ENGINEERING

Bridges Made Safe

It has taken a major catastrophe and several near disasters to stimulate the development of bridge aerodynamics which is making bridges safe.

By RALPH SEGMAN

➤ ON A WINDY November morning, the engineer in charge of the Tacoma Narrows Bridge rushed to the telephone. Alarmed at the rhythmic rise and fall of the 2,800-foot suspension span (the third longest in the world), he ordered stiffening wire ropes for immediate installation. When he returned, the span was gone.

Out of this death in 1940 of a four-month-old engineering masterpiece came the phoenix-like birth of a new science, bridge aerodynamics.

In less than two decades, the science has reached perhaps its ultimate expression in the new Straits of Mackinac Bridge in upper Michigan. The bridge is the first utilizing the concept of "perfect aerodynamic stability."

The world's longest suspension bridge, 8,614 feet from anchorage to anchorage, "Big Mac" can withstand virtually infinite wind velocity. Even with its deck openings shut solid by ice and snow, it could shrug off a 632-mile-an-hour wind, a blow that is far beyond what might occur. What is more remarkable is this: the stronger the blow, the more rigid and resisting the bridge becomes.

Tragic Lesson

The lesson learned from the Tacoma collapse had been a shocking one to bridge engineers who venerated the principle of flexibility in suspension spans. The Tacoma Bridge was the most flexible ever built and was hailed as one of the safest.

During its construction the motions of the span, even in gentle breezes, caused "seasickness" among the rugged workers. Yet, the supreme confidence of authorities, designers and builders was not shaken. Motorists seemed to enjoy the bouncing, swaying ride on the bridge they dubbed "Galloping Gertie."

Then came the 42-mile-an-hour wind, violent up-and-down oscillations and writhing. Like a narrow wooden ruler being twisted in opposite directions at each end, the span snapped. Tearing away from suspending cables, it crashed into Puget Sound more than 200 feet below.

The catastrophe was not unexpected to Dr. David B. Steinman, designer of hundreds of bridges, among them the Mackinac. He had previously suggested that the span be stiffened.

Before most of his profession had recognized aerodynamic oscillations as a problem, Dr. Steinman had begun to work on the solution. He recently said that some 20 bridges completed since 1930 have been subjected to disturbing or dangerous oscillations. At least two of them, the Golden Gate and the Bronx-Whitestone, have undergone costly stiffening reconstruction.

Dr. Steinman credits John A. Roebling, designer of the Brooklyn Bridge more than 90 years ago, as being the first man to do something about aerodynamic instability. With an intuitive rather than scientific grasp of the problem, Roebling built his suspension spans using special stiffening methods. For nearly three-quarters of a century thereafter, this phase of bridge building was totally ignored.

Mere stiffening is not the best way to build large and safe suspension bridges. Dr. Steinman maintains that it is both more scientific and more economical to eliminate the cause of aerodynamic instability than to build heavy powerful structures to resist the force of the wind.

It is surprising that aerodynamics was not applied to bridges sooner since it has been utilized by aircraft designers from the beginning of the air age. Wings are shaped in such a way that the airflow around them produces a greater pressure on the under surface, thus a lifting force.

Similar forces act on bridge roadways which are supported by cables from above and a network of steel girders below. In a steady wind, the flexible span tends to oscillate up and down in harmony with the air pressure which acts rhythmically to force it up and then down. These oscillations are self-exciting and may, in a short time, become violent in non-aerodynamic bridges.

Dr. Steinman can demonstrate this effect. Mounting half a solid sphere between two light springs he exposes the flat side to a stream of air from an electric fan. He pulls the half-sphere up or down slightly and lets go. The resulting small oscillation rapidly builds up into a violent one. When the round side of the half-sphere faces the fan, any oscillation that is started promptly damps out.

Employing this "round-side" principle, Dr. Steinman designed the Mackinac Bridge. As he described it:

"When the bridge floor is moving up, the resultant aerodynamic forces act down; and vice versa. As a result, any incipient vibration (as from traffic) is quickly brought to rest. The bridge actually utilizes the force of the wind to produce stability; the stronger the wind, the more stable the bridge!"

As an added safety factor, the two inner traffic lanes are constructed of open steel grillwork, thus eliminating some of the solid surface that otherwise would be exposed to wind pressures. For the same reason, there are open slots at the far edges of the outer lanes.

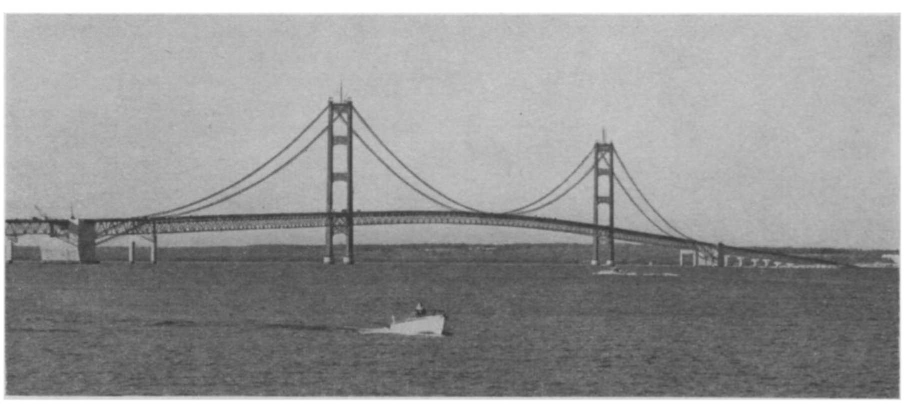
Dr. Steinman believes that the design of the Mackinac Bridge permitted a saving of $15,000,000 in its construction (its total cost was nearly $100,000,000).

The finished structure represents to him a triumph of mathematics applied to bridge design and a symbol of future bridges.

A generation ago, Dr. Steinman said, the feasibility of suspension spans of 3,000 feet was seriously questioned. Today, the world's longest span, the Golden Gate Bridge, extends 4,200 feet. The Mackinac's span is 3,800 feet, the George Washington's is 3,500 feet and the new Tacoma Narrows (aerodynamically safe) span is 2,800 feet.

A span 5,000 feet long has been designed to cross over the Messina Straits between Italy and Sicily. A 6,300-footer is in the planning stage, and Dr. Steinman predicts suspended spans as long as 10,000 feet.

In addition to suspension spans, used primarily to bridge deep waters, there are



"BIG MAC"—With the world's second longest span, 3,800 feet, the new Straits of Mackinac Bridge is built to shrug off the most powerful winds ever recorded. Considered the safest suspension bridge, it is also the longest, from anchorage to anchorage.

some 20 other types of bridges. Development of long spans for them has created an urgent need for improved materials. There now are alloy steels, heat-treated carbon steels and cold-drawn high-carbon bridge wire. Some materials already have three or four times the safe working strength of ordinary steel. The principal lightweight material is structural aluminum. One of the newer materials is prestressed concrete, or concrete compressed and strengthened by pre-stretched steel wires running through its length.

Among the most recent structures are:

The Greater New Orleans Expressway. The longest highway bridge in the world, extending 24 miles across Lake Pontchartrain, it is made of hundreds of 56-foot prestressed concrete spans and two movable bascule spans.

The Tappan Zee Bridge. Carrying New York Thruway traffic more than three miles across the Hudson River, this bridge employs the cantilever principle. Its 1,212-foot main span rests like a board lying across the gap between two seesaws standing end to end. Its weight is balanced by counterweights on the far ends of the "see saws."

The Nagasaki-Sasebo Bridge. Built in Japan, this steel arch bridge has a 1,042-foot span, the fourth longest of its type. The roadway is supported by the arch which stretches from shore to shore.

The New South Capitol Street Bridge. Crossing the Anacostia River in Washington, D. C., it has the world's longest plate-girder bascule span, 386 feet. A bascule span is one which allows ships to pass by swinging up and open like the flaps of a box.

These examples are indicative of the tremendous increase in bridges of all kinds. The growing American turnpike system has added hundreds of bridges, large and small. The impelling demands of industrial expansion and motor travel have brought almost complete extinction to the era of the ferryboat.

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Questions

ASTRONOMY—Study of what planet indicated inaccuracies in Newton's theory? p. 291.

MEDICINE—What is one new method for treating severe burns? p. 293.

PHYSICS—Why does hydrogen take over as the most important constituent of the exosphere at about 600 miles? p. 295.

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Do You Know

Short-lived blue supergiant *stars,* 6,000 times brighter than the sun, may give clues to the evolution of our stellar systems.

Boron-phosphorus compounds that may lead to the development of heat-stable *plastics* have been synthesized.