Nonlinear Wind Design of Steel Reinforced Concrete (SRC) Coupling Beams: Design Recommendations

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Design Recommendations

The study conducted by Hill et al (2023) on nonlinear wind behavior of steel reinforced concrete (SRC) coupling beams included testing and analysis of data for four tests, namely SRC-W1, SRC-W2, SRC-W3, and SRC-W4. The formulation of design recommendations for nonlinear wind behavior of SRC coupling beams were included in Chapter 4 and Chapter 5 of Hill et al (2023). A summary is provided here:

- It is recommended that nonlinear wind design of steel reinforced concrete (SRC) coupling beams follow the seismic provisions in AISC 341-22 Section H5, with exceptions noted in subsequent points. The loading protocol used for the tests had a maximum displacement demand of three times the yield rotation. As described in Hill et al (2023), this level of displacement demand was deemed to be more consistent with the seismic design provisions in AISC 341-22 Section H5 for special walls than AISC 341-22 Section H4 for ordinary walls, such that the provisions in H5 were used for design of the test specimens. The exception was a reduction to the quantity of wall longitudinal reinforcement crossing the embedment, which was reduced for SRC-W3 and SRC-W4, and the quantity of wall boundary transverse reinforcement, which was reduced for SRC-W4, to examine potential instances in which these provisions may be overly conservative. The study conducted by Hill et al (2023) did not include testing on SRC coupling beams that were designed using provisions in AISC 341-22 Section H4 and tested to peak deformation demands more consistent with ordinary walls. The study conducted by Hill et al (2023) also did not include testing on the reduction of wall boundary transverse reinforcement relative to that required by AISC 341-22 Section H5 for SRC coupling beams that were otherwise compliant with provisions in AISC 341-22 Section H5.

- It is recommended that the quantity of wall longitudinal reinforcement crossing the embedment length prescribed by AISC 341-22 Section H4 and Section H5 be reduced by 50% for cases in which wall demands do not exceed that applied for SRC-W3. This recommendation applies for seismic and wind design, as favorable performance of SRC-W3 under wind demands to a peak deformation of 4.65% chord rotation was observed. The poor performance of SRC-W4 did not support further reduction to the quantity of wall reinforcement crossing the embedment length or reduction to the quantity of wall boundary transverse reinforcement required by AISC 341 Section H5. The peak wall moment and tensile strain demands for SRC-W3 were $0.29M_y$ and 0.00019 tensile strain in outermost reinforcement at the coupling beam mid-height and an average of $0.04M_y$ and -0.00001 tensile strain (0.00001 compressive strain) in outermost reinforcement over one story height, taken as half a story above and below the coupling beam mid-height. These demands were determined from moment-curvature analysis for the moment and axial load, with moment and axial load diagrams determined based on transfer of coupling beam moment and shear to the wall at mid-height of the coupling beam. The moment-curvature analysis used the Hognestad (1951) concrete model, with the compressive strength of concrete taken as the average tested value for SRC-W3, which was 4.67 ksi. The M_y indicated here was based on reaching 70 ksi, the expected yield strength of A615 Grade 60 reinforcement (PEER TBI, 2017), in the outermost longitudinal reinforcement. The tested yield strength of the reinforcement was not used here, since the demands were less than yielding.

- The load-deformation response of SRC coupling beams under nonlinear wind demand was found to be generally consistent with seismic demand, with the exception of stiffness degradation, which was substantially greater for wind demand due to the additional loading cycles. It is recommended that the effective stiffness for nonlinear wind design be 75% of that prescribed in AISC 341-22 for seismic design.
- A bilinear backbone model for nonlinear wind design is suggested, with effective stiffness of 75% of that prescribed in AISC 341-22 for seismic design, a yield force computed using moment-curvature analysis at full yielding of the tension flange using expected material properties, and a post-yield slope determined using Eq. (5-5) from Hill et al (2023). It is recommended that the hysteretic model be determined by modeling the tests with calibration to dissipated energy test data for SRC-W1, SRC-W2, and SRC-W3 provided in Figure 4.20 and Table 4.6 of Hill et al (2023).
- The peak deformation reached during testing was 5.7% chord rotation for SRC-W1. Aside from the difference in stiffness degradation, the load-deformation response of SRC-W1, SRC-W2, and SRC-W3 was similar to SRC1 tested by Motter et al (2017a) using a seismic protocol to deformation demands in excess of 12%. Strength degradation for initial loading cycles to larger increments was minimal-to-none in all of these tests. Similar to seismic design, a specified deformation capacity limit on the coupling beam is likely unnecessary for nonlinear wind design. However, based on the available data, the use of a deformation capacity limit of 6.0% chord rotation could be considered, based on modest extrapolation of data for SRC-W1. The peak deformation demands reached in the coupling beam are expected to be limited by the deformation demands reached in the walls.

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