

COMPARISON OF EARTHQUAKE RESPONSES BETWEEN MDOF STRUCTURE AND ITS EQUIVALENT SDOF STRUCTURE CONSIDERING FOUNDATION UPLIFT

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1. INTRODUCTION

A building structure supported by a shallow foundation may uplift when subjected to relatively large ground motion. Hayashi (1996) discussed the damage reduction effect due to the basemat uplift of the buildings by using joint elements with two-dimensional FEM. Iwashita (2000) suggested that the story shear force of a structure was reduced due to foundation uplift. The buildings can be modelled by MDOF structure with considering foundation uplift, however, simplified SDOF modelling may be even better for practical use, if it gives a solution with sufficient accuracy. This study examines the structural responses between the multi-story building and its equivalent single-story system considering foundation uplift.

2. ANALYTICAL MODEL

2.1 Building model

Referring to Osaki (1996), this study considers a five-story building supported by a mat foundation, and conversion of the five-story building to the equivalent single-story system, as shown in Figs.1a) and 1b). The equivalent lumped mass, M_{eq} , in a one-story system can be defined by Eq. (1), referring to a textbook of Structural Dynamics (2018). Stiffness, K_{eq} can be determined so that natural frequency of the MDOF and SDOF structures becomes the same equal as Eq. (2). Where m_i is lumped mass in the i -th story and Φ_i is the natural mode shape of the i -th story. Each lumped mass has one degree of freedom, and the foundation has three degrees of freedom. The first period for the fixed base foundation case, T_1 is 0.3581 sec.

$$M_{eq} = \frac{\sum_{i=1}^N m_i \phi_i^2}{\left(\sum_{i=1}^N m_i \phi_i \right)^2} \quad (1)$$

$$K_{eq} = \omega_1^2 M_{eq} \quad (2)$$

2.2 Soil-Foundation System

To discuss the effect of foundation uplift, this study considers the building on a mat foundation sustained by stiff soil (shear wave velocity, V_s is 300 m/s). Fig. 1 also shows the vertical, horizontal, and rotational direction of springs and dashpots for the soil-foundation system, which can be determined by Gazetas (1991) by assuming the foundation width, B is 5 meters; Poisson's ratio, ν is 0.4; ground density, ρ is 1.8 ton/m³. The parameters of the soil-foundation system are summarized in Table 1.

3. EARTHQUAKE GROUND MOTION

The ground motion recorded at MYG001 station during the 2011 Tohoku earthquake was applied as the earthquake loading in this study. Fig. 2 shows the acceleration time history and Fourier spectrum of the ground motion recorded at MYG001 station. The peak ground acceleration (PGA) is 426.34 cm/sec² and the predominant frequency is approximately 4.2 Hz.

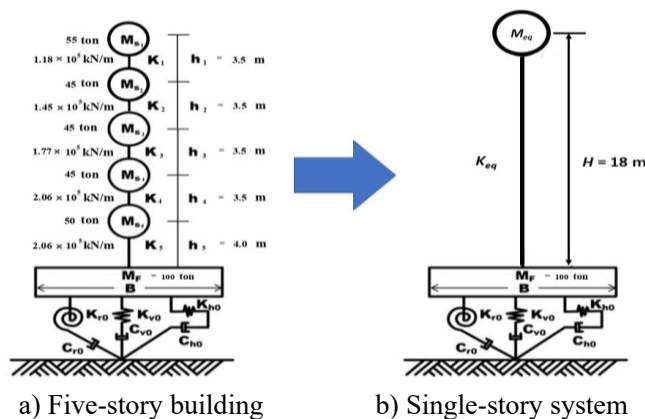


Fig. 1 Analytical model

Table 1 Parameters of the soil- foundation system

Parameters	Value
K_v (kN/m)	3.06×10^6
K_h (kN/m)	2.28×10^6
K_r (kN·m/rad)	1.52×10^7
C_v (kN·s/m)	2.19×10^4
C_h (kN·s/m)	1.35×10^4
C_r (kN·s·m)	1.02×10^4

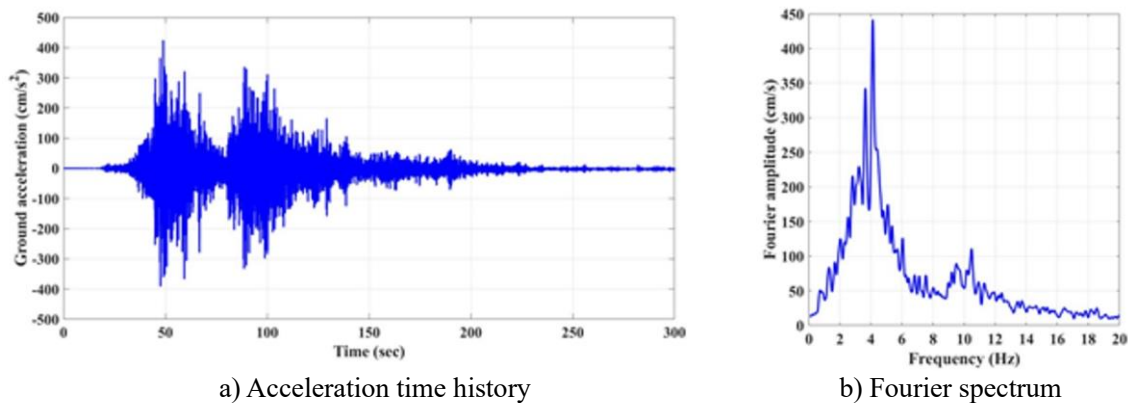


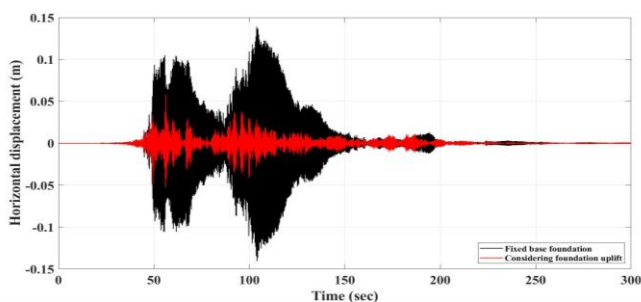
Fig. 2 Ground motion recorded during the 2011 Tohoku earthquake at the MYG001 station.

4. RESULTS AND DISCUSSIONS

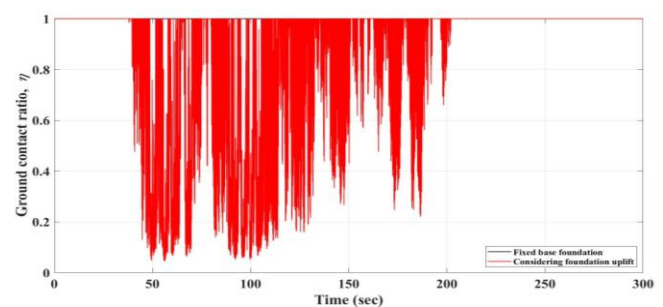
The comparison of two different structural responses for the five-story structure and the equivalent one-story system are shown in Figs. 3a) and 3b), respectively. To discuss the effect of foundation uplift, the structural responses for fixed base foundation and for the case considering foundation uplift are compared for the five-story structure and the equivalent one-story system. To pursue the phenomenon of foundation uplift, the ground contact ratio responses for the five-story structure and the equivalent one-story system are illustrated in Fig. 4. The structural responses are reduced to nearly the same degree due to foundation uplift for both the five-story structure and the equivalent one-story system. This can be regarded as the "seismic isolation" effect.

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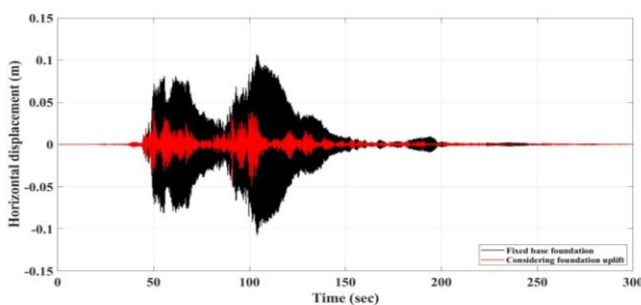
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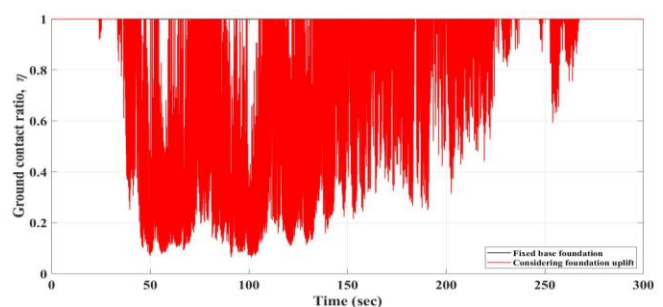
a) Structural response of the five-story building



a) Ground contact ratio response of the five-story building



b) Structural response of the equivalent SDOF system



b) Ground contact ratio response of the equivalent SDOF system

Fig. 3 Structural response

Fig. 4 Ground contact ratio response