CEE 4803F/8813A Infrastructure Failure Analysis

Course Overview: Failures can be broadly defined as "a condition where an object or system fails to perform the function which it was intended or designed". There are many variants of how and why failures occur including those that might be described as either operational failures (e.g. traffic congestion during rush-hour on a highway system), those that result from a gradual decrease in capacity to where normal design demand exceeds capacity (e.g. fatigue due to repeated loadings or material degradation/aging) and those where demand rapidly exceeds design capacity as a result of some unanticipated natural (e.g. earthquake, flood, tsunami, hurricane) or man-made (e.g. terrorist attack) extreme event. Other categories of failures can be the result of not implementing design procedures or specifications during construction (e.g. not following or achieving material design criteria) or inadvertent modification of design details in the field during construction that lead to catastrophic but readily explainable failure once the event is examined (e.g. changing design details to facilitate construction process without appropriate design re-review and therefore recognition of the consequences of such actions). Yet other failures may ultimately be what have been termed "normal accidents" – those that occur as a result of an object or system being so complex that none of those involved in the design or operation even conceived that such a failure could occur (e.g. creating objects or systems that function beyond and thus differently than anticipated based on understanding from existing simpler objects or systems).

There can be many undesirable consequences to the failure of an object or system ranging from partial/temporary loss of functionality to complete/permanent failure that results in not only physical destruction of the object or system but further consequences that include loss of life or revenue. At the same time, if failures are recognized as a full-scale object or system test under real boundary conditions, then if they are carefully studied utilizing a rigorous failure investigation methodology, they can be the best source of insight into complex interconnected mechanisms that lead to failure, and more importantly yield clear insight into rehabilitation strategies for existing similar systems or design considerations to be incorporated into future systems. In some cases, this may lead to radical change in a design philosophy and approach while in others, it may focus on strategies for partial recovery either during or following failure (e.g. use of HOV lanes during rush-hour) where the approach is based on acceptance that failure will occur but the rate of occurrence and recovery can be impacted by the adopted approach.

This course begins with a focus on discussing failure and how it can manifest in various systems. The components of a rigorous failure investigation methodology are discussed and then applied in examining a series of case histories where infrastructure failures have occurred. In addition to discussion of specific failure case histories, in class discussion will examine the degree to which many of these failures might have been avoided. Selected classes will involve lectures and forums by non-engineering experts (e.g. attorney, social scientist, economist, policy analyst, contractor, consultant, owner, accident reconstruction expert) so that the impacts of other factors on failure genesis and occurrence can also be integrated into the course. For example, the role of failures on policy development and implementation will be discussed.

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Meeting Format/Schedule: There will be 75 minute lectures twice a week (Monday/Wednesday – 2:00 pm to 3:15 pm)) during the semester. One or two local field-trips to actual infrastructure failure sites or other relevant venues (e.g. courthouse, elected city/county/state official meeting venues,

DRAFT

airport/highway operations center) will be conducted as feasible during course to enrich the learning experience. In addition, a required 3-day (Thursday evening departure to Sunday afternoon return) field trip to W. North Carolina to observe the impacts of Hurricane Helen and associated flooding in the area as well as a visit to the ongoing multi-year repair work being conducted. Project 2 will be based on this activity. Funding to cover hotel costs for 3 nights will be provided. The in-classroom portion of the course will consist of meetings that will include lectures by the primary instructor, occasional lectures by guest instructors and group problem-based learning studio discussion/presentation sessions. The anticipated distribution of meeting types is as follows:
Primary Instructor lectures – 60%
Guest Instructor lectures – 10%
Classroom/studio group presentation sessions – 30%

Example Topics and Their Role in Course:

Operational Failures: Students will be assigned a task to review the activities of a highway operations center and develop a full understanding of how it functions. Subsequent group activities will seek to propose and develop new approaches and strategies by which the activities of such a facility might be enhanced (e.g. adop`tion of new software to predict when certain failure conditions are imminent).

Construction Change Accident: Primary instructor will review the original and as-constructed design of the Kansas City Hyatt Regency Walkway collapse to illustrate how field decisions failed to recognize the simple change in load-path that occurred and led to collapse of the walkway under elevated load conditions. The formal presentation will be complemented by simple physical and on-line models that will allow students to explore the details of this milestone case.

Role of Instrumentation in Monitoring Impending Failure: Primary instructor will describe potential role of instrumentation in monitoring an impending failure. Topics discussed will range from types of local and remote sensors now available for use, as well as role of pre-determination of critical changes or actions (e.g. at what stage should evacuation of personnel occur). Specific cases ranging from 1963 Vajont landslide in Italy to 2010 Maule earthquake generated tsunami in Chile will be used to illustrate the need for specific strategies following triggering of monitoring sensors.

Complex Slow Evolving Failure: Primary instructor will review the construction, performance and rehabilitation history of the Leaning Tower of Pisa over an almost 800 year period. The manner in which interacting design, construction, performance and repair characteristics transcend disciplinary boundaries will be discussed. While the recent repair of the Tower involved a geotechnical based solution, the likely failure of the Tower, had the geotechnical remedial measures not been implemented, would have been a structural one.

Complex Interacting Events: Students will be tasked to review the various aspects of the 2011 Tokohu, Japan earthquake which led to the Fukushima nuclear incident. The initial earthquake, the subsequent tsunami, the overtopping of the coastal levees, and the placement of the reactor pumps below ground level have all been credited with contributing roles leading to this disaster. The manner in which one of several analysis, design and construction details could have averted this sequence of events will be examined in the group setting.

DRAFT

Legal Approaches to Failures: Guest instructor (attorney) will review several infrastructure failure cases and show the approach taken by attorneys for both defendant and plaintiff took different approach to presenting the key aspects of the case. The role of experts in this process will also be described.

Extreme Event Failures: The primary instructor will review the history of levee construction and maintenance in New Orleans area which involved multiple agencies at local, state and federal levels. In class discussions involving engineering, social science and policy officials will seek to create a realistic environment for students to understand the complex manner in which this various perspectives can limit appropriate preparation for events of this type and more importantly lead to the type of consequences observed during and after Hurricane Katrina.

Note that topics listed above are intended to illustrate the approach being used in the course. Numerous additional cases, each with specific objectives, will be developed and associated materials archived on-line for future offerings of the course as well as other different educational approaches described below.

Textbook: None required but various ones recommended throughout course. These include Beyond Failure – Forensic Case Studies for Civil Engineers by Norbert Delatte to several others that focus on topics ranging from philosophical insights into failure occurrence (e.g. Normal Accidents by Charles Perrow; Success Through Failure: The Paradox of Design by Henry Petroski) to failure analysis of specific milestone cases (e.g. The Warning: Accident at Three Mile Island by Michael Gray; The Tragedy of the Space Shuttle Challenger by Henry Holden).

References: Lists of selected suggested references provided in conjunction with individual case histories presented/discussed in class. Student self on-line searches will be the primary sources of information.

Exams: None

Individual Homework Assignments: Few homework assignments periodically during semester.

Group Projects: There will be 2 Group Projects and a Group Field Exercise Project culminating with group presentations and/or short reports. The details including schedule for these is as follows:

Project 1: ASCE Infrastructure Report Card Project - Assigned by Instructor
Project 2: Group Field Trip Inspired Project
Project 3: Failure Case History Investigation - Assigned by Instructor

Dates for Project deliverables:

Project #	Date Assigned	Project Duration	Report Due Date	Report Presentation
1	TBD	TBD	TBD	TBD
2	TBD	TBD	TBD	TBD
3	TBD	TBD	TBD	TBD

Assessment:
Periodic Individual Homework Assignments: 10% of total grade
(note there will be different assignments for 4803A and 8813D registrants);
Group Projects: 25% each for Projects 1 and 2 including 15% for ppt report and 10% for oral;
40% for Project 3 including 25% for ppt report and 15% for oral.

DRAFT

Presentations: Project presentations using PowerPoint are to be given by each team for each project. The typical duration for presentations is 15 minutes/group with 5 minutes Q&A for Projects 1 and 2. Presentations for Project 3 may be longer.

Field Trip: To be scheduled during semester – depending on project access.

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General Instructions:

Course mode: All classes will be taught in person.

Academic Integrity:
Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.
Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities
If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Final Instructional Days (4/26/27 and 4/27/27): No tests or quizzes or homework will be given on these days. All tests and quizzes must be graded and returned to students on or prior to the Final Instructional Class Day, Dec 4/27/27. Complete rules can be found here:
http://www.catalog.gatech.edu/rules/12/

Reading Days: No assignments, projects, presentations, or other graded activities can be given on Reading Days: April 28 and April 29 (until 2:40pm).

Please remember these important dates:
Monday, January 11: First day of classes
Monday, January 18: No classes, MLK Day
Monday - Friday, March 8-12: No classes, Spring Break
April 27: Final Instruction Day

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