Large-Scale Landslides on Surprisingly Gentle Slopes: Lessons from Recent Earthquakes in Japan

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Abstract:

Recent large earthquakes in Japan have revealed that catastrophic landslides can occur even on surprisingly gentle slopes, challenging the traditional view that steep gradients are necessary for large-scale failure. This presentation examines two representative cases: the Aratozawa landslide triggered by the 2008 Iwate–Miyagi Nairiku Earthquake (Mw 7.2) and the Horonai landslide induced by the 2018 Hokkaido Eastern Iburi Earthquake (Mw 6.7).

The Aratozawa landslide displaced about 67 million m³ of material from a prehistoric landslide deposit along an ultra-gentle sliding surface of only 0–2°. The enormous mass enabled a long runout, generating a 6 m wave in an adjacent reservoir. Field investigations, MASW and microtremor surveys, and laboratory shear tests revealed a saturated, highly liquefiable sandy layer at the base. Newmark analysis using seismic records and ring shear test results showed that strong shaking and high groundwater levels were both essential for triggering failure on such an ultra-gentle slope.

The Horonai landslide was a deep-seated, dip-type rockslide that occurred along a gently dipping (~6°) bed plane. It displaced about 15 million m³ of materials with the main sliding body being about 80 m thick. Field drill revealed that the sliding surface was developed within the coarser tuffaceous sandstone layer with the exitance of sand boil laying above the sliding surface. Laboratory tests confirmed that liquefaction could occur within the saturated sandy strata, and dynamic ring-shear experiments successfully reproduced accelerating movement under strong seismic loading, demonstrating how transient pore-pressure rise can promote rapid failure and long runout.

Comparison of these cases shows that large-scale landslides on gentle slopes require the coincidence of weak saturated layers, strong ground motion, and mass-related mobility effects. These findings emphasize the need to incorporate subsurface hydro-mechanical properties and site-specific seismic response into hazard assessments, since even gentle terrain may host devastating coseismic landslides when conditions align.