In this study, the retrofitting of a reinforced concrete column that lost part of its internal steel reinforcement due to adverse environmental conditions is numerically assessed using NSM FRP rods. Fig. 1 Example of a column's steel deterioration.

Methodology

A 3D nonlinear analysis of a slender column was performed on ANSYS and validated based on the experimental work of Gajdosova and Bilcik (2013). A short parametric study is performed to evaluate the influence of different NSM FRP and steel reinforcement configurations.

Numerical Modeling


One fourth of the column modeled. Concrete: 8-node translational DOF with cracking and crushing. Steel: truss element.

Numerical Model

Fig. 2 3D model with boundary conditions and column information.

Validation

Based on Axial Force - Moment relationship. Failure by crushing at mid-height of the column, with a calculated to experimental difference of: 8.9% in axial force and 0.25% in moment.

Fig. 3 Experimental failure (Gajdosova and Bilcik, 2013) and axial-moment response.

Parametric Study

10 models (6 in this poster) with partial removal of internal steel reinforcement retrofitted with NSM CFRP rods. Same FRP area as lost steel area, resulting in a diameter of 14.2 mm. Groove size of two times the rod diameter. The bonding between Epoxy-Concrete was also included in the nonlinear 3D model.

Results

• Loss of compression steel (C1 and C4)

Fig. 4 Parametric study sections.

Retrofitted columns are about 2% weaker. Crushing occurred at mid-depth of both columns. However, tangential slip occurred on the CFRP rods of column C4. Rod's stress at failure is about 10% of rupture (2800 MPa).

• Loss of tension steel (C2 and C3)

The overall response is 10% stronger. Failure remains crushing at mid-depth. Column C2 present normal debonding values very close to debonding stage at failure. Rod's stress is about 15% of rupture.

Fig. 5 C1 and C4 calculated response.

Conclusion

• All retrofitting techniques presented in this poster provides a column axial-moment capacity similar or greater than the original, un-retrofitted column.

• The substitution of tension steel reinforcement by NSM CFRP bars provides, in general, higher axial-moment column capacity. On the other hand, a smaller improvement is provided by compression CFRP rods are reduced.

• Debonding of the CFRP rods needs to be considered as it plays an important role in the failure modes of the columns.

• Debonding is more likely to occur when two CFRP rods are used in a face with no internal steel reinforcement.

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