Initial Stiffness of Reinforced Concrete Columns with Moderate Aspect Ratios

Cao Thanh Ngoc Tran\textsuperscript{1} and Bing Li\textsuperscript{2,}\textsuperscript{*}

\textsuperscript{1}Department of Civil Engineering, International University, Vietnam National University, Ho Chi Minh City, Vietnam
\textsuperscript{2}School of Civil and Environment Engineering, Nanyang Technological University, Singapore 639798

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Abstract: The estimation of the initial stiffness of columns subjected to seismic loadings has long been a matter of considerable uncertainty. This paper reports a study that is devoted to addressing this uncertainty by developing a rational method to determine the initial stiffness of RC columns when subjected to seismic loads. A comprehensive parametric study based on a proposed method is initially carried out to investigate the influences of several critical parameters. A simple equation is then proposed to estimate the initial stiffness of RC columns. The applicability and accuracy of the proposed method and equation are then verified with the experimental data obtained from literature studies.

Key words: reinforced concrete, column initial stiffness, stiffness ratio.

1. INTRODUCTION
In recent years, earthquake design philosophy has shifted from a traditional force-based approach toward a displacement-based ideology. The assumed initial stiffness of reinforced concrete (RC) columns could affect the estimation of the displacement and displacement ductility, which are crucial in displacement-based design. In addition, the assumed initial stiffness properties of columns also affect the estimation of the fundamental period and distribution of internal forces of structures. Therefore, an accurate evaluation of the initial stiffness of columns becomes an inevitable requirement.

Literature reviews show that there is a considerable amount of uncertainty regarding the estimation of the initial stiffness of columns when subjected to seismic loads. Current design codes often employ a stiffness reduction factor to deal with this uncertainty. In an attempt to address these uncertainties, the study presented within this paper is devoted to developing a rational method to determine the initial stiffness of RC columns when subjected to seismic loads. A comprehensive parametric study based on the proposed method was carried out to investigate the influences of several critical parameters. A simple equation to estimate the initial stiffness of RC columns is also proposed within this paper. The applicability and accuracy of the proposed method and equation are then verified with the experimental data obtained from the literature.

2. DEFINING INITIAL STIFFNESS OF RC COLUMNS
There are two methods as illustrated in Figure 1(a) that are commonly utilized to determine the initial stiffness of RC columns ($K_i$). In the first method, the initial stiffness of RC columns are estimated by using the secant of the shear force versus lateral displacement relationship passing through the point at which the applied force reaches 75\% of the flexural strength (0.75 $V_u$). In the second method, the column is loaded until either the first yield occurs in the longitudinal reinforcement or the maximum compressive strain of concrete reaches 0.002 at a critical section of the column. This corresponds to point A in Figure 1(a). Generally, the two approaches give similar values. In this study, the later approach was adopted.