Vertical Vibration Isolataion Device using Constant Load Supporting Mechanism

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In Japan, strong near-fault earthquakes of magnitude 7, such as Hyogoken-nanbu earthquake (1995), Tottoriken-seibu earthquake (2000), Niigataken-Chuetsu earthquake (2004) and Noto-hanto earthquake (2007) have been recorded frequently in recent years. Near-fault earthquake has strong vertical acceleration because an active fault slides up and down. With such a background, the demand is increasing for developing vibration isolation devices not only for horizontal earthquake ground motions but also for vertical ones to protect important objects prone to large response accelerations and to guarantee their continuous use after such severe events. Cultural assets and precision instruments are typical examples of this kind of objects.

Although the development of horizontal vibration isolation devices has reached a mature stage, this is not so for vertical vibration isolation devices. The reason of this is existence of gravity. In horizontal vibration isolation, there is no problem with reducing the stiffness to prolong the natural period, which is a key ingredient of vibration isolation. In vertical vibration isolation, on the other hand, very large deformation due to gravity takes place if the stiffness is simply reduced to achieve a long natural period.

To overcome this difficulty, we use constant-load springs, which sustain constant load regardless of displacement. This paper presents a vertical vibration isolation device, wherein a combination of constant-load springs having different capacities are used as a resisting mechanism. With the effective use of the springs in conjunction with gravity, we realize a resisting mechanism that gives a downward constant force to target object to be isolated when it moves up from the reference (static equilibrium) state and an upward one when it moves down.

Since the object placed on the device is supported only by constant-load springs, transmission of the reaction force from the ground to the object can be limited within a specified value. This way, the maximum response acceleration of the object can be controlled regardless of the kinds and magnitudes of earthquake ground motions, which is a suitable feature for protecting the objects sensitive to response accelerations. In addition, this type of vertical vibration isolation device does not have the problem of resonance even under sinusoidal excitations because its natural period is infinity.

This paper demonstrates the effectiveness of the present vertical vibration isolation device thorough experiments and simulations. The experimental results show that the response acceleration can be controlled within about 0.2G for a variety of sinusoidal and recorded earthquakes ground motions whose maximum accelerations are scaled up to 1G. Numerical results obtained by Runge-Kutta method predicted the response acceleration and displacement of the present vertical vibration isolation device properly.

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