Learning from bridge failure

Collapses such as the I-35W in Minneapolis give engineers the best clues about what not to do. Let's hope the lessons are remembered.

By By Henry Petroski

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The collapse of an interstate highway bridge over the Mississippi River in Minneapolis took everyone, including engineers, by surprise.

We do not expect our bridges to drop out from beneath us, and their designers take great pains to ensure that they do not. Among the surest ways to obviate the failure of any structure is to anticipate all the different ways in which it can fail. Thus, in designing the Minneapolis bridge, engineers had to consider the consequence of a single steel member breaking, buckling or otherwise failing to carry its intended load.

The intended load on a bridge consists of two distinct parts. The so-called dead load is the weight of the steel and concrete that makes up the structure itself. This can be on the order of 80% or more of the total weight that a bridge is expected to bear.

The remainder of the load consists of the weight of the traffic, which in theory can be controlled, and the less controllable forces produced by ice, snow, wind and possibly an earthquake. All expected combinations of these loads -- and how the structure responds to them -- must be taken into account when a bridge is designed. The size and configuration of structural elements, like beams and girders, are chosen to give the bridge more strength than it needs under a worst-case scenario, a concept known as a "factor of safety."

Engineers often look to examples of success and failure to guide their designs. Paradoxically, it is the failures that are the more reliable teachers. As the case of the Minneapolis bridge so clearly shows, a structure that stands successfully for decades is not necessarily a sound design. However, when a bridge fails, it provides invaluable lessons in what not to do.

There are many historical examples of major bridge failures, but one that comes fast to mind today is the 1967 collapse of the 41-year-old Silver Bridge across the Ohio River at Point Pleasant, W.Va. Silver Bridge -- which took its name from the color of its paint -- was a chain suspension structure that collapsed suddenly in rush-hour traffic, sending 75 vehicles into the water and killing 46 people.

It was a year and a half before the Federal Highway Administration issued a definitive report, which attributed the collapse to the growth of an undetected crack in one of the enormous chain links. Aided by corrosion and the repetition of traffic loads over the years, the fatigue crack had grown to such a size that it weakened the link until it could no longer hold up the load it was designed to take.

Because the connection details of the Silver Bridge suspension chains made it difficult, if not impossible, for such a crack to be detected, a twin bridge upriver was dismantled before it suffered the same fate. A more far-reaching immediate consequence was a new requirement that all bridges in the nation be inspected according to federal guidelines. Many bridges throughout the country were closed or had speed limits and traffic loads imposed on them. The Silver Bridge, which had been so vital to the life of the area, was replaced within two years by one of a cantilever design -- the type that failed at Minneapolis.

In the decades since the collapse of the Silver Bridge, there have been other sudden highway bridge failures, most notably the Mianus River Bridge on Interstate 95 in Connecticut in 1983 and the Schoharie Creek Bridge carrying the New York Thruway over its namesake stream in 1987. In both cases, lax inspection and maintenance procedures were found to be at fault.

The Mianus failure was traced to exessive corrosion that resulted when roadway drains were paved over and missing gutters were not replaced. At Schoharie, severe, undetected scour under one of the bridge's piers led to its sudden collapse.

No matter how carefully bridge designers anticipate failure on the drawing board (or computer screen), their structures will only be as reliable as how carefully built, maintained and inspected they are. Just because a bridge has given decades of successful service under adverse conditions of increasingly heavy traffic and neglect does not mean that it will continue to do so. It is the function of regular and careful inspections to catch what designers might not have anticipated.

In the wake of Minneapolis, there will no doubt be renewed vigilance. More careful inspections and more conservative interpretations of their findings may cause some immediate inconveniences, but they will also likely prevent some imminent failures.

In bridge design, as in all structural engineering, success can breed hubris and catastrophe, while failure nurtures humility and caution. Unfortunately, it does seem to take a collapse to re-sensitize inspectors and operators to the real dangers that lurk among rusting steel and cracking concrete. Let us hope that the lessons learned in Minneapolis are not forgotten once more.

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