.crossing grand canyon: the kaibab trail suspension bridge

jonnathan upchurch, p.e., ph.d., p.t.o.e., f.asce, made his first visit to the grand canyon in 1961 when he was in middle school. he and his parents attempted to hike to the bottom and back to the rim on a hot day in june. “my mother and i didn’t make it all the way to the bottom,” he says. “dad made it. we were naive flatlanders from illinois who didn’t understand what we were getting into.”

despite that inauspicious start, upchurch remained closely connected to the canyon throughout his life. he took frequent hikes on subsequent vacations and while living in the phoenix area. from 2006 to 2012 he lived on the south rim, part of the time working as a national park service (nps) transportation scholar. he estimates he has hiked roughly 2,400 mi in the canyon.

of course, moon visitors see only the sprawling view from the top. down below, where trees give way after the first 1,000 ft and are replaced by cacti and yuccas, it’s “also awesome,” he says. “awesome in terms of the scenery, the scale, the environment, all the things you are sensing. i think it’s absolutely more impressive (than the rim).”

and at the bottom of the canyon lies one of few projects within a national park to be named a national historic civil engineering landmark in asce’s historic civil engineering landmark program. the 440 ft, single-span kaibab trail suspension bridge, completed in 1928, crossed the colorado river using four 550 ft long suspension cables. it helped launch tourism in one of the country’s most visited national parks, but the most remarkable thing about the bridge is that it was able to be built at all in such an inaccessible location.

the bridge is located close to the junction of the bright angel creek and the colorado river. near the bridge there’s an inner gorge cut through the granite. “once you get down in that inner gorge, you can’t see the rim,” upchurch explains. while the area around the creek is more open, with a floodplain a few hundred yards wide at the canyon base, upchurch says, “at the bridge itself, the canyon is very narrow. the river basically extends from the cliffs on one side to the cliffs on the other.”

before 1907, the only way to cross the river in this part of the 277 mi long grand canyon was on a boat, according to historic civil engineering landmark nomination for the kaibab trail suspension bridge grand canyon national park, a paper written by upchurch for asce’s arizona section in 2016. it was a dangerous crossing that cost many travelers their lives. in 1907, outdoorsman david rust built a cableway across the river at the location of the current bridge, according to upchurch. (rust also built the first trail from the north rim to the canyon floor.)

the cableway “consisted of one main cable with a six-foot by ten-foot by six-and-a-half-foot-high steel cage suspended beneath,” upchurch says. the first two passengers were women, rose evans and lida biveal, who had hiked down from the south rim. in 1913, former u.s. president theodore roosevelt used the cableway to cross the river.

rust’s work helped tourism at the canyon boom in the 1910s. the cableway joined two trails that allowed tourists to descend and ascend the canyon on opposite sides. rust also opened a camp for travelers, now known as phantom ranch. the cableway, upchurch wrote, “lasted until 1917 when the cable cage was damaged in a colorado river flood.” grand canyon national park was established in 1919, and soon after, engineers with the nps began planning a replacement for rust’s cableway.

the first bridge to cross the river was completed in 1920, according to a historic american engineering record (haer) report on the bridge prepared and submitted by donald c. jackson and jeff p. yeary in 1984, which included papers written in 1929 by, respectively, ward p. webber, the bridge’s design engineer, and john h. lawrence, its construction supervisor. this early bridge “afforded the only safe means of crossing the river in a stretch of several hundred miles,” webber wrote. “the completion of this bridge made it possible to travel by saddle horse from the south rim to the north rim for the first time in the history of the park.”

during the 1920s, according to webber, the nps constructed the kaibab trail “to provide a more direct route across the canyon. the site of the original river crossing was retained as it was admirably situated but the first bridge was too light and elastic to accommodate the increased traffic safely and a stronger and more rigid structure became necessary.”

additionally, the bridge could only support the weight of one mule at a time, which made crossing with larger groups time-consuming. and its lack of wind bracing made it vulnerable to heavy gusts. on april 30, 1923, a wind storm heavily damaged the bridge, upchurch wrote, breaking an anchor cable and 33 hanger rods. additionally, the bridge floor buckled and broke in two places.

with more tourists visiting the canyon, nps engineers decided that a new bridge on the same alignment would be required, and it would also have to be able to withstand fierce winds.

but first engineers had to contend with how to access the site. access was as difficult as any project ever considered for asce’s landmark program. “transporting materials to the construction site via the colorado river was completely impractical,” upchurch wrote. “the nearest upstream point where the river could be accessed was 87 miles away. there were several world-class rapids between that access point and the bridge site.”

led by webber, the nps considered building a cableway but settled on the most practical, though laborious, solution: the building components would be packed on a mule.
Havasupai tribe, whose members had lived in a remote village at the base of the canyon for more than 1,000 years, to bring down the suspension cables from the South Rim.

"Each man’s share of the load was approximately 50 pounds," wrote Lawrence. "The round trip was made in two days." Upchurch describes the line of men as winding down the trail like a centipede, hoisting the cables the whole way.

Engineers selected a Warren truss for the bridge’s design because it contains few main components and could be "interchanged between panels," Webber wrote. This made storing the steel easier on such a tight site.

To guard against the heavy winds like those that debilitated the 1920 bridge, engineers took special care to provide sufficient wind bracing. Webber wrote, "Although the stiffening truss is constructed as a continuous structure rigidly riveted together, the narrow width in comparison to its length tends toward elasticity," he wrote. "The necessary lateral strength is provided by two wind cables, one on each side, which are connected to the trusses by wind guys similar to vertical hangers."

The wind cables were positioned at a 26-degree angle downward from the bridge deck to protect against excess uplift. The wind cables, like the suspension cables, also had to be transported in long lengths. The initial cable was about 900 ft long and was cut in half at Yaki Point on the South Rim. Then the two cables were slided to the bridge site on a "go-devil" sled (a simple, horse-drawn carrier) that Lawrence designed. This method showed considerable saving in cost over the method used in transporting the main cables," Lawrence wrote. But the method couldn’t be used for the main cables because it would have taken more than twice as long.

"The south upstream wind cable anchorage was quite difficult to place," he continued. "It was necessary for the jackhammer operator to hang in a sling from two ropes one hundred and twenty five feet below where the rope was secured and with a seventy foot sheet wall to the river below him."

The new bridge was built roughly 16 ft higher than the old one, which "required the construction of new bridge approaches in the sheer canyon walls for the trail," Upchurch wrote. "A 105-ft long tunnel was built on the south end, which avoided rock overhanging the trail and the danger of falling rock, allowed for a straight approach... and eliminated the danger of undermining the bridge cable [anchorages]."

Construction equipment, including two Ingersoll Rand air compressors, were brought in from a U.S. Forest Service warehouse in San Francisco. "The compressors were so ineffective that the danger of undermining the bridge cable [anchorages]." Lawrence. "This slowed up the work considerably, there being at times hardly enough air to run even the one drill."

In all, the bridge weighed 108 tons—each cable weighed 1.16 tons, according to Webber. The length of the bridge stiffening truss was 440 ft, and the loading was 380 lb per linear ft of bridge per cable, giving the bridge a maximum tensile stress of 103.8 tons per cable. "The entire weight of the bridge together with the live load is supported by the main cables and anchorages," Webber wrote. The weight of the stiffening truss is supported "by the cable and is called upon only to resist deformation caused by an unbalanced live loading. The maximum stress from this condition arises when only one half of the truss is covered with the full load."

"I think the other thing that’s remarkable is how quickly this bridge was authorized and built," says Upchurch. He explains that the superintendent of Grand Canyon National Park at the time, Miner R. Tillotson, wrote to the chief engineer of the NPS, Frank Kittredge, in early December 1927, proposing the bridge. By early January 1928 the NPS had allocated $50,000. By mid-February, the NPS had requested bids, and construction began in early March. No fewer than six civil engineers were involved with designing and building the bridge.

The work was completed by early August, despite treacherous heat in the summer months that contributed to a 300 percent rate of turnover in the labor force. (Getting workers who needed medical attention out of the canyon was difficult; they had to be put on a mule.)

The Kaibab Trail Suspension Bridge remains a fundamental link in the only cross-canyon trail connecting the North and South Rims and is crossed more than 100,000 times each year, Upchurch wrote. It also influenced the design of the Verde River Sheep Bridge, which was built across the Verde River in Arizona primarily to allow sheep to be driven between grazing sites and was completed in 1944.

The Kaibab Trail Suspension Bridge, which cost all of $35,473.52, was named to ASCE’s Historic Civil Engineering Landmark Program in 2017, and at press time, the bridge was scheduled to be dedicated on February 23. "The dedication of the Kaibab Trail Suspension Bridge includes many stories—stories of history, civil engineering ingenuity, the development of Grand Canyon National Park, and park visitors who have, for over 90 years, used the bridge to explore and experience the Grand Canyon," Upchurch says. "I’ve now successfully hiked to the canyon bottom many times. Knowing that the bridge has been designated as a national Historic Civil Engineering Landmark brings all those stories together for me.”—T.R. WITCHER

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