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# Simplified Assessment of the Effects of Columns Shortening on the Response of Tall Concrete Buildings

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**Abstract**

The constructive process as well as the time-dependent effects must be considered in the assessment of the response of complex concrete structures. For tall buildings, the adequate prediction of vertical elements shortening is required to determine its effects on other structural and nonstructural elements, usually overestimated by linear elastic analysis. Thus, simple numerical methods which make it possible to consider the most relevant aspects of the structural behaviour may be useful in the early stages of a project. In the research presented herein a simplified method, which considers the viscoelasticity of concrete as well as the construction sequence, was used. Its adequacy was assessed by comparison of the results for a tall concrete building with those obtained with a commercial software which incorporates a nonlinear staged construction analysis package. The good correlation between the obtained results indicates that the simplified method used may be applied to help make appropriate design choices.


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*Keywords:* Tall buildings; Concrete; Time-dependent effects; Columns shortening; Constructive process.

## 1. Introduction

Over the years, buildings height has increased to economize on land area, and the construction of reinforced concrete (RC) high-rise buildings became popular. As a result, problems due to differential axial shortening of vertical

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elements have been observed and reported (Moragaspitiya et al., 2009a; Kurc and Lulec, 2011). The total column shortenings are rarely of practical interest. However, the effects of differential axial shortenings between vertical elements can lead to excessive deflection and unacceptable crack widths on horizontal elements. The former may additionally result in damage on nonstructural elements, such as façades, partitions, claddings and mechanical installations (Fintel et al., 1987). Furthermore, when vertical elements are rigidly connected through slabs or beams, relative vertical deformations can generate substantial internal forces (Pan et al., 1993; Kim et al., 2010), and significant redistribution of forces may be required at the ultimate limit states. Thus, the axial deformations of columns, both elastic and inelastic, require special consideration in the design and construction of tall building structures (Fintel et al., 1987).

It should be noted that linear elastic analysis often overestimates these effects, thus more complex analyses must be performed to prevent the exclusion of adequate structural solutions based on inadequate analysis. Several methods were developed to quantify the magnitude of the mentioned effects, making it possible to define competent design provisions and procedures (Moragaspitiya et al., 2010). The finite element method, combined with step-by-step integration methods, for example, is a reliable solution for the prediction of the time-dependent deformations. However, these procedures are often complicated and time-consuming, or do not capture the complexity of the problem, because they are limited to a few analysis parameters (Au et al., 2007; Huang et al., 2007; Moragaspitiya et al., 2009b; Kurc and Lulec, 2011). For early design stages, it is useful to use simple numerical methods, adequate for an engineering practice environment, which consider both the constructive process and the time-dependent response of concrete.

A simplified method to predict the internal forces due to axial shortening of columns was used in the research presented herein, making it possible to consider the more relevant parameters in the response assessment of concrete structures. The study reported now is intended to assess the adequacy of the simplified method used through the comparison of the results for a RC tall building with those obtained with SAP2000, using its nonlinear staged construction analysis package.

## 2. Axial shortening of concrete columns

The construction and loading sequence may be relevant for the analysis of complex structures, namely regarding the axial deformation of columns (CTBUH, 1980; Smith and Coull, 1991). During construction, dead loads are applied step-by-step. As indicated in Fig. 1, at the time of construction of a given level *N* there are *N*-1 previous load stages due to slabs concrete pouring, to which adds all subsequent load stages, owing to other installations, such as cladding and partitions, that occurred up to the time of construction of level *N*. Because each column segment undergoes elastic and inelastic deformations due to the different loads, axial shortening of columns is directly related to the construction sequence and its pace. At the design stage, an assumption of the loading history, as realistically as possible, is required to assess the differential shortening consequences.

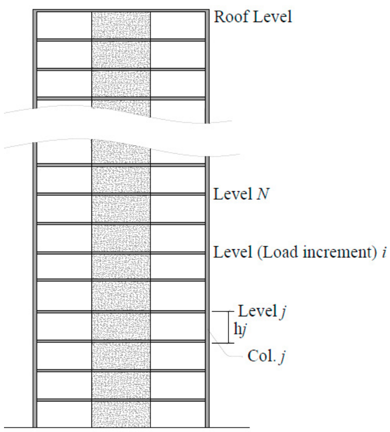


Fig. 1. Schematic of a multi-story building.