

TAP 307- 11: Tacoma Narrows Bridge

Text to read

Engineers need to take oscillations and resonances into account when building bridges. This reading indicates what can go wrong if the static forces on a structure are accounted for, but the dynamic forces are ignored.

Tacoma Narrows

On 1 July 1940, a new bridge was opened up at the narrowest point in Puget Sound, connecting Tacoma, Washington to the Olympic Peninsula. At the time it was the third longest suspension bridge in the world. Right from the beginning, even before the construction was completed, the bridge behaved in a peculiar way. Whenever there was a slight breeze, ripples would run along the bridge. After a while local people began calling the bridge affectionately by the name Galloping Gertie. Driving across the bridge on a windy day became a favourite local pastime because it was like riding a roller coaster, although it was disconcerting to people driving across the bridge to see the car in front of them disappear over the crest of a wave.

Four months after the bridge was opened, on 7 November 1940, a new mode of oscillations showed up in the bridge in a prevailing south-westerly wind of about 42 mph. Instead of rippling motions down the bridge, twisting motions set in. The peculiarities of the bridge were being studied by a hydrodynamicist from the University of Washington, Bert Farquharson. He rushed down to take pictures of the new mode of oscillations. At 11 o'clock in the morning that day, the Tacoma Narrows Bridge collapsed. An inquest into the collapse determined that the bridge had been built according to the best engineering standards of the day. No-one was guilty of wrongdoing, but also no-one could figure out why the bridge collapsed.

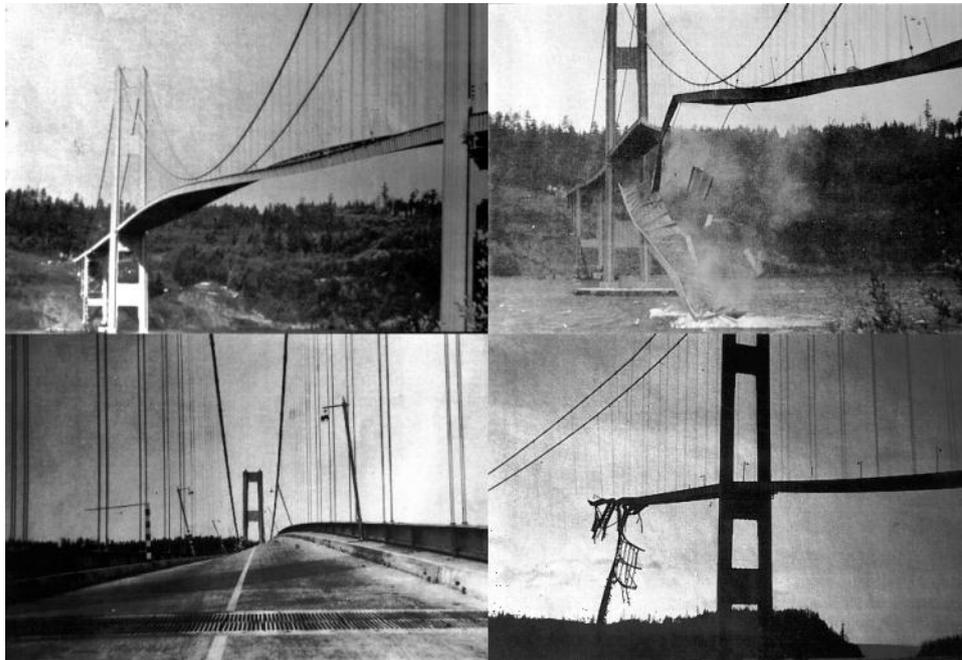
A national commission investigating the collapse included Hungarian aerodynamicist Theodore von Kármán of Caltech. He explained that vortices were pouring out of the top and bottom of the deck of the bridge, driving the bridge at its resonant frequency, which eventually led to its collapse. His explanation was confirmed by experiments conducted in wind tunnels with structural models both at the University of Washington and at Caltech. In spite of the confirmation, the bridge-building community was very reluctant to accept the explanation. Why? Bridge architects were concerned with static forces. They built in brute strength to confront maximum load, water flow, wind, etc. They didn't consider the dynamic forces. Von Kármán said that the shape the roadway presented to the wind acted like an airplane wing. The displaced air formed vortices whose action induced vibrations in the deck. Since that disastrous event, models for all major bridges have been tested in wind tunnels, and bridge engineers have been forced to consider the aerodynamics of their designs.

In the twisting mode, the centre line hardly moves at all – the vibrations go all around it.

The car belongs to a man called Leonard Coatsworth, who was a reporter on a local newspaper; he was the last person to try to cross the bridge. Farquharson himself tried to rescue a cocker spaniel from Coatsworth's car. For his trouble, he was rewarded by the dog biting him on the hand, which was the only injury in the incident; the cocker spaniel, which never left the car, was the only fatality. A local college student named Winfield Brown decided to walk across the bridge that morning; it was a popular sport on a windy day. He came off crawling on his hands and knees, and reported one moment of sheer terror when the bridge had tilted so much under him that he looked straight down 200 ft into Puget Sound.

At the same spot there is now a new suspension bridge built with modifications suggested by von Kármán. The principal changes were to make the bridge four lanes wide, to use open side trusses, and to place ventilating grills between lanes to equalise wind pressures above and below the deck. The bridge has never had the slightest difficulty. People still look at it nervously on windy days, but it never budes.

Here are some stages in the collapse of the Tacoma Narrows Bridge on that fateful day.



Further pictures and a short video clip are available at:

<http://www.enm.bris.ac.uk/research/nonlinear/tacoma/tacoma.html#file>

(as at September 2005)

Practical advice

This is a straightforward reading, which students should be able to manage without help.

Further pictures and a short video clip are available at:

<http://www.enm.bris.ac.uk/research/nonlinear/tacoma/tacoma.html#file> (as at September 2005)

There is some debate to the exact cause but teachers may wish to look at:

<http://www.engsoc.org/~leito/Billah-Scanlan.pdf> It is not suggested that this article is for students.

Alternative approaches

There are many video clips showing the bridge in resonant oscillation, and the eventual collapse. One source is the Mechanics in Action video produced by the project team of the same name based at Leeds University.

Social and human context

The human-interest story here would have made it front-page journalism. The fun value of treating the oscillating bridge as being like a fairground activity, and giving it a silly name, has to be contrasted with the potential for human disaster, which fortunately did not occur. A more serious angle is the catastrophic mistake made by well-reputed engineers, and their reluctance to accept the reason for the bridge's destruction once it had been pointed out. There is a lesson here for any physicist constructing a model which omits significant effects.

External reference

This activity is taken from Advancing Physics chapter 10, 30T