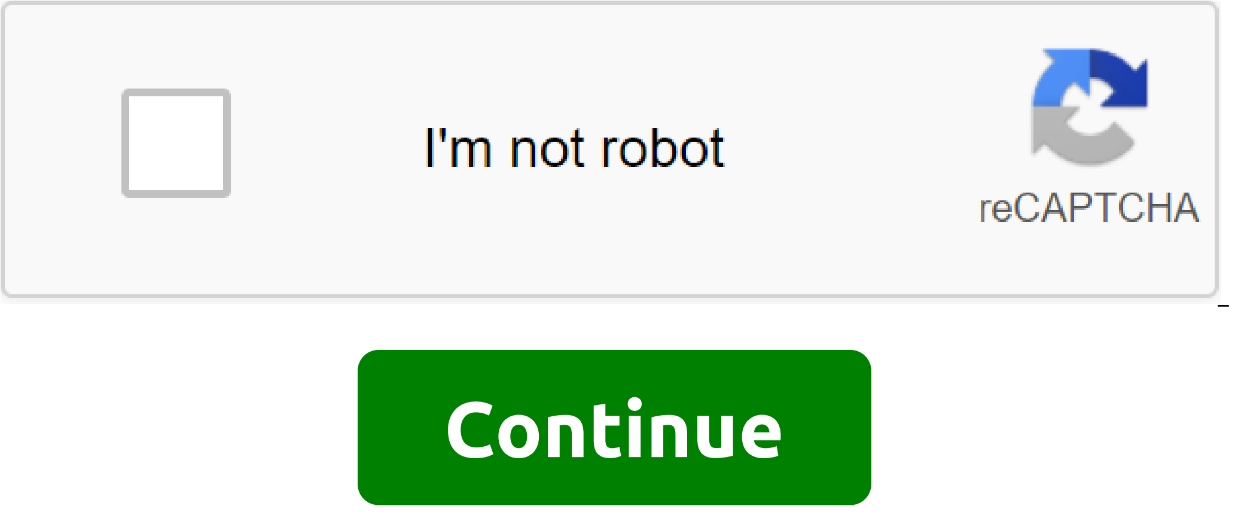
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Seismic slope stability analysis pdf

The current state of practice in North America to assess the performance of slopes during earthquake loading is to use one of the following approaches: 1. Limit Equilibrium Approach This approach uses horizontal and vertical seismic coefficients (k_h and k_v) to assess seismic loads and performs traditional balance assessment analysis to assess the safety factor from slip. Figure 1 below illustrates this approach. The slope is considered safe to design an earthquake if the safety factor is equal to or more than 1.10 (NCHRP Report 611, 2008 and Olson and Stark, 2003). Using this approach, you can assess the stability of the slope and the potential for any flow failure, however you cannot get an approximate estimate of the slope deformation. Figure 1. Pseudo-static analysis of the balance limit (Melo and Sharma, 2004). A wide range of computer programs (e.g. SLOPE/W, SLIDE) is commercially available to conduct the necessary pseudo static balance of limits. The analysis procedure is straight forward, however, determining a seismic factor that can properly represent the characteristics of earthquake design is not easy. It should be noted that the seismic factor is not equivalent to the adjusted at the ground peak speed (PGA) place, as acceleration varies to the depth of the sliding block, and the PGA occurs only on its surface. Thus, the equivalent seismic ratio should be only a percentage of the adjusted on the PGA website. A number of recent publications have provided guidance on the selection of the corresponding seismic factor, in which the coefficient is a function; (i) Earthquake characteristics (magnitude, M, distance from fault, R, peak earth speed, PGV) and ii) lateral slope displacement. The choice of the appropriate seismic factor depends on both local code requirements and engineering judgments. The procedures outlined below are recommended to determine the seismic factor. 1.1. The condition of the non-fresh site Is a reliable approach to design that can be used is the Bray et al. (1998) approach. It is worth noting that sp 117-Guidelines for assessing and mitigating seismic hazards in California recommend the use of this approach to calculate the seismic factor. The wording is given as k_h'f_'eq' time MHA_r where the MHA_r is the PGA in a rock seat state, and f_eq is a factor associated with the characteristics of the earthquake structure and the threshold side slope displacement. f_etz is given as f_'eq'frac-NRF 3.477 (time 1.87-log_{10} (Fracoa (MHR_r/g) times D_ 5-95) where D_ 5-95 is the average duration calculated on the approach, presented by Abrahamson and Silva (1996), the NRF is a factor that takes into account the non-linear reaction of soil material over the slide and you tilt the displacement threshold in units see. slope, u would be a permissible deformation of the slope prescribed by the design team. If you just appreciate the deformation of the existing slope, as mentioned above at the beginning of the article, this method is not appropriate. For further development of the equations above, please read Chapter 11 Recommended Procedures for the implementation of DMG Special Publication 117: Guidelines for Analyzing and Mitigating the Danger of Landslides in California (link). For your convenience, I have formulated the above equations in the table. You can download it here: Seismic-Coefficient-Calculator.xlsx Bray et al (2002) simplified the f_'eq assessment process) and presented the results of the above calculations in the picture (figure 2 below) for different ranges of earthquake magnitude and distance for two levels of displacement of threshold slopes, 5 and 15 cm. Values f_eic as a function of MHA_, earthquake of magnitude and distance of fault (r) ro thresholds (a) 5cm and (b) 15 cm (SP117, 2008). 1.2. Although the procedure described above was originally designed for the non-liquefied state of the site, it is also used for liquefied gas conditions. There are two main problems when liquefaction is involved in the analysis of slope stability; (i) Determining the representative parameters of the soil to appropriately approximate soil softening and loss of liquefaction strength; (ii) Definition of a representative seismic factor. Note that liquefaction usually triggers after the strongest pulses of the earthquake movement have hit the liquefied layer. To this end, a certain percentage of the seismic coefficient calculated in the previous section (0.0 leq k_'h, liq and k_h) should be used for the stability of the slope. As for the goods (i); in the current state of practice, soil stiffness/degradation of liquefied soil strength is represented by the use of residual soil strength in the analysis of slope stability. Residual strength can be assessed on the basis of correlations based on CPR and CPR recommended by Idris and Boulanger (2008). See Figure 3 to determine the residual strengths of the haircut. Figure 3. Normalized ratio of the strength of the residual sheath of liquefied sand compared to the equivalent number of strokes adjusted for pure sand SPT (Idriss and Boulanger, 2008). Figure 4. Correlation between the normalized ratio of residual sheepa strength for liquefied soils and over-adjusted resistance to CPR penetration (Idriss and Boulanger, 2008). As for the paragraph (ii); the use of k_, liq' and k_'h in the analysis of slope stability will lead to too conservative construction, as liquefaction and peak acceleration of the ground do not occur simultaneously. However, it should be noted that there is a high level of conservatism included in the prediction of liquefaction triggering, peak (PGA), earthquake magnitude (M), and residual SL. liquefied soil. To this end, using k_, liq' 0.0 in the analysis of tilt stability seems appropriate. Most geotechnical consulting firms use k_, liq' 0.0 for the condition of liquefied soil. 2. A move-based approach, this approach involves either a simplified concept of Newmark sliding blocks or improved continuum modeling techniques. This article will focus only on the approach to Newmark sliding blocks. The advanced continuous modeling method is summarized here. Newmark's sliding block method treats the potential mass of failure as a rigid body, relying on a failed plane. When the movement of the intake ground, induced along the failure plane, exceeds the threshold acceleration, the deformations accumulate over time, leading to residual deformations of the slope (see figure 5). Threshold acceleration is also called acceleration of yield (k_ yoy) and is defined as horizontal acceleration, which results in a safety factor of 1.0 in a pseudo static analysis of the balance limit. Figure 5. Newmark Slope Sliding Block Concept (NCHRP 611 Report). The method is shown as a function of earthquake features such as magnitude (M), PGA, PGV, and distance from fault. Accordingly, based on this approach, several research teams conducted statistical analysis for a wide range of historical earthquake movements and developed equations to calculate slope deformation as a function k_ Most of these equations were well articulated in the SLAMMER computer program. In case you don't want to use equations, this program can also analyze Newmark sliding blocks to set ground time stories. One of the drawbacks of the original sliding block model is that it treats the failure mass as a hard body and ignores the sliding block deformation. Seeds and Martin (1966) and Maqdisi and Seeds (1978) showed that the method does not accurately reflect the dynamic reaction of deformable earth/waste sliding mass during earthquake shaking. Bray and Travasaro (2007) proposed a method that takes into account the deformation of the sliding block. The method is also available in the SLAMMER computer program. 2.1. The non-liquid state of the site, as indicated above the analysis, is completed in three stages: Determination of acceleration of yield (k_): to perform a pseudo-static equilibrium limit is analyzed iteratively by changing the values of k_.h.). The most k_ that leads to a safety factor of 1.0 will be the acceleration of yields, determine the characteristics of earthquake design for the site in question, using computer programs such as SLAMMER to calculate slope deformations. If the slope is made up of a soft material, it is recommended to use the Bray and Grassaro (2007) approach, as it explains the inability of mass If the slope consists of a hard/dense material obscured by a very soft layer, layer, It is also recommended to consider Newmark sliding hard block. The state of the liquefied area Analysis includes the above steps with two main changes: the residual strength of the liquefied layer should be used in the balance limit analysis to calculate the k_; The Bray and Travasaro method (2007) should NOT be used because the sliding mass behavior is more like a hard body, relying on liquefied soil. It is recommended to use Newmark sliding hard blocks. There are some empirical methods for assessing lateral bias caused by liquefaction, based on a standard penetration test (SPT) and a cone penetration test (CPT), such as Youd et al. (2002) and Chang et al(2004). These methods are not discussed here for brevity, and note that the methods are not applicable if you are going to find a solution to stabilize the slope through some techniques such as soil-nail, piles, deep soil mixing supports, etc. 3. The Final Comments Move-based Approach has two advantages over the ultimate equilibrium approach: unlike the balance-to-balance approach, the move-based approach provides an approximate estimate of slope deformation. In a move-based approach, there is no need to assess the seismic factor (k_'h). Last but not least, in my opinion, both methods described above are approximate and may be related to some level of error. The most reliable tool for this purpose is to adopt advanced numerical approaches and to simulate a full-scale continuum model of the system. So there is no need; (i) Assess the pseudo static seismic coefficient, (ii) assess the residual strength of liquefied soils and (iii) make any engineering judgments about the level of deformation of potential moving masses. Important note: The methods described above were originally developed and formulated for small earthquakes of the earth's crust, and the characteristics of earthquake subduction zones were not included in these approaches. Very recent studies, such as the Bray et al. study (2017), provide recommendations for calculating lateral slope displacement when exposure to earthquakes in the subduction zone. They have included their approaches, including the 2007 version (Bray and Travasarou, 2007) in a spreadsheet that is available online for free. The spreadsheet is also able to estimate the seismic factor (k_'h). For easy access, I downloaded the table here in the following link: BT07_BMT17_Seismic_Slope_Displacement_v5.xlsx (by Bray et al. 2017). 2017). probabilistic seismic slope stability analysis and design. a screen analysis procedure for seismic slope stability. how are seismic factors incorporated in slope stability analysis. seismic rock slope stability analysis