Seismic Behavior of Nonseismically Detailed Interior Beam-Wide Column Joints—Part II: Theoretical Comparisons and Analytical Studies

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The experimental results of four full-scale reinforced concrete interior beam-wide column joints with nonseismic detailing and limited seismic detailing have been presented in the previous paper. Due to the unique features of the test specimens and the inherent complexity of beam-column joints, however, such a study is not sufficient. Therefore, in this paper, an analytical investigation would be useful to provide a better understanding of the seismic behavior of such beam-wide column joints. The developed finite element models were described and verified using the results of the experimental results presented in the previous paper. The global behavior and the principal stresses of the interior beam-wide column joints were discussed and examined in detail. The calculated results indicated that global behavior of the joints can be simulated to correlate well with the experimental observations. In addition, the effects of several critical design parameters on the joint’s behavior are explored by means of the developed finite element models; implications of the results on code specifications are discussed.

Keywords: ductility; joint; reinforced concrete.

INTRODUCTION

In Singapore, there are a large number of wide-column moment resisting frames built for residential and commercial purposes. The current Singapore building code is mainly based on the British Standard: the BS 8110, which has no provision for seismic loading. Hence, almost all these frames are built without seismic consideration in design and detailing, for example, no joint reinforcement in the joint cores. Recent studies, however, have shown that although Singapore is located in a low seismicity region and there has never been any earthquake damage in the country, the seismic hazard potential in the country should not be ignored. This makes it necessary to study the performance of these wide-column moment resisting frames under possible earthquake conditions, and as a critical part of such frames, the nonseismically detailed beam-wide column joints deserve more attention. In addition, beam-wide column joints have rarely been studied before, and this makes the study of such joints even more valuable and necessary.

Reliable information on the seismic behavior of full-scale beam-wide column joints can be obtained by experiments such as those reported and discussed in the previous paper. Experiments, however, are expensive and time consuming; thus, it is necessary to develop a numerical tool for the reasonable prediction of beam-wide column joints’ behavior. To better understand the behavior of such joints, further discussions on these experimental results and comparison with theoretical results are presented in this paper. In this study, the nonlinear behavior of beam-wide column joints under reversed cyclic loading was analyzed by the finite element analysis method with the emphasis on the effect of joint transverse reinforcements, column axial load, and bond condition on the joint’s behavior. By using this method, not only were the experimental results further verified and analyzed, but an investigation into the effects of some critical parameters has been carried out.

RESEARCH SIGNIFICANCE

The seismic behavior of beam-column joints is influenced by many parameters. Due to the inherent complexity of the joints, the effects of the combined effect of the parameters still have not been validated through many studies. In the experimental study, full-scale beam-wide column joints were tested; however, there was no column axial loading applied to the specimens. Column axial loading is one of the most controversial parameters and up until now, its effect has not been definitely decided. An analytical model that has been properly calibrated with available experimental results can be very useful for conducting parametric studies to enhance understanding. In this paper, the predictions of FEM models are compared with the experimental results, and parametric studies are conducted to quantify the major variables influencing the seismic behavior of beam-wide column joints.

ANALYTICAL MODELLING OF REINFORCED CONCRETE BEAM-WIDE COLUMN JOINTS

To supplement and further verify the test results obtained from the experimental work, the finite element method (FEM) was employed to improve the understanding of the structural response of the joints. The program used for the study was the FEM software package, developed at the University of Tokyo. It includes nonlinear and path-dependent material constitutive models applicable to loading, unloading, and reloading as well. The software package is capable of conducting a large-deformation nonlinear two-dimensional reinforced concrete structural system under static and dynamic loading using a multidirectional fixed smeared cracking feature. The finite element models of the joints are developed using the as-built dimensions and measured material properties to predict the local and global response of the test specimens and to provide better insight into the structural behavior of the joints.

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