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Near Field Effects of Hidden Seismic Faulting on a Concrete Dam

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ABSTRACT

The 2000 Western Tottori earthquake (M_J 7.3), Japan, was caused by a hidden seismic fault underlying the Kasho Dam, a 46 m-high concrete gravity dam. Strong-motion accelerometers registered peak accelerations of 2051 at the top of the dam and 531 gal in the lower inspection gallery. Integration of the acceleration records in the gallery showed a permanent displacement of 28 cm to the north, 7 cm to the west, and an uplift of 5 cm. The dam survived the earthquake without serious damage, but the reservoir water level dropped suddenly by 6 cm followed by damped free vibration that continued for several hours. Based on numerical simulation and field observations, the water level change is attributed to ground displacement in the near field and subsequent seiching of the reservoir. The vibration period of the dam in the upstream-downstream direction changed noticeably during the main shock, probably due to hydrodynamic pressure variation. The earthquake caused cracking of concrete floor beams in a sub-gate control room, which was repaired by post-tensioning with steel bars. Micro-tremor measurements were used to evaluate the effectiveness of the repair work.

1. INTRODUCTION

The 2000 Western Tottori earthquake (M_J 7.3), Japan, occurred at 13:30 (local time) on October 6. Kasho Dam, in the near field of this earthquake, is a concrete gravity dam constructed in 1989 with a height of 46.4 m and crest length of 174 m. The seismic design of the dam was basically conducted by the seismic coefficient method using a horizontal coefficient of 0.12. The full water level of the reservoir is EL 118 m, and at the time of the main shock the water level was EL 112 m.

Strong motion accelerometers at the dam registered a peak acceleration of 2051 gal at the top of the dam and 531 gal in the lower inspection gallery (Japan Commission on Large Dams, 2002). Despite such high acceleration, the dam body escaped serious damage, only suffering cracking of the concrete floor in its sub-gate control room. Although no increase in water leakage was recorded, the water level of the reservoir suddenly dropped 6 cm immediately after the main shock. This was followed by damped free vibration that continued for several hours. The drop in reservoir's water level was mysterious and raised concern among dam engineers.

The location of the dam is shown in Fig. 1 together with the hypocenter locations of the main and aftershocks. A seismic fault appears to run through the Kasho Dam site. No clear trace of fault rupturing was found on the ground surface in the epicentral area (Inoue et al., 2002). The earthquake therefore appears to have been caused by seismic rupturing of a hidden fault underlying the dam site (Ohmachi et al., 2002).

2. NEAR-FIELD GROUND DISPLACEMENT

2.1. Ground displacement inferred from strong-motion records

Several monitoring systems are installed at the dam. Three-component strong-motion accelerometers (seismometers) are bolted firmly to the concrete floor of the upper elevator room at EL 124.4 m and on the concrete floor of the lower inspection gallery at EL 87.0 m (Fig. 2). The horizontal components of both accelerometers are set N-S and E-W (the dam axis is oriented N110° E). A reservoir water-level meter is installed in a concrete well on the crest 0.8 m in diameter. Figure 3 presents a downstream view of the dam, showing the elevator tower and small concrete well structure on the downstream side next to the dam's crest.

Acceleration records of the main shock obtained at the two seismometer installations are shown in Fig. 4. Earthquake acceleration was sampled at 100 Hz with 24-bit resolution and reliable from DC to 41 Hz. Seismic ground displacement was estimated by

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