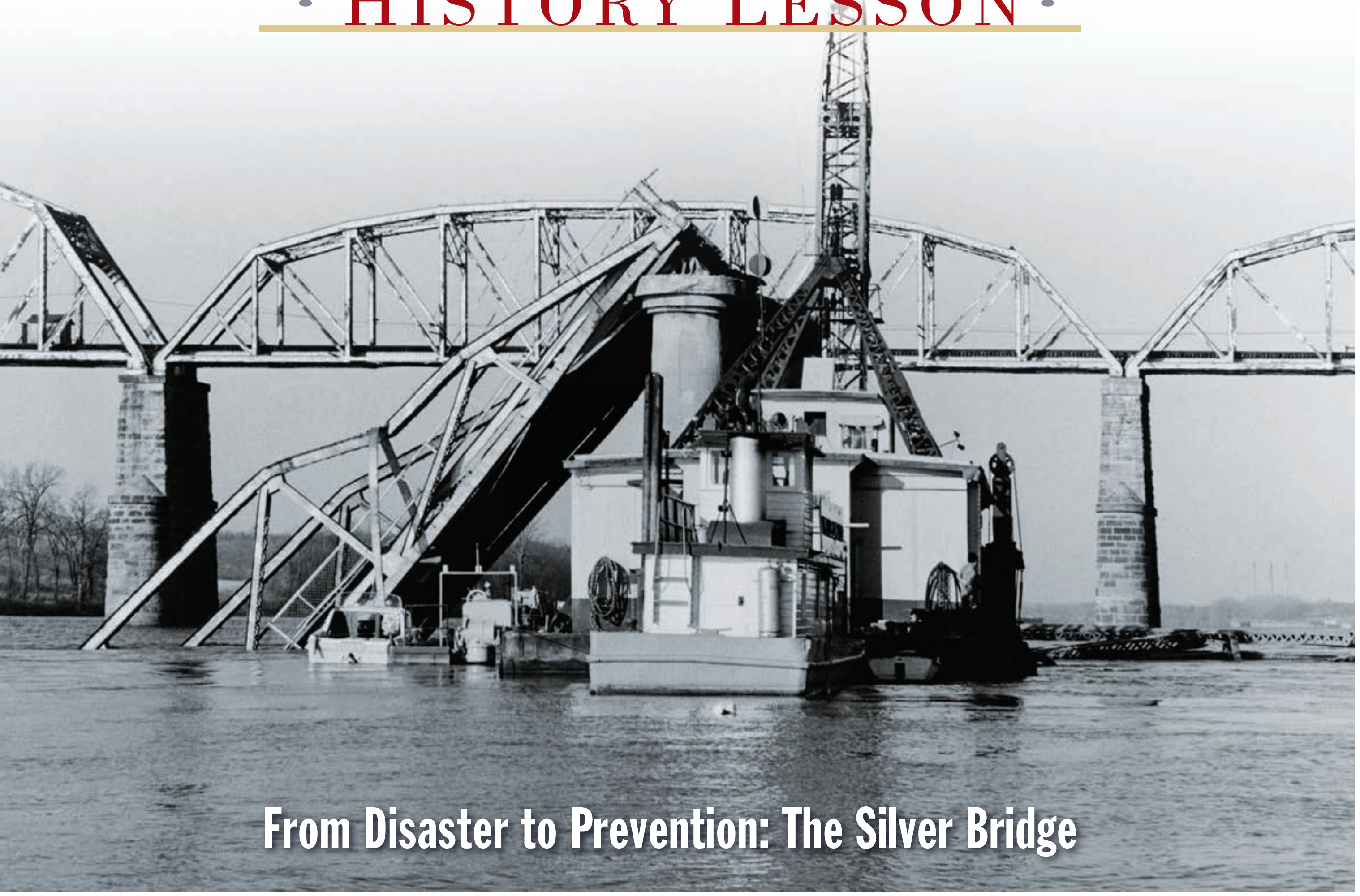

From Disaster to Prevention: The Silver Bridge

WEST VIRGINIA STATE ARCHIVES, MAURICE HAMILL COLLECTION, HERB CLAGG, PHOTOGRAPHER

THE 1967 COLLAPSE of the Silver Bridge, which connected West Virginia to Ohio, was simultaneously the most devastating vehicular bridge collapse in American history—killing 46 people—and the most important, because it led to the creation of a nationwide, standardized bridge inspection program. (Read "Bridge Inspections Come of Age," page 68.)

The 1967 collapse of the Silver Bridge killed 46 and led to the creation of a nationwide bridge inspection program.

The tiny communities of Point Pleasant, West Virginia, and Gallipolis, Ohio, straddle the Ohio River near the boundaries of Appalachia and the Midwest. The bridge was the brainchild of physician and surgeon Charles Holzer, who had practiced medicine in the region since 1909. Without a bridge across the river, getting to patients was difficult. According to *The Silver Bridge Disaster of 1967* (Stephan G. Bullard, Bridget J. Gromek, Martha Fout, Ruth Fout, and the Point Pleasant River Museum; Arcadia Publishing, Mount Pleasant, South Carolina, 2012), "some patients died waiting for help simply because the doctor could not reach them in time. After a particularly dangerous winter crossing, Dr. Holzer decided that action needed to be taken."

In the 1920s, Holzer organized community groups to spearhead a plan to build the bridge. Those community groups eventually merged into the West Virginia Ohio River Bridge Company.

An early design, by the Baltimore firm J.E. Greiner Company, called for a "familiar combination of steel-wire cables and a distinct stiffening truss," according to Henry Petroski, Ph.D., P.E., Dist.M.ASCE, the Aleksandar S. Vesic professor of civil engineering at Duke University, in his book *To Forgive Design: Understanding Failure* (Belknap Press of Harvard University Press, Cambridge, Massachusetts, 2012). But Holzer's company chose the U.S. Steel subsidiary American Bridge Company to build the bridge instead, and it proposed a novel and less expensive design. Rather than suspension cables, it would use chains of eyebars—each eyebar being 50 ft long, 1 ft wide, and 2 in. thick. The eyebars, Petroski noted, "would be linked together bicycle-chain style with steel pins to form the main part of the suspension system."

The suspension chains also doubled in some places as the "top chord of the trusses that stiffened the roadway, a system that had not previously been used in the United States," Petroski wrote. In all, 1,460 ft of common links served as the top chords of trusses and suspension chains.

"Each segment of suspended chain was composed of two parallel eyebars," Bullard et al. stated. "At every connection point, four eyebars converged and were linked together by a single pin."

Finally, the bridge would be the first in the country to use heat-treated steel, which had a strength that was unprecedented at the time: 120,000 psi. "Because chain links made of such steel could carry more load relative to their own weight," Petroski wrote, "the bridge itself would be a lighter and thus less costly structure."

Tracy W. Brown, P.E., the bridge engineer for District 1 of the West Virginia Department of Transportation, speculates that engineers at the time likely figured that "they had it covered with the high strength of those eyebars." The system was "so overdesigned," he says, that the engineers probably thought it "never will fail."

The bridge towers were not rigidly fixed on their piers, but rocked back and forth "in response to slight changes in cable pull," according to Petroski, which caused the bridge to sway some.

Construction of the bridge began in 1926; the crossing opened on May 30, 1928. Officially it was called the Point Pleasant Bridge, but it quickly became known by a more colorful name: the Silver Bridge, owing to the fact it was coated with aluminum paint.

Ten thousand people attended the Memorial Day opening, still the largest crowd ever assembled in Point Pleasant. Attended by political dignitaries from both states, the opening featured an airplane squad, automobile parade, and fireworks and was capped off with a dance.

The Silver Bridge was nearly 2,235 ft long, including a main span of 700 ft and two side spans of 380 ft each. Its suspension chains were composed of parallel eyebars made of heat-treated steel.

The bridge was nearly 2,235 ft long, including a main span of 700 ft and two side spans of 380 ft each. Most sources report that the bridge cost $1.2 million, though Bullard et al. cited a 1928 financial statement from American Bridge Company that put the cost at $900,000.

For decades the Silver Bridge was an economic boon to the communities along the river as well as a source of civic pride. In 1928, 685 vehicles crossed the bridge each day. By 1967, the year it collapsed, vehicle crossings had risen to 9,400.

In 1941, according to Bullard et al., the bridge was extensively renovated. Its original wooden plank roadway was widened and replaced by a steel grid filled with concrete. The bridge had been inspected in 1951, but according to Petroski, subsequent inspections were of "varying thoroughness." Brown says that bridge inspections in the state in those days were often conducted by people with other primary jobs. The inspections, often conducted from a distance with binoculars, did not focus on structural stability.

There's obviously no good time for a bridge to fail, but the Silver Bridge's collapse, on Friday, December 15, 1967, at 4:58 PM, was about the worst moment possible. The bridge was packed with end-of-the-workweek traffic, and Christmas was less than two weeks away, so many people were out shopping. The bridge went down just nine minutes before sunset, which made recovery efforts all the more difficult. As one witness put it in *The Silver Bridge Disaster*, the bridge "just dropped out of the sky."

Sixty-four people dropped with it. In all,

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Once the suspension chain was severed, the bridge was doomed.

46 died: 37 drowned and nine died from trauma. Survivors, ironically, were treated at a hospital that was named after Charles Holzer.

One survivor, Charlene Wood, saw the bridge collapse up close. Pregnant with twins, she had just driven onto the suspension span when she felt a strong shake. It was so severe that it stalled the motor in her car. She put her car in neutral and coasted back onto the approach. The bridge collapsed a moment later, leaving hers as the last car standing on the eastern approach. (The bridge approaches on either side did not fall.)

"It was like someone had lined up dominos in a row, and gave them a push," Wood later recounted in *The Silver Bridge Disaster*, "and they all came falling down and there was a great big splash of water. I could see car lights flashing as they were tumbling into the water. The car in front of me went in. Then there was silence."

Thirty-eight vehicles were on the bridge when it fell. Twenty-four fell into the river, seven fell onto the riverbank, and seven remained on the bridge approaches.

First responders and volunteers reached the disaster site quickly, but conditions were difficult. It was dark and cold—21 degrees F, with a water temperature in the low 40s. Nevertheless, people tried to help survivors trapped in cars and trucks, many upside down or on their sides. According to one witness mentioned in *The Silver Bridge Disaster*, "People were hanging on to flotsam from the tractor-trailers that had been on the bridge." Christmas presents floated in the water.

"Many victims never got out of their vehicles," wrote Bullard et al. "Some of those who did escape were injured and drowned before help could reach them."

Brown adds, "With all those environmental hurdles very soon after the collapse, only five survivors were pulled from the river, even though there was a quick response time."

The next morning, according to Bullard et al., "Only the piers, the approaches, and a small amount of twisted metal remained of the Silver Bridge." But there was a massive amount of debris on the Ohio side of the river.

Conditions for recovery divers continued to remain dangerous. Under the water was a maze of bridge wreckage, which had to be cut into smaller pieces before it could be removed. Fallen vehicles were pulled from the river by derrick boats and loaded onto coal barges. Many cars, because of debris falling on top of them, looked "like they had been impacted from a car crusher," says Brown. Survivors looked in vain for loved ones. Brown relates a story about one man who volunteered to help on the recovery boats a day after the collapse. Unbeknownst to his companions at the time, the man had lost his wife and child in the disaster and was looking for them. According to Bullard et al., one survivor, Margaret Cantrell, remembers "a deep, oppressive silence" that set in after the bridge fell. For the rest of her life, she had to have a radio or TV on, because silence reminded her of the collapse.

Crews recovered just about all the bridge elements from the river and laid them out in sequence on a 27-acre pasture on the Ohio side of the river. "It was one of the most significant incident recovery investigations ever performed," says Brown.

President Lyndon Johnson set up a task force to investigate why the bridge had collapsed, as well as to plan a new bridge and assess bridge safety across the country. Investigators with the National Transportation Safety Board considered a variety of reasons to explain the Silver Bridge disaster, including sabotage, tower failure, vehicle collision, scour, and wind failure. Inspectors eventually found the culprit—eyebar number 330, on the north side of the bridge, 50 ft west of the Ohio-side bridge tower. The collapse was due to a 1/8 in. cleavage fracture, which, says Brown, had "propagated due to stress corrosion and corrosion fatigue." It's an unimaginably small crack to have caused so much destruction. "You could put two of your thumbnails together and have an eighth of an inch," he says.

First responders had to contend with cold weather, limited visibility, and tons of bridge wreckage in their efforts to save people who had fallen from the bridge.

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While few traces of the bridge remained over the Ohio River, the bridge wreckage formed a massive debris field on the Ohio side of the river. Investigators were later able to organize the pieces to help determine why the bridge collapsed.

Once that eyebar broke, the change in the forces caused the adjacent eyebar to slip off the end of its connecting pin. Once the suspension chain was severed, the bridge was doomed. According to a 2009 report by the National Institute of Standards and Technology (archived at http://archive.is/oGn7), "The adjacent tower was subjected to an asymmetrical loading that caused it to rotate and allow the western span to twist in a northerly direction. This span crashed down on the western shore, folding over on top of the falling cars and trucks. Loaded by the whole weight of the center span, which had now become unsupported on its western end, the east tower fell westward into the river along with the center span. Finally, the west tower collapsed toward Point Pleasant and into the Ohio River."

The "double duty" of some of those eyebars—serving as both part of the top chord of the stiffening truss and as suspension members—probably didn't help matters. "If there had been a separate top chord for the stiffening truss," says Brown, "it might have been possible that the stiffening truss could have prevented, at least temporarily, a total collapse of the bridge."

But what had caused the crack? According to Petroski, John Bennett of the National Bureau of Standards, one of the inspectors, concluded that the rust-encrusted crack "had grown over a long period of time from some much smaller manufacturing imperfection. The mechanism by which it grew from an imperfection to a flaw was a combination of repeated concentrated forces and corrosion that assisted in the resultant crack's extension into the metal." Cars and trucks by 1967 had also grown significantly heavier than the vehicles the bridge was designed for in the 1920s.

Petroski continued that once the crack grew large enough, the load on the chain grew too strong for the link. "Spontaneous brittle fracture occurred on the side of the eye containing the crack. This shifted the entire load that the eyebar had carried to the other (unbroken) side of the eye and caused it to tear apart in a nonbrittle way."

The task force's final report, three years after the collapse, assigned no blame to the bridge designers; it noted that "stress corrosion and corrosion fatigue were not known to occur in the classes of bridge material used under conditions of exposure normally encountered in rural areas."

But Petroski pointed out that the design did have a flaw. "The failure was rooted in a design that inadvertently made inspection all but impossible and failure all but inevitable," he wrote. (And, as Bullard et al. noted, similar corrosion cracks were found on other eyebars.)

While the community grieved and inspectors investigated the collapse, the towns around the bridge had to determine how to get traffic moving again. The closest bridges were miles away. Ferries were launched by February 1968, but they were only a temporary fix. The bridge collapse was costing the local economy $1 million a month.

President Johnson had vowed that the federal government would replace the bridge within two years, and on December 15, 1969, the 1,950 ft Silver Memorial Bridge, built with a conventional cantilever design, opened 1.5 mi south of its predecessor. The old approaches to the Silver Bridge were eventually demolished in the 1970s, and a brickwork memorial was placed in downtown Point Pleasant.

While the Silver Memorial Bridge still stands, the more important legacy of the Silver Bridge collapse was the creation of the National Bridge Inspection Program, which modernized a previously scattershot approach to bridge inspection in which states had essentially been on their own to establish standards. A series of laws, beginning with the Federal-Aid Highway Act of 1968, which required an inventory of the federal highway system, began to put in place America's contemporary bridge inspection program.

Brown says that over the years the federal inspection program has allowed bridge inspectors in West Virginia to identify problems with some bridges that, left uninspected, might otherwise have collapsed.

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"[The] loss was tremendous, and everybody realizes that, but they didn't perish in vain," says Brown. "Hopefully [people] get a little bit of solace in the fact that some good came out of it."

—T.R. WITCHER

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