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Pure Sliding Bases, Considering Variable Friction Coefficient and Vertical Component of Earthquake

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ABSTRACT

The effect of vertical component of earthquake on the behavior of sliding foundations is studied here. The superstructure is considered as a rigid block, which can be a representative of short masonry buildings, regarding complication of the problem and in order to focus better on the main subject. Recent research studies show that the value of coefficient of friction is not constant, and depends on instantaneous frequency and amplitude of the vertical vibration which change during an earthquake. These instantaneous parameters can be calculated by WAVELET transforms. Both horizontal and vertical components of earthquakes as well as the variation of friction coefficient are considered in this study. The results for five different earthquake records show that the applied acceleration of the block rises by considering the vertical earthquake, however variable frictional coefficient, compared with the constant one, decreases the acceleration. Considering the influences of both vertical earthquake and variation in friction coefficient causes having more sliding in the block in most cases.

KEYWORDS:

Coefficient of Friction, Pure Sliding Base, Vertical Earthquake, Wavelet Transform

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1- INTRODUCTION

To have resistant buildings against earthquakes, the story drifts are controlled mostly by increasing the structural stiffness. However, this may lead to increasing the base and story shear. Therefore, supplying base isolation is known as an optimum method to control the story drift as well as having low base shears. There are many technologies for base isolation, among which sliding base is one the best, regarding high efficiency and low costs.

Many research studies on sliding bases are in the literature, most of them have assumed constant values for friction coefficient during vibration and ignored influences of vertical components of earthquakes [1-4]. Despite, Liaw et.al. [5] have shown that vertical components of earthquakes have considerable effects on the behavior of sliding bases and they cannot be ignored. Takahashi et. al. [6] and Iemura et al. [7] have also focused on the influence of the vertical earthquake on sliding bases experimentally. However, they concluded that the influence of vertical earthquake is ignorable on the frame maximum displacement.

Khoshnoudian and Haghdust [8] have studied the influence of variable friction coefficient on a single degree of freedom building. They concluded that assuming constant values for friction coefficient leads to error in estimating the structural response; it overestimates the maximum shear but underestimates the maximum displacement of the base, compared with real case, having variable frictional coefficient. In this research, Mokha and Constantinou formula [9] was applied for estimating the frictional coefficient.

In the present study, Chowdhury and Helali formula [10, 11] is applied for calculating the friction coefficient during earthquakes. The formula is based on some experimental test results and gives the friction coefficient as a function of instantaneous frequency and amplitude of the vertical displacement history as well as the relative velocity of the sliding surfaces. Schematic diagram of the experimental setup is shown in Fig. 1. This is a pin-on-disc machine, i.e. a pin which can slide on a rotating horizontal surface (disc). In this setup a circular test sample (disc) is to be fixed on a rotating plate (table) having a long vertical shaft clamped with screw from the bottom surface of the rotating plate. The direction of vibration is perpendicular to the sliding direction of the pin. More information are in references 10 and 11. The vertical movement of the test can be regarded as vertical displacement of the ground in earthquake, which can be calculated by Wavelet transform functions. The instantaneous frequency and amplitude of the vertical seismic vibration is required to estimate the frictional coefficient, regarding Chowdhury and Helali study [10, 11].

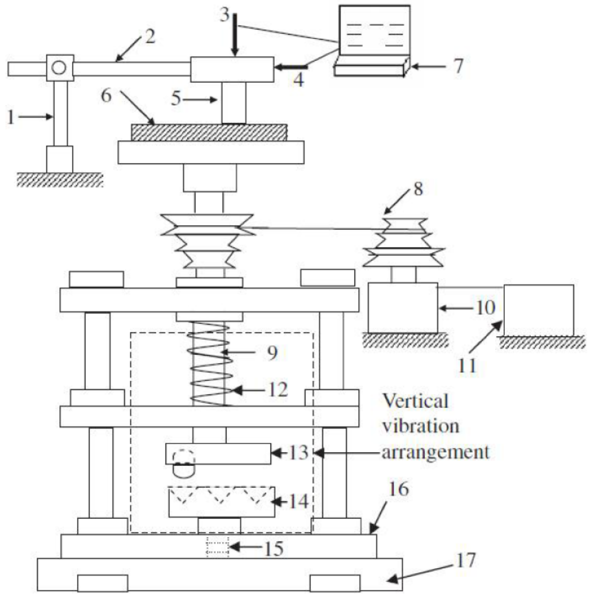

Figure 1. Schematic diagram of the experimental setup [10]: (1) Load arm holder. (2) Load arm. (3). Normal load (dead weight). (4) Horizontal load. (5) Pin sample. (6) Test disc with rotating table. (7) Computer. (8) Belt and pulley. (9) Main shaft. (10) Motor. (11) Speed control unit. (12) Compression spring. (13) Upper plate with ball. (14) Lower plate with V-slots. (15) Height adjustable screw. (16) Base plate. (17) Rubber block.

In this study behavior of a rigid block, representing a one story masonry building, on a sliding base is studied, regarding influences of variable friction coefficient and vertical component of earthquakes. For this, the friction coefficient is calculated by Chowdhury and Helali formula, by calculating instantaneous frequency and amplitude of the vertical vibration, calculated by Wavelet transform functions. Among the functions, sym2 is selected for this calculation, since displacement records is almost smooth.

2- METHODOLOGY

Regarding Fig. 2, the governing formula of a block on the ground is as follows. The block starts sliding if:

$$\mu.m_b(g+\ddot{Y}_g) \geq m_b.\ddot{X}_g \tag{1}$$

Where $m_b, \ddot{X}_g$ and $\ddot{Y}_g$ are the mass, horizontal acceleration and vertical acceleration of the block

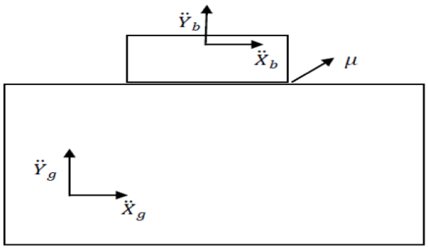

Figure 2. A rigid block on the ground

and μ is coefficient of friction between the block and the ground, calculated by the proposed formula of chowdhury and Helali [10, 11] for mild steel.

The block acceleration in sliding is as follows, cause just by the friction force:

$$\ddot{X}_g = \mu(g + \ddot{Y}_g) sign(\dot{X}_g - \dot{X}_b) \quad (2)$$

Where $\dot{X}_g$ and $\dot{X}_b$ are velocity of the ground and the block, respectively.

A code has been prepared for time history analysis of the block for constant as well as variable friction coefficient. Five earthquake records with considerable vertical component is chosen for this study.

3- DISCUSSION AND RESULTS

The obtained results show that vertical component of earthquakes cannot be ignored. For the variable frictional coefficient, the results are shown for Bam earthquake in Fig. 3; acceleration of the block is decreased by assuming constant value for the coefficient of friction. The same is true for other considered earthquake records. A firm conclusion cannot be drawn for the displacement of the block relative to the ground, because it may be increased or be decreased by assuming constant value for the coefficient of friction, depending on the selected record of the analysis.

4- CONCLUSIONS

The obtained results of the present study shows that supplying sliding base is beneficial for low masonry buildings, especially in severe earthquakes with high PGAs.

Assuming constant friction coefficient leads to base shear overestimation, which is conservative. Despite, this assumption cannot be used for evaluating the displacement of the block relative to the ground. It is because; the displacement may be increased or decreased by assuming constant frictional coefficient, depending on the earthquake record. For the displacement of each step of analysis, the variable friction coefficient should be calculated and applied in the governing formula.

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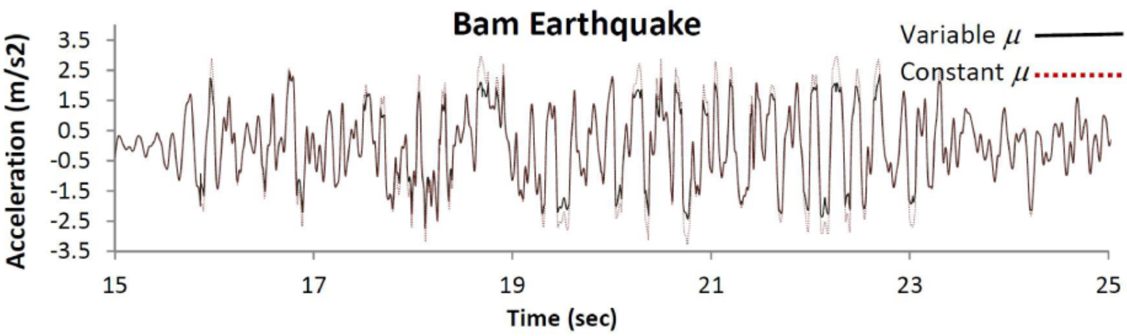

Figure 3. Results of the analyses for Bam earthquake

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