15 B ENGINEERING DISASTERS –WHAT WENT WRONG?

Although engineering is typically viewed as a highly honorable profession that benefits mankind, every few years some story of an engineering-related disaster hits the news. Disasters may occur for a number of reasons:

- The designers didn't understand some material properties.
- The design was used in a way or in an environment that the designers didn't anticipate.
- The system was re-designed without consultation.

Of greater concern would be failures that were caused by ethical failure, cases where those involved

- Ignored warnings
- Let unqualified workers carry out the design or construction
- Tried to complete designs or work too quickly and became careless
- Put profits ahead of safety
- Didn't communicate concerns
- Failed to maintain a system

Civil Engineering professor Stephen Ressler writes that a study of engineering disasters, sometimes involving deadly mistakes, can teach us important lessons about structure, safety, ethics, and technological progress. Examining the story behind each disaster sometimes reveals scientific and engineering principles that were ignored or misunderstood and sometimes reveals personality issues, interpersonal conflicts, or dysfunctional organizations that led to the catastrophe. [1]

Among the disasters studied by Ressler were: [2]

- The Tay Bridge collapse-1879, Scotland (wind loading)
- Kemper Arena roof collapse-1979, Kansas City (rainwater loading)
- Hyatt Regency Walkway-1981, Kansas City (structural design)
- "Galloping Gertie" bridge disaster- 1940, Tacoma Narrows (bridge aerodymanics)
- "Plywood Palace" (John Hancock Tower windows)-1973, Boston (dynamic response)
- Florida International Univ. pedestrian bridge-2018, Miami (concrete shear)
- Great Molasses Flood – 1919, Boston (brittle fracture, cylinder stress failure)
- The Silver Bridge collapse- 1967, West Virginia (stress corrosion)
- Challenger Disaster -1986, Cape Canaveral (o-ring failure, decision-making failure)
- Chernobyl -1986, Ukraine (nuclear meltdown)
- Deepwater Horizon explosion and oil spill- 2010, Gulf of Mexico (well blowout)

While there are a myriad of engineering ethics issues, the most serious issues would be those that result in serious harm to an individual, loss of lives, serious property damage, and those that involve theft, lies and cover-ups, basically, 10 Commandments-oriented issues.

Gayle Ermer writes:

Like many engineers, I am concerned about and intrigued by situations in which technological designs do not behave as predicted. When human death and injury occur because of a failure of engineering, I want to know why that failure occurred, not just to satisfy my own curiosity but to learn from the errors of history. It is important for all people involved with modern technology to know why catastrophic failures occur. Not only does blame need to be assigned justly in these situations, but the avoidance of such failures in the future depends on accurately predicting how technology and the individuals and societies with which it interacts will behave. [3]

Ermer suggests three basic roots of engineering failure:

1. Human finitude
2. Ethical failure
3. Social evil

While the first is excusable, the other two are not.

"Classic" Disasters

Disaster	Cause(s)	Result
Sinking of the Titanic (1912)	Multiple issues: High speed impact with iceberg; design of "watertight" compartments; brittleness of high sulfur steel in freezing water; insufficient number of lifeboats	Over 1500 passengers and crew drowned
Bhopal Gas Leak (Union Carbide, India) (1984)	30 tons of toxic gas released for insecticide plant directly into atmosphere; minimum or poor safety systems; refrigeration system disconnected; flare tower improperly sized	2, 250 immediate deaths, over 500,000 injuries
Ford Pinto gas tank explosions (1978)	Fuel tank location; rear-end collisions led to explosions; design changes not implemented	Multiple fires and explosions, over 30 deaths

Space Shuttle Challenger explosion (1986)	O-rings failed to seal on the Solid Rocket Booster; warning went unheeded	Shuttle broke apart 73 seconds after launch; seven crew members died
BP Gulf Oil Spill (Deepwater Horizon) 2010	Drilling platform exploded and sank from methane leak; faulty blowout preventer	11 died in the explosion and fire; millions of gallons of oil spilled into the Gulf
Hyatt Regency walkway collapse Kansas City (1981)	Ceiling anchored threaded bolt design was altered	114 died when the walkway fell apart
Bjork-Shiley heart valve failures (1994)	Faulty design which allowed portions of the metal flap to break off within the heart	663 patients experienced catastrophic failure between 1978 and 2012
New Orleans flooding after Hurricane Katrina (2005)	50 failures with six major breeches of levees; engineering flaws and failure to maintain	Over 1800 died, over $100B in property damages
Boeing 737 MAX crashes	Design alteration: large engines at wing front caused pitch-up; software patch instead of hardware fix; pilots not adequately trained for change	2 crashes, 346 died

The role of the engineer is to respond to a need by building or creating something along a certain set of guidelines (or specifications) which performs a given function. Just as importantly, that device, plan or creation should perform its function without fail. Everything, however, must eventually fail (in some way) to perform its given function with a sought after level of performance. Hence, the engineer must struggle to design in such a way as to avoid failure, and, more importantly, catastrophic failure which could result in loss of property, damage to the environment of the user of that technology, and possibly injury or loss of life. Through analysis and study of engineering disasters, modern engineering designers can learn what not to do and how to create designs with less of a chance of failure…

Often, a deficiency in engineering ethics is found to be one of the root causes of an engineering failure. An engineer, as a professional, has a responsibility to their client or employer, to their

profession, and to the general public, to perform their duties in as conscientious a manner as possible. Usually this entails far more than just acting within the bounds of law. An ethical engineer is one who avoids conflicts of interest, does not attempt to misrepresent their knowledge so as to accept jobs outside their area of expertise, acts in the best interests of society and the environment, fulfills the terms of their contracts or agreements in a thorough and professional manner, and promotes the education of young engineers within their field. [4]

References

1. Ressler, S., *Epic Engineering Failures and the Lessons They Teach*, The Great Courses, 2022.
2. Ibid.
3. Ermer, G., "Understanding Technological Failure: Ethics, Evil, and Finitude in Engineering Disasters," ASEE Annual Conference, 2008.
4. Srinivasan, V., and Halada, G., "Engineering Disasters and Learning from Failure," Stony Brook University, 2015, http://dol1.eng.sunysb.edu/disaster/