

# Learning from Experience

*D. J. Hagerty<sup>1</sup> / J. P. Mohsen<sup>2</sup>*

**Abstract** - A case histories course was introduced into the CEE curriculum at University of Louisville in fall 2004, to address various specialties and to synthesize what the students from various specializations learned in different courses. The course, patterned after a course taught by Dr. Ralph B. Peck at the University of Illinois, satisfies many ABET course outcomes and educational objectives. By involving practitioners, the course fosters a partnership among the department and local CEEs. The cases teach strong lessons about professional practice. On Monday, the presenter treats the class as consultants, gives the case background, and poses questions similar to those asked by a client. On Thursday, the class must have answers to the questions posed by the presenter, and the presenter discloses the resolution of the problem in the actual case. On the following Monday, the students submit a one-page case summary, to be graded by the presenter.

*Keywords:* CASE HISTORIES, ABET outcomes, practitioners.

## INTRODUCTION

A case histories course was introduced into the Civil and Environmental Engineering curriculum at the University of Louisville in fall 2004, as a way to meet several goals identified by the department faculty. Faculty members felt that, all too often, graduate students become very specialized in their research and course work, and need a reminder of the breadth of the discipline. This course addresses the various disciplines within Civil and Environmental Engineering and it works to promote an inherent synthesis of what the students have learned in different courses. Students with different backgrounds work together in this course; two or three students know something more about one special area than do the other students, who are more informed in other areas, so they must depend on each other. They work in groups with diverse backgrounds. The presenters also have different backgrounds and thus they bring different points of view into the course. The cases also are diverse in subject matter; each case highlights a different specialty, but also illustrates the need for cooperation among different specialists.

Why did the faculty choose to use case histories instead of developing a forensic engineering or failure investigation course based on well-documented and famous failures as many instructors have done? The goal in this course is to present complicated situations to our students, situations drawn from real practice. The situation does not have to involve a failure; success stories, including cases in which failure was averted, can be analyzed profitably by our students. We are stressing problem-solving and not necessarily failure analysis. The emphasis in this course is placed on work done by our faculty and, to a lesser degree, by our alumni. Our students develop a relationship with the presenters; students see faculty members in a new light.

In developing this course, the CEE faculty wanted a graduate course to expand our program to fill the needs of a growing number of students entering the PhD program. We wanted a course that would reinforce the students' different backgrounds but would bring them together and show them how they are likely to practice. We wanted a course that would involve as many faculty members as possible, showing the students the faculty members involved

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<sup>1</sup> CEE Department, U. Louisville, Louisville, KY 40292, hagerty@louisville.edu

<sup>2</sup> CEE Department, U. Louisville, Louisville, KY 40292, jpm@louisville.edu

in practice. The faculty discussed the course concept, and decided to follow the model of a course taught by Dr. Ralph B. Peck at the University of Illinois in which he treated students as consultants. Dr. Peck and other speakers acted as the client who needed answers. The course concept was modified slightly for the situation at the University of Louisville. Along the way we wanted to satisfy multiple ABET course outcomes and educational objectives because the Master of Engineering program at the University of Louisville is accredited at the Advanced Level, and graduate students from that program will provide the future candidates in our PhD program. Finally, we wanted to involve alumni and practicing engineers to foster a partnership among the department and local CEE practitioners.

## **COURSE ORGANIZATION**

“Nothing succeeds like telling a story.” This basic precept of educational psychology was one of the guiding principles in the organization of the new course. But the faculty of the department did not want stories told primarily to amuse, to entertain or to recruit, although elements of humor certainly can be present. The stories told in this course must have a strong lesson to teach and they must relate to professional practice; they must be case histories. The organization of the course is relatively simple: Classes are held on Mondays and Thursdays, in the late afternoon. On Monday, typically, a case is begun. The presenter treats the class as a group of consultants or reviewers. The presenter gives the background of the case problem or topic, and poses to the students questions similar to those that would be asked by a client of a consultant (e.g., Is that true? Should I worry about that? What do I do now?). On Thursday, the class is expected to have answers to the questions posed by the presenter. Also, on Thursday, the presenter gives the conclusion to the case, the solution to the problem, or whatever is needed to end the presentation. On the following Monday, the students are required to submit a typed one-page summary of the case, with all pertinent and significant facts. The presenter grades the summaries.

Within this general framework, a presenter can make modifications to the basic format. For example, instead of a case history of construction or design, a presenter described how a utility group positioned itself to make a positive response to anticipated federal regulations. Two other presenters enlisted the help of a geographer at another university and described how engineers interact with citizens in public formats on controversial projects. In the latter instance, students got to participate in an interactive assessment of highway noise barriers as part of the exercise. Another presenter showed nine instances of damage or distress, or design flaws, and asked the students to diagnose the problem and recommend cures. The latter presentation included two instances of distress caused by 2004 hurricanes that impacted Florida. The course is about practice, not solely design and construction.

## **INITIAL SCHEDULE**

The schedule for the course in Fall 2004 included the following presentations:

<u>Week</u>	<u>Dates</u>	<u>Presenter</u>	<u>Topic</u>
1	August 23/26	Hagerty	Introduction to the course
2	August 30/Sep 2	Ullrich	Underground Space Utilization
3	Sep 6/9	Hagerty	Being an Expert Witness
4	Sep 13/16	Lederer	Offshore Structure Design/Build
5	Sep 20/23	Karem	Geotechnical Value Engineering On a Design/Build Project
6	Sep 27/30	Hagerty	“Changed Conditions??”
7	Oct 4/7	Hubbs	<i>Cryptosporidium</i> Chronicles

8	Oct 11/14	Hagerty	Fall Break, and the Hyatt Collapse
9	Oct 18/21	Hagerty	Building a Tunnel...to Leak
10	Oct 25/28	Cohn and Harris	Highway Noise Barriers and Citizen Involvement
11	Nov 1/4	Weigel	From Extreme Events to Everyday Action
12	Nov 8/11	Rockaway	Structural Cracking—Why?
13	Nov 15/18	Delatte	Quebec Bridge Collapse-1907
14	Nov 22/25	Hagerty	Discussion Session, Thanksgiving Holiday
15	Nov 29/Dec 2	Parola	Bridge Collapse in a Catastrophic Flood
16	Dec 6	Hagerty	Summary Session

One of the authors is the course coordinator, and spent the first week of the semester introducing the course and explaining course requirements. He introduced the idea that there are many facets to a difficult case, and many viewpoints among various participants. Periodically, the instructor also discussed the course with the students and had them use formal assessment tools to ensure that the educational objectives of the course were being met.

The instructor also used material from a well-known case to bring depth into the course. The Kansas City Hyatt Hotel failure is a notorious case, but one which is often oversimplified by instructors wanting to find a quick example to use in illustrating principles of statics or behavior of materials. The Hyatt Hotel walkway collapse is a well-documented case that changed practice and clearly illustrated deficiencies in the way construction projects were being managed. Students are asked to write down anything they know about the case (what happened, why the failure occurred, and who was responsible). Then, they are given four published papers and an editor's comments [1, 3,4,5,6] all of which were published in volume 14, number 2, of the ASCE *Journal of Performance of Constructed Facilities*. Those papers document views of several engineers involved in the case. Reading papers written by engineers that were close to the project provides different and valid viewpoints for this case. After they read the four papers, the students wrote a one-page summary of the situation, addressing the same three questions, and discussed the case with the instructor. The instructor used an excellent analysis of the case prepared by Delatte [2]. Delatte also was a participant in the course, describing another famous failure.

## OBJECTIVES OF THE COURSE

Why tell stories, other than the fact that story-telling is a lot of fun? The rationale for the course is based on key concepts of the ABET accreditation criteria (shown in bold).

**1. Provide an educational experience that prepares students for the challenge of professional practice** through expositions of problem-solving activities by practitioners from among the faculty and from professionals outside the school. Such exposure will **promote problem-solving skills**. How better to teach problem-solving skills than to pose problems to students in their assumed roles as consultants? The cases have been selected by the faculty members and practitioners from outside the university to illustrate economic and non-technical aspects inherent in engineering practice. How do you measure the benefits and costs of a project that has not been defined fully and may be changed from conception through construction? How do you explain to a client that what she thinks is the nature of the problem is not really the issue that must be addressed? How do you show the impact of cash flow difficulties, and interactions with project investors? Tell the right kind of story!

**2. Promote service to the profession and to society** by presenting examples of outstanding practice and service. Some of the cases that are presented illustrate mistakes that were made by project designers or consultants, and

show the students how discussion of such mistakes, especially in published papers, can bring great benefits to the profession and to the public. Completing an important project, finding solutions to difficult technical problems, or interacting with the public who will be impacted by a project all can bring great personal satisfaction to an engineer. Exposure to such experiences, even if it comes by second-hand involvement, encourages students to engage in similar activities in order to share such profound professional satisfaction. Even small projects can provide great satisfaction when the benefits to people are obvious, immediate and readily acknowledged by those who reap the benefits.

**3. Foster an appreciation for professional development and life-long learning** by showing students how practitioners develop professionally through their experiences and through their continuing education required for solution of problems (described in case histories). The most interesting cases are those in which the practitioner or faculty member did not have an easy answer to the problem that was encountered. Interactions with other professionals, research on the identified processes or phenomena involved in a case situation, and field testing or experimentation all show how engineers must continue to learn throughout their careers, or face professional obsolescence. Failure to pursue new knowledge not only can lead to professional stagnation, but also often is a primary factor in many of the difficult situations in which engineers confront recalcitrant clients or incompetent colleagues.

**4. Develop in students an ability to apply knowledge from math, science, and engineering**, by exposing them to the real-world applications of such knowledge by practitioners involved in case studies. A primary purpose of the course is to train students to identify, formulate and solve engineering problems. Experienced consultants know that one of the most fundamental activities for problem-solvers is accurate identification of the problem. In many situations, clients, non-technical experts, other engineers or the public have preconceptions about why something cannot be done, or why something must be done in a particular way, or the reasons why project costs are estimated to be so high. Frequently, the real problem has unanticipated social or political aspects that drive design choices or selection of technical electives. Proper formulation of the problem in a complex must be a preliminary to developing technical solutions based on mathematics, science and engineering. Case histories can be an excellent means of illustrating complex situations in which preconceptions mislead clients and consultants.

**5. Develop an ability to analyze and interpret data;** practitioners will treat the students as consultants and present information for them to analyze and interpret, and will expect requests for additional data. Case history presenters strike a delicate balance between starving the students for required data and giving them too much information. Students are encouraged to ask questions and demand more information, but determining whether or not sufficient data is available requires at least a preliminary analysis of what already has been said or shown. Sometimes the most important question is, "What exactly does this mean?" Clients frequently give information to a consultant that is irrelevant or superfluous. At times, clients don't even remember where certain "facts" originated. Students quickly learn that they must analyze and evaluate data for credibility, relevance and significance, demand more data when necessary. Students are encouraged to get together and discuss the information presented during the first class session before they offer their own suggestions and solutions at the beginning of the second class of the week.

**6. Develop student competence in the design of systems, components, and processes to meet specific needs** because the case histories will emphasize the interactions among design, construction and operations personnel to fit specific user-defined criteria. The essence of a good case history is the specific aspects of the case that make it different from all those other cases that already have been described, dissected and reported in the literature. How is this case different from all others? What is new about this situation? Why will standard or routine solutions not work in this situation? What particular features of this case are unusual? What is there to learn from this case? In some situations, clients pose dilemmas or ask for solutions that are constrained by non-technical factors. Why must concrete be poured in freezing weather on this project (to convince investors that the project is moving ahead)? Can an engineer approve such construction activities and still satisfy codes of ethics? What specifically about this situation allows such practice?

**7. By means of the case histories presented in this course, give students indirect experience and guidance on working with and as part of teams with diverse technical makeup.** Some of the most rewarding experiences of professional practice for engineers come from their interactions with colleagues in other engineering disciplines, with non-technical design professionals and with construction personnel. Many of the most effective solutions to engineering problems combine techniques and methods suggested by experienced and inventive constructors. Workers building a facility or operating a system often supply the clues to what is happening in a particular case. Viewing a situation from a different perspective can be a very enlightening experience. Years ago, one of the authors, a geotechnical engineer, had occasion to work with the late John Kennedy, an eminent hydraulics engineer,

on a problem of unexpected and unexplained riverbank erosion. Kennedy observed that engineers on the study team were at odds because the geotechnical engineers were looking at the riverbanks from boats floating on the stream and the hydraulic engineers were all standing on the banks looking at the river. Neither group was addressing the interactions involved in the erosion process.

8. Instill in students by means of the case histories described in this course, an **understanding of professional and ethical responsibilities**, both in education and in practice. One of the interactions between clients and engineers, that is most difficult for engineers, occurs when the client wants to do something that is ill-advised, unsafe or against the public interest. The engineer can say to the client, “You really don’t want to do that,” and the client may respond, “Yes, I do!” The conflict may revolve around the client’s desire to do something that will entail a costly future repair or remediation, even if the action is not illegal or unethical. How to convince the client not to proceed? The client may say, “After all, it’s my money,” or “If you don’t do it, I know another engineer who will!” The conflict becomes more serious when the proposed action will present a hazard to construction personnel or future users of the completed facility or system. The hazard may not be obvious to the client or to other engineers. The most important such dilemmas occur when the perceived hazard will affect a large number of people and the engineer is the only person who has that perception of the hazard. In other instances, a consultant may review other engineers’ work and find deficiencies that indicate incompetence or even unethical practice. Case histories can reveal such dilemmas in credible and dramatic detail.

9. Through the cases described in this course, **expose students to contemporary issues pertinent to the practice of civil engineering**. Five of the cases included in the fall schedule of the course introduced at the University of Louisville dealt with issues of the latest currency. One case pertained to the introduction of new national standards for water treatment required because of risks posed by pathogens in surface water systems, and the means taken by a water supply utility to anticipate and satisfy those new rules. Another case involved choices among the latest construction methods for soft-ground and bedrock tunnels. A third case involved an application of value engineering to a problem in geotechnical engineering design and included description of an innovative technique for construction. A fourth case involved interactive evaluation of transportation noise barriers, and illustrated common misperceptions involved in noise assessment, as well as demonstrating interactive technology being developed to obtain citizen input to design. In another presentation, examples of distress caused by hurricanes in 2004 and recent seismic events were analyzed, based on a faculty member’s participation as a member of a disaster assessment team for concrete masonry industry associations.

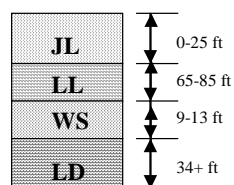
## EXAMPLE CASE HISTORY

To illustrate the kind of case that was described by presenters in this course, a summary submitted by a student has been given *verbatim* in the paragraphs on the next two pages. Only the name of the student has been omitted from the summary. The student received a grade of 95 % for this summary. The original summary was submitted in 8-point type and would have been very difficult to read here, so the font has been changed for the reader’s convenience. Can the reader find spelling mistakes that cost the student several points?

### Case 1

### Case Background

*In the 1980’s a team of civil engineers from the University of Louisville were commissioned to evaluate the feasibility of developing a man-made cavern under the Louisville Zoo. The cavern, which was more than 100 acres in area, was the result of more than 40 years of limestone mining operations. The structural support in the mine consisted of 223 rock pillars of various shapes and heights. The area extent of the mine was limited by three factors including: lack of ground cover, Trevilian Way, and a subdivision. The mine has four entrances located in a close proximity of one another.*



**Geology** The geology stratification in the area of the mine consisted of four main layers including (1) the Jeffersonville Limestone (JL), (2) the Louisville Limestone (LL), (3) the Waldron Shale (WS), and (4) the Laurel Dolomite (LD). The Jeffersonville Limestone was located at the surface. Of the lower layers, only the Louisville Limestone and Laurel Dolomite were desirable for use in roadways and concrete. The Waldron Shale was a poor quality shale that is susceptible to slaking and of little commercial

value. See schematic of a geologic column in the vicinity of the mine (NTS).

#### Initial Evaluation/ Site Condition

Area	Pillar Height (ft)	Exposed Waldron Shale	Distinguishing Features
A	25	No	Sinkhole Outlet
B	70-75	Yes	Deep Section
C			Window in pillar
D	25-30	Yes	Clean Pillars, Waldron Shale near bottom
E	80	Yes	Gunnite treated pillars with overhang Rock debris falling from pillar; Slaking
F		Yes	High seepage; Water on floor; Caves near ceiling; Least cover
G			Shale Pile
H		Yes	Slaking; N-S orientation of large pillars

During the initial evaluation, the mine was divided into eight areas with similar properties that were designated A-H. Some of the distinguishing features among the areas included ceiling height/extent of mining, amount of seepage, and the relative location of the

Waldron Shale. For example, area A was characterized by a 25 feet ceiling height and the presence of a sinkhole outlet. See the table on the left for information on areas A-H. The ceiling was found to be consistent throughout the mine. It was a natural horizontal bedding plane in the Louisville Limestone that was segmented by both N-S joints and E-W joints. The N-S joints were of consistent spacing and direction and were filled with calcite. The E-W joints occurred less consistently and were more likely to leak water.

#### Concerns for Development

One of the biggest concerns that arose from the sight evaluation was the erosion of the Waldron Shale. Natural cyclic changes in humidity caused slaking in the shale, which could both result in falling rock debris and jeopardize the stability of the pillar. Another big concern was ceiling and overall pillar stability. Other problem areas included seepage, inconsistent floor elevation due to the different depths of mining, sinkhole activity, and loose rocks on pillars. The seepage was considered to be minor problem that could either be treated at each site or utilized for an activity such as mushroom farming. The loose rocks on the pillars could be removed. The concerns that required further evaluation were stability of the pillars and ceiling, the deterioration of the shale, and the sinkhole activity.

#### Stability Analysis

The condition of the pillars was considered to be dynamic, worsening with time. A worst-case scenario investigation of the safety of the existing condition was completed by evaluated the factor of safety for a pillar with the smallest cross-sectional area, longest length, and deepest amount of overburden. The analysis was completed using strength of the weakest layer, Waldron Shale ( $q_u = 5500$  psi), and resulted in a factor of safety between 10 and 15. The strength of the Waldron Shale was obtained from an unconfined compressive strength test of the small cylinder. The test likely overestimated the strength of the rock because it was too small to be representative of the imperfections in the actual pillars. However, the samples were long and thin (twice as high as wide) whereas the pillars whereas the wide and short (three times as wide as tall). The difference in geometry between the pillars and the cylinders would result in an underestimation of strength. Therefore, the overestimation caused by the size of the sample tended to be cancelled out due to underestimation from the geometry. The pillars in the existing condition were considered adequate.

The ceiling stability was also evaluated. Sections between joints were stabilized by horizontal pressure that tended to decrease with less cover. Three failure modes were evaluated including buckling, sliding, and crushing. Crushing was the controlling mode of failure. Factors of safety against crushing were calculated. Area B had the lowest average factor of safety, with a value of 4.49. The ceiling was considered safe. However, it since accumulation of water above it could result in a significant stress increase, it was recommended that no swimming pools be built on the surface above the mine.

*Sinkhole Treatment/Provisions for Sub-division* Plans were made to develop a subdivision over the mine. A special treatment was designed to stabilize sinkholes in the area of the subdivision. The treatment directed the sinkhole drainage down a pipe into the mine and sealed the area around the pipe to prevent expansion of the sinkhole.

*Shale Deterioration Prevention* Many different options were considered for preventing further deterioration of the shale. The shale could be treated with gunnite. However, past experience has shown that the gunnite would fail eventually. Other treatments considered included reinforced concrete and shotcrete. These treatments, while potentially feasible, would be expensive to owner. Since the area of the mine above the shale would be adequate for the mines intended use, the owner elected to fill the deeper section of the mines, where the shale was exposed, instead of treating the shale. Construction debris from a nearby highway construction project (I-264) and debris stored in area G of the mine were used for fill. Both of these materials were available at no cost. This solution was earth friendly since it prevented the construction debris from being landfilled. It was economical since the fill materials were available for free and effective since it ended the exposure of the Waldron Shale to the conditions that had caused deterioration.

*Conclusion* The civil engineers from U of L evaluated the mine, addressed important problems, and designed treatments that enabled the eventual development of an underground storage space. The mine is now being used for underground storage. Underground Vaults & Storage moved in and plans to expand. It is also being utilized by the Louisville Metro Public Works for storage of road salt. The owner plans on further developing the mine.

## **OBSERVATIONS**

Since the course was offered for the first time during fall 2004, assessment of the course was very important. The students were asked to provide an anonymous midterm written critique of the course. The course instructor also had an informal discussion with the students to identify the strengths and weaknesses of the course, and a second assessment was submitted at the final class session.

Students initially thought that writing one-page summaries would be easy. After they tried to digest all that was said during two class periods, and all that they had considered in discussion sessions outside the classroom, they realized how difficult their task was. The faculty felt that the one-page summary was a very important part of the course design. One of the glaring deficiencies in many of the papers and presentations that the faculty had received from students was an inability to identify and focus on key factors in a situation or key issues in a dispute. Writing a one-page summary forces the students to concentrate on crucial questions: "What were the really important facts? On what issues did the case resolution hinge? What non-technical motives drove the clients? How did preliminary analysis clarify the issues and indicate the need for more data? How were choices made among a number of viable alternatives?" After they identified significant and relevant facts, important issues, factors that mandated certain choices, and reasons for the selection of the actual solution to the real problem, they were faced with getting all that information on one page of paper.

The requirement for one page was designed to teach the students how to be concise but complete. All too often, in practice, the time allowed for a presentation to clients, or the time provided at a meeting of professionals, is very short. The aim of the one-page requirement was to make the students eliminate unnecessary verbiage, state the key points, and provide a very brief conclusion to each case—just what they will be called upon to do in practice. The rules were simple: one page; half-inch margins; no font size smaller than 8-point. The instructor urged the students to make judicious use of figures and tables. The groans and complaints from the students resounded in the Halls of Academe, but a grudging respect for clear, concise communication was born.

What did the instructor get from the introduction of this course? Organizing this course took a lot of time and effort; finding faculty members and practitioners who were willing to make a case history presentation required contact time, coordination time, and time for reconciliation of schedules. Emergency changes in schedules also had to be accommodated when unforeseen events intervened: one presenter was called away to do evaluations of structures damaged by Hurricane Ivan. Another presenter had to travel to the Czech Republic to participate in a NATO conference a week earlier than previously anticipated. The instructor also was present during the case

history presentations, to monitor the quality of the presentations and to form an independent opinion about what the students should have gotten out of the cases. Finally, as mentioned, the instructor also met with the students several times during the semester to conduct student assessments of the course and to discuss the advantages and disadvantages of the course format, the difficulties in making concise but comprehensive summaries, etc. On the other hand, the instructor had an opportunity to share, with the students, the interesting cases and rewarding experiences of the presenters.

What did the faculty gain from this exercise? Each person got to talk about one of his favorite cases! In some cases, the presenters shared the satisfaction of finding a workable solution to a complex problem; in some cases, they shared their surprise and chagrin at the unexpected impact of non-technical factors on engineering evaluation. Students began to look at the faculty members from a new perspective: the presenters obviously knew about the “real world” and not just the classroom or laboratory, because they were involved in important ways in major projects affecting public welfare, corporate success and/or environmental protection. Non-faculty presenters had “real world” credentials when they came in the door, so they gave more credibility to the entire course. The similarity in approach and execution of engineering tasks among the faculty members and the practitioners also impressed the students with the practical abilities of their teachers. The practitioners enjoyed the contact with intelligent young engineers-to-be who were intrigued with their projects and asked some very incisive questions. Truly, there were no losers in this educational experiment. This course is destined to become a permanent feature in the CEE curriculum of the University of Louisville.

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### D. J. Hagerty

Joe Hagerty has BCE and MEng degrees from Uof L and MS and PhD degrees from University of Illinois. He has been a professor in the Civil & Environmental Engineering Department at UofL for more than 35 years. Hagerty has written seven books and over 100 papers. His most recent honor was being selected Alumni Scholar for Teaching for the Speed School of Engineering for 2005-7.

### J. P. Mohsen

J. P. Mohsen has BCE and MEng and MS degrees from the University of Louisville and PhD degree from the University of Cincinnati. He has been a professor in the Civil & Environmental Engineering Department at UofL for more than 23 years and is currently serving as acting chair of the department. Mohsen served on the Board of Directors of ASEE as Zone II Chair in 2002-2004 and is currently serving on ASEE BOD as PIC I Chair. He received the University of Louisville Distinguished Service to the Profession Award in 1999 and the Distinguished Teaching Award in 2003.