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

Development of Soundness Assessment Techniques for Aged Overhead Transmission Steel Towers

Background and Objective

The aging of overhead transmission steel towers constructed in the high economic growth period has progressed rapidly, giving rise to a need for the standardization of their repairing and rebuilding, which must also be performed with efficiency. Meanwhile, The 2011 off the Pacific coast of Tohoku Earthquake, larger accelerations than these observed in The Southern Hyogo prefecture earthquake in 1995 were observed, and as such, it is also necessary to gain an understanding of 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 clarify the seismic margin of steel towers considering the elastic-plastic behavior against high level earthquake ground motion.

Main results

1 Evaluation of the corrosion rate inside steel pipes of transmission towers

For clarification of the mechanism of corrosion inside steel pipes of transmission towers and for quantitative evaluation of the corrosion rate, corrosion environment measurement devices were introduced and an exposure test of steel pipes with atmospheric corrosion monitoring (ACM) sensors*1 was begun at CRIEPI's Yokosuka coastal testing field (Fig. 1). In the exposure test, output of ACM sensors, temperature and relative humidity inside/outside and along the inside of the steel pipes were measured. The results revealed that, in a coastal environment, corrosion rate inside steel pipes depends on the season, the corrosion rate is greater at low temperature and dry seasons than at high temperature and humid seasons. Results also revealed that the corrosion rate inside steel pipes depends on the position, for example more sever corrosion was observed at the end than at the center (Fig. 2) (Q12003).

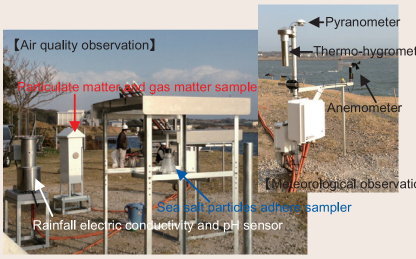
2 Assessment of the applicability of corrosion inspection method for steel pipes

To establish an inspection technique of the corrosion inside steel pipes at low cost and high efficiency as an alternative to impact hammer or bore scope inspections, we proposed a nondestructive inspection using a high frequency guided waves method*2 and a dry type phased array ultrasonic thickness measurement*3 with conformable wedges*4, and verified the performance. The high frequency guided waves method is expected to quickly screen the presence of corrosion as a brief inspection. On the other hand, as a detailed inspection, the phased array ultrasonic measurement provides a profile of corrosion without fluid couplant. Based on a basic study of measurement conditions such as the relationship between signal response and steel pipe shape, we applied the proposed method to corrosion inside an actual aged steel pipe. As a result, we confirmed that the proposed method could identify the corrosion with practical accuracy (Fig. 3) (Q12004).

3 Evaluation on steel transmission tower responses during galloping vibration based on recorded data in a field observation system

The field observation system on an ultra-high voltage transmission steel tower maintained by TEPCO in Fukushima recorded responses of the tower during galloping vibration*5 caused by low atmospheric pressure passing. Based on the obtained data, it was identified that a large amplitude of cable vibration due to galloping vibration had been observed for more than a four hour period. In addition, it was clarified that the maximum cable tension was more than twice that of buffeting responses under the same wind level as galloping. Moreover, an axial force amplitude of a bracing member was about three times as large as that of the buffeting responses (Fig. 4). These observed data help to develop fatigue lifetime prediction method of steel transmission tower.

*1 Sensor for measuring the corrosion rate of metal. In this sensor corrosion current, that is a kind of electrochemical signal, flows between anode and cathode due to environmental corrosion factors.
*2 An approach to inspect thickness loss of pipes in power stations using guided waves whose wave lengths are shorter than the wall thickness of the inspected pipe.
*3 Thickness measurements by dry coupling as accurate as the typical ultrasonic thickness testing.
*4 Wedges put in ultrasonic transducers and conformable to the geometry of test object, which are filled with non-flowable gel instead of resin to make the ultrasonic testing simple and quick.
*5 Up and down large amplitude vibration of a conductor due to strong winds and snow or ice accretion on the conductor

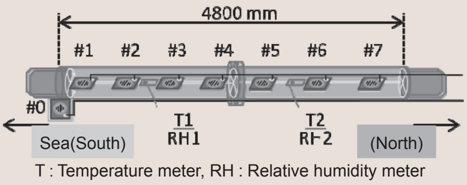


(a) Corrosion environment measurement devices (from March 2013)

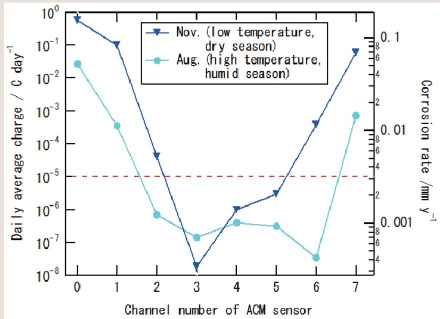
(b) Exposure test of horizontal steel pipe members (from August 2012)

Fig. 1: Corrosion environment observation and exposure testing situation

In regards to corrosion environment observation, measurement of meteorological factors (such as wind direction and speed, solar radiation, temperature, relative humidity, and time of wetness) and measurement of air quality (such as sea salt, sulfur dioxide, rainfall amount, and electric conductivity and pH of rainfall) will be conducted. For the exposure test, the corrosion rate and wet condition inside steel pipes are evaluated. The corrosion rate is estimated using atmospheric corrosion monitoring (ACM) sensors. Steel pipes were arranged horizontally or with slope to ground which simulates horizontal and bracing members, respectively.



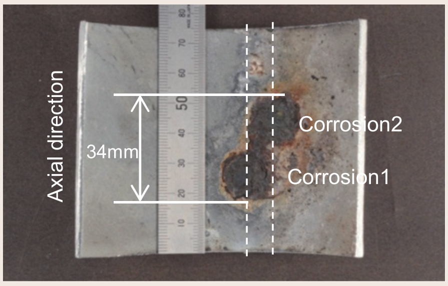
(a) Schematic diagram of the arrangement of ACM sensors inside/outside steel pipe at the exposure test



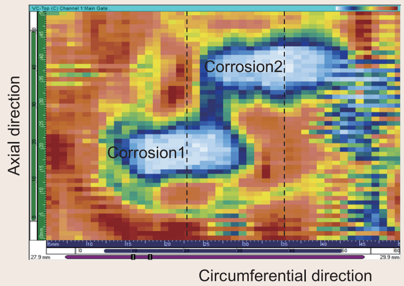
(b) Seasonal corrosion rate inside/outside steel pipe

Fig. 2: Results of corrosion test inside/outside steel pipe

The results of an exposure test on horizontally arranged steel pipe revealed that the corrosion rate is largest on the outside, followed by on the inside at the ends, then the inside at the center. The corrosion rate in the low temperature season was high, which is considered to be due to the fact that water film from dew tends to form easily in this season, and this film contributes to corrosion. The minimum value of the ACM sensor for estimation of the corrosion rate is 10^{-5} C day^{-1}, which corresponds to a corrosion rate of 0.003 mm year^{-1}.



(a) Test specimen with corrosion inside an actual aged steel pipe



(b) Measurement result using proposed method

Fig. 3: Nondestructive inspection method for internal corrosion of steel pipes

Nondestructive testing is proposed in which ultrasonic transducers scan a pipe member in its axial direction using high frequency guided waves propagating along circumferential direction to detect the presence of corrosion, and the phased array ultrasonic testing technology using dry coupled conformable wedges is subsequently used to profile the corrosion.

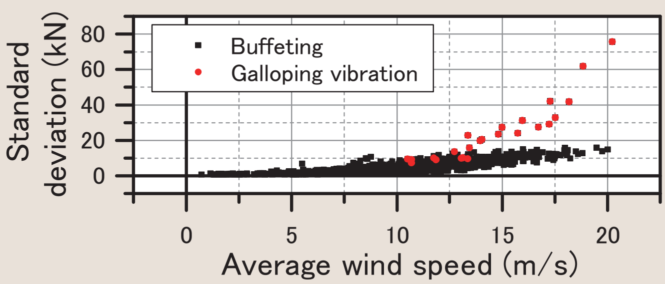


Fig. 4: Observed response data of the tower during galloping vibration

Response data, such as cable tensions, axial forces of tower members and so on, and movie data which recorded cable motion were obtained during galloping vibration. In Fig. 4, a relationship between average wind speeds and axial forces of a bracing member at the panel below a cross-arm effected by cable tension variation was shown. An axial force variation of the bracing member during galloping vibration was three times as large as that of buffeting responses under the same average wind speed.