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Intelligent seismic isolation system using air bearings and earthquake early warning

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ABSTRACT

Recently strong seismic waves or long period seismic waves have been observed in various earthquakes that occurred in Japan. As a result improvements of existing seismic isolation systems are deemed necessary. The present study proposed an intelligent seismic isolation system encompassing air bearings and earthquake early warning (EEW) system. Such system exhibits adequate isolation performance. The air bearings are isolation device that may render infinite the superstructure natural period by floating them, and the EEW is applied for a trigger of isolation. This paper illustrates the proposed system and discusses the experimental results of a test carried out with the system. Laboratory tests carried out in the present research demonstrate the effectiveness of the proposed base isolated systems and prove its efficacy in mitigating the effects of three-dimensional seismic waves. For example, the system suppressed the horizontal response acceleration of an isolation target to 38% of input acceleration.

1. Introduction

General expectations regarding seismic resistant technologies have been increasing after the great Hanshin-Awaji earthquake [1] in Japan. The earthquake early warning (EEW) [2] is one of these technologies. EEW is a system that can forecast earthquake intensity and arrival time before principal motion arrives. At first, seismographs set up near earthquake focus detect primary wave, and transmit it to Japan Meteorological Agency (JMA). Then earthquake intensity and arrival time at a particular place are analyzed using information from seismographs in JMA. Finally EEW is transmitted from JMA to medical institutions, transportation facilities, news centers, residence, etc. in order to avoid secondary disaster. EEW is generally used as a warning system at present, and application of EEW to various technologies is anticipated.

Another effective seismic resistant technology is seismic isolation technology [3]. Seismic isolation technology is one of the most effective seismic resistant technologies. The basic principles of a seismic isolation system is to extend the natural period of a superstructure by inserting isolation bearings such as laminated rubber bearings between the superstructure and the foundation. Through the application of the typical seismic isolation system, it is possible to reduce the response acceleration by 1/3 of the response acceleration of a non-isolated structure. In addition none of the base isolated structures was damaged in the great Hanshin-Awaji earthquake. Consequently several thousand base isolated structures have already been built in Japan.

On the other hand, concern over long period seismic waves that have a predominant period of more than a few seconds has been increasing. For example, the sloshing phenomenon of petroleum tanks in the Tokachi-oki earthquake (2003) was caused by long period seismic waves. Moreover, long period seismic waves spread to Tokyo in Mid Niigata prefecture earthquake (2004), and the wave caused resonances in high-rise buildings. Therefore base isolated structures may resonate with long period seismic waves as well as petroleum tanks and high-rise buildings. Additionally, metropolies of Japan such as Tokyo, Osaka, and Nagoya are located on sedimentary layers, and it is believed that long period seismic waves are excited in large earthquakes.

The authors have proposed an intelligent seismic isolation system as an application of EEW [4–6]. This system is able to

Abbreviations: EEW, earthquake early warning; JMA, Japan Meteorological Agency; UPS, uninterruptible power supply; PC, personal computer; NS, north–south; EW, east–west; UD, up–down; μ, friction coefficient of air bearings; F_H, frictional force of air bearings; m, mass of an isolation frame for experiments; g, gravity acceleration

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