Equivalent Plastic Hinge Length of Extended Pile-Shafts embedded in Sand

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Summary

Under strong seismic excitation, the extended pile-shaft will inevitably form a plastic hinge in its underground portion. The underground damage is difficult for post-earthquake restoration and may cause large residual displacement at the top of the pile-shaft. In this regard, the ductile behavior, especially the characterization of the underground plastic hinge needs to be investigated. In this paper, a Beam on Nonlinear Winkler Foundation (BNWF)-based finite element (FE) model embedded in a homogeneous sand layer was developed in the Open Sees platform and calibrated by an in-situ full-scale test. This study focused on the effect of different structural and soil parameters on the equivalent plastic hinge lengths(EPHLs) of extended pile-shafts. Results indicate that the EPHLs of piles are affected by many parameters of pile-soil systems. A typical range of EPHLs of the pile is also obtained from the parametric study.
Keywords: Extended Pile-Shafts, BNWF, Seismic Performance, Equivalent Plastic Hinge Length.

1. Introduction

The current specifications for seismic design of bridges [1-2] follow the Philosophy of Capacity Design, i.e. providing a differential strength between the ductile and non−ductile components in bridge structures to prevent potential brittle failures. Since the foundation is difficult to inspect and expensive to repair after earthquakes, it may be strategically designed to remain elastic while the pier portion of substructures is detailed carefully for inelastic deformation and energy dissipation. However, sometimes plastic hinging cannot be avoided in the foundation system, for example, in the extended pile-shaft. An extended pile-shaft is a kind of foundation where the column is continued below the ground level as a pile shaft of approximately the same diameter. Extended pile-shafts, without any expensive pile-caps, are cost-effective and widely used in urban viaducts. Under seismic loading, the maximum bending moment will occur in the below ground portion of the pile, which will definitely leads to plastic hinging as long as the earthquake is sufficiently severe. The ductile seismic design for foundation is needed if necessary, particularly for the extended pile-shafts. Actually, seismic design specifications in America and Japan [3-5]have had the rules that withhold ductile damage from arising in foundation system during some extreme design situations.

The most important question in extended pile-shaft ductile design is how to determine the ductility capacity with the aid of the ductility index, such as the lateral displacement at the top of the pile. A common approach assumes that the extended pile-shaft can be replaced by an equivalent cantilever, which is fully restrained against lateral translation and rotation at the base. Then a relationship between the lateral displacement at the top of the pile and the EPHL is obtained. In order to limit the yielding of the pile, the EPHL should be determined exactly.

Many similar studies have been conducted by previous researchers. Budek and Priestley (1996, 2000) [6] studied the effects of above-grade height and soil stiffness on the EPHL by numerical simulation. Chai and Hutchinson (1999, 2002) [7-9] carried out four full-scale tests of the extended

https://doi.org/10.2749/222137816819258438