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STRENGTHENING OF CONCRETE DEEP BEAMS WITH EXTREME DISCONTINUITIES USING NEAR-SURFACE-MOUNTED COMPOSITES

by

Moustafa Seifeddin Mansour

Faculty Advisor

Prof. Tamer El Maaddawy, Department of Civil and Environmental Engineering
College of Engineering

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Abstract

Installation of a web opening that fully interrupts the natural load path in concrete deep beams produces regions of extreme discontinuities and reduces the shear strength. This research examined the effectiveness of using near-surface-mounted carbon fiber-reinforced polymer (NSM-CFRP) reinforcement to restore the shear strength of deep beams with extreme discontinuities. The strut-and-tie model (STM) procedures were utilized to develop three different strengthening solutions around the discontinuity regions. A total of eight deep beam specimens (150 x 500 x 2700 mm) with a shear span-to-depth ratio of a/h = 0.8 were constructed and tested. One beam was solid. Seven beams had a square opening in the middle of the shear span with an opening height ratio of h_o/h = 0.2. Six beams were strengthened with NSM-CFRP around the discontinuity regions. Three-dimensional finite element (FE) models were developed to simulate the nonlinear behavior of the tested specimens. Experimental results were compared to predictions of the FE models and the STM design solutions to examine their accuracy and validity. Installation of the web opening resulted in a 40% reduction in the shear strength. The NSM-CFRP strengthening solutions fully restored the original shear strength, except in two cases where only 93% and 94% of the capacity were restored. The laboratory test results were used to determine the optimal NSM-CFRP strengthening solution. The STM based on provisions of the American Concrete Institute provided realistic and consistent predictions for the nominal strength of the tested specimens with an average predicted-to-measured strength ratio of 1.01±0.09. In contrast, the STM predictions based on provisions of the Canadian Standards Association tended to be conservative with an average predicted-to-measured strength ratio of 0.71±0.29. Predictions of the FE models were sensitive to the mesh size and the concrete constitutive law adopted in the analysis. The inclusion of a bond-slip model between the CFRP and concrete resulted in up to a 5% reduction in the predicted strength. The use of a small mesh size of 15 mm and a "user" concrete constitutive law rather than a "default" law yielded more accurate predictions that were insignificantly different from those obtained from the tests.

Keywords: Deep beams, discontinuity, experimental, NSM-CFRP, numerical, simulation, STM, strengthening.