# Behavior of Low Height Embankment Under Earthquake Loading

Debabrata Ghosh, Jadavpur University, India
Narayan Roy, Jadavpur University, India*
Ramendu Bikas Sahu, Jadavpur University, India

## ABSTRACT

Low height embankments are widely used as road embankments for highways and rural roads in India. Sometimes, the construction of such types of embankments on soft foundation soil becomes mandatory. In addition to the problematic soft foundation soil, seismic excitation might also play a significant role in the stability of such an embankment. The present study analyses the response of a low height embankment with soft foundation soil under earthquake loading. Numerical simulations have been performed using FLAC2D program. A stiffer half-space with higher shear wave velocity (Vs) has been considered below the soft foundation soil and the earthquake loading has been applied at the bottom of this stiffer half-space. Simulation has been performed considering two different thicknesses of soft foundation soil. In addition to that, three different levels of earthquake shaking and Vs of the stiffer half-space have been considered in the analysis. Results have been presented in the form of PGA amplification, excess pore water pressure, horizontal, vertical static/seismic displacement, etc.

## KEYWORDS

Embankment, Excess Pore Water Pressure, PGA, Seismic Excitation, Soft Soil

## 1. INTRODUCTION

Embankment is a widely used civil structure serving various purposes since a long time. It can be used as earthen dam, rock-fill dam, roadway, railway embankment etc. An embankment can be used for different purposes depending on which it may be said as low height or high embankment, steep slope or gentle slope embankment, homogeneous or composite embankment. According to the purpose of use, it gets subjected to several kind of forces and their combinations. An embankment can be subjected to the gravitational forces, sudden drawdown forces, seepage forces, seismic forces, artificial hazards etc. The dynamic analysis is comparatively new. As since the 1960 several earthquake events around the world caused damages to several major structures and the significance of the response of earthen structures under dynamic loading has become evident. In this particular study, the response of a low height embankment (roadway, railway) built over soft foundation clay followed by stiff clay

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*Corresponding Author

layer will be assessed and analyzed. Since last few decades, the researchers across the world have developed several analytical, empirical, semi-empirical methods to analyze the slopes or embankment under seismic condition and determined the settlement, factor of safety etc.

Terzaghi (1950) proposed the pseudo-static method with introduction of pseudo-static horizontal and vertical pseudo-acceleration in the zone of failure mass that represents the dynamic forces induced due to earthquake. This method provides FOS of the embankment but does not calculate the settlement and it is widely approximate method. Newmark (1965) hypothesized the failure mass in a slope as sliding block on an inclined plane. The permanent deformation doesn't occur as long as the seismic induced acceleration amplitude is less than the yield acceleration. By double integrating the acceleration in excess of the yield acceleration over the seismic period the permanent deformation is determined. Seed et al. (1973) developed a procedure to calculate seismic induced slope deformation from the results of linear or equivalent linear analyses. The cyclic shear stresses are calculated in each element of dynamic finite-element analysis. Deformations are then estimated as the product of the average strain potential along a vertical section through the slope and the height of that section. Makdisi and Seed (1978) used block theory and Chopra's method (1966) for calculating the permanent deformation of a slope and embankment and expressed that in form of chart. Lefebvre & Pfendler (1996) showed that the shear strength of undisturbed soft clay decreases rapidly with no initial static stress with increase in number of scale but compensated by strength mobilization associated with high strain. Cyclic resistance decreases with increase in initial static stress but cyclic degradation is less. Wartman et al. (2001) conducted a series of shaking table tests using clayey slope under two successive test motions. Accelerometer and displacement potentiometer were installed at salient points to records the behavior of the model under two successive identical earthquake motions. Egawa et. al (2004) investigated the behaviour of embankment on peat ground under seismic loading through a series of centrifuge model tests. The author studied the effects of thickness of peat ground, the height of embankments, frequency and acceleration level of the input motion. It was observed that as the frequency of input motion approaches the natural frequency, the settlement of the peat layer increased because of high acceleration response. The acceleration response increases in the central depth of the ground. The higher the initial shear modulus of the peat ground, the decline in acceleration response is more prominent. Endi Zhai et. al. (2004), analysed and compared the results of shaking induced cyclic shear stresses and permanent deformations obtained by equivalent linear and nonlinear effective-stress approach with the finite difference code FLAC. The authors analysed Stone Canyon Dam located in Los Angeles, California by both equivalent linear method and fully non-linear method. Although the total accumulated pore pressures at the end of shaking doesn't vary too much, but the shaking induced permanent deformation obtained from two methods differs significantly. For more realistic analysis, the authors used FLAC3D which resulted in maximum crest deformation. The authors also concluded that the shaking induced excess pore-water pressure and reduction of stiffness of the soil affects the dynamic response of the embankment significantly. Melo and Sharma (2004) studied the dependency of the seismic coefficient on the geometry and slope angle, characteristics of the input loading etc. They used horizontal accelerogram data recorded for Northbridge earthquake (1994) and Mohr-Coulomb constitutive model and FLAC software program for analysis. Singh and Roy (2009), studied 152 published case histories about the performance of embankment during the earthquake to correlate the crest settlement of the embankment with the major influencing factor. Authors concluded that settlements are larger when the fundamental period of the embankment is close to the dominant period of the input motions, and the crest settlement may lead up to 1 metre depending on $a_y/a_{max}$ ratio. Parish et. al. (2009) analysed the behaviour of core and shell of an embankment subjected to seismic excitation using the Mohr-Coulomb constitutive model. Authors showed that plasticity should be included in the analysis of the embankment under seismic loading. As the plasticity may change the natural frequencies, which in turn can significantly changes the response of an embankment. Giri and Sengupta (2010) conducted a shaking table test on physical models and the results were compared with the results of numerical modelling using finite difference program. In shaking table tests, the