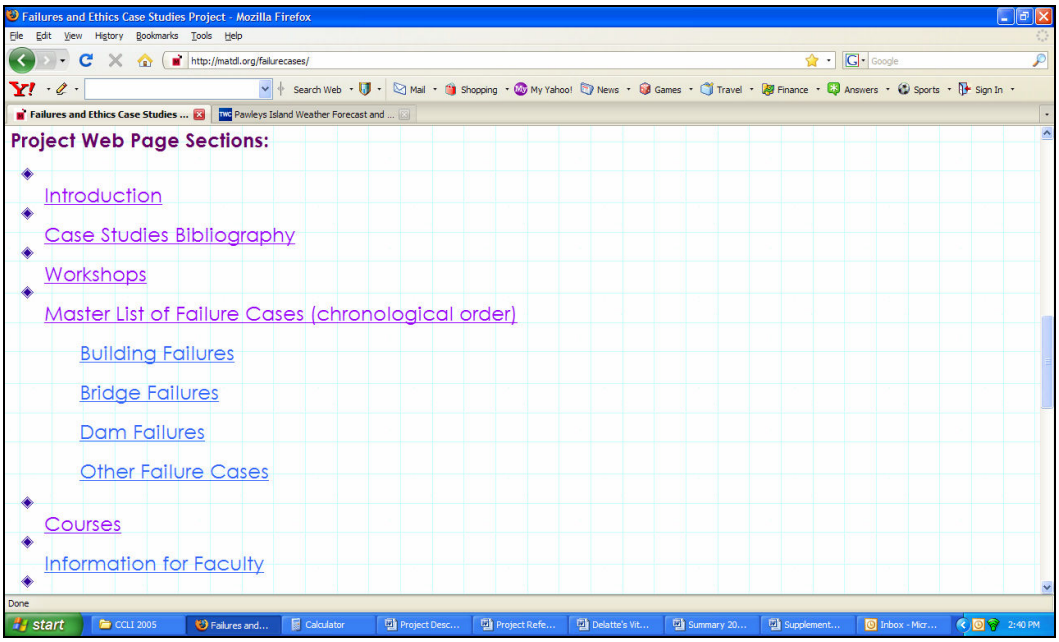

Figure 3: Sections of the web site

The web site is not merely a web version of the book. The book has more detail about many of the cases. There are also short cases on the web site which are not in the book. The two are intended to complement each other, and the web site can provide future updates for the book. The web site has links to some of the forensic investigation reports available on the web, such as the Hurricane Katrina and National Transportation Safety Board reports (e.g. Boston Tunnel and Minneapolis I-35W Bridge).

Potential Uses

The book was envisioned as a supplement to existing courses. It would, of course, be most effective if it could be used for multiple courses across the curriculum, with the students purchasing a copy when taking statics and referring to it in subsequent courses. To facilitate this, the book will be provided in future offerings of faculty workshops on integrating failure case studies in the curriculum.

In the past, the author has argued that there is no room in the curriculum to add a required course in failure case studies, failure analysis, or forensic engineering. However, a number of universities have developed elective undergraduate courses in the topic.

One example of a course adoption of this book is CENG 475: Forensic Engineering, taught by Professor Kelly A. Salyards at Bucknell University (spring semester 2009). There are 15 students enrolled and the book is required as the only text. Professor Salyards has been using a lot of handouts in lieu of another textbook. The course also features approximately one guest speaker per week. Similar courses are offered at other universities[12].

The book also has an important potential role in continuing education and life-long learning of practicing engineers. Shortly after publication, the book was used at a half-day workshop on teaching with failure case studies held in December 2008 in London, UK. Although much of the audience was from academia, a substantial fraction consisted of practicing engineers. The practicing engineers noted the important of failure case studies in continuing education.

In response, a section of CVE 601/701 Civil Engineering Graduate Seminar focusing on failure case studies has been scheduled for the summer 2009 semester at Cleveland State University. This course will meet one credit hour toward a Master's or Doctoral degree, but also can provide 15 professional development hours toward Professional Engineer (PE) License continuing education requirements. A similar professional development program is offered at Kansas State University (http://www.dce.k-state.edu/engineering/profdev/engineering_failure.html).

Discussion and Conclusions

The new textbook discussed in this paper has potential applications in the civil engineering and engineering mechanics curriculum. The design of the book was intended to facilitate supplementing the technical material in commonly taught courses, as outlined in the

separate chapters listed in table 1. The rationale for including failure case studies in the curriculum has been presented elsewhere[1, 2, 3, 10, 11, 12] and is not included in this paper.

The book may also be used for a stand-alone elective course in forensic engineering or failure analysis, at either the undergraduate or the graduate level. While still rare, these courses are becoming increasingly more common as the role of failure in successful design is more broadly recognized.

A final application is in the continuing education of practicing engineers. Most jurisdictions have now adopted continuing education requirements for retaining PE licenses, with Ohio adopting the requirement in 2008. In the past, some practicing engineers have participated in the faculty case study workshops and have been quick to see the relevance and importance of the material.

Acknowledgement:

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