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Behaviour of concrete columns reinforced with GFRP bars under different loading scenarios

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Period
2017-2021

Funding
Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão – FAPEMA (BD-08789/17)

Summary

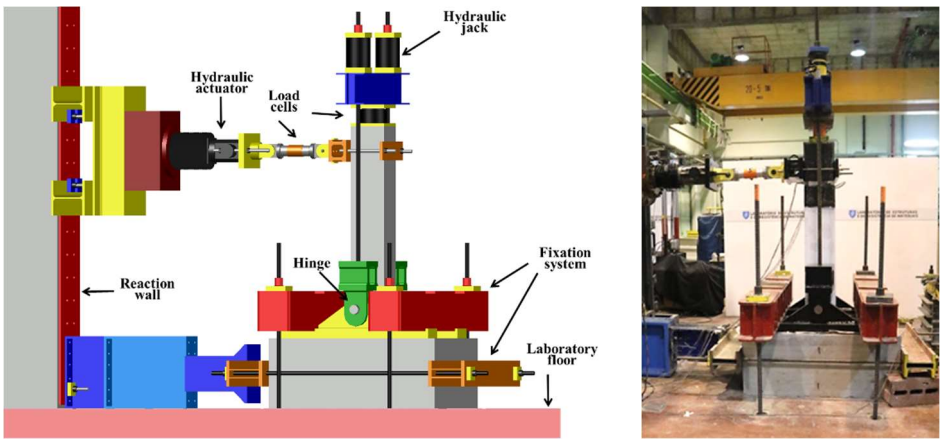
The research carried out in this thesis had the following main objectives (i) to understand the structural behavior of GFRP-RC columns under different loading conditions, assessing the behavior and strength of GFRP rebars, namely under compression; and (ii) to analyze the structural performance of RC columns with hybridized reinforcement, combining GFRP bars and SS bars (G/SS), under cyclic lateral loading. Experiments were carried out at Instituto Superior Técnico and at the National Laboratory of Civil Engineering, in two distinct phases that included: (i) characterization of materials to determine their mechanical proprieties and also the bond between the rebars and concrete; and (ii) tests of RC columns to evaluate their structural behavior up to failure. In parallel, analytical and numerical studies were also developed using MATLAB and Abstract iv ATENA, respectively, (i) to develop bending moment-axial load interaction diagrams and (ii) to simulate, with tridimensional finite element models, the experimental tests of the columns, thus obtaining a deeper understanding of their behavior.

In the experimental study of columns under compression (RC-C) or combined compression and bending, with monotonic (RC-CM) and cyclic (RC-CC) lateral loading, full-scale columns were built, without and with footings, comprising different materials as longitudinal reinforcement (carbon steel, GFRP and SS), subjected, in the case of columns under compression and bending, to two different axial load levels (20% and 33% of the axial capacity). The level of confinement of the concrete core in the columns with steel and GFRP stirrups (closed, with the same axial stiffness of the steel stirrups) was also object of this study. The experimental results showed that the participation of the GFRP rebars under compression was effective for all loading conditions – those rebars exhibited relatively high maximum compressive strains which, however, were significantly lower than the maximum tensile strains. The tests of the RC-CM and RC-CC columns highlighted the efficiency of the GFRP stirrups, namely for the lowest axial load level, regarding the confinement of the concrete core, which resulted in significant levels of ductility and energy dissipation. The hybridization of the longitudinal reinforcement, combining GFRP and SS bars, contributed to smoothen the spalling of the concrete cover and to maintain the lateral strength after the peak load; however, the exploitation of the SS bars plasticity was limited, due to the high yield strain of the SS bars.

Regarding the analytical and numerical studies, the bending moment-axial load interaction diagrams and the numerical models provided good agreement with the experimental results until the occurrence of spalling of the concrete cover (not captured by the models), confirming the contribution of the GFRP bars in compression. The numerical study allowed to analyze in further depth the behavior of RC-G/SS-CC columns; in particular, it was possible to assess the specific conditions, in terms of material properties, that allow increasing energy dissipation with a low permanent deformation level in the columns.

Keywords

Glass fiber reinforced polymer (GFRP), stainless steel, hybrid longitudinal reinforcement, reinforced concrete (RC) columns, experimental tests, numerical and analytical studies, monotonic loading, cyclic loading.



Overview of the test setup adopted to evaluate the behaviour of GFRP-reinforced concrete columns subjected todifferent loading scenarios.