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EARTHQUAKE RESPONSE OF SLOPES UNDER MASSIVE LOADS

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Many buildings and other structures have been constructed on sloping grounds. They may pose a considerable mass on the slope particularly in congested urban areas located on sloping grounds. Traditionally, the additional mass is assumed as a rigid body connected to the ground of slope. In this case, existing approaches for stability analysis of slopes and embankments can be directly applied to solve the problem with the consideration of additional mass to the soil mass above the slope failure surface. However, the complete inertial interaction of the structures supported by the slope is not considered in this approach. In this case, the amplification of the base shear transmitted to the ground may be significantly underestimated resulting in a non-conservative evaluation of the seismic slope stability. This paper aims to study the significance of the load of massive constructions on the slope stability problem with considering soil-structure interaction.

In geotechnical earthquake engineering, slope stability is one the most important issues which has been in the center of attention due to its huge and widespread damage potential. Generally, three procedures are available for slope stability analysis, i.e. pseudostatic analysis, Newmark sliding block analysis and stress-deformation analysis. Pseudostatic approach was firstly presented by Terzaghi for slope stability analysis (Terzaghi, 1951). This procedure provided an index of slope stability. However, it does not provide any information when the instantaneous stability is compromised.

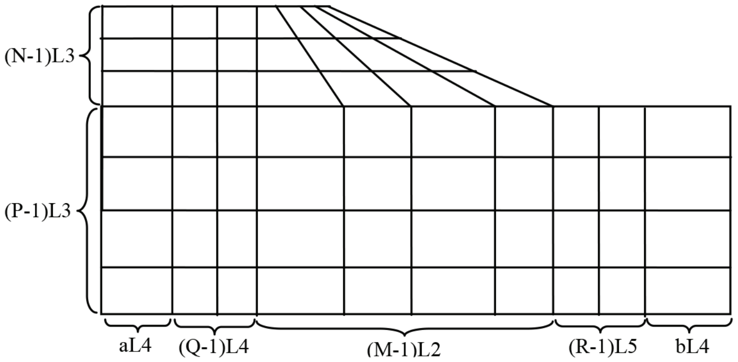
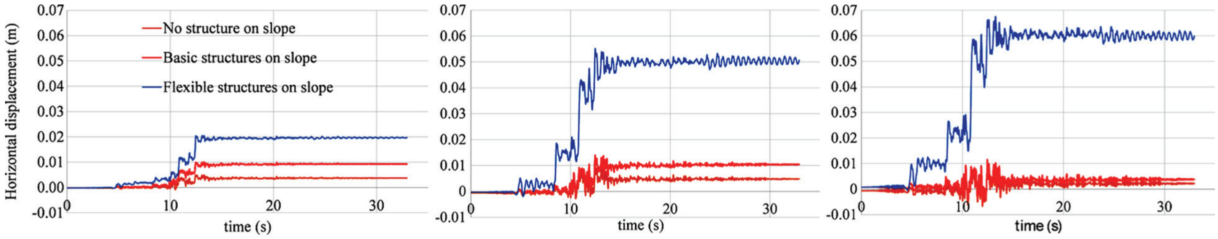


Figure 1. The schematic view of the slope and geometric modelling parameters.

After that, stress-deformation analysis was developed, which may quickly become a complicated approach depending on the complex details of the soil properties and the degree of the required accuracy in modelling (Seed, 1979). The result of this approach deem to be closer to reality. Finally, a kinematic sliding block analysis was presented to introduce a new procedure that does not contain shortcomings of the pseudostatic or complication of the stress-deformation analysis (Newmark, 1965). However, since the flexibility of the sliding soil block is not considered in the Newmark approach, its results should be considered with caution. Recently, some procedures have been developed to account for the flexibility of sliding blocks (Kramer et al., 1997; Rathje and Bray, 1999). However, in all these analyses, there is no way to directly consider the inertial interaction of the structures with the supporting slope. Considering the aforementioned limitations in slope stability evaluation and the large direct and indirect consequence of slope instability, it is important to study the effects of growing massive constructions particularly in urban areas on the slope stability of the supporting ground.

In this study, a two dimensional (2D) slope as shown in Figure 1 is modelled in OpenSEES, 2000. The soil stress-strain constitutive model is elastic-plastic in which plasticity exhibits only in the deviatoric stress-strain response. The volumetric stress-strain response is linear-elastic and is independent of the deviatoric response. This material is implemented to simulate monotonic or cyclic response of materials whose shear behavior is insensitive to the confinement change. During the application of gravity and other static loads, material behavior is linear elastic. In the subsequent seismic excitation, the stress-strain response is elastic-plastic. Plasticity is formulated based on the multi-surface (nested surfaces) concept, with an associative flow rule. The yield surfaces are of the Von Mises type. Moreover, it is assumed that the sloping ground is underlain by a rigid bedrock. A massive column of rectangular elements with a large aspect ratio is assembled on both right and left hand sides of the model as free-field columns. The horizontal movements of element nodes in each horizontal level of the columns are constrained to simulate the free-field motion of each infinite side of the model. Building structures located on the slope are modelled by means of single-degree-of-freedom (SDOF) mass-spring-dashpot assemblies. Each building was simulated by a node connected by a zero-length element to a node of a soil element on the slope. Input acceleration records were applied to the bedrock surface.

Results of the above-mentioned total stress analyses were categorized and plotted in Figure 2 with three different assumptions. Firstly, it is assumed that there is no structure on the slope. Then, it is considered that each structure is solely represented by its gravity load and all analyses were repeated. Finally, in addition to the gravity load of structures imposed to the slope ground, each structure represented by an equivalent SDOF. By comparing the results of these three different models, it is revealed that the sliding displacement is increased when solely the weight of constructions is considered on the slope; however, when the structures are represented by their weight and flexibilities, i.e., equivalent SDOF, the sliding displacement is further exacerbated. Therefore, it is very important to consider the effect of inertial interaction of widespread constructions on seismic slope stability.



(a) (b) (c)

Figure 2. (a) Bottom, (b) middle and, (c) top displacements of a 20° slope.

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