Wireless Sensors for Atmospheric Exposure Corrosion Monitoring of Steel Elements

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1. Introduction

Atmospheric Corrosion Monitoring (ACM) is a monitoring method for measurement of the environment corrosivity using bi-metal galvanic sensors. Corrosion progresses unevenly on various surfaces of the structure, and could lead to localized damage. This paper describes the development of a low-power wireless ACM sensor and its applications to corrosion monitoring. The contribution to atmospheric corrosion of various factors such as surface inclination and orientation, relative humidity, rain fall, wind intensity and wind direction is investigated.

2. Experiment description

For evaluation of corrosion progress three experimental setups were created, in which H type and box type SM490 steel specimens are exposed in normal urban environment, marine environment near the shoreline and in a setup simulating accelerated corrosion by using salt solution spraying. For determining the effect of inclination angle of the surface, the H type specimens are mounted with the web inclined at 45°, 60° and 90° and with different orientation in regard to dominant wind direction and water spraying direction. 44 wireless and wired ACM sensors are installed.

Fig.1 H60° type and box type specimen

The wireless sensor is compact (120x122x55mm) so it can be installed in narrow spaces and operates up to 200 days on a set of batteries. ACM galvanic current, temperature, humidity are measured every 10 minutes. The sensor also measures the tilt and records triggered 3D accelerations for structural health monitoring purposes.

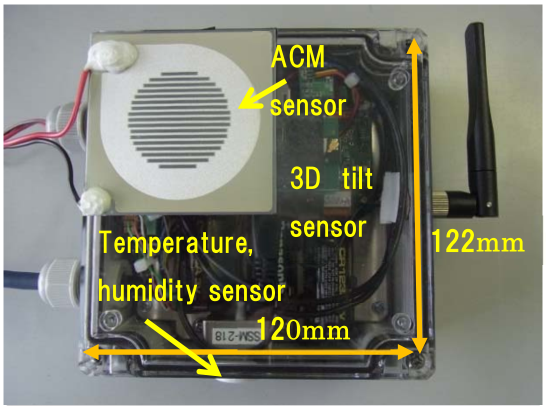

Fig.2 Wireless sensor device

3. ACM corrosion monitoring

Average monthly values of ACM galvanic current intensity in urban and in marine environment conditions are plotted in Fig.3. ACM value increases in the months with increased rainfall such as August, and is higher in marine coastline environment due to corrosive effect of airborne salt.

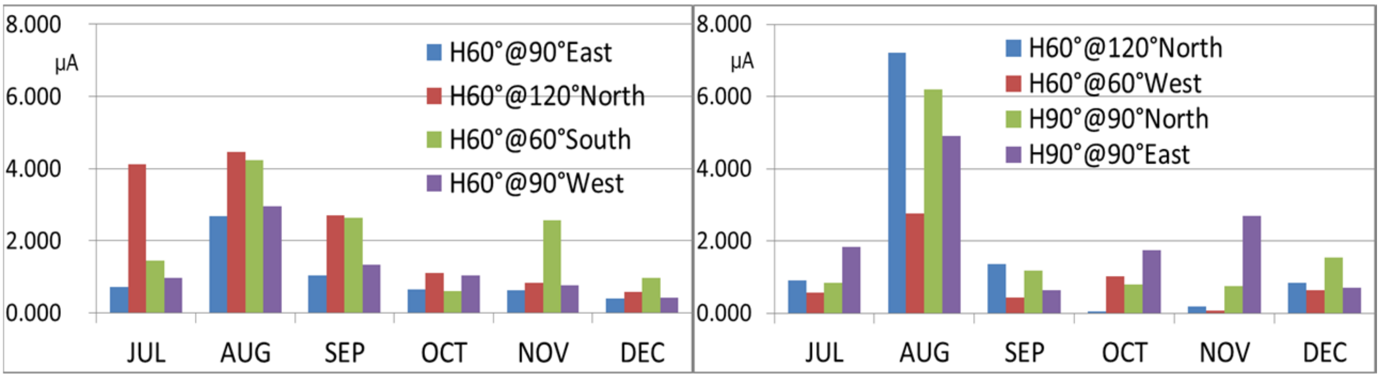

Fig.3 Average ACM galvanic current intensity in urban (left) and marine (right) environment

Keywords: steel corrosion, Atmospheric Corrosion Monitor sensor, environmental factors, corrosion exposure test

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4. Electromagnetic corrosion scale thickness measurements

Electromagnetic (EM) thickness measurements of corrosion scale were collected regularly. EM sensor used could measure corrosion scale up to 1.5mm in thickness with 2% accuracy. Measurement was performed on all surfaces of the element, and at each location several values were averaged. Higher corrosion was measured on the underside and on less inclined surfaces, as shown in Table 1. Higher corrosion rate on the underside surfaces is a consequence of corrosive substances accumulating on the surface, substances which are not easily washed away by the rain.

Table 1 Average values of corrosion scale determined by electromagnetic thickness sensors [μm]

	NORTH	EAST	WEST	SOUTH	TOP	UNDER	90°	45°	60°	120°	135°	AVERAGE
URBAN [μm]	61.3	52.7	61.0	70.8	63.2	105.6	58.2	111.5	71.5	59.5	69.4	71.3
MARINE [μm]	102.8	130.2	123.0	86.8	116.2	276.2	102.1	63.7	116.5	132.1	159.0	128.1

Table 2 Average values of galvanic current intensity measured by ACM sensors [μA]

	90° NORTH	90° EAST	90° WEST	45° SOUTH	60° SOUTH	120° NORTH	135° NORTH	60° NORTH	60° WEST	45° WEST	INSIDE BOX	90° AVERAGE
URBAN[μA]	0.263	0.913	1.150	1.462	1.950	2.045	1.431				0.326	0.830
MARINE[μA]	2.109	2.230	0.989	1.013	1.338			0.943	0.406	0.511	0.016	1.984

5. Estimation of local corrosion rate by ACM corrosion monitoring

Corrosion progresses unevenly in various locations in the structure (Table 2). The corrosion rate is influenced by the surface orientation, exposure to rain and accumulation of water on the surface. Localized higher corrosion is identified at the base of the H type elements (Fig.4), due to water accumulation and wash-out of pollutants. Inside surfaces of the box type elements show little corrosion, with the exception of the box floor where rain water accumulates during intense rain. Corrosivity variation function of the surface orientation is listed in Table 3, values are normalized by the average ACM value for all vertical sensors. In marine environment North and East surfaces show higher corrosion due to airborne salt brought in by the predominant wind, blowing in E, N-E directions, refer to Table 3. Predominant wind (and rain) direction have larger influence on corrosion than the angle of inclination of the surface.

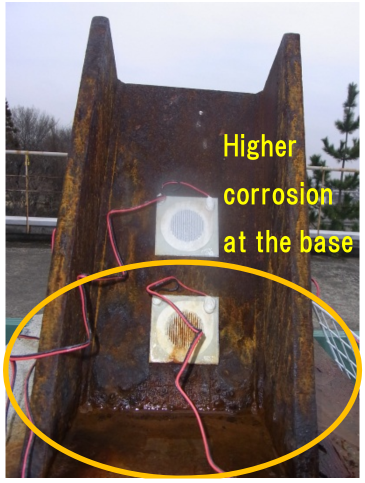

Fig.4 Localized corrosion

Table 3 Relative corrositivity of environment measured by ACM sensors function of surface orientation

	90° NORTH	90° EAST	90° WEST	45° SOUTH	60° SOUTH	120° NORTH	135° NORTH	60° NORTH	60° WEST	45° WEST	INSIDE BOX	90° AVERAGE
URBAN	0.317	1.099	1.385	1.761	2.348	2.463	1.723				0.392	1.000
MARINE	1.063	1.124	0.499					0.475	0.205	0.258	0.008	1.000

6. Summary

- Atmospheric corrosion monitoring of steel elements was performed by ACM sensors using a new compact ultra-low power wireless device which integrates ACM, temperature, and relative humidity sensors.
- Corrosion rates are determined considering ACM current, TOW, temperature, rain fall, and surface orientation by the analysis of first one year data for three atmospheric exposure test conditions. Comparison is made with corrosion scale measurements by electromagnetic thickness sensor for various orientations of the surfaces.
- Corrosion progresses unevenly on various surfaces, depending on surface orientation and exposure to rain. The horizontal surfaces show higher corrosion rates, corrosion being reduced on vertical or near vertical surfaces.

Ref.: E. Sasaki, et. al., "Study on Performance Evaluation Method of Weathering Steels Based on Exposure Tests", Proceedings of 11th Korea-Japan Joint Symposium on Steel Bridges, 2011.

National Institute for Land and Infrastructure Management is acknowledged for providing funding for the research.