SEATTLE IS A CITY BLESSED by its proximity to the ocean, large lakes, rain forests, and mountains. But for transportation planners and engineers, that breathtaking setting has been more of a curse. How else to account for the formidable challenge engineers faced in the 1930s and 1940s in designing a highway and tunnel that would connect Seattle to the east—over a 200 ft deep lake and through a 260 ft tall ridge?

The solution was just as formidable: the largest floating bridge in the world—the first to be made of reinforced concrete—and the world’s largest-diameter soft-earth tunnels.

For years, Seattle leaders wanted to find a way to connect the growing communities east of Lake Washington—roughly 20 mi long and 4 mi wide—to Seattle and its enormous port. At a meeting of ASCE in 1921, Seattle civil engineer Homer More Hadley, who worked for the Seattle school district at the time, announced his idea for a series of concrete barges, joined end-to-end.

“The primary reason the floating bridge is the ideal choice for the lake is the depth of the lake and what lies on the bottom of the lake,” explains Nick Rodda, P.E., S.E., the floating bridge and special structures manager in the Bridge and Structures Office of the Washington State Department of Transportation (WSDOT). Lake Washington varies from about 200 to 250 ft in depth and is roughly 200 ft deep at the center of the bridge span, which now carries Interstate 90. “That depth…makes caisson construction really challenging,” he says.

Additionally, the bottom of the lake is basically volcanic ash. “That’s another 200 ft deep, and it’s really soft stuff,” Rodda says. “It’s really not load-bearing material.”

To build a tower for a suspension bridge, for example, on such a soft surface would require an enormous and expensive foundation. “When you start looking at that,” says Rodda, “the floating bridge becomes a much more cost-effective solution.”

Pontoon bridges have existed since ancient times; most were temporary, buoyant structures made from timber and designed to transport military personnel over water. But despite the soundness of his idea, Hadley found no backing for his plan. In fact, potential investors considered him a “screwball,” according to a 1993 Historic American Engineering Record report written by historian William Michael Lawrence. It wasn’t until 1937 that Lacey V. Murrow, director of the newly established Washington Department of Highways, reconsidered Hadley’s idea and ultimately threw his support behind it.

Murrow and his consultants concluded that a pontoon bridge made sense because the lake had “only a slight variation of its level, no current, no ice, no drift,” and limited chances of experiencing waves, according to Lawrence. They considered steel or wood pontoons but concluded that properly anchored reinforced-concrete pontoons would not only be the least expensive but also more stable due to their greater mass.

Groundbreaking for the bridge, later named for Murrow, took place in December 1938, and the last pontoon was
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launched in April 1940. The Lacey V. Murrow Memorial Bridge consisted of 25 mostly hollow reinforced-concrete pontoons, 59 ft wide and between 117 ft and 378 ft in length. The total length of the span was 6,620 ft. Additionally, at each end of the bridge, transition spans and transition pontoons connected the floating bridge with its land approaches, which were supported by trusses on piers.

To keep grade changes to a minimum, the transition pontoons used a system that could regulate water ballast via pumps and valves, keeping the roadway level and the transition onto the floating bridge consistent as the lake level rose or fell.

The pontoons were built in two graving docks on Harbor Island south of downtown Seattle, then towed to Lake Washington. The pontoons were bolted together and secured to anchors embeded at the bottom of the lake, according to Lawrence. Radio transponders helped workers triangulate the position of the anchors and the pontoons.

Three kinds of anchors were used to stabilize the pontoon bridge. Forty-one V-shaped type A anchors, constructed from reinforced concrete and weighing 65 tons each, were buried into the soft clay below the lake with help from 16 attached jet hoses. These could pump 2,500 gal. of water per minute at 200 lb of pressure. For portions of the lake bottom that were too hard for jetting, engineers used four type B anchors, which were essentially huge concrete boxes that were open at the top. These anchors were filled with water and 85 tons of rubble, then sunk and filled with an additional 400 tons of gravel. Lastly, 19 type C anchors were used in shallow water. These anchors consisted of two steel piles, spaced 20 ft apart and braced by a turnbuckle.

According to Lawrence, on the day the first pontoon was anchored to the lake bottom, one witness described the anchors as being as “big as a small house.”

The 2.75 in. anchor cables were, according to Lawrence, connected to the pontoon through a watertight hawse. They then “passed over a cast-steel saddle set in the concrete, and then proceeded to a large steel-jacking casting. This casting could move back and forth in a channel frame set in a slot in a transverse wall.” Two 25-ton hydraulic systems could keep the cables in tension as the lake rose and fell.

The Murrow Bridge featured another engineering milestone: a sliding draw span that was capable of moving to create a 200 ft wide channel for boat passage at the south end of the lake. According to Lawrence, this draw pontoon moved back and forth in a slot between flanking guide pontoons, each 30 ft wide and 15.5 ft deep. The four-lane roadway on the bridge would split at this “bulge,” as it was later known, diverging onto the guide pontoons and then reuniting on the draw pontoon.

Two 75 hp electric motors could, as Rodda describes it, turn reduction gearboxes, which turned a set of gears, which rolled in a track to retract the draw pontoon. Lawrence noted that the motors could open or close the 10 million lb draw pontoon in just 90 seconds.

Though it was an engineering achievement, motorists still had to “negotiate a sharp curve at high speed,” Lawrence explained. So the draw pontoon “became an accident-prone area and the bridge became notorious for sometimes fatal mishaps. The Washington Department of Highways replaced the bulge with straight pontoons in 1981.”

And the Murrow Bridge was only half the solution; it could only cross Lake Washington. From there, the roadway confronted Mount Baker Ridge, which rises 260 ft above Lake Washington. Once again, Hadley had figured out what
to do. In the 1920s he had walked Mount Baker Ridge in search of the narrowest spot in the ridge, which he found along Atlantic Street. According to Lawrence, who quoted a Seattle Times article from 1964, Hadley wrote in his journal that he “felt like Balboa when I discovered this place.”

But Mount Baker Ridge wasn’t a rocky massif. Instead it was composed of a “tight, heavy blue clay of glacial origin, with a 28 to 35 percent water content,” wrote building historian Jonathan Clarke in a Historic American Engineering Record report from 1993. Its consistency ranged from a “fairly dry, lumpy structure to a wet, slippery material,” he wrote.

As Clarke described it, tunneling through hard rock “is usually performed using a semi-circular arch section with vertical side walls.” However, when “cohesionless” materials such as clay are involved, tunnels are often bored in a circular section to better resist pressure from all sides. Engineers split the difference and selected a horseshoe section, which represented a compromise “between the straight sided semi-circular arch, and the circular section,” Clarke wrote. The horseshoe was strong, and its flat bottom offered the crew more room to work.

The Mount Baker Ridge Tunnel is actually two identical concrete-lined tunnels, 1,466 ft long and spaced 60 ft apart from center to center. Each tunnel carried a 24 ft wide roadway and a 3 ft wide sidewalk.

Both tunnels were driven simultaneously. The clay was bored with compressed-air tools and electric shovels; no drills or explosives were needed. According to Clarke, an initial crown heading with a 9 by 8 ft cross section was hand-driven by pneumatic air spades to make the roof safe before the bulk of the excavation began. This tunnel was supported at 6 ft intervals by 10 by 10 in. timber sets, he wrote. Two wall-plate drifts of roughly the same section were then driven in on either side of the floor of the tunnel, following the crown drifts. “When this was completed,” he wrote, “permanent [12 by 16 in.] timber-wall plates were installed” to provide support for the soft material.

According to Clarke, once the initial arch timbering was placed at the tunnel’s entrance, the hill directly above the portal began to slump, “pushing the timbering out of line and downwards so that there was insufficient clearance.” Engineers had to place timber across the mouth of the tunnel and brace this with 18 by 18 in. timbers supported by concrete anchors resting on the ground some 40 ft ahead of the tunnel, he wrote.

Despite their ingenuity, both the Murrow Bridge and the Mount Baker Ridge Tunnel faded into the background somewhat. Motorists,
gliding across the lake, didn’t feel like they were on a bridge at all. And tunnels tend to be inconspicuous by nature. But in the late 1930s artist James FitzGerald and the state architectural engineer, Lloyd Lovegren, crafted a three-tiered, circular art deco entrance portal on the east side of the tunnels. Three low-relief panels depict cultural motifs, including a stylized sperm whale and totem-like iconography of the region’s native people.

Over the years, Seattle added more floating bridges to cross its challenging topography. Once the decision was made to carry the interstate highway system across Lake Washington, the original Murrow Bridge had to be modernized. It had featured four lanes, with the interior lanes capable of being reversed so that three could flow in one direction and one could flow in the other, as needed. “There was a signal on the bridge that would tell you which way the [reversible] lane was going, but no barrier, so there were lots of head-on accidents,” says Rodda.

This failed to meet interstate standards, and as the city grew, the lanes lacked sufficient capacity. So highway officials planned for a new bridge that would create three lanes of traffic plus two barrier-separated, reversible express lanes. This new bridge, at first called the Third Lake Washington Bridge, connected to a stacked tunnel through Mount Baker Ridge, the westbound lanes riding above the express lanes and then “unstacking” on the west side of the ridge. The new bridge opened in 1989.

The Murrow Bridge was then converted into three lanes of eastbound traffic, away from Seattle, and widened to accommodate safety shoulders and larger lane widths. The plan was to use a high-pressure hydrodemolition system to remove the sidewalks and barriers on each side, then build cantilevers off the edges of the pontoons to create a wider roadway. However, state regulations prohibited the water used for the job from being discharged into the lake. So transportation officials decided to store the water in the hollow pontoons themselves until it could be pumped out to a truck and removed from the site. To do this, openings were created along the sides of the pontoon.

But a storm rolled through, and the windy and rainy conditions filled the open pontoons with too much water, sinking the bridge on November 25, 1990. No one was injured, but as a result of the sinking, the state issued tougher rules around bridge work to prevent a repeat. Floating bridge work before 1990 typically occurred during the Pacific Northwest’s stormy season, from October through the first of April, Rodda explains. Since then, the state generally doesn’t allow work on the region’s floating bridges to be conducted during those months. Hatches can’t be left open after working hours. No water can ever be stored in pontoons. And the pontoon walls cannot be breached. “The sinking in 1990 was a disaster for the state and we learned a lot from that episode, and we’ve tried really hard not to repeat those mistakes,” Rodda says.

A new Murrow Bridge opened in September 1993. That same year the Third Lake Washington Bridge was renamed to honor Hadley, who died in 1967. The original bridge and tunnels were designated national historic civil engineering landmarks in ASCE’s Historic Civil Engineering Landmark Program in 2008.

Today, the replacement Murrow Bridge and the Hadley Bridge each carry an average of 142,000 vehicles a day. Sound Transit, Seattle’s regional transit agency, is converting Hadley’s express lanes to light-rail. The I-90 bridges have a consistent maintenance crew, comprising 10 full-time employees who perform a host of preventative maintenance and preservation work on both bridges in addition to adjusting the cable tensions as needed.

The Murrow Bridge and Mount Baker Ridge Tunnel are testaments to the can-do spirit that has fueled Seattle’s growth and prosperity. “If you read through the history of it, a lot of people questioned whether it was possible and a good idea,” Rodda says. “Its legacy, its meaning to this region, is that it was possible. It worked.”

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