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Seismic performance of composite column with double plastic hinges

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Abstract: A composite column including the reinforced concrete column, steel I-beam embedded in foundation, and strengthening steel plate was proposed in this paper. The seismic performance of the composite column was studied based on experiments and finite element analysis. Results showed that two plastic hinges could be formed at the column bottom and at the upper edge of the strengthening steel plate. Influences of the slenderness ratio, axial compression ratio and strengthening height on the seismic behavior of the composite column with double plastic hinges were analyzed. Compared with a single plastic hinge, the two plastic hinges significantly improved the ultimate deformation, strength capacity, stiffness and energy dissipation capacity of the column, reduced the ultimate stiffness, and effectively improved the seismic performance of the column. A theoretical method to calculate the ultimate deformation and maximum strength capacity of the composite column with optimized double plastic hinges was proposed.
Keywords: Composite column; Double plastic hinges; Seismic performance; Experiments; Finite element analysis

1. INTRODUCTION

In disastrous earthquakes, the reinforced concrete bridge columns are generally severely damaged. The damage investigation on 1081 major highway bridges after the 2008 Wenchuan Earthquake in China indicated that the percentages of intact or slightly damaged bridges, moderately damaged bridges, seriously damaged bridges, failed bridges and bridges under construction accounted for 78%, 11%, 9%, 1.5%, and 0.5%, respectively. The column damage was the main damage type of the bridges[1].

As for the reinforced concrete (RC) column, the traditional strengthening methods mainly include bonding steel plate[2-5], FRP[6-11] or other strengthening materials[12]. The improvement of the deformation capacity of the strengthened columns is paid much attention[13-18], and the similar conclusions is drawn: the strengthened columns have a better deformation capacity, and because of the energy dissipation effect of the non-elastic phase, structures can withstand a large earthquake without failure[19-23]. The deformation of the column mainly comes from the plastic hinge, so the plastic hinge is very important for the seismic performance of the column.

However, in traditional strengthening methods for the RC columns, there exists a gap between the strengthening material and the column foundation, resulting in the location of the plastic hinge stays unchanged after strengthening. In other words, at the bottom of the strengthened column there is only one plastic hinge.

Chung-Che Chou[24] studied the post-tensioned precast concrete segmental bridge columns by model tests and found two plastic hinges formed respectively at the bottom of the column and in the second segment. Based on the shake table test of a cable bridge, Sun Li-min[25] found that the failure of the bridge tower obviously had double plastic hinge mode, and the pylon top and bottom regions were both subjected to serious damage. The tests[24,25] have approved that two plastic hinges can be formed in the cantilever structures.

The double plastic hinges of the column have not been well explored. In this paper a new composite column with double plastic hinges at bottom area was developed. The composite column includes the RC column, steel I-beam embedded in the foundation, and strengthening steel plate. The strengthening steel plate with a proper