DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Confinement Effects of Hollow Bridge Columns

Modifications to confinement models improves the accuracy of seismic design

Seismic

FEBRUARY 2015

Project Title:
Understanding the Confined Concrete Behavior on the Response of Hollow Bridge Columns

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WHAT IS THE NEED?

In seismic design practice, hollow concrete columns offer unique advantages for bridge construction, especially with tall piers, because of reduced seismic mass, efficient use of materials, and greater strength-to-mass and stiffness-to-mass ratios when compared to solid concrete columns. The reduced seismic mass can improve the overall structural behavior due to the decrease in inertia forces generated during an earthquake. The decreased inertia force makes the column design efficient and contributes to reducing the overall structural cost. However, the behavior of confined concrete in hollow concrete is not well understood, resulting in conflicting findings.
A systematic investigation on the confined concrete behavior in hollow concrete columns has not been undertaken. Instead, the confinement models developed for solid concrete sections have been used.

WHAT WAS OUR GOAL?

The goal was to understand the confinement effects in hollow concrete columns and seismic behavior and how to design and reinforce them.

WHAT DID WE DO?

Caltrans, in partnership with the Iowa State University Department of Civil, Construction and Environmental Engineering, investigated the confined concrete behavior in hollow concrete columns using small-scale experimental and detailed analytical studies. The researchers evaluated the flexural behavior of hollow concrete columns when confined with one or two layers of reinforcement. They examined the applicability of current confined concrete models and subjected 16 small-scale columns to a combination of axial and lateral loads, with the section shape, wall thickness, axial load ratio, and loading type as the main variables. The researchers proposed preliminary seismic design guidelines and provided an example.

WHAT WAS THE OUTCOME?

Based on the results of the analytical and experimental investigations, the column with two layers of confinement reinforcement connected with cross ties is the most effective at confining the concrete wall. However, the layers should not be equal in quantities, as assumed in the past. Additional longitudinal reinforcing bars are also needed closer to the inner concrete wall surface. This detail is cumbersome and difficult to construct, making it more labor-intensive and costly.

A hollow concrete column confined with a single layer could be designed to achieve limited displacement ductility. The inside concrete wall is not confined, while the concrete near the outside face experiences reduced confining pressure from the outer layer of reinforcement compared to solid columns. To address the reduced confinement effectiveness, the researchers proposed a modification factor to a widely used confined concrete model in current seismic design practice, expressed as a function of wall thickness-to-section diameter ratio for circular sections and is conservatively defined as a constant for square sections.

Based on small scale tests, the experimental study indicated that hollow concrete columns experience much more shear deformation compared to solid columns. Therefore, the researchers suggest considering the shear component carefully when designing the columns to accurately define member displacement and ductility. Lastly, further large-scale experimentation is needed to validate the performance of square hollow columns with a single reinforcement layer and the shear capacity of hollow columns. This additional work would provide more efficient design guidance for hollow columns.

WHAT IS THE BENEFIT?

The experiments revealed that the confinement effects in hollow concrete columns differ from assumptions made in the past. Engineers have a good understanding of the lateral load response of hollow columns. The proposed modified model for hollow concrete columns confined with a single layer of transverse reinforcement improves the accuracy of seismic design and analyses. Bridge designers now have preliminary design guidance to aid in the design of hollow columns.

LEARN MORE

To view the complete report:
www.dot.ca.gov/research/researchreports/reports/2015/CA15-2264_FinalReport.pdf

IMAGES

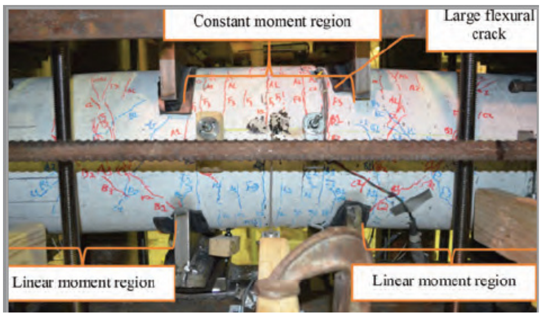

Figure 1: Close-up of test region

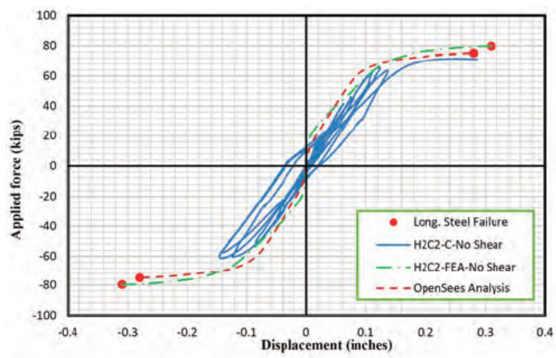

Figure 2: Measured force-displacement response of specimen H2C2-C with shear deformation removed compared to analytical response