

# Civil Engineering Research Laboratory

#### Brief Overview

The Civil Engineering Research Laboratory extensively promotes studies regarding geology and geotechnical engineering, earthquake engineering, structural engineering, and fluid dynamics, which are essential for maintenance work and natural

disaster mitigation at electric power civil engineering facilities, as well as for back-end management in nuclear fuel cycle and underground energy utilization technologies.

#### Achievements by Research Theme

### Geosphere Science

To solve issues associated with the siting and construction of electric power facilities and maintenance and asset management for aging facilities, we quantify evaluation methods for earthquake faults, estimation methods for explosive magnitude of volcanic eruptions, assessment methods for the stability of underground facilities, and methodology for groundwater solute transport modeling.

■ To understand the seismic activity of faults, we have investigated surface fault ruptures and slip distributions caused by the normal-fault earthquake which was thought to be triggered by the 2011 off the Pacific coast of Tohoku Earthquake. Results showed that maximum displacement was observed the closer the distance to the epicenter and frequency distributions of slip for this event were consistent with those of other normal-fault

earthquakes that have occurred in the past

■ To evaluate fault activities and eruption histories, we expanded the applicability of radiometric dating methods such as radiocarbon, K-Ar, and U-Pb. Especially, by using LA-ICP-MS U-Pb method, we found that latest intrusion age of exposed granite in the Northern Japan Alps is around 800,000 years ago and showed that this method is applicable for Quaternary dating.

### Earthquake Engineering

We aim to establish proper countermeasures to control risks on natural disasters, mainly earthquakes, for electric power facilities and equipment. We also develop low-cost solutions to maintain electric power facilities.

■ We clarified that the damage of a transformer bushing in a substation during the 2011 off the Pacific coast of Tohoku Earthquake was caused by strong ground motion exceeding the current design level. We also found that the acceleration response spectrum enveloping over 90% of the observed records corresponded to two times the design level (N12016).

■ The early restoration of the power-supply system after a great earthquake depends on not only electricity in isolation but also critical infrastructures such as communications, transportation, etc.,. We

reviewed the current research status of critical infrastructure interdependency analysis in order to contribute to the optimal strategies for early restoration of the power-supply system. We found that the causes of critical infrastructure interaction are classified into two types, namely physical proximity and functional dependency. The review also showed that four modeling methods, such as the Agent-based Model, are the typical methods for analyzing interdependency, and the selection of a method appropriate for the intended use is necessary (N12017).

### Structural Engineering

To secure the safety and reliability of steel and concrete structures as well as extend their lifespans, we develop structural performance evaluation methods considering natural hazard actions such as earthquakes, wind, heavy snow, along with aged deterioration caused by environmental actions such as chloride-induced deterioration, frost damage and temperature changes.

■ By conducting cyclic loading tests using full-scale specimens of a reinforced concrete (RC) underground structure, we evaluated the effects of cracking damage caused by earthquakes and the following reinforcing steel corrosion on load carrying capacity of an RC box-culvert (Fig. 1). We also developed a consideration method of cracking damages for evaluating the residual load carrying capacity. These results can be applied to the soundness evaluation of the RC underground structures at thermal and nuclear power plants that experience earthquakes. (N12013)

■ To enable the evaluation of effective diffusion coefficient of chloride ion more precisely in a short time, one of the most important physical properties used for prediction of chloride induced degradation in RC structures, we developed a quick evaluation method which can estimate the coefficient in approximately 1/3 of the time as conventional measurements, by combining the standard test method (electrical migration method) authorized by the Japan Society of Civil Engineers and a numerical analysis model. (N12018)

## Fluid Dynamics

In order to evaluate the impact of volcanic eruption and fires on the safety of nuclear power plants and also to improve construction, operation, maintenance, and natural disaster mitigation technologies for hydro, solar and wind power plants, we strive to develop basic evaluation technologies of hydraulic and atmospheric fluid flows relevant to such facilities.

■ We have developed a method to evaluate the reliability of solar radiation forecasts using weekly ensemble forecasts provided by the Japan Meteorological Agency so that we can effectively utilize a one-day forecast result produced by our weather model for prediction of solar power generation. The applicability was examined by checking the degree of correlation between the reliability indicator and the prediction error of our weather model. Moreover, a method has been developed using geostationary meteorological satellite data in order to forecast solar

radiation at ground level in several hours. (V12015)

■ A hydraulic experiment was conducted to acquire data of temporal evolution of a scour hole upstream from a dam gate using prolonged automatic configuration measurement. The experimental results are successfully summarized in a dimensionless manner to draw a correlational formula between scour volume and relevant hydraulic parameters. The empirical formula allows us to predict a temporal evolution scour in actual dams for hydro-electric power stations. (N12002)

## Underground Energy Utilization Technologies

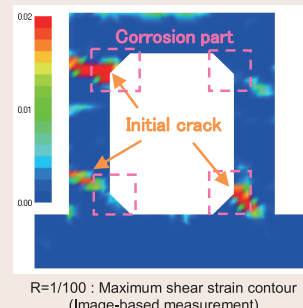
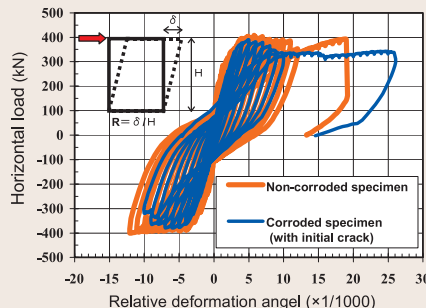
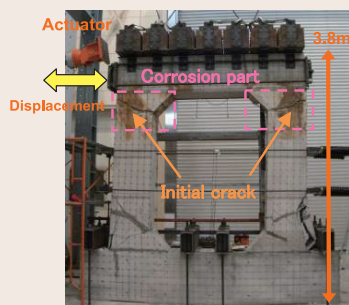
We aim to develop exploration and evaluation technologies for utilizing underground space and developing underground energy such as CO<sub>2</sub> geological storage, large scale electric power storage, geothermal power generation, and so on.

■ It is necessary to prepare information for discussing the introduction of CCSR\* policy to construct new coal power plants in the future in Japan. We collected information of present overseas CCSR regulation and policy. Furthermore, we illustrated results of CCSR assessment conducted by an electric power company as part of consent application for constructing new power stations in the United Kingdom. (V12013)

CO<sub>2</sub> was emitted under the sea floor in the United Kingdom, we predicted underground CO<sub>2</sub> behavior and CO<sub>2</sub> dispersion in the sea by numerical simulation. We also conducted monitoring of underground CO<sub>2</sub> distribution using electric methods and measuring CO<sub>2</sub> concentration in the seawater using an autonomous underwater vehicle. We obtained important practical data for considering environmental impact of CO<sub>2</sub> migration from under the sea floor to the sea.

■ Through collaborative field experiments in which

\* CCSR is the abbreviation of "Carbon-dioxide Capture and Storage Ready". This means to secure lands and so on for preparing addition of CCS apparatuses in the future.



(a) Outline of loading test (ultimate state) (b) Example of experimental results (case of initial crack corresponding to yielding of steels)

**Fig. 1: Full-scale loading tests for RC box-culvert**

Despite the degree of initial cracking damage, the maximum strength of the RC box-culvert specimens with corroded reinforcing steels slightly decreased, although the average corrosion amount of the cross section of reinforcing steels decreased up to approximately 10%. This was because sectional forces were redistributed after cracking. However, in cases where the initial cracking damage levels corresponded to yielding of the reinforcing steels, such as an initial crack width of 0.4mm, the local damage became larger in the after maximum strength due to the corrosion of reinforcing steels. And, in these cases, the strength at a 1/100 relative deformation angle decreased to approximately 80% of when there is no corrosion.