CONCRETE BRIDGE PRESERVATION
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# When Concrete Isn't Concrete: Preserving the Dry Canyon Bridge

by Rebecca Burrow, Oregon Department of Transportation

In 2017, nearly a century after it was constructed, the Dry Canyon Bridge on the scenic Historic Columbia River Highway underwent its first major rehabilitation, which included repairs to low-strength concrete, realkalization of the superstructure, application of a cementitious render, and an experimental deck overlay. With the completion of these repairs, it is expected that the bridge will have another 100 years of service life under the Oregon sun.

## Concrete Mysteries

Constructed over a deep canyon in the basalt walls of the Columbia River Gorge, the Dry Canyon Bridge consists of a single-span 75-ft-long reinforced concrete deck arch with two hidden slab spans making up the approaches. Because bid prices for the original 1920–1921 construction project were high, the engineers chose to use state maintenance workers for construction. Their lack of bridge construction experience led to some quality issues but also resulted in a wealth of records beyond the usual design documents. Of historical interest, these records include details on the construction camp, such as food orders. More importantly for engineers, they include critical documentation of the construction materials and material tests.

The bridge has remained on a low-volume road, is in a dry climate, and has required little use of deicing salts. These beneficial conditions significantly delayed deterioration until around 2015, when the bridge inspector started noticing active spalling of the concrete.

Initially, a simple bridge preservation project was planned. However, during preliminary design on the preservation project, closer examination of the arch revealed that the deterioration was much more significant than originally thought, and it could not be explained by the standard mechanisms of concrete breakdown, chloride intrusion, and freeze-thaw cycles. Following that discovery, an examination of the original records showed that the concrete used to construct the bridge was abnormal, and tests of the original concrete indicated that it had a compressive strength well below normal. Instead of the specified 2200-psi compressive strength, tests came back as low as 730 psi.

The below-normal strength was likely due to a bad batch of cement with added lime, but no additional testing was done at the time of construction. Instead, the engineer, Conde B.

The Dry Canyon Bridge was constructed over the winter of 1920–1921, before highway construction had reached this remote location in the Columbia River Gorge. The timber for the falsework and formwork was brought in by mule train. Photo: Oregon Department of Transportation Bridge Engineering Section.

Although concrete spalling and corrosion of the reinforcement were widespread on the concrete arch, the reinforcement maintained its integrity, leading to the decision to rehabilitate rather than replace the bridge. Photo: Rebecca Burrow.

The realkalization system involved wrapping the bridge with insulation matting to store the electrolyte, folding titanium mesh over that, and containing the system with a plastic covering. Photo: Rebecca Burrow.

McCullough, verified that the arch would be able to carry the expected loading with this lower-strength concrete, and construction continued.

Although concerning, this low strength did not explain the sudden spalling nearly 100 years after construction. To solve that mystery, a concrete core was sent for petrographic examination. The results showed that the concrete had undergone carbonation at least 2 in. deep, and later tests found that carbonation in some locations was more than 3 in. deep. Carbonation of concrete is a chemical reaction whereby the calcium hydroxide ($Ca(OH)_2$) in the concrete reacts with atmospheric carbon dioxide to form the more brittle calcium carbonate ($CaCO_3$). In reinforced concrete, this means that embedded steel is no longer protected from corrosion by a high-pH environment.

Though the process of carbonation occurs in all concrete, it is typically slow enough that other deterioration mechanisms happen first. However, in the case of the Dry Canyon Bridge, the low-strength concrete was more porous, allowing the reaction to occur deeper into the concrete. Once the reaction reached the reinforcing steel, which typically had 2 in. of cover, the steel began to corrode, resulting in widespread spalling. There are three long-term solutions to this problem: (a) replace the bridge; (b) remove and replace all of the carbonated concrete; or (c) realkalization.

Spalling of the concrete was widespread on the arch, but the underlying reinforcement still had sufficient integrity despite surface corrosion. This was a factor in the decision to rehabilitate rather than replace the bridge

## Realkalization

Realkalization is an electrochemical treatment where an electric field is created between the reinforcing bars and an anode mesh that is temporarily applied on the surface of the concrete. The anode is surrounded by an alkaline electrolyte, typically sodium or potassium carbonate, which is pulled into the concrete surface by the electrical current. Over the course of a week, the process reverses the carbonation, re-passivates the steel, and densifies the concrete, slowing the carbonation process for the future.

A life-cycle cost analysis determined that realkalization was the preferred alternative for the Dry Canyon Bridge. As a first step in the process, the already spalled concrete had to be patched. Given the extremely soft concrete, the decision was made to use masonry mortar, Type S, as the patch material for compatibility. Next, the realkalization system was applied, which involved wrapping the bridge with insulation matting to store the electrolyte, folding titanium mesh over that, and containing the system with a plastic covering. Gravity flow was used to supply the

### CONDE B. MCCULLOUGH

*In 1919, Conde Balcom McCullough (1887–1946) became the state bridge engineer for Oregon, where he was responsible for the design of many beautiful and innovative bridges. He is best known for his large coastal bridges, but many of his smaller bridges, such as the Dry Canyon Arch, are also noteworthy for their economical yet aesthetically pleasing designs. Prior to joining the highway department, McCullough was the head of the engineering department at the Oregon Agricultural College (now Oregon State University); once he left, he recruited many students from there. These former students often became the resident engineers at his construction projects.*

After being coated with a cementitious render and silane sealer, the rehabilitated bridge looks almost brand new. Photo: Rebecca Burrow.

electrolyte to the entire bridge. Because of the historic and scenic requirements of the site, the bridge was also coated with a cementitious render and silane sealer following the realkalization to restore its appearance. Overall, the work on the bridge took three months and never closed the roadway for longer than 20 minutes.



## Another Surprise

After the realkalization work, the bridge had one more surprise in store for the project team. The intended scope of work had included removing the asphalt pavement, installing a waterproof membrane, and repaving. When the asphalt was removed, it became clear that some previous paving project had addressed grade issues at the site by grinding concrete off the bridge deck. The supposedly 12-in.-thick concrete approach slabs were actually less than 10 in. thick. Left in that condition, the bridge would have had to be restricted to small vehicles.

Instead, the decision was made to add a structural overlay to the bridge. Given the width of the structure and the length of the detour, it was not considered feasible to use Oregon's traditional microsilica overlay, which would have required closing the roadway for up to seven days. As an alternative, the contractor proposed the use of a latex-modified concrete, which had not been used previously in Oregon. This method allowed the entire overlay to be constructed in a single day. Despite some shrinkage cracks, the bridge is now able to carry normal legal loads with no restrictions.

## Conclusion

With the overlay completed and the site cleaned up, the rehabilitation project was complete. What had seemed to be a simple preservation project had turned into much more, with new methods and materials helping to successfully restore the bridge. The result is a beautiful bridge that will complement its scenic location for generations to come.

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