DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Seismic

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Project Title:
Required Embedment Length of Column Reinforcement Extended into Type II Shafts

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Task Manager:
Charles Sikorsky
Research Program Manager
charles.sikorsky@dot.ca.gov

Length Requirements for Embedded Bridge Column Shafts

New data shows that bar lengths can be reduced, saving construction costs

WHAT IS THE NEED?

Cast-in-drilled-hole piles are frequently used to support reinforced concrete bridge columns because they have smaller footprints than spread footings or pile caps. Using enlarged pile shafts (Type II) also provides more tolerance in pile positioning and prevents the formation of below-surface plastic hinges in the piles in the event of a severe earthquake, making it easier to perform post-earthquake inspections. The Caltrans Seismic Design Criteria (SDC) specifications require that the diameter of the Type II shaft be at least 2 feet larger than the cross-section dimension of the column. Hence, the column reinforcement extended into the pile shaft forms a non-contact splice with the shaft reinforcement. Because information on the performance of these splices is lacking, the SDC specification for the embedment length is rather conservative, especially for large-diameter columns (No. 14 and 18), complicating construction and increasing costs. Experimental data was needed to assess whether the minimum embedment length could be reduced. In addition, the development length requirements for large-diameter bars in the American Association of State Highway and Transportation Officials (AASHTO) bridge design specifications are largely based on experimental data obtained from smaller bars. Because of a lack of data, tensile lap splices are not permitted for bars larger than No. 11.

WHAT WAS OUR GOAL?

The goal was to determine the minimum embedment length required for column longitudinal reinforcement extended into Type II shafts and the necessary transverse reinforcement required in the shaft's bar anchorage region.

WHAT DID WE DO?

Caltrans, in partnership with the University of California, San Diego Department of Structural Engineering, examined the bond-slip behavior, bond strength, and anchorage capacity of large-diameter bars in Type II shafts. To identify the minimum embedment length for column reinforcement and validate new design formulas for the transverse reinforcement in the anchorage region of the shaft, the researchers tested four full-scale column-shaft assemblies of differing quantities and sizes of longitudinal reinforcing bars, embedment lengths, and quantities of transverse reinforcement in the columns and shafts under quasi-static cyclic lateral loading.

WHAT WAS THE OUTCOME?

The bond strength and cyclic bond deterioration of large-diameter bars is similar to smaller bars for well-confined situations comparable to a Type II shaft. The AASHTO length requirements for large-diameter bars are adequate to develop tensile strength. However, when considering possible uncertainties in material properties and construction quality, the conducted reliability analysis indicated that the AASHTO requirements have an acceptable reliability level to develop a bar's expected yield strength but do not have the desired reliability to develop its full tensile capacity. Based on these findings, the researchers propose design recommendations that significantly reduce the embedment length but increase the recommended quantity of transverse reinforcement for the shaft's bar anchorage region. Lowering the amount of transverse reinforcement to the new AASHTO formula could result in more severe splitting cracks, leading to premature bond failure. One test showed that an engineered steel casing was effective in controlling tensile splitting cracks in the shaft.

WHAT IS THE BENEFIT?

Although this study recommends that the amount of transverse reinforcement be higher than required by Caltrans and AASHTO specifications, it also demonstrates that the embedment length can be reduced by as much as 50%, significantly lowering the construction costs for large-diameter Type II shafts. Using engineered steel casings to confine the shaft can also reduce the amount of reinforcing hoops in a shaft and effectively control tensile splitting cracks, thus minimizing the need for post-earthquake damage repair for these shafts

LEARN MORE

To view the complete report:
www.dot.ca.gov/newtech/researchreports/reports/2013/final_report_task_2240.pdf

IMAGES


Figure 1: Bond-slip test
Figure 2: Column-shaft assembly instrumented