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The effect of preloading on the strength of jacketed *R/C* columns

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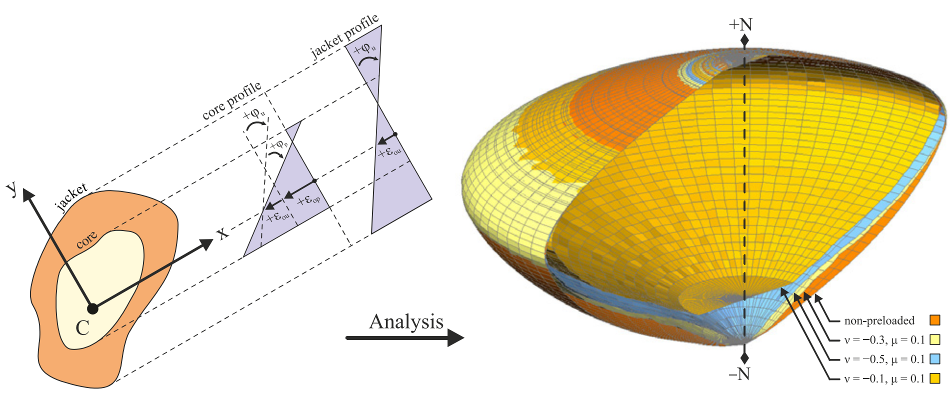
HIGHLIGHTS

- ▶ Analysis of jacketed *R/C* columns including preloading effects.
- ▶ Improvement of an existing section analysis method.
- ▶ New quantitative index for section capacity.
- ▶ Extended parametric analyses on preloaded jacketed *R/C* columns.

GRAPHICAL ABSTRACT



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ABSTRACT

The influence of core preloading on the strength of jacketed reinforced concrete (*R/C*) columns is analytically investigated. A recently proposed method for arbitrary composite section analysis in biaxial bending and axial load is extended to include preloading actions. A parametric evaluation of the preloading effect using quantitative indices is performed, considering the variability of several parameters such as section geometry, amount of reinforcement, and various axial and moment preloading levels. Results are presented in the form of 3D failure surfaces and moment–curvature curves. Specific cases where the preloading effect is more pronounced are finally highlighted.

1. Introduction

Strengthening of *R/C* columns for enhancing their structural performance under seismic loading is naturally applied on preloaded cores (i.e. the ‘old’ column), due to existing gravity loads. In columns with high axial loading, it is practically difficult – if not impossible – to construct the concrete jacket after unloading the column from service loads. The preloading actions of the core may be in the form of axial compression with or without bending moment, depending on the structural system (e.g. corner columns in buildings or monolithic pier to deck connections in bridges). However, for the design or assessment of repaired or strengthened columns, it is usually assumed, for simplicity, that the concrete jacket is constructed on an unloaded core, considering a monolithic section during analysis [1], i.e. the concrete core and the jacket are assumed to share the same strain profile.

The effect of core preloading on the flexural capacity of jacketed *R/C* columns has been addressed in some studies, yet mainly on the basis of experimental testing. The common experimental procedure involves the axial preloading of the core to a certain amount of its axial capacity and the subsequent strengthening with concrete jacketing. In fewer cases, core preloading is continued until considerable crushing and buckling of the longitudinal reinforcement

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occurs, therefore the concrete jacket is introduced mainly for repair reasons. In the study by Takeuti et al. [2] the concrete core was axially loaded from 44% to 87% of its capacity. The preloaded specimen was subjected to an increasing compressive axial loading (without moment) and finally exhibited an increase of its strength up to 14% compared to its non-preloaded counterpart. Therefore, it was concluded that preloading does neither affect the strengthening process nor does it adversely affect the load bearing capacity of the retrofitted column. Ersoy et al. [3] applied axial preloading on the core of jacketed *R/C* columns up to 75% of its axial capacity, and tested the performance of the preloaded specimens under uniaxial and combined axial and bending loading, respectively. The specimen subjected to uniaxial loading exhibited a 5% to 10% decrease in its strength compared to its non-preloaded counterpart while, in the case of combined axial and moment loading, the strength capacity of the preloaded and non-preloaded specimens turned up to be almost identical. Finally, Vandoros and Dritsos [4,5] compared the performance of axially preloaded and non-preloaded jacketed *R/C* columns under combined axial loading and bending moment. Comparison on the basis of flexural capacity revealed a significant increase in strength up to 35% when axial preloading of the core was considered. It is noted that in the above cases, the thickness, as well as the longitudinal reinforcement, of the jacket were kept constant in all test specimens, however different concrete strengths for the core and the jacket were considered.

As described above, the effect of core preloading has been experimentally investigated only for the case of uniaxial compressive preloading (without bending moment). Analytical investigation involving preloading effects on jacketed *R/C* sections is generally lacking; a somewhat relevant studies by Ong and Kang [6] and Liew and Xiong [7] are concerning steel–concrete composite sections with preloading on the steel core. The key objective of the present study is to analytically investigate the effect of combined axial and moment preloading of the core on the strength of jacketed *R/C* columns. In the following sections, a recently suggested numerical method [8] for arbitrary composite section analysis under biaxial bending and axial load is suitably extended to account for preloading effects. A parametric evaluation of the preloading effect using quantitative factors is presented, considering a range of values for several parameters, i.e. section geometry, amount of reinforcement, and various normalised axial and moment preloading levels. The analysis results are presented in the form of 3D failure surfaces and moment–curvature curves. Specific cases where the preloading effect is more pronounced are finally highlighted.

2. Theoretical background

The present analytical procedure is based on a recently proposed numerical method for the analysis of arbitrary composite sections under biaxial bending and axial load [8]. According to this method, the section under consideration may consist of an unlimited number of individual components, namely surfaces (S_i), multi-segment lines (L_i) and fibre groups (FG_i), for simulating various section elements, e.g. concrete or structural steel areas, distributed reinforcement or fibre-reinforced polymer strips, and reinforcement bars or tendons, respectively (Fig. 1, left). These components can also be 'negatively' defined, in order to explicitly simulate voids or multi-nested materials [9], which is a requisite feature for compiling *R/C* jacketed sections (Fig. 1, right), without resorting to complicated fictitious cuts [10].

Each section component can be associated with a different material constitutive law, i.e. a series of stress–strain arbitrary functions in piecewise form (Fig. 2, left), which are integrated by applying a numerical, adaptive strain-mapped integration scheme, based on Gaussian sampling on a Green path integral. In order to perform stress integration, the ultimate strain profile (ε_{ou}, φ_u) is imposed on the section, following the Bernoulli–Euler assumption (Fig. 2, right). This ultimate strain profile is derived using multicriteria limit states, which are preset for each material model, usually according to Code regulations (e.g. [11,12]). Following derivative-free solution strategies, the axial and moment capacity values (N, M_X, M_Y) in the form of biaxial moment or axial–moment interaction plane curves or 3D failure surfaces are calculated. Moreover, the complete moment–curvature response of the section can also be extracted. An in-depth presentation of the aforementioned numerical procedures is provided in Papanikolaou [8].

The limitation of the existing method is that the same ultimate strain profile is attributed to all section components (see Fig. 2, right); however, if the effect of preloading is taken into account, the section core already exhibits initial strains due to preloading actions (N_p, M_p), which should be included in the stress integration

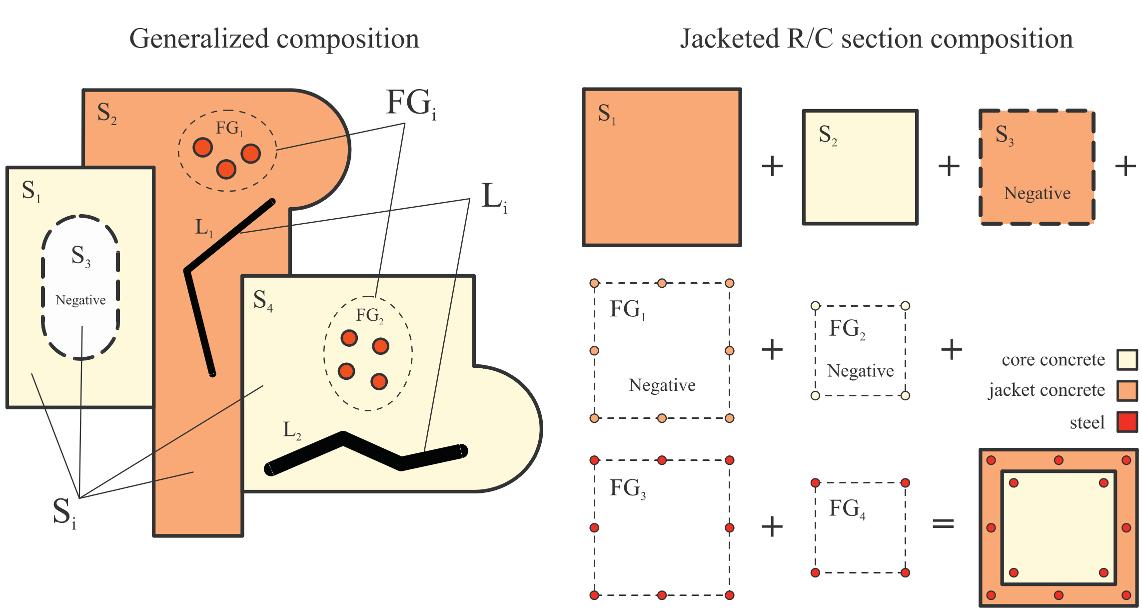

Fig. 1. Generalized (left) and jacketed *R/C* section composition (right).