

Lesson 2	Resource 2O	Long Reading (page 1)
----------	-------------	-----------------------

Time: 20 minutes

Very often, the discipline of engineering surprises the world with marvelous feats such as the longest bridges, tallest buildings, and most sophisticated space exploration technologies. Occasionally, it sinks people's hearts with unexpected failures and tragedies, like the explosion of Space Shuttle Challenger. In today's media-rich society, this type of sad story travels faster than ever as engineering accidents may be more eye-catching than celebrity news. Like other applied fields, engineering continues to build upon previous errors and mistakes. Taking the proverb "To err is human; to forgive, divine," Professor Henry Petroski titled his book *To Engineer is Human: The Role of Failure in Successful Designs* to highlight the truth that engineering failures happen; what matters most is to learn from them. The attention around engineering failures and disasters has brought new courses and professionals to the field, such as failure analysis and forensic engineers.

What are the common causes of engineering failures? A number of factors, including violation of codes of practice, miscommunication, extreme weather conditions during construction, or questionable engineering ethics, can come into play. Based on an analysis of 800 cases of structural failure before 1976, Miroslav Matousek and Jörg Schneider, two researchers at the Swiss Federal Institute of Technology, found that human factors constituted the main causes of failure. These included carelessness, negligence, or unpreparedness. In a more recent study, George Sowers (an honorable member of the American Society of Civil Engineering), evaluated 500 failure cases in civil engineering to identify the stages the failures stemmed from and the causes that led to the failures. About 58% of the cases had issues in the design stage, 38% in the construction stage, and 4% in the operation stage. In terms of causes, 88% of the cases were related to "human shortcomings"—ignorance (33%) and the absence of contemporary, appropriate technology (55%). The lack of technology accounted for only 12% of the cases.

The collapse of two levels of walkways in a major hotel in Kansas City, Missouri, USA, in 1981 is an example of structural failure caused by human error. A dance was held in the hotel lobby about one year after the grand opening. Many people watched the show on one of the four levels of the elevated walkways. Suddenly, the fourth-level walkway, suspended directly above the second-level walkway, fell down onto the second-level walkway, which then collapsed. The incident injured 216 people and accounted for 114 fatalities. Multiple causes were identified in

Lesson 2	Resource 20	Long Reading (page 2)
----------	-------------	-----------------------

the investigation; the largest one was associated with a lack of communication between two stakeholders: the designer and the steel fabricator. The fabricator questioned an original structural design of the walkways after finding certain connecting parts too challenging to build. It turned out that the components were actually never a finalized design from the designers! As a result, the fabricator suggested a change to the design. However, this change was not rigid enough to hold the expected weights. This proposal was approved by the designer—over the phone—without any review or re-calculations.

Similarly, communication issues between software systems can be disastrous. The Mars Climate Orbiter (MCO), a robotic space probe launched in 1998, is a case frequently taught in engineering for its huge loss—328 million US dollars—caused by “the failed translation of imperial units into metric units” in the trajectory calculation. The orbital insertion of the MCO was miscalculated due to a confusion of the two measurement systems, one using pound-seconds and the other newton-seconds. As a result, the thrusters generated more force than needed, pushing the MCO too close to the Mars. The increased atmospheric stress ended up disintegrating the probe.

Engineering ethics, which is now a scholarly discipline, determines the obligations engineers have to society and reminds us that a product is only as good as how safe it can be. The Quebec Bridge, which collapsed twice (1907 and 1916), brought engineering ethics to the forefront of the profession and the industry in North America. One of the causes was a lack of supervision of the consulting engineer and chief designing engineer. These tragedies led to the birth of new professional organizations of engineers in Canada. It is believed that the iron and steel from the collapsed bridge, which could not be re-used in construction, were used to forge the early iron rings worn by engineering graduates of Canadian schools starting in 1925. As a result, a Canadian-trained engineer may know what the iron ring symbolizes—the responsibility that comes with the profession and the paramount importance of the public’s health and safety. Is it possible to eliminate engineering failures completely? Not likely, but one can learn from previous failures to make better and safer products.

Lesson 2	Resource 2O	Long Reading (page 3)
----------	-------------	-----------------------

1. Professor Henry Petroski is likely to be teaching which one of the following engineering courses?
 - ☐ Integrated Engineering
 - ☐ Material Engineering
 - ☐ Engineering Ethics
 - ☐ Environmental Engineering

2. What does the book title *To Engineer is Human* suggest?
 - ☐ the wisdom of the idiom
 - ☐ the tendency of making errors
 - ☐ the nature of engineering
 - ☐ the consequences of failures

3. Which case has a highlight about monetary loss?
 - ☐ a major hotel walkway collapse
 - ☐ the Mars Climate Orbiter case failure
 - ☐ the explosion of Challenger
 - ☐ the Quebec Bridge collapse

4. Which of the following professionals is inspired by failures in engineering?
 - ☐ material fabricator
 - ☐ blueprint designer
 - ☐ forensic engineer
 - ☐ project supervisor

5. According to the article, which the following are some of the common causes of engineering failures? Choose 3.
 - ☐ poor weather at the construction site
 - ☐ insufficient funding
 - ☐ miscommunication between stakeholders
 - ☐ unreliable building materials
 - ☐ failure to comply with established codes of practice

Lesson 2	Resource 2O	Long Reading (page 4)
----------	-------------	-----------------------

6. Which of the following is true about George Sower's study?
 - ☐ It investigated engineering failures in the 1980s.
 - ☐ It was found in line with the study by Matousek and Schneider.
 - ☐ It was funded by the American Society of Civil Engineering.
 - ☐ It focused exclusively on the causes of engineering failure.

7. Fill in the blank with one number from the passage.
 In George Sowers' study, ____% of engineering failures were found to be caused by human error.

8. What does the collapse of the major hotel walkway demonstrate the importance of?
 - ☐ complete and accurate communication
 - ☐ accurate and up-to-date building plans
 - ☐ considerations of social events at the venue
 - ☐ testing and re-testing of the finished structures

9. According to the reading, what was the most important lesson from the Mars Climate Orbiter disaster?
 - ☐ Space exploration can be very unpredictable.
 - ☐ Consistent measurement units should be maintained.
 - ☐ More powerful calculations should be implemented.
 - ☐ Alternative plans should be prepared in advance.

10. Which of the following is true about the Quebec Bridge disasters?
 - ☐ They prompted new designs in civil engineering.
 - ☐ They contributed to the art design of iron rings.
 - ☐ They raised awareness of engineering ethics.
 - ☐ They led to the questioning of material quality.

11. Why do Canadian engineering graduates often wear an iron ring on their little finger of the working hand?
 - ☐ to make sure that the projects are completed on time
 - ☐ to remind them of the paramount responsibility of public safety
 - ☐ to employ the latest technology in their original designs
 - ☐ to concentrate on designing the details of the blueprints