Analysis of Passive Earth Pressure and Displacements of Retaining Walls Using Pseudo-Dynamic Approach

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ABSTRACT

Using additional dynamic parameters in the pseudo-static method like shear wave and primary wave velocities of soil, phase change in the shear and primary waves, and soil amplification for seismic accelerations, one can benefit from another useful tool called pseudo-dynamic method to solve the problem of earth pressures. In this study, the pseudo-dynamic method is used to compute the seismic passive earth pressures on a rigid gravity retaining wall by considering both the planar failure and composite failure (log-spiral and planar) mechanisms. To validate the present formulation, passive earth pressure computed by the present method are compared with those given by other authors. Seismic passive earth pressure coefficients are provided in tabular form for different parameters. The sliding and rotational displacements are also computed and results of the comparative study showed that the assumption of planar failure mechanism for rough soil-wall interfaces significantly overestimates passive earth pressure and underestimate the sliding and rotational displacements.

Keywords: Log-Spiral Failure, Passive Earth Pressure, Pseudo-Dynamic Method, Retaining Walls, Seismic Design, Sliding Displacements, Rotational Displacements

INTRODUCTION

Gravity retaining walls are one of the most important structures which would suffer disastrous damages during earthquakes. Siddle et al. (2005) reported that during the October 23, 2004 Chuetsu earthquake, several residential developments constructed on reclaimed land in Nagaoka city, Niigata Prefecture, experienced damages to houses and roads due to seismically-induced failure of artificial fill slopes. Post-earthquake field reconnaissance surveys revealed that many fill slope failures were caused by the excessive seismic displacements of the gravity retaining walls supporting the fill material. Housner and Thiel (1995) indicated that excessive wall displacements are undesirable. Due to earthquakes, the permanent

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tilting of retaining wall can be either outward or inward, depending on the active or passive state of earth pressure that is dominant. In this article, the evaluation of inward movement of wall is discussed. Due to integral connection of wall with the superstructure, gravity walls attempt to move towards the backfill which compress the backfill and hence, it is of practical significance to assess the seismic passive earth pressure acting on the retaining walls and the associated displacements.

The calculation of passive earth pressure is very important as the permanent displacements of gravity walls (like base sliding and rotation) are governed by the passive earth pressure. In design practice, such wall needs to be proportioned to resist the earth loading for safety against base sliding and rotation in earthquakes. Design methods based on displacements are desirable for defining the comprehensive seismic performance and are required in the context of performance based design in earthquake geotechnical engineering. For gravity wall, typical failure modes during earthquakes are due to excessive deformation such as sliding and tilting. Therefore it is necessary to develop a seismic design approach of gravity walls considering earthquake forces, and control the damage within an acceptable extent.

The seismic effects are generally considered as pseudo-static forces to be added to the other static forces. A detailed review of the literature regarding the computation of passive earth pressure using planar failure, composite failure mechanism and experimental investigations are presented in the following sections. In addition, the review of the literature for the computation of earthquake-induced displacements is also presented.

Studies Pertaining to Static Passive Earth Pressures

In Coulomb’s theory, it is assumed that the failure surface in the backfill is planar. However Terzaghi et al. (1996), Kumar and Subba Rao (1997) and Zhu and Qian (2000) indicated that the assumption of planar rupture surface seriously overestimates the passive pressures for higher wall friction angles. Terzaghi et al. (1996) reported that due to the influence of wall friction, the surface of the sliding in the backfill consists of a curved lower part and a straight upper part. They have also reported that for smooth walls, the rupture surface is planar and for values of the wall friction angle greater than one third of friction angle of the backfill, only curved rupture surfaces should be assumed in the analysis for the passive case.

Studies Pertaining to Pseudo-Static Passive Earth Pressures

The conventional method for the calculation of seismic passive earth pressure is the Mononobe and Okabe method (Kramer, 2003). Morrison and Ebeling (1995) reported that the Mononobe and Okabe equation assumes a planar failure surface, which is not the most critical mode of failure for determining the passive failure load. Soubra (2000), Kumar (2001), Soubra and Macuh (2002) and Subba Rao and Choudhury (2005) used the pseudo static method along with the curved rupture surfaces for the computation of passive earth pressures. However, all these methods have the similar type of limitations as observed in Mononobe–Okabe method of analysis.

Studies Pertaining to Experimental Investigations

Duncan and Mokwa (2001) reported the experimental results and concluded that the logarithmic spiral earth pressure theory provides more accurate estimates of passive pressures for conditions where the interface friction angle is more than about 40% of the friction angle of the backfill. Fang et al. (2002) presented the results of experimental investigation on the passive earth pressure on retaining walls and concluded that for low wall friction angles, Coulomb and Terzaghi theories were found to be in good agreement with the experimental ultimate thrusts.
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