Newmark Deformation Analysis

1 Introduction

SLOPE/W can use the results from a QUAKE/W dynamic analysis to examine the stability and permanent deformation of earth structures subjected to earthquake shaking using a procedure similar to the Newmark method. QUAKE/W is a finite element program for analyzing the effects of earthquakes on embankments and natural slopes. QUAKE/W computes the static plus dynamic ground stresses at specified intervals during an earthquake. SLOPE/W can use these stresses to analyze the stability variations during the earthquake and estimate the resulting permanent deformation.

The purpose of this example is to illustrate how to use the stresses computed with QUAKE/W in SLOPE/W to examine the stability and permanent deformation of a slope subjected to earthquake shaking. Features of this simulation include:

- Initial stress analysis with QUAKE/W
- Multiple stage analyses with QUAKE/W and SLOPE/W
- Homogeneous soil with Mohr Coulomb model
- No pore-water pressure
- Multiple slip surface with Grid and Radius

2 Configuration and setup

To do a QUAKE/W dynamic analysis, you must start your analysis with QUAKE/W. First, you need to establish the initial static stress of the slope, then you do the dynamic stress analysis of the slope using the initial static stress as the initial condition. Please refer to the QUAKE/W engineering book for details of doing a QUAKE/W analysis. It is important that you are satisified with the computed results in QUAKE/W before you proceed to the dynamic analysis in SLOPE/W.

Assume that you have done the QUAKE/W analysis and you are happy with the results; you can then add a SLOPE/W analysis inside GeoStudio. You are now ready to define the shear strength properties of the material and the trial slip surface method. Figure 1 shows the geometry, the finite element mesh, the soil model of the material, and the position of the search grid.

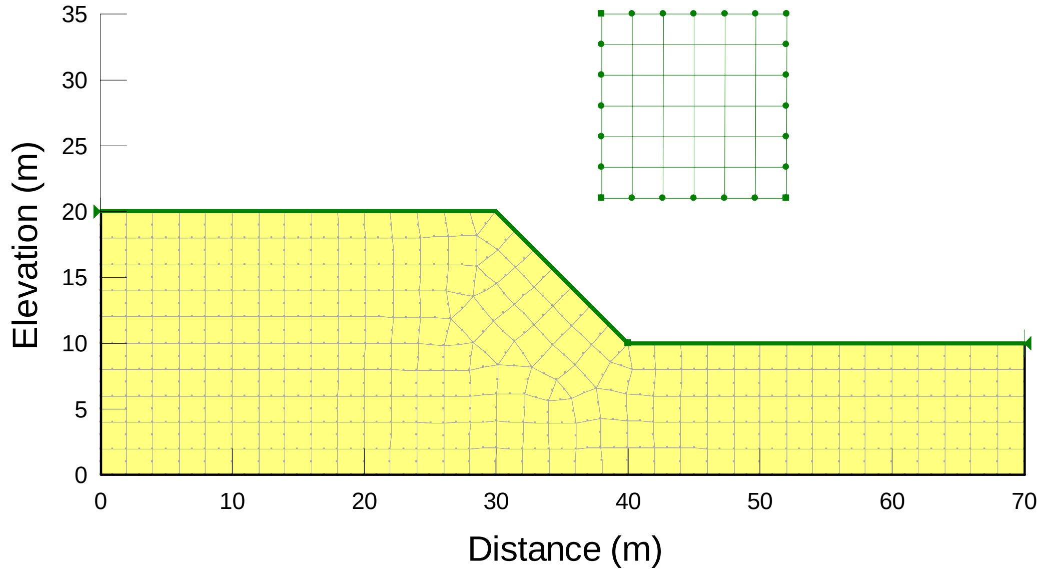

Figure 1 The geometry, finite element mesh and search grid

For each trial slip surface, SLOPE/W uses the initial stress condition to establish the static strength of the slope and the dynamic stress at all time steps to compute the dynamic shear stress of the slope and the factor of safety at all time steps during the shaking process. SLOPE/W determines the total mobilized shear arising from the dynamic inertial forces. This dynamically driven mobilized shear is divided by the total slide mass to obtain an average acceleration. This average acceleration for the entire potential sliding mass represents one acceleration value that affects the stability at an instance in time.

In this example, the shaking of the slope is 10 seconds long and is modeled with 500 time steps. Figure 2 shows the critical slip surface at the end of the shaking (i.e., at time step 500). The critical factor of safety is 1.103 at time step 500, the smallest factor of safety during the entire shaking may occur at other time steps.

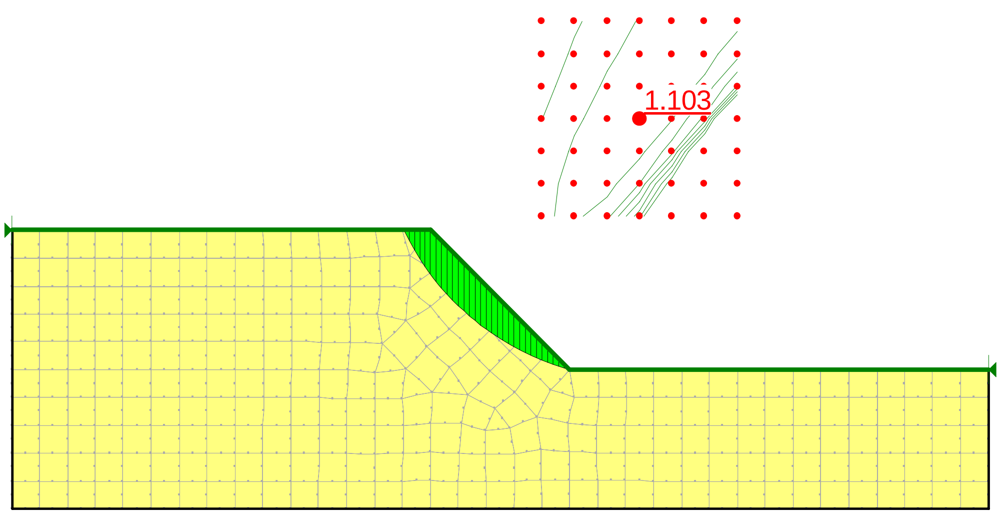

Figure 2 Critical slip surface and factor of safety at time step 500

Figure 3 shows the factor of safety of the same slip surface (Slip # 25) during the shaking process. You can see that the smallest factor of safety of this slip surface is about 0.88 at about 3.0 seconds into the shaking, and the highest factor of safety of this slip surface is about 1.59 at about 6 seconds into the shaking.

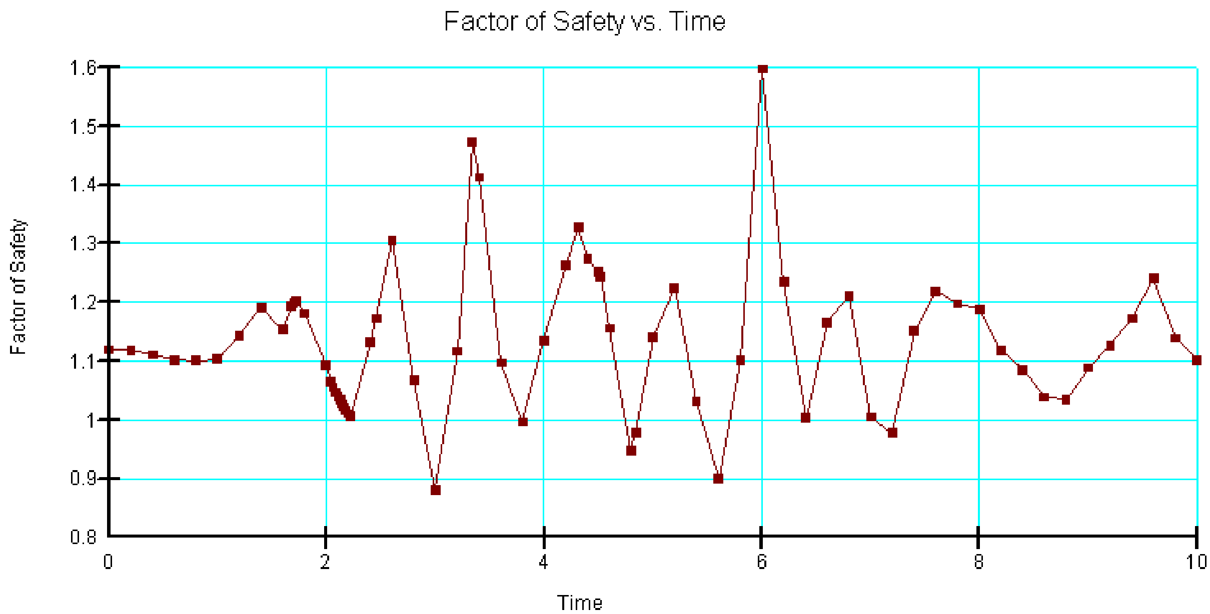

Figure 3 Factor of safety of a slip surface during the 10 seconds shaking

Figure 4 shows the computed factor of safety versus the average acceleration of the slip surface. As expected, the factor of safety is inversely proportional to the average acceleration. From this plot, SLOPE/W computes the acceleration corresponding to a factor of safety of 1.0. This is the called the yield acceleration. The yield acceleration of this slip surface is 0.06476.

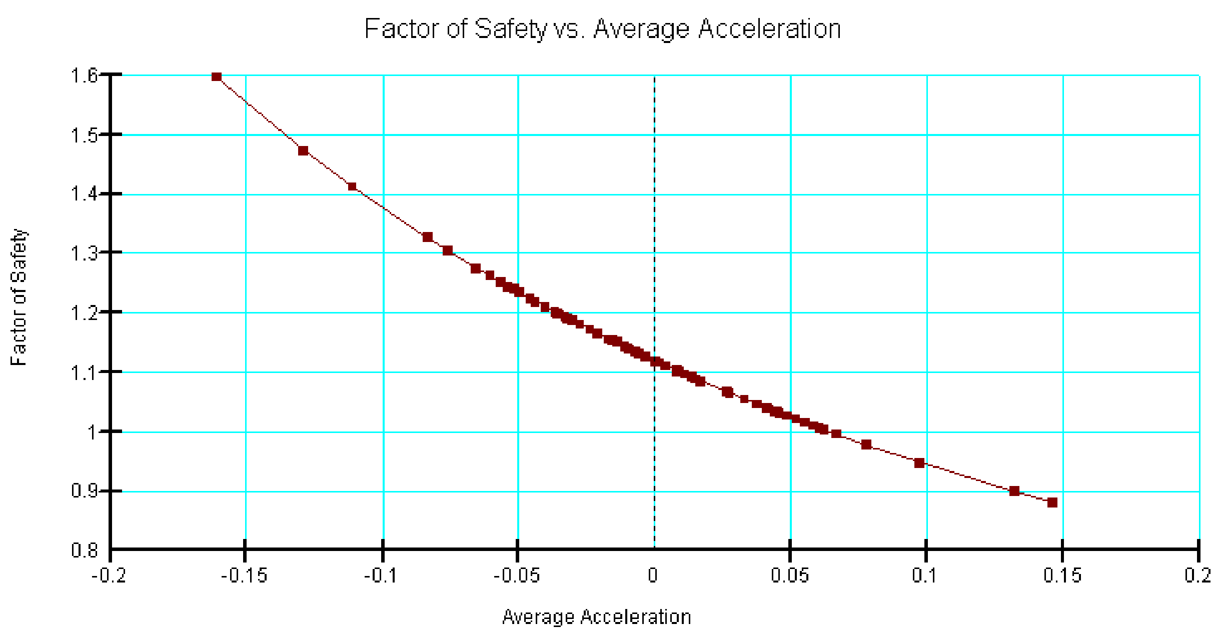

Figure 4 Factor of safety versus average acceleration

Figure 5 shows the average acceleration of the slip surface during the 10 seconds of shaking. By integrating the area of the graph when the average acceleration is at yield acceleration, we can get a velocity versus time plot during the shaking period (Figure 6).

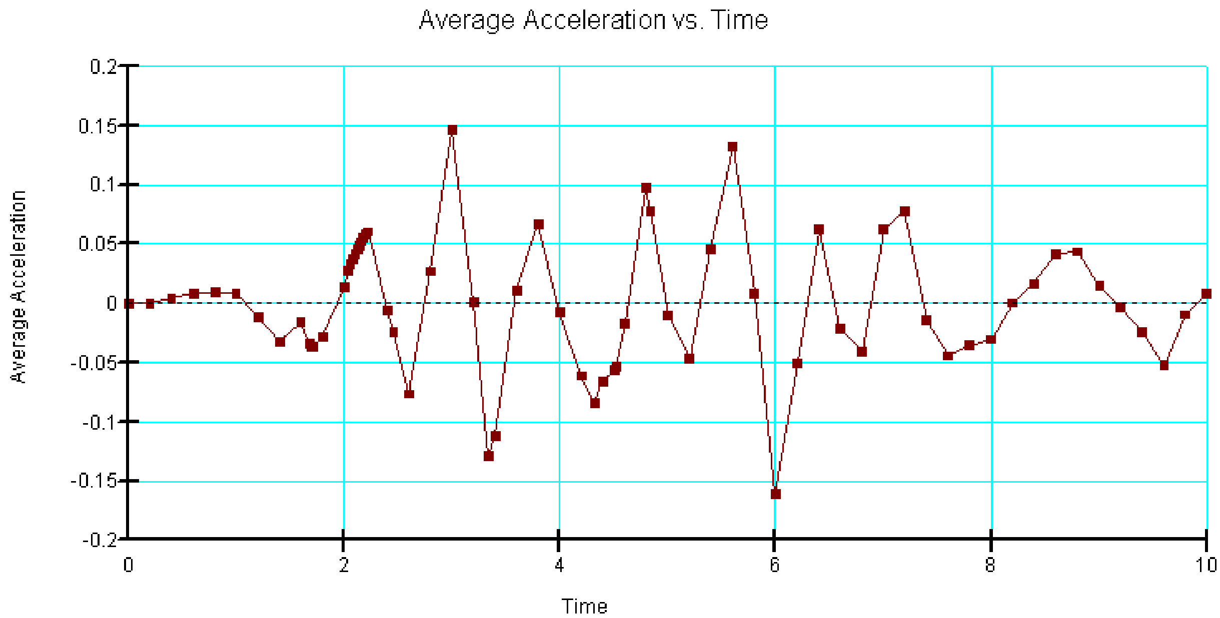

Figure 5 Average acceleration versus time

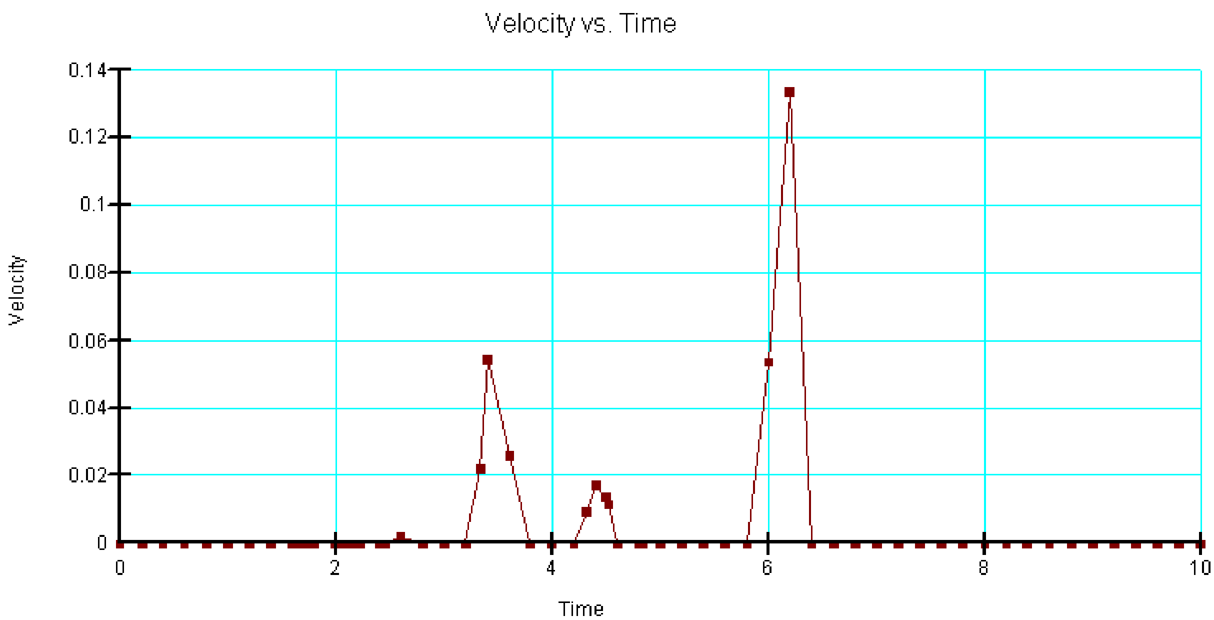

Figure 6 Velocity versus time plot

Figure 7 shows the permanent deformation versus time of the slip surface. It is obtained by integrating the area under the velocity graph (Figure 6) when there is a positive velocity. The maximum permanent deformation of this slip surface is 0.056 m. You may examine and plot results of any slip surfaces at any time steps using the Draw Slip Surface feature in CONTOUR.

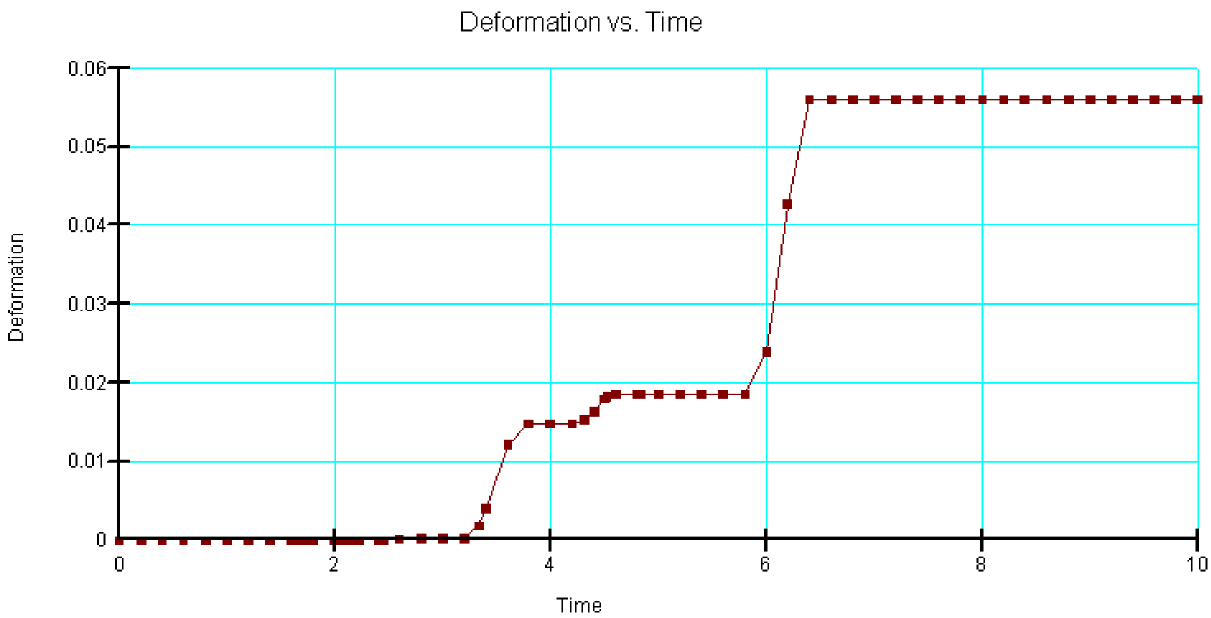

Figure 7 Permanent deformation versus time

Please note that this type of analysis is sometimes referred to as an undrained dynamic deformation analysis. The soil is deemed to behave in an undrained manner during the earthquake shaking; that is, the total soil strength does not change much during the shaking. According to S.L. Kramer in his book "Geotechnical Earthquake Engineering" (page 462), this type of analysis is only appropriate if there is less than about 15% degradation in strength due to the shaking. This type of analysis is not considered appropriate for cases where there is a large build-up of pore pressures, which in turn may lead to large strength losses causing the soil to liquefy. Examining the possibility of a liquefaction flow failure requires a different type of analysis.