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Investigation of Failure Criteria for Concrete Quay Walls during Earthquake Using Finite Element Method

Maryam Massahfard [1], Saeid Pourzeynali [2], Mir Ahmad Lashteh Neshaei [3]
1- M. Sc. Student
2, 3- Associate Professor
Department of Civil Engineering, Faculty of Engineering, The University of Guilan, Rasht, Iran

maryam.massahfard@yahoo.com

Abstract

Quay walls are commonly constructed to prevent landward erosion of shorelines and maintain configuration of the area behind them against wave action. Earthquake waves, acting on the foundation of a quay wall, cause an oscillatory motion of the wall body. Because of the vital role of the quay walls in protection of the coastal areas, special attention to design and construction of them is necessary. According to present study, a typical concrete quay wall with backfill soil is modeled using finite element method (FEM) by taking the effects of foundation and sea into account, and several real earthquake records are applied as the base accelerations. According to dynamic equations and applying earthquake motions, the dynamic behavior of the quay wall is characterized and its failure criteria are investigated. The results demonstrate a great step for optimum design of quay walls against different loading combinations particularly for earthquake forces.

Keywords: Concrete quay wall, FEM, earthquake, dynamic behavior, failure criteria.

1. INTRODUCTION

Since Iran is almost bounded by water (in the North by Caspian Sea and South by Persian Gulf), major ports are the basic necessities for these areas. Main forces applying to quay walls include: wave's force, earthquake force, hydrostatic force, hydrodynamic force, soil pressure and vertical forces (inertia and uplift) [1]. Earthquake waves are one of the most important forces applying to the quay wall. The societal and economic impact of a large earthquake can be so devastating. The earthquake disasters in Los Angeles, USA, in 1994 (61facilities and 40 billion US dollars in losses); Kobe, Japan, in 1995 (over 6400 fatalities and 20 billion US dollars in losses) are recent examples [2]. These disasters are caused either by strong earthquake motions, often in the near field of seismic source areas, or by moderate earthquake motions in the regions where the damage due to ground failures has not been anticipated or considered in the seismic design.

In present study, a typical concrete quay wall is analyzed by using FEM and several real earthquake records are applied as the base accelerations. Displacements and Von mises stresses at critical points of the quay wall are presented.

2. DYNAMIC BEHAVIOR EQUATION

The principal equation for a time dependent movement of a volume affected by a dynamic loading is:

$$M\ddot{u} + C\dot{u} + Ku = F \quad (1)$$

where:
M expresses mass matrix, C, K and F indicate damping matrix, stiffness matrix, and force vector, respectively [3].
The displacement vector (u), speed vector ($\dot{u}$) and acceleration vector ($\ddot{u}$) can be time dependent vectors. C is a function of mass and stiffness matrix (Railey damping). In this study Railey damping is ignored.
Figure1 shows the 2D finite element model of a concrete quay wall with 13.7 meters height, 9.6 meters width, which is affected by the earthquake accelerations mentioned in Table1[2].