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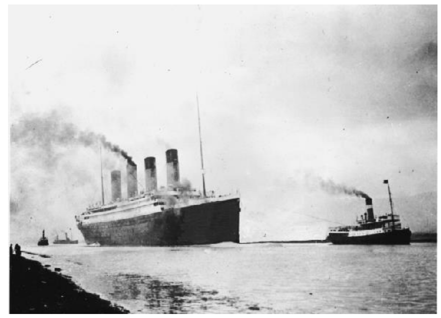
Famous Failures Case Studies Answer

Tipping of the Titanic

On April 14, 1912, the Titanic—the largest and most elegant ship of the time—-struck an iceberg and sank into the waters of the Atlantic Ocean, resulting in the deaths of more than 1,500 people. What caused this incredible ship to sink? The Titanic had a double-bottomed hull divided into 16 different watertight compartments. When the engineers initially tested the ship, they determined that at least four of these components could be flooded without sinking the ship. However, in the design, these compartments were not sealed at the top, and water was able to flow from compartment to compartment (like water filling an ice cube tray). When the starboard side of the Titanic scraped the iceberg, small ruptures caused several compartments to fill, tipping the ship to one side and ultimately causing it to sink.



The Titanic during sea trials.

Toppling of the Tacoma Narrows Bridge

The original Tacoma Narrows Bridge was the first suspension bridge built across the Puget Sound in Washington. The bridge was strong but relatively light, narrow, and as it turns out—(too) flexible. On the morning of November 7, 1940, in a 42 mph (68 kph) wind, the 2,800-foot (853-m) main bridge span went into a series of torsional oscillations (side-to-side and up-and-down motion) in which the amplitude (size of the motion) steadily increased. This movement tore several suspension cables and broke the main span, causing the bridge to collapse. The failure of the bridge was a shock to the engineering community. How could a structure weighing more than tens of thousands of tons topple in moderate wind? Most experts agree that the collapse had something to do with a phenomenon called "resonance"—the same force that causes a soprano's voice to shatter glass. Although the engineers had designed the bridge to withstand the pressure of winds much greater than 42 mph, they did not consider the interaction of moderately strong wind and the flexibility of the bridge.

The new Tacoma Narrows Bridge.

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QUESTION: What factor(s) did the engineers of both the Titanic and the Tacoma Narrows Bridge fail to include in their engineering analysis?

ANSWER:

In both the **Titanic** and **Tacoma Narrows Bridge** cases, the fatal mistake was that a purely **static view** of the design was used in the engineering analysis. This means that the engineers analyzed the objects (the ship and the bridge) **as if they were not moving**.

In the case of the Titanic, even though engineers determined that four of the hull compartments could rupture without catastrophe, they failed to consider the "tipping effect" caused by a series of hulls on *one* side of the boat filling with water. A more appropriate (and life-saving!) analysis would have been a **dynamic analysis**—one that accounted for **interactions and uncertainties in the environment,** such as collision with an iceberg and water flow between compartments.

The failure of the Tacoma Narrows Bridge can also be attributed to a **static analysis** used in the bridge design. The engineers *did* design the bridge to withstand the pressure of very high wind speeds—as long as the bridge remained static (unmoving). However, the engineers did not design the bridge to withstand the fluid/structure (wind/bridge) interaction.

So, what have we learned from these "failures"? One thing we have learned is that good engineering analysis involves **creating a realistic environment** to help us better evaluate the dynamic interaction between the design and the external elements that contribute to uncertainty. Today, wind tunnel testing of bridge designs is mandatory. Wind tunnel testing helps engineers create closer approximations to real-world conditions.

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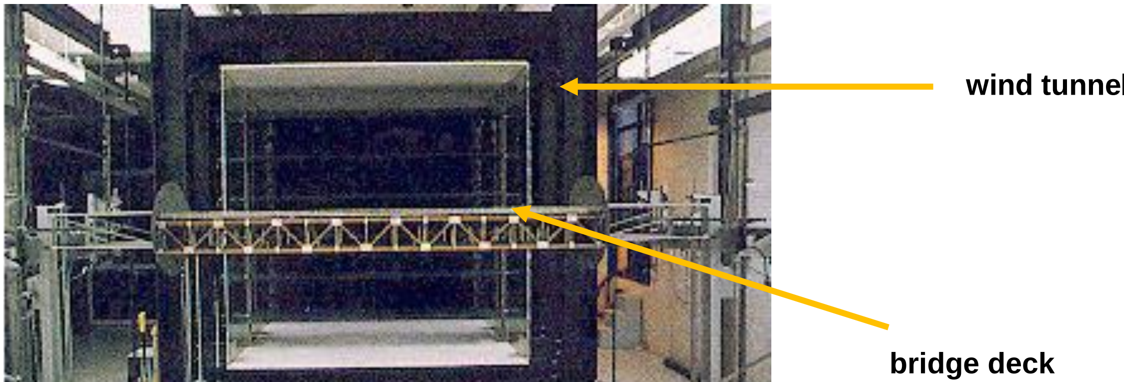

A typical bridge deck model (in this case, for the Golden Gate Bridge) being submitted to a wind tunnel test.

Photo source: U.S. Department of Transportation
http://www.tfhrc.gov/pubrds/winter96/imgs/p96w46c.gif