Project Research — **Further Improvement of Facility Operations and Maintenance Technologies**

Disaster Prevention and Maintenance for Hydropower Facilities

Background and Objective

The proper maintenance and operation of hydropower facilities owned by electric power companies are important in terms of provisions for stable electric power supply and renewable energy utilization, while the number of such facilities that were constructed more than 50 years ago and their subsequent aging is progressing. In recent years, changes that appear in environments surrounding forests along rivers and reservoirs are remarkable, and the preservation of facility environments including sediment management becomes an important subject. In addition, the number and scale of natural disasters such as earthquakes and rainfalls severely affects hydropower operations.

In this project, evaluation and analysis methods for existing dam and spillway gate structures will be established to secure safety against strong earthquakes considering the damaged state of the structures. Also, the total management of watershed-sedimentation techniques that estimate the points/places of sediment yield in dam basins and that observes the behavior of sedimentation and turbidity in rivers and reservoirs will be enacted, along with a simple analysis model that predicts sediment level and turbidity.

Main results

1 Development of Seismic Performance Evaluation for Aged Dam and Gate Structures

To obtain the basic information of fractures at the contact zone between dams and their foundations, experiments and numerical analyses of concrete gravity dams during earthquakes were studied. Based on those results, a non-linear FEM analytical method considering the damages at dams and their foundations was developed (N11025). Using this method, the earthquake response analysis of actual-size dams was carried out. As a result of the analyses, the relationship between the damage of the dam body (Fig. 1) and the remaining load capacity at seismic performance was clarified, and the evaluation of the seismic safety of concrete gravity dams was suggested (N11026). In addition, a basic procedure for the safety evaluation of dam gates and numerical examples were prepared against strong earthquakes.

2 Evaluation of Predominant Factors in Determining Sediment Yield

We developed an observation system for simultaneously monitoring the kinetic energy of throughfall (V11001), soil splash detachment, surface runoff, and sediment yield to clarify the predominant factors of generating sediment in forests. We found that forest floor cover can contribute to a decrease in soil sediment yield by preventing both soil splash detachment and surface runoff (Fig. 2) (V11030). These results and the landscape, the topographical watershed environment DB that includes information on degraded forest land, and abandoned forests after clear-cutting (V11003) are utilized for the evaluation of the turbidity and sediment in the reservoirs of dams using our water circulation model.

Furthermore, an analytical method was constructed that could evaluate slope stability by simulating heavy rainfall infiltration into the ground to estimate the hazard of slope failure with a large volume of earth and sand caused by pore water (Fig. 3).

3 Development of an Evaluation Method for Current and Sediment in Rivers and Reservoirs

In order to investigate the current profiles and processes of sedimentation in rivers and dam reservoirs, a movable current and topography measuring system that is equipped with a Acoustic Doppler Current Profiler (ADCP), an echo sounder, and Global Positioning Systems (GPSs) were developed and applied to the strong currents near the hydraulic structures (Fig. 4).

In addition, in order to predict flood discharge and sedimentation in rivers and dam reservoirs, C-HYDRO 2D, which can calculate two-dimensional horizontal flow and topography, was combined with a prediction model of rainfall intensity and discharge (NuWFAS and HYDEEMS).

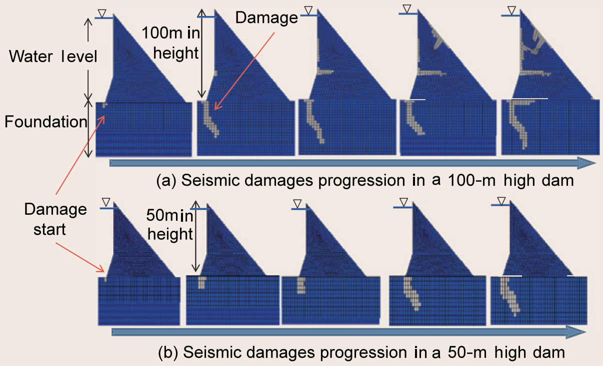


Fig. 1: Analyzed result of seismic damages of concrete gravity dams

The non-linear seismic response analysis of dam considering damages in dam body, contact zones between dams and foundations, and basement rock was carried out. It can be possible to evaluate the seismic damage condition and degree according to the characteristics of dams. For the case of dam crests at 100 m in height, the damage of high elevation in a dam body becomes severe, as the seismic response of a dam apex is hard. In the case of a dam crest a 50 m in height, the damage of the foundation becomes severe, as the seismic response of the dam apex is soft compared to the case of a dam crest at 100 m in high.

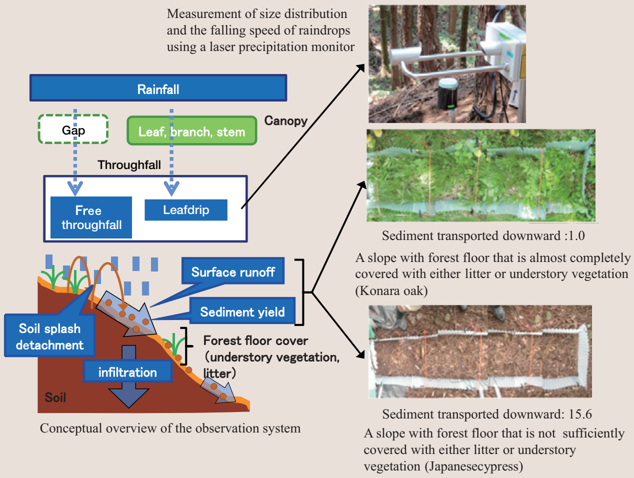
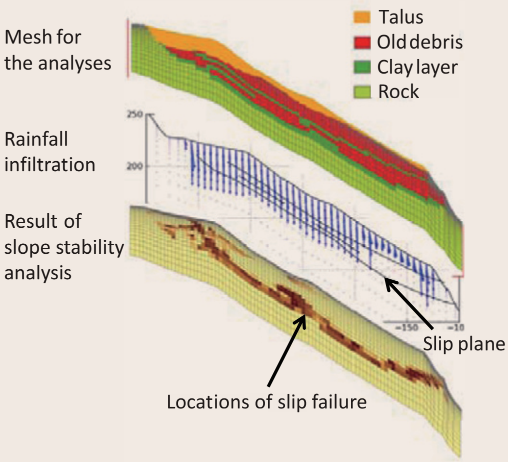


Fig. 2: Schematic diagram of a system for the monitoring of soil erosion rates

Monitoring for 15 months found that sediment yield was 15.6 times higher in a slope with sparse forest floor cover (Japanese cypress) than in a slope with dense forest floor cover (Konara oak). We developed a system for simultaneously monitoring the kinetic energy of throughfall, soil splash detachment, and detached soil sediment transported downward by surface runoff. This enabled us to determinate soil erosion rates in the forested slope.



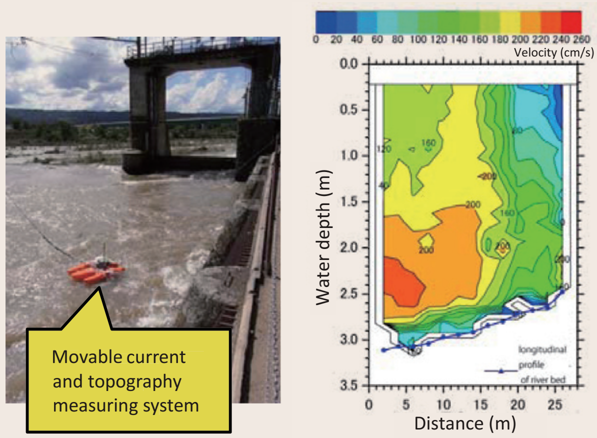


Fig. 3: Examples of an analytical evaluation for the slope stability of slips

The location of slip failure in a slope was estimated by calculating heavy rainfall infiltration into the ground and slope stability by using the change of water saturation and water level in the ground. These figures showed that the depth of the rainfall infiltration corresponded largely to the location of slip failure.

Fig. 4: Movable current and topography measuring system

The left figure shows an appearance of the observation in front of the inlet of a hydroelectric power plant using the movable current and topography measuring system. The right figure shows the measuring results that consist of the vertical velocity profile and a riverbed feature.