New models assess bridge support repairs after earthquakes

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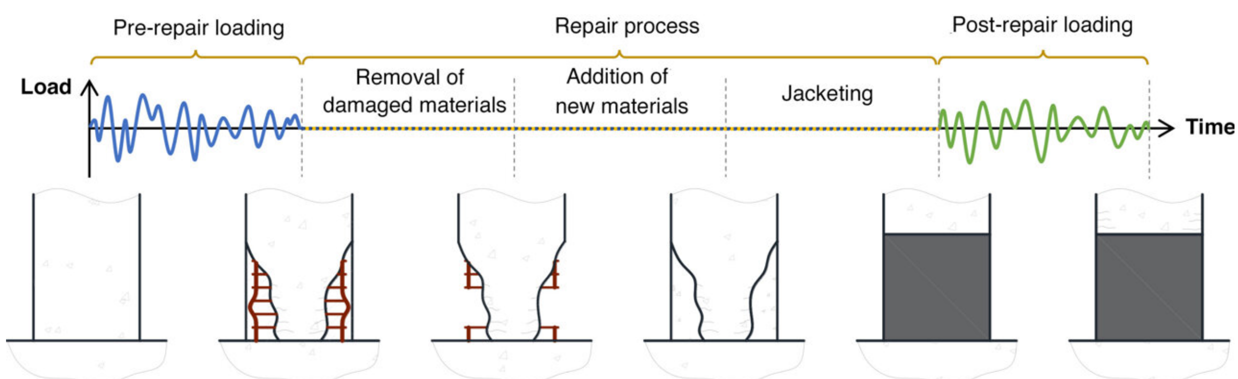

Civil engineers at Rice University and Texas A&M have developed a computational modeling strategy to plan repairs to damaged reinforced concrete columns. This illustration shows the sequence of earthquake damage and repair involved in restoring columns to their original strength. Credit: Mohammad Salehi/Rice University

Steel-reinforced concrete columns that support many of the world's bridges are designed to withstand earthquakes, but always require inspection and often repair once the shaking is over.

These repairs usually involve replacing loose concrete and fractured steel bars and adding extra materials around the damaged area to further strengthen it against future loads.

Engineers at Rice University's George R. Brown School of Engineering and Texas A&M University have developed an innovative computational modeling strategy to make planning these repairs more effective.

The study by Rice postdoctoral research associate Mohammad Salehi and civil and environmental engineers Reginald DesRoches of Rice and Petros Sideris of Texas A&M appears in the journal Engineering Structures. DesRoches is also the current provost and the incoming president of Rice.

"When we design bridges and other structures for earthquakes, the goal is collapse prevention," DesRoches said. "But particularly in larger earthquakes, we fully expect them to be damaged. In this study, we show analytically that those damages can be repaired in a way that the original—or close to the original—performance can be achieved."

Their models simulate how columns are likely to respond globally (in terms of base shear and lateral displacement) and locally (with stress and strain) in future earthquakes when using various repair methods.

The models also predict the effects of slipping and buckling of reinforcement bars on the columns' strength and ductility before and after repair.

The models will be made freely available through the open-source structural analysis software OpenSees to help engineers understand what types of repairs are preferable, Salehi said.

"What we mainly care about is life safety, of course, and we know that after a strong earthquake, we are going to see some level of damage to the structure," he said. "If a column is severely damaged, it might need to be replaced, but that can be prohibitively expensive. Our computer models can help engineers determine whether the column can be repaired in a cost- and performance-effective way."

The concrete and steel in reinforced columns are represented in the models by "fiber" elements. The models predict how they will respond to arbitrary loading considering the nonlinear stress-strain behaviors of columns and repair materials.

After initial loading to simulate a certain level of damage, Salehi said the models allow engineers to manipulate the model's fibers and analyze the performance of repaired columns under seismic loads.

He said the bar slip and buckling modeling tools, unique to the software, were validated against existing experimental data. Salehi also validated the overall modeling strategy using data from tests on real reinforced concrete bridge columns before and after various repair methods, including concrete and carbon fiber-reinforced polymer jacketing.

DesRoches is also chair of the National Institute of Standards and Technology (NIST) National Construction Safety Team (NCST) Advisory Committee, formed in 2002 to investigate building failures. Although the new study focuses on seismically damaged bridge columns, he said the tools could also be used to evaluate the repair of any structural elements.

"We're seeing more and more that existing infrastructure is deteriorating due to corrosion and other causes," DesRoches said. "So this general methodology can be applied in terms of understanding how repairs can restore and improve the performance of deteriorating structures, too."

More information: Mohammad Salehi et al, Numerical modeling of repaired reinforced concrete bridge columns, *Engineering Structures* (2022). DOI: 10.1016/j.engstruct.2021.113801

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