Priority Subjects — **Further Improvement of Facility Operations and Maintenance Technologies**

Development of Soundness Assessment Techniques for Aged Overhead Transmission Steel Towers

Background and Objective

Overhead transmission steel towers constructed during Japan's high economic growth (almost two full decades beginning from 1954) are aging rapidly, giving rise to a need for the standardization of their repair and rebuild, which must be performed with efficiency. Meanwhile, in the 2011 Tohoku Earthquake, larger accelerations than those of the 1995 Southern Hyogo prefecture earthquake were observed, therefore, it is also necessary to gain an understanding of the seismic performance of steel towers against high-level earthquake ground motion. In order to contribute to the efficiency and rationalization of maintenance for aging overhead transmission steel towers, this project aims to develop comprehensive diagnostic methods for their soundness, including a remaining life assessment considering corrosion and fatigue, a more efficient corrosion inspection method and a foundation stability assessment. In addition, we aim to clarify the seismic margin of steel towers considering elastic-plastic behavior against high level earthquake ground motion.

Main results

1 Development of a rate estimation and inspection method for corrosion inside steel pipe

The validity of ACM sensors for evaluating corrosion rate was demonstrated. The distribution of corrosion rate inside steel pipe acquired by ACM sensors showed good agreement with corrosion loss distribution measured on a cross-section of the steel pipe (Fig. 1) (Q14004). In order to estimate the corrosion distribution, a sea salt deposition evaluation method utilizing CFD was developed. The correspondence of calculated sea salt value and measured sea salt value on exposed pipe was verified. Regarding inspection, corrosion loss of the internal pipe was detected by the magnetostrictive sensor technology for long-range guided wave testing (Fig. 2) (Q14003). An accelerated corrosion test method, dry and wet acceleration, was employed for further investigation of internal pipe corrosion. Validity of the method was demonstrated by several tests.

2 Development of corrosive environment maps and a corrosion rate function

For quantitative evaluation of corrosion factors in coastal and inland areas, observations of corrosive environments were carried out continuously at a coastal testing field (Yokosuka city, Kanagawa prefecture) and an existing transmission tower (Narita city, Chiba prefecture) (Fig. 3). Also, maps of corrosive environment factors such as airborne sea salt, temperature and humidity (in almost the whole of Japan) were made by using the sea salt transport evaluation system, NuWiCC-ST, and ultra-high resolution weather reproduction data from the past 53 years, which was reproduced by the weather prediction and analysis system, NuWFAS (Fig. 4). In addition, in order to develop appropriate maintenance plans for transmission towers including inspection prioritization, dose-response functions defined by ISO9223 and ISO994 were improved based on existing atmospheric exposure test results. As a result, a Japanese version of corrosion rate functions was proposed. The proposed functions enable us to approximately estimate the corrosion amount of transmission towers installed in various corrosive environments.

3 Construction and trial of a database system for aging steel towers

A database for the corrosion risk evaluation of transmission steel towers managed by all electric power companies was constructed. The database includes maintenance history data, weather meteorological observation records, survey reports associated with removal corrosion materials, estimated corrosion values using the proposed corrosion rate evaluation models, and maps associated with corrosion environmental factors. In addition, the functions of the developed database system include data searching, data downloading, and data display in the form of an open street map. Currently, the developed system is being trialed by all power companies.

4 Development of a nonlinear analysis model for a transmission tower members' junction in consideration of bolt slippage

In the soundness confirmation of transmission steel towers, which have suffered differential displacements among the main leg members, high-level earthquakes or heavy winds, a more realistic evaluation in consideration of bolt slippage of a transmission tower members' junction is required. In order to contribute to this study, we developed a structural analysis method for the bolt slippage in terms of double nodes and nonlinear spring elements between the nodes, which models the tower members' junction. By using this method, we have made it possible to conduct a highly-precise soundness evaluation which takes the stress redistribution caused by the bolt slippage into account (Fig. 5).

* Sensor for measuring the corrosion rate of metal in a given environment.

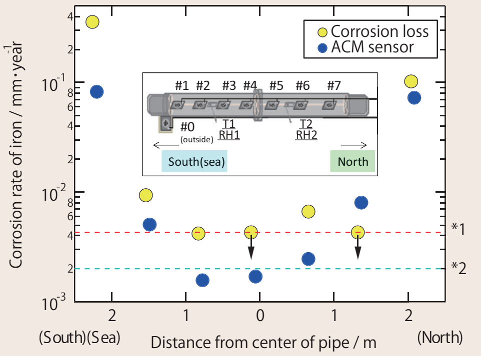

Fig. 1: Distribution of corrosion rate inside steel pipe

Corrosion rate acquired by the cross sectional observation of pipe wall thickness showed similar distribution as the result of experiment using ACM sensors.

*1: lower limit of corrosion rate based on the cross sectional observation.
*2: lower limit of corrosion rate which can be calculated from the output of ACM sensor.

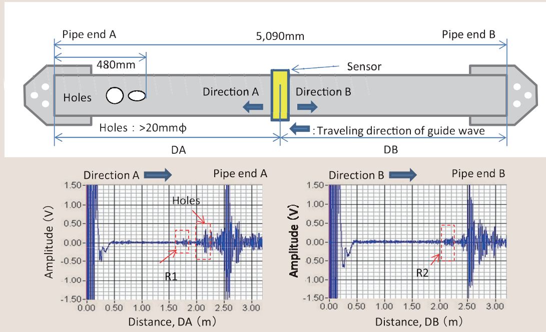

Fig. 2: Guide wave inspection of internal material losses

Reflectors at locations R1 and R2 of an externally painted steel pipe removed from a transmission tower except for pipe ends and holes were observed by transmitting guided waves in directions A and B. Internal material losses at different degrees were detected at the location by ultrasonic testing.

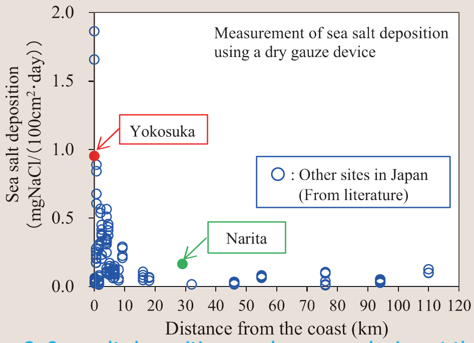

Fig. 3: Sea salt deposition on dry gauze device at the monitoring stations

Sea salt deposition was measured by using dry gauze device at Yokosuka and Narita sites. The measured depositions were compared with those at other Japanese sites previously published in literature. Reduction in the sea salt deposition with distance from the coast is clearly represented.

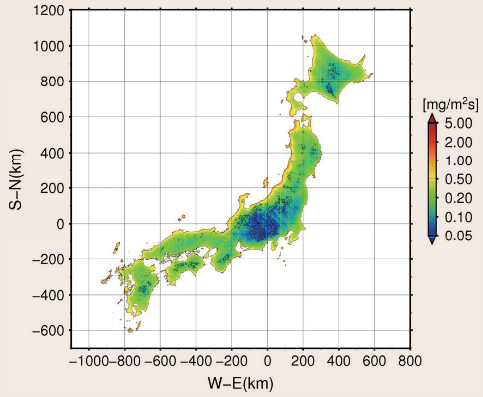

Fig. 4: A map of the annual mean amount of airborne sea salt

A map of the annual mean amount of air borne sea salt with a spatial resolution of 1 km at a ground height of 20 m is shown here. The NuWiCC-ST was used for making it with the frequency distribution data of offshore wind in the past 53 years, which was reproduced by NuWFAS.

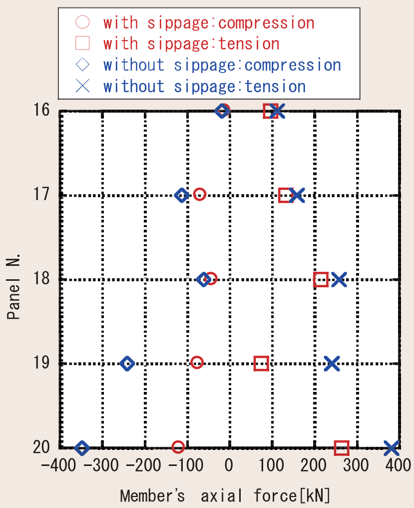

Fig. 5: Wind response analysis in consideration of bolt slippage

In regards to a 500 kV transmission steel tower (69.5 m in height, all 20 panels), we compared the main member's axial forces for two cases in which bolt slippage is either considered or ignored. Fig. 5 shows the maximum and minimum axial forces that occurred under the action of the wind load from the 16th to 20th (bottom layer) panels. The values with slippage are smaller, and it was suggested that estimation could be excessive if bolt slippage was not considered.