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Centrifuge-model test study of key hazard factors of deep toppling deformation and disaster pattern of anti-dip layered-rock slope under gravity

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To study the toppling deformed body before construction of the dam at the Gushui hydropower station, we developed here a physical model of the slope on the basis of known local geology and of similarity theory. We simulated valley trenching by a method using prior produced block modules and three levels of excavation, and we studied key hazard factors of deep toppling deformation and the disaster pattern related to anti-dip, layered-rock slope under gravity by a five-stage centrifuge-model test and Universal Distinct Element Code numerical-simulation analysis. The results show the following: (1) The occurrence, development and destruction of deep toppling deformation of anti-dip layered rock slopes must have gone through a long geological history; the accumulation of energy and deformation is a very long process, and accelerated-deformation is closely related to changes in external conditions (such as excavation, earthquake, etc.); (2) lithologic conditions (relatively weak rock mass), structural conditions (appropriate layer thickness and dip angle), and external conditions (valley trenching or excavation of slopes) are key factors for deep toppling deformation, while the free-surface condition is the key hazard factor; (3) deep toppling deformation can lead to multilevel bending zones at different depths inside the slope after the several stages of valley trenching (multilevel excavation); the bending zone is gradually connected from the foot of the slope all the way to the top, which eventually becomes the failure boundary; and the development and connection of the bending zone may result in the overall shear failure of the slope along the bending zone; (4) for deep toppling deformation, we propose a qualitative-judgment index and quantitative-judgment indicators of the degree of toppling deformation. We derived quantitative-judgment formulas for the degree of toppling deformation and the calculation formulas were used for the maximum depth of toppling deformation, and we established a system for discrimination of destruction patterns for deep toppling deformation of anti-dip slope.

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