Engineering Disasters

These tragic episodes are a reminder of the importance that engineers have in ensuring the safety of the public and what can happen when engineering failures occur.

Hyatt-Regency Walkway Collapse – Kansas City, MO, 1981 ***114 Fatalities***

The Hyatt Regency Walkway Collapse was one of the most tragic engineering disasters and occurred on July 17, 1981, at the Hyatt Regency Hotel in Kansas City, Missouri, USA. The collapse of two suspended walkways in the hotel's atrium resulted in the death of 114 people and injuries to many others. This event and its aftermath serve as a poignant lesson in the fields of engineering and professional ethics.

During a tea dance event in the hotel's atrium, the walkways suddenly collapsed, with the upper walkway falling onto the lower one and then both crashing to the ground below. The collapse was swift and catastrophic.

Causes

The disaster was caused by a design flaw in the construction of the walkways. The original design called for two walkways to be suspended from the ceiling, one above the other, with a set of steel rods connecting the two walkways. However, this design was later changed to a single set of rods, supporting both walkways. This change significantly increased the load on the connections. The connection between the walkways and the rods was inadequately designed and constructed. The walkways were suspended from a set of threaded rods and nuts, and this connection was not able to withstand the load placed on it.

After the incident, investigations revealed the design flaw and construction errors as the primary causes of the collapse. Engineers, architects, and contractors involved in the project faced legal repercussions, including civil lawsuits and professional consequences.

New London School, TX, 1937 ***300 Fatalities***

The New London School explosion was a devastating and tragic event that occurred on March 18, 1937, in New London, Texas, USA. It is commonly referred to as the New London School explosion or the New London School disaster.

The New London School was a large, modern (for its time), and school in an affluent area of East Texas. It was particularly prosperous due to the region's significant oil industry. The school was known for its cutting-edge facilities, including a natural gas heating system.

On the day of the disaster, a gas leak in the school's basement led to a massive explosion. The natural gas, which had been leaking for some time, ignited, causing a powerful blast. The gas was sourced directly from nearby oil fields in an effort to save money. The explosion was so intense that it lifted the school off its foundation and then caused the building to collapse. The explosion resulted in the tragic loss of nearly 300 lives, the majority of whom were students. Many others were severely injured. It was one of the deadliest school disasters in U.S. history. The explosion prompted a large-scale rescue and recovery effort. Local volunteers and emergency personnel rushed to the scene to help, and a makeshift morgue was set up to identify the victims.


Causes

Experts from the United States Bureau of Mines concluded that the connection to the oil field gas line was faulty. The connection had allowed gas to leak into the school, and because natural gas is invisible and is odorless (at the time there was no odorizer added to the gas), the leak went unnoticed.

The London School was built on sloping ground, and a large air space was enclosed beneath the structure. The school board had overridden the original architect's plans for a boiler and steam distribution system, instead opting to install 72 gas heaters throughout the building.

At approximately 3:17 PM an electric sander was switched on in the school's woodshop. The sander's switch is believed to have caused a spark that ignited the gas-air mixture. To reduce the risk of future gas leaks, the Texas state legislature granted the Texas Railroad Commission regulatory authority to adopt and enforce regulations for the odorization of natural gas in order to prevent such accidents. Within weeks of the explosion, thiol (mercaptan, an odorous sulfur compound) was added to natural gas across the United States. The strong odor of many thiols makes leaks quickly detectable. The disaster also formed the basis for new standards governing the practice of engineering in the State of Texas.

Dzhrashen School Collapse, Armenia, 1988 ***400 Fatalities***

The Dzhrashen Elementary school was located in Spitak, Armenia. It collapsed after a 6.8 magnitude earthquake struck the region in 1988. The source of the earthquake was a fault rupture 40 kilometers (25 mi) south of the Caucasus Mountains, a mountain range that has been produced by the convergence of the Arabian and the Eurasian tectonic plates. The mountain range is situated along an active seismic belt that stretches from the Alps in southern Europe to the Himalayas in Asia. The seismicity along this belt is marked by frequent major earthquakes from the Aegean Sea, through Turkey and Iran, and into Afghanistan.

The Dzhrashen school had the most concentrated death toll in the area, with 400 people dead on the one site alone.

Causes

A strong earthquake led to the precast concrete floors of the school building collapsing, which was caused by poor ties with the walls. The earthquake caused extensive damage in the region.

Malpasset Dam Collapse, France, 1959 ***459 Fatalities***

On 2 December 1959, the failure of Malpasset dam was a major industrial catastrophe that occurred in France.

There were warning signs of an imminent collapse starting in November 1959 in the form of seepage of water exiting at the right downstream face of the dam. Later cracks were noticed a few weeks later in the concrete apron at the dam toe.

The dam failure occurred at 9:21 PM on December 2, 1959. Seepage forces had increased in the dam due to rainfall that had raised the reservoir level. By noon on 2 December 1959, the reservoir had reached its maximum level. The dam superintendent André Ferro asked for permission to release the excess water and was denied the ability to do so until 6:00 PM (just a few hours before the dam failure. The entire wall then collapsed with only a few blocks remaining on the right bank. Pieces of the dam are still scattered throughout the area.

The breach created a massive dam-break wave, or wall of water, 130 feet high moving at a speed of 45 miles per hour which resulted in the complete destruction of two small villages, Malpasset and Bozon. The deluge contained with large chunks of the concrete wall from the

dam, some weighing up to 600 tons. Roadway and railway infrastructure were also destroyed, with water flooding the western half of Fréjus before finally reaching the sea.

The death toll of the dam breach was reported as 423, with 83 injured. Other damage included 155 buildings destroyed, 796 buildings damaged, and 3,300 acres destroyed. The amount of destruction totaled about $450 million in 2010 terms. The event also ushered in the practice of posthumous marriage in France for civilians, as many women who lost their fiancés were granted the right to marry them after death.

Remains of the dam

Causes

There were two main features of the rock mass the dam was built into proved to be the root cause of the dam failure due to seepage and were related to unfavorable rock structures which included a fault. Neither the fault nor the foliation had been recognized at the time of construction as there had been no geotechnical or geologic investigation of the area before the dam was constructed.

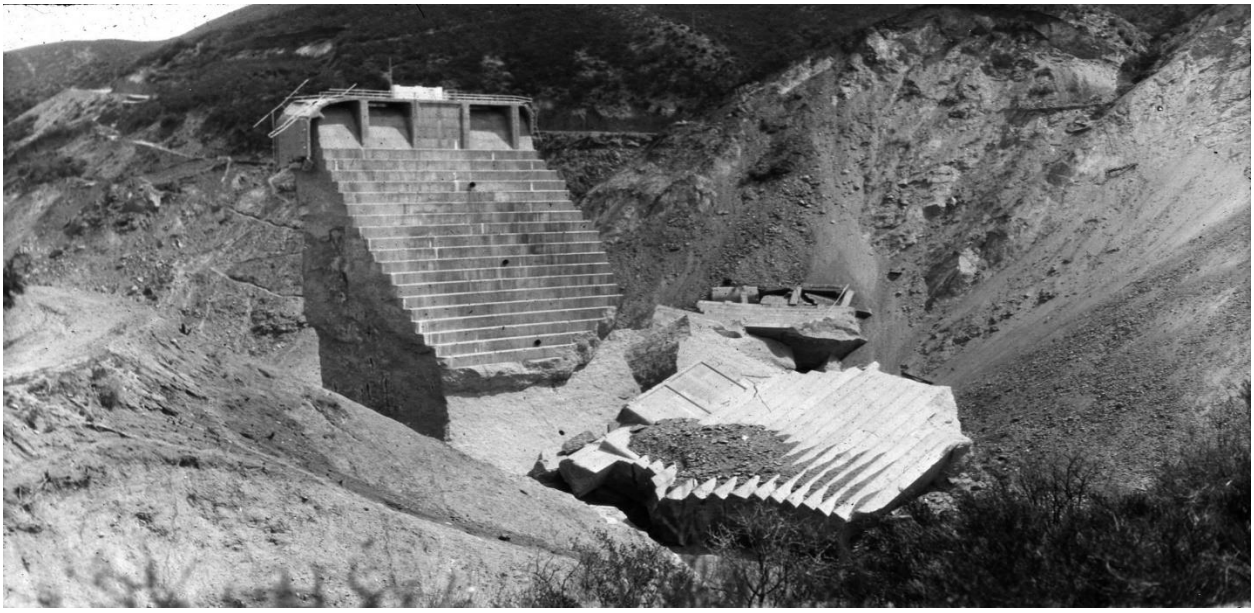
St. Francis Dam Collapse, Los Angeles, CA, 1928 ***450+ Deaths***

The St. Francis Dam Collapse was a major engineering disaster that occurred on March 12, 1928, in Southern California, USA. The collapse of the St. Francis Dam resulted in catastrophic flooding and significant loss of life and property. The dam was designed by the Los Angeles Department of Water and Power under the direction of its general manager and chief engineer William Mulholland.

On the evening of March 12, 1928, the St. Francis Dam suddenly failed, sending a massive wall of water down the Santa Clara River Valley.

The released water formed a deadly flood wave that raced through the valley, destroying everything in its path. Entire communities, farms, and infrastructure were swept away. The flood continued for nearly five hours, finally reaching the Pacific Ocean, covering a distance of over 50 miles.

The disaster resulted in a tragic loss of life, with an estimated death toll of over 450 people. The victims included men, women, and children, making it one of the deadliest civil engineering failures in U.S. history.



Causes

Inadequate geologic evaluations of an underlying thrust fault and a landslide, as well as poor dam operation and maintenance caused the under-seepage that led to the collapse of the dam. Today, geologists also believe the increased saturation and hydrostatic pressure from the dam further reduced the structural integrity of the underlying rock in the foundation and abutment contacts. As a result of this tragedy, the State of California created the board of registration for Civil Engineers in 1929.

Sampoong Department Store, South Korea, 1995 ***502 Fatalities***

The Sampoong Department Store collapse was a major engineering disaster in Seoul, South Korea. The structural collapse of the Sampoong Department Store building resulted in significant loss of life and was attributed to a combination of design and construction flaws.

On June 29, 1995 the building suddenly collapsed. The top floors of the building fell downward, causing a domino effect that led to the complete collapse of the building structure. The disaster was swift and catastrophic.

The collapse the deaths of approximately 502 people with more than 1,000 people injured.

Causes

Once the investigation focused on structural failure, it was initially believed the building's poorly-laid foundation and the unstable ground that it was built on, both led to the failure. Investigation of the rubble revealed that a substandard concrete mix of cement and seawater and poorly-reinforced concrete was used for the ceilings and walls.

Further investigation indicated that the building was built incorrectly using what was called "flat slab construction". Reinforced concrete buildings are often built by using columns and beams, with the floor slab supported over the full length of the beams. "Flat slab construction" does not use beams but supports the floor slab directly on the columns. The area of floor around the columns must be reinforced in order to carry the load; if the columns are too narrow, they can punch through the slab.

Examination of the building showed the concrete columns installed were only 24 inches in diameter, which was much smaller than the required 31-inch column diameter indicated in the plans. To compound this issue, the number of steel reinforcement bars embedded into the concrete was 8, not the required 16, which gave the building only half its needed strength. Steel reinforcements intended to strengthen the concrete floor were placed 4 inches from the top instead of 5 inches which further decreased the strength of the structure.

Fire shields were installed around all escalators to prevent the spread of fire from floor to floor, but to install them, the support columns were cut, further reducing their diameter. The reduced diameter concentrated the load on a smaller area of the slab, leading to an eventual puncturing of it. Those factors, along with the addition of a fifth floor including restaurants and heavy restaurant equipment, all contributed to the building's eventual failure. The original building design would have been more than twice as strong as needed to remain erect. As it is, the flawed structure managed to stand for almost five years.

Investigators pinpointed the direct cause of the collapse, known as the "trigger" or tipping point, for the building. It was revealed that two years before the collapse, the building's three rooftop air-conditioning units had been moved because of noise complaints from neighbors on the east side of the building. The building's managers admitted noticing cracks in the roof during the move, but instead of lifting them with a crane, the units were put on rollers and dragged across the roof, further destabilizing the surface.

Rana Plaza, Bangladesh, 2013 ***1,134 Fatalities***

The Rana Plaza collapse was a tragic building disaster that occurred on April 24, 2013, in Savar, a suburb of Dhaka, the capital of Bangladesh. The collapse of the Rana Plaza building, which housed several garment factories, resulted in one of the deadliest building collapses in modern history.

Rana Plaza was an eight-story commercial building that housed numerous garment factories, as well as shops and offices. These factories produced clothing for several major global brands and retailers.

Prior to the collapse, there were warning signs of serious structural issues in the building. Cracks had been observed in the structure, but workers were still forced to continue working in the factories.

On the morning of April 24, 2013, the Rana Plaza building suddenly collapsed, trapping thousands of workers inside. The disaster resulted in the tragic loss of over 1,100 lives, with many more injured. The victims were mostly garment workers, including many young women, who were working in the factories at the time.

Causes

Parts of the building were built without proper city permits. The 5th to 8th floors were added to the building without load-bearing walls. The garment factory's heavy equipment was more than the building structure could sustain. The foundation was weak and was built on soft, swampy ground.

These poor conditions were magnified due to the inferior quality of materials used in the building's construction, as well as shoddy building design and poor building practices.

Federal Levee Failures, New Orleans, LA, 2005 ***1,577 Fatalities***

On Monday, August 29, 2005, there were over 50 failures of the levees and flood walls protecting New Orleans, Louisiana, and its suburbs following passage of Hurricane Katrina. The failures caused flooding in over 80 percent of New Orleans and all of St. Bernard Parish. In New Orleans alone, 134,000 housing units which was 70 percent of all occupied units sustained major damage from Hurricane Katrina and the subsequent flooding.

Causes

The primary mechanisms of failure at the 17th Street Canal, London Avenue Canal and Industrial Canal (east side north) were improper design of the canal floodwalls. The failure mechanism for the Industrial Canal (east side south and west side) was overtopping of levees and floodwalls by the hurricane storm surge. The primary mechanism of failure for levees protecting eastern New Orleans was the existence of sand in 10 percent of the levee locations instead of compacted clay. The primary mechanism of failure for the levees protecting St. Bernard Parish was overtopping due to improper maintenance of the Mississippi River Gulf Outlet.

With the exception of four foundation design failures, all of the major breaches were caused by overtopping and subsequent erosion. There was significant levee overtopping and erosion that caused overtopping and subsequent wide-spread flooding, particularly in Orleans East. The levee-floodwall designs for the 17th Street and London Avenue Outfall Canals and the northeast breach of the IHNC were inadequate due to steel sheet-pilings driven to depths that were too shallow. In four cases the structures failed catastrophically prior to water reaching design elevations. A significant number of structures that were subjected to water levels beyond their

design limits performed well. Typically, in the case of floodwalls, they represented more conservative design assumptions and, for levees, use of higher quality, less erodible materials. In the aftermath of these failures, the U.S. Army Corps of Engineers instituted widespread repairs and additions to the flood control system in and around New Orleans at a cost of over $100 billion.

Vajont Dam - Landslide and Wave, Italy, 1963 ***2,000 Fatalities***

The Vajont Dam Collapse was a catastrophic failure that occurred in 1963 in northern Italy. The collapse of the Vajont Dam resulted in a massive landslide and one of the deadliest dam related incidents in history. It was one of the tallest dams in the world with a structural height of 860 feet.

The Vajont Dam was an arch-gravity dam built across the Vajont River in the Italian Alps. The dam was constructed in the late 1950s and early 1960s, primarily for hydroelectric power generation. It was located in a narrow gorge with steep mountain slopes on either side.

The area around the dam was known for its geological instability. Several factors, including the dam's construction and the abundant rainfall in the region, led to concerns about the stability of the mountain slopes in the upstream reservoir area.

On the night of October 9, 1963, a massive landslide occurred on the northern slope of Mount Toc, which was above the Vajont Dam into the reservoir. The landslide was triggered by a combination of factors, including heavy rainfall and an unfavorable orientation of bedding plans of the rock that tilted towards the reservoir. The displaced mass of water created a tsunami-like wave 820 feet tall that surged over the dam and into the Piave Valley below. The wave was extremely powerful, and it caused extensive damage to the downstream areas, including the town of Longarone and several other villages.

The disaster resulted in the tragic loss of approximately 2,000 lives, with entire communities swept away by the massive wave.

Causes

Filling of the reservoir began in February 1960 and in October the lake was already 550 feet deep. Soon afterward, the first fissures were noted on the slopes of Mount Toc and November 4, when a landslide with over 700.000 cubic yards of rock occurred and slid into the reservoir. Alarmed, technicians decided to slightly reduce the rate the reservoir was filled. This strategy was successful until mid-1963 when, between April and May, the depth of the reservoir was rapidly increased from 640 feet to 750 feet. By mid-July, the reservoir depth was 780 feet.

On October 9th, the entire slope of Mt. Toc collapsed. Within 25 seconds estimated and 240 to 270 million cubic yards of rock and forest plunged into the reservoir, filling the 1,300 feet deep gorge behind the dam. The wave generated by the impact of the landslide traveled 460 feet up on the opposite shore, reaching some buildings of the village of Erto. At the moment of the impact the reservoir contained 115 million cubic yards of water. The landslide pushed part of the water out of the lake, producing a wave with a maximum height of 860 feet.

Johnstown Flood, Pennsylvania, 1889 ***2,209 Fatalities***

The Johnstown Flood, sometimes referred to locally as Great Flood of 1889, occurred on Friday, May 31, 1889, after the catastrophic failure of the South Fork Dam, located on the south fork of the Little Conemaugh River. This dam was located 14 miles upstream of the town of Johnstown,

Pennsylvania. The dam ruptured after several days of extremely heavy rainfall, releasing over 14 million cubic yards of water. With a volumetric flow rate that temporarily equaled the average flow rate of the Mississippi River, the flood killed 2,208 people.

Causes

On May 28, 1889, a low-pressure weather system formed over Nebraska and Kansas. By the time this weather system reached western Pennsylvania two days later, it had developed into what would be termed the heaviest rainfall event that had ever been recorded in that part of the U.S. Government officials estimated that 6 to 10 inches of rain fell in 24 hours over the region. During the night, small creeks became roaring rivers, ripping out trees and debris. Telegraph lines were downed, and rail lines were washed away. Before daybreak, the Conemaugh River that ran through Johnstown was about to overflow its banks.

On the morning of May 31, in a farmhouse on a hill just above the South Fork Dam, Elias Unger, president of the South Fork Fishing and Hunting Club, noticed that Lake Conemaugh was swollen after a night-long heavy rainfall. Unger ran outside in the still-pouring rain to assess the situation and saw that the water was nearly overtopping the dam. He quickly assembled a group of men to save the dam by trying to unclog the spillway; it was blocked by the broken fish trap and debris caused by the flooding. The men also started digging a ditch at the other end of the dam, on the western abutment which was lower than the dam crest. The idea was to let more water out of the lake to try to prevent overtopping of the dam, but this was not successful.

John Parke, an engineer for the South Fork Club, briefly considered cutting through the dam's end, where the pressure would be less to create another spillway, but eventually decided against it as that would have quickly resulted in failure of the dam. Unger directed Parke to ride on horseback to a telegraph office in the nearby town of South Fork to send warnings to Johnstown explaining the dangerous situation unfolding at the dam. Parke did not personally take a warning message to the telegraph station and instead sent a man in his place. However, the warnings were not passed to the authorities in Johnstown, as there had been many false

alarms in the past of the dam not holding against flooding. Unger, Parke, and the rest of the men continued working until exhausted to save the dam from overtopping. They had to abandon their efforts at around 1:30 p.m. since it was observed that their efforts were futile and the dam was at risk of imminent collapse. Unger ordered all of his men to fall back to high ground on both sides of the dam where they could do nothing but watch and wait. During the day in Johnstown, the situation worsened as water rose to as high as 10 feet in the streets, trapping many people in their houses.

Between 2:50 and 2:55 p.m. the South Fork Dam breached. A Lidar analysis of the Conemaugh Lake basin reveals that it contained over 14 million cubic yards of water at the moment the dam collapsed.

World Trade Center Towers Collapse, NYC, 2001 ***2,763 Fatalities***

The collapse of the World Trade Center occurred on Tuesday, September 11, 2001, after two commercial airliners hijacked by Al-Qaeda terrorists were deliberately flown into the Twin Towers of the World Trade Center complex in New York City as part of the September 11 attacks. The North Tower (WTC 1) was the first building to be hit when American Airlines Flight 11 crashed into it at 8:46 a.m., causing it to collapse at 10:28 after burning for one hour and 42 minutes. At 9:03 a.m., the South Tower (WTC 2) was struck by United Airlines Flight 175; it collapsed at 9:59 a.m., after burning for 56 minutes. The towers' destruction caused major devastation throughout Lower Manhattan, and more than a dozen adjacent and nearby structures were damaged or destroyed by debris from the plane impacts or the collapses. Four of the five remaining World Trade Center structures were immediately crushed or damaged beyond repair as the towers fell.

Causes

The North Tower was struck between the 93rd and 100th floors; at least six core building columns were severed while others sustained heavy damage. The South Tower was struck by the plane (impact load) between the 78th and 85th floors, and the damage to the core was much more severe. The plane was traveling more than 100 mph faster (542MPH) than the one that struck the North Tower, and it struck the tower on its south face. It penetrated the building core from its short side rather than the middle, as in the case of the North Tower. This caused at least 10 core columns to be severed, including one of the corner columns. It was noted that the corner core columns carried 20 percent of the weight of the tower. Throughout the eight floors of the impact of the North Tower and seven floors of the impact area of the South Tower the core's steel was stripped of its Sprayed-on fire resistive membrane (SFRM). This exposed the resulting unprotected steel on those floors to the fires initiated by the 10,000 gallons of jet fuel and sustained by the combustible contents, such as carpets, cubicles, furniture, and finishings. The jet fuel was atomized and did not burn for more than 30 minutes. The resulting fires were due to the combustibles on the floors themselves. The core columns, now without protection, would be exposed to significant heat for one hour and 42 minutes in the North Tower and 55 minutes within the South Tower.

The National Institute of Standards and Technology (NIST) determined the fires to be the main cause of the collapses, finding that sagging floors pulled inward on the perimeter columns, causing them to bow and then buckle. Once the upper section of the building began to move downward, a total progressive collapse of the towers occurred.

Links

Hyatt-Regency

https://www.npr.org/2021/07/17/1016603199/one-of-the-deadliest-u-s-accidental-structural-collapses-happened-40-years-ago-t

New London School

http://nlsd.net/index2.html

https://www.texasmonthly.com/articles/oh-my-god-its-our-children/

Malpasset Dam Failure

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St. Francis Dam Collapse

https://www.geoforward.com/saint-st-francis-dam-geology-geological-disaster-los-angeles-william-mulholland-history/

Sampoong Department Store Collapse

https://www.theguardian.com/cities/2015/may/27/seoul-sampoong-department-store-disaster-history-cities-50-buildings

Rana Plaza

https://www.re-thinkingthefuture.com/architectural-community/a9215-structural-failure-2013-rana-plaza-factory-collapse/

Federal Levee Failures

https://ready.nola.gov/hazard-mitigation/hazards/infrastructure-failure-levee-failure/

Vajont Landslide

https://www.geotech.hr/en/vajont-a-tragedy-that-killed-more-than-2000-people/

World Trade Center Tower Collapse

https://www.scientificamerican.com/article/what-structural-engineers-learned-from-9-11/