The Influences of Ground Surface on Vibrations of Structures

Saori Agata  
Research Division in Engineering, Tokyo City University  
Setagaya-ku, Tokyo, Japan

Toshiyuki Kataka  
Department of Urban and Civil Engineering, Tokyo City University  
Setagaya-ku, Tokyo, Japan

Naoaki Suemasa  
Department of Urban and Civil Engineering, Tokyo City University  
Setagaya-ku, Tokyo, Japan

Fumitaka Arai  
Research Division in Engineering, Geodesign Co., Ltd.  
Minato-ku, Tokyo, Japan

ABSTRACT

The seismic behavior of a structure is affected by many factors, which include oscillation properties of the structure, seismic properties of the ground surrounding the structure and so on. If the structure is supported by piles, the interactions among the structure, the pile foundation and the ground may be an important factor to be added. In this system, the pile foundation assumes a key role as a transmitter of seismic energy from ground motion to the structure or a pathway sending vibration energy of the structure to the ground. The purpose of this study is to evaluate comprehensively the influences of various factors like ground properties, types of structures and piles on the behaviors of structures during earthquakes. A series of vibration analysis for a system of structure-pile foundation-ground using a spring mass model was carried out. In the analysis, four kinds of simplified ground profiles, two types of seismic motions, five types of building heights and five types of pile lengths were used, respectively. The results of the analysis were evaluated through the principal component analysis and classified into four groups using two principal components obtained in the analysis.

The influences of various factors on seismic response characteristics of the buildings were discussed with the results of the principal component analysis. From the results, the ratio of pile length to building height was an important factor for the responses of buildings. It was also found that the effects of radiation damping increased as the ratio was increased.

KEY WORDS: ground properties, principal component scores, response characteristics, pile foundations, radiation damping

INTRODUCTION

The seismic behavior of a structure is affected by many factors, including oscillation properties of the structure and seismic properties of the ground surrounding the structure. Especially, a seismic affinity between types of structure and ground is so important that it can dominate damage level of the structure. For example, in diluvium highlands in uptown Tokyo, many rigid warehouses were seriously damaged in Kanto Earthquake (Mg=7.9, Sep. 1st, 1923). On the other hand, in alluvial lowlands in downtown Tokyo, a lot of wooden houses instead of rigid warehouses were collapsed. It was because the natural frequencies of the structures matched those of the ground.

Many tall buildings have been constructed on reclaimed soft grounds in waterfront areas along Tokyo bay after Kanto earthquake. For such flexible tall buildings on the soft ground, as well as wooden houses in Kanto earthquake, there is concern about seismic responses of the structures.

For the seismic design of a structure, there are many kinds of design consideration conducted. As the consideration is, however, individually executed for one structure, the results of the consideration have not been accumulated. It led to lack of the knowledge to understand the effects of various factors on the seismic responses of structures. It is, therefore, necessary to evaluate quantitatively and comprehensively the influences of various factors on the behaviors of structure-foundation-ground system during earthquakes.

Results of earthquake response analysis are generally shown with response acceleration waves, response speed waves and/or response displacement waves. Also, there are many other indexes which can show seismic response characteristics of structures. Seismic force acting on a structure is one of the indexes, calculated from the response acceleration. A strain of a structure is also an index derived from the response displacements during an earthquake.