Considering the effect of six component of near-fault earthquake ground motions on the three dimensional systems

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Abstract

The rotational component of seismic strong-motion is attracting attention since it is becoming evident that it may contribute considerably to the overall response of structures to earthquake motions. This paper presents an improved method for calculating the time histories of torsional and rocking components of ground motion corresponding to a set of three recorded orthogonal translational components. Using the multicomponent input, the maximum structural response to an arbitrarily oriented earthquake is derived. The mathematical model and numerical results of the torsion and rocking obtained from a set of three recorded translational components are also presented.
Keywords: Rotational components of earthquake; Near-fault; Far fault

1. INTRODUCTION

Rotational motions (torsional and rocking) induced by seismic waves have been essentially ignored for a long time, first because rotational effects were thought to be small for man-made structures, and second because sensitive measuring devices were not available until quite recently. This has been a widely accepted practice in engineering community, mainly caused by the lack of recorded strong motion accelerograms for these motions. Many structural failures and the damage caused by earthquakes can be linked to differential and rotational ground motions. In earthquake engineering, the rotational ground motion effect has also been recognized for causing structural damage especially for long structures such as bridges and pipelines or transmission systems (e.g., Hart et al., 1975; Zerva & Zhang, 1997). Torsional responses of tall buildings in Los Angeles, during the San Fernando earthquake in 1971, could be ascribed to torsional excitation, while rotational and longitudinal differential motions may have caused the collapse of bridges during San Fernando (1971), Miyagi-ken-Oki (1978) [11] and Northridge (1994) [12] earthquakes. In the beginning, those effects were supposed to be due to the asymmetry of the structure or building. Yet, recent studies show that even symmetrical buildings would also be excited into rotational modes (e.g., Awad & Humar, [6] 1984; Li et al., 2001; Newmark,[7] 1969). Bouchon & Aki (1982) simulated rotational ground motion near earthquake faults buried in homogeneous layered media for strike-slip and dip-slip fault models. They showed that the maximum rotational velocity produced by a buried 30 km long strike-slip fault with slip of 1 m is $1.5\times10^{-3} rad/s$. The benefits of the determination of rotational motion in seismology and engineering are still under investigation. The current processing of earthquake records provide information only about the three translational (two horizontal and one vertical) components of the ground motion, primarily because these are the only components that can be directly measured [1]. However, the translational components during a seismic event are always accompanied by rotational components because of the traveling wave effects. Several studies (Singh and Ghafory-Ashtiany[2], 1985; Gupta and Trifunac[3]; Shakib and Tohidi[4], 2002; Ghayamghamian and Nouri[5] 2007) have shown the importance of rotational components in the seismic analysis and design of structures. Singh and Ghafory-Ashtiany differentiated numerically two orthogonal translational records and obtained the associated free-field rotational motion [2]. A similar technique was implemented by Shakib and Tohidi to generate the record of the torsional ground motion from the two components of earthquake. When available, the acceleration time histories recorded by strong motion differential arrays can be used to generate rotational components by numerical differentiation of translational components. This technique was used by Ghayamghamian and Nouri to estimate the torsional components earthquakes recorded at the circular array in Chiba array system, located 30 km east of Tokyo, Japan, is composed of 15 boreholes with separation distances varying from 5 to 320 m. This provides a unique opportunity to examine the characteristics of rotational components. For this purpose, 17 events are