Seismic Response of Rigid Faced Reinforced Soil Retaining Walls

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ABSTRACT

Reinforced soil walls offer excellent solution to problems associated with earth retaining structures under seismic conditions. Among different types of reinforced soil walls, rigid faced walls are widely used in various infrastructure projects. Presented is the seismic response of such rigid faced reinforced soil retaining walls through numerical models. Development of numerical model for simulating the shaking table tests on rigid faced reinforced soil retaining walls and its application in investigating the seismic response of wall models are presented. These models are discussed in depth in the article. The results obtained from the numerical simulations are validated with that of experimental studies reported in the literature. Sensitivity analyses are conducted to understand the affect of different material properties like backfill friction angle, backfill dilation angle and stiffness of reinforcement on model response.

Keywords: Numerical Models, Reinforced Materials, Reinforced Soil Walls, Retaining Walls, Seismic Response, Soil

INTRODUCTION

Reinforced soil technology is one of the major developments in the field of civil engineering in the recent decades. The use of reinforced soil structures is enormously increasing from past three decades and they found to be effective even for several critical conditions compared to conventional soil structures. Reinforced soil retaining walls offer competitive solutions to earth retaining problems associated with less space and more loads posed by tremendous growth in infrastructure in recent times. Moreover, they offer improved performance in addition to the advantages in ease and cost of construction compared to conventional retaining wall systems. Recent earthquake experiences all over the world evidenced the effective performance of reinforced soil retaining walls during earthquakes, in the absence of foundation liquefaction, lateral spreading or sliding (Sakaguchi, 1996; Tatsuoka et al., 1997; Koseki et al., 2006) while a number of conventional walls during the same events were seriously damaged. However, the damages of reinforced soil retaining walls due to earthquakes are also reported in literatures (Sandri, 1994, 1997;

Studying the performance of the retaining structures under cyclic ground shaking condition helps to understand better about the behavior during earthquakes. Reinforced soil walls are constructed using different reinforcing elements and facing system. Reinforcing elements may be metal strips or polymer products like geotextile, geogrid, geomembrane etc. Wall facing system may be: Wrap facing, full height rigid facing, segmental block facing and modular block facing. The study of seismic behavior of reinforced soil walls can be classified into three categories: experimental studies mainly based on shake table and centrifuge tests, analytical model studies based on pseudo-static and pseudo-dynamic approach, and numerical model studies. Numerical modeling techniques are useful tools to study the seismic behavior of reinforced soil walls. These are particularly advantageous to those situations where prototype structures are too big to be tested in laboratory and to have insight into the stress strain variation within the model. These advantages make numerical modeling popular day by day. Finite element or finite difference methods are used for numerical modeling. In each case, the model should be validated first with some laboratory test results and calibrated model can be used for large scale studies.

In this paper, the rigid faced walls are modeled using three dimensional explicit finite difference program FLAC\textsuperscript{3D}. The numerical models developed are validated with laboratory model test results. Parametric studies are conducted to understand the effects of various parameters on behavior of wall.

BACKGROUND

Many researchers worked on static performance of reinforced soil walls (Karpurapu & Bathurst, 1992; Ho & Rowe, 1996; Rowe & Ho, 1997; Rowe & Skinner, 2001; Ling & Leshchinsky, 2003; Hatami & Bathurst, 2005, 2006; Skinner & Rowe, 2005). The effect of geometric parameters such as reinforcement length, numbers of layers of reinforcement, distribution of reinforcement and wall height on the static forces developed were analyzed.

The dynamic behavior of reinforced soil retaining walls and slopes are studied by various physical models which include studies on full scale structures (Kazimierowicz-Frankowska, 2005; Lee & Wu, 2004), reduced scale models (Nova-Roessig & Sitar, 1999; Chen et al., 2007; El-Emam & Bathurst, 2007; Murali Krishna & Madhavi Latha, 2007, 2009; Sabermahandi et al., 2009). The analytical studies were conducted by different researchers (Bathurst & Cai, 1995; Cai & Bathurst, 1996; Ling et al., 1997; Ling, 2001; Huang et al., 2003; Ling & Leshchinsky, 2005; Huang & Wang, 2005; Nimbalkar et al., 2006; Huang & Wu, 2006, 2007; Nouri et al., 2008; Reddy et al., 2008; Shekarian et al., 2008; Biglin, 2009) to know about the behavior of the reinforced soil retaining wall and to establish some design curves. The analytical methods cannot incorporate the behavior of reinforcement, interface between the soil and reinforcement, cyclic behavior of soil and reinforcements.

Numerical simulation is one of the useful techniques to study the behavior of the retaining wall structure. A properly calibrated numerical model can be used to study the real field problem that facilitates extensive parametric analyses. The numerical approaches can be mainly divided into two categories: finite element method and finite difference method. A number of numerical tools are available in finite element method such as Tara 3, Dyna 3D, Plaxis, Ansys etc. Segrestin and Bastic (1989) and Yogendrakumar et al. (1992) used the programmes SUPERFLUSH and TARA-3 to study the dynamic behavior of the reinforced soil walls. Cai and Bathurst (1995) carried out dynamic finite element modeling of geosynthetic reinforced segmental retaining walls using modified TARA-3. Helwany et al. (2001) and Helwany and McCallen (2001) conducted both two and three dimensional finite element analysis of a 6m high segmental retaining wall subjected to El Centro earthquake us-
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