Rotational effects in seismology and engineering

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Abstract

During the last half of the 20th century a number of attempts were made to measure or estimate rotational component of strong ground motion, but still there are no consistent measurements of rotations during earthquake shaking. Classic way of measuring rotations by using two identical pendulums was suggested by Golitsin (1912). We modified this idea and created a system to record strong motion and tilt in the near-field of a nuclear explosion (Graizer, 1991).

Most devices used in seismological practice to record ground motion are pendulum instruments sensitive not only to translational but also rotational motion of the instrument's base. Analysis of the response of pendulum type seismological instrument to complex input motion that includes translational and rotational components demonstrated that even for small oscillations, pendulum is sensitive to the translational acceleration, angular acceleration, cross-axis motion and tilt. Studies show that a horizontal pendulum similar to an accelerometer used in strong motion measurements is practically sensitive to translational motion and tilt only, while inverted pendulum commonly utilized to idealize structures is sensitive not only to translational components, but also to angular accelerations and tilt (with most dramatic impact on response produced by the tilting component). Tilting the accelerograph's base can severely impact its response to the ground motion.

The method of tilt evaluation using uncorrected strong-motion accelerograms was developed and tested in a number of laboratory experiments with different strong-motion instruments and using numerical testing (Graizer, 1989, 2006). The method is based on the difference in the tilt sensitivity of the horizontal and vertical pendulums and allows estimating relatively large amplitudes of tilting if they occur during earthquake strong-ground shaking. It requires usage of uncorrected records. Method was applied to a number of strongest free-field and building records of the M_W 6.7 Northridge earthquake of 1994. Tilt extracted from the strong-motion record at the Pacoima Dam – Upper Left Abutment reached 3.4^0 with residual of about 3.1^0 in $N45^0E$ direction, and was a result of local earthquake induced tilting due to high amplitude shaking. Processing of most of the strongest free-field and building records of the Northridge earthquake shows that tilts, if happened, were within the uncertainty of the method, or less than about 0.5^0. In a few cases including buildings damaged during Northridge earthquake tilts in buildings reached few degrees during the strongest shaking.

Most seismological instruments recording ground motion use standard configuration with two horizontal and one vertical sensor. Sensors differ in their construction because of gravity acceleration always applied to a vertical sensor. An alternative way of symmetric sensor configuration was introduced by Galperin (1955). In this arrangement three identical sensors are also positioned orthogonally to each other but are tilted at the same angle of 54.7^0 to the vertical axis (triaxial system of coordinate balanced on its corner). Records obtained using symmetric configuration must be rotated into an earth referenced *X*, *Y*, *Z* coordinate system. Response of pendulums in symmetric orientation to complex input motions including rotations, and the resultant triaxial system response was considered. Possible implications of using symmetric sensor arrangement for strong motion studies are discussed.