When Good Engineering Ideas Go Wrong

By Jeremy Herauf

For centuries, engineers have come up with great new ideas and leveraged them to build stronger, better, lighter, longer, taller, and more beautiful bridges.

Throughout history, some design and procedural innovations have gone wrong, leading to serious structural problems, failures, collapses, and even deaths. Many bridges that seemed like great ideas on the drawing board and in the planning process failed during construction or soon thereafter. This article examines engineering and design concepts, and construction procedures, that led to these problems.

Tacoma Narrows Bridge

The first bridge across the Puget Sound in Washington was proposed in 1889 when the Northern Pacific Railway was looking for ways to speed travel from Tacoma to the Kitsap Peninsula. A simple trestle bridge was considered but never built because engineers determined that it would not hold up to the extreme winds and tides it would have to endure. Also, they could not find an engineering solution to span the extreme distance across the sound.

It took almost 50 years – and a costly study – to finally design a span that engineers felt confident about. Designer Leon Moisseiff came up with a plan for a solid, rigid suspension bridge that many believed was ideally suited for the challenging location.

Despite all the great engineering minds that reviewed the bridge plan, they failed to see that all the factors that made the bridge *strong* and *stable* also made it *too rigid* to withstand the extreme winds that would batter it day after day.

While under construction, workers noticed that the bridge shook in unprecedented ways whenever the wind blew. It was so extreme, they nicknamed the bridge "Galloping Gertie." Surprisingly, Moisseiff and the on-site engineers dismissed the shaking, assuming the issue would resolve itself once construction was complete. Work continued, and the bridge opened on July 1, 1940.

Just over five months later, on November 7, the bridge collapsed under 42 mile-per-hour winds, due to aeroelastic flutter.

It took ten years for a lighter, more flexible bridge to be completed. The replacement structure still stands today and serves as the westbound lanes of the current pair of bridges that cross the Puget Sound.

Tacoma Narrows Bridge collapse, 1940.

Nipigon River Bridge

The Nipigon River Bridge is an integral part of the Trans-Canada Highway, a critical roadway that moves traffic, including vital deliveries, across the continent.

The first vehicular bridge at the location was opened in 1937, replacing an earlier railroad bridge. It was replaced in 1974 and again in 2013 when higher traffic volume necessitated it. The 2013 replacement is a pair of innovative cable-stayed structures, novel because they were the first bridges of this type constructed in a cold-weather climate.

The first of the twin bridges opened in late November 2015. It was forced to close less than two months later when an expansion joint shifted more than two feet after a winter storm. The closure led to a major failure in the Canadian roadway system. It forced traffic to detour hundreds of miles south into the United States, leading to a state of emergency.

The bridge was partially re-opened to traffic using a temporary fix several days later. However, it took until September of that year for officials to determine the cause of the fissure. The immediate reason for the break was attributed to a simple failure of the bolts that connected the bearings to the bridge girders. The bigger issue was that the shoe plates, which connected the two components, were too flexible. When stressed by extreme cold, the plates twisted and pried out the bolts. Also, bearings that should have been flexible and mitigated this issue failed and were unable to rotate. To fix the problem, a new linkage system was designed and implemented that allowed for greater flexibility during periods of thermal expansion and contraction.

In the end, a bridge design that was effective in more temperate climates was not adequate for the cold of an extreme Canadian winter.

Quebec Bridge

The Quebec Bridge failed not once, but twice, during construction because of engineering and construction errors on the breakthrough bridge designs.

Pont de Québec Bridge collapse, 1907.

The first time anyone thought of connecting Lévis on the south shore of the St. Lawrence River to Quebec City on the north was back in 1852, but no one came up with a solution to bridging the chasm. Options were explored in 1867, 1882 and 1884.

Finally, near the turn of the 20th century, a record-length cantilever bridge structure was decided on for the site. Edward Hoare was selected as the chief engineer for the project even though he had never worked on a similar type of bridge on such a large scale.

Several people assisted in engineering this ambitious project. The design and construction phases were chaotic because no one on the team could agree on the correct load calculations to support the span. In the end, the recommendations of the engineering team were overruled by a government agency. Work on the structure continued.

As early as 1904, when the bridge was almost half completed, engineers confirmed that the bridge itself weighed far more than its carrying capacity. They apparently ignored this, as construction kept going through 1907. In the summer of that year, the team began noticing stretching and contorting of important structural elements. Some engineers claimed that they were installed in this condition and the issues were once again ignored.

Soon after, the southern and central sections of the bridge suffered a catastrophic collapse, tumbling into the river in less than 15 seconds. Of the 86 workers on the bridge at the time, 75 were killed and the rest seriously injured. It is the world's worst bridge construction disaster and was officially blamed on engineers not closely monitoring and managing the development of this novel design.

Once the investigation into the collapse was completed, work began on a replacement bridge. The new design would be an even more massive cantilever structure with a broad center span.

Once again, engineers raised concerns, this time over the weight and size of the center span that was to be raised into place by a new type of hoisting device. The novel technique was used to speed construction. Sure enough, the hoists failed, and the span fell into the river, killing 13 workers. It still sits at the bottom of the St. Lawrence River today.

Another center span had to be built, which was difficult because it was hard to source steel during World War I. The bridge finally opened in 1919, and remains the longest cantilevered bridge in the world.

This innovative structure brought home the fact that careful calculations and project management are necessary when developing record-breaking structures. Just because something works on a small scale does not mean it will work on a larger one.

Conclusion

Innovative bridge design and engineering are constantly improving the capacity and function of critical structures.

The biggest lesson designers and engineers can learn from the bridge failures outlined here is that it is important to be cautious and pay attention to signs something could be wrong with a cutting-edge structure or building technique. Numbers, measurements, and physical clues often indicate something is wrong. Paying attention to them allows for innovation to continue while keeping workers and the general population safe.▪

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