Enhancement of Electric Conductivity of the Rust Layers on Weathering Steels by Water Adsorption

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For growth of the rust layers on weathering steels, wet-and –dry cycles play an important role. According to the Evans model for atmospheric corrosion of steels, the FeOOH in the rust is reduced with an oxidation of the substrate steel by the wet period and the consequent reduced rust layer is oxidized by oxygen in air by the following dry period. During the wet period, enhancement of electrnic and ionic conductivity is required for the prompt coupling of the reduction of the FeOOH in the rust with the oxidation of substrate steel. In this paper, adsorption of water vapor from humidified air onto the rust layers and enhancement of conductivity by the water adsorption was presented. A simple measurement is proposed for the AC conductivity of the rust layers, and a relation between the conductivity and rust growth is discussed.

Experimental

The five different rusted steels were supplied from the Public Works Research Institute, the Japan Society of Steel Bridge Construction and Kozai Club. The steels were exposed to different sites in Japan for 17 or 18 y. One of the steels is mild steel and the other four are weathering steels doped by effective metals with different amount. Amount of water adsorbed onto the rust layer on the steel was gravimetrically measured by a balance at 25^{0}C as a function of relative humidity (RH). AC impedance of the rust layers was also measured under dry and wet conditions. The AC impedance was measured between two gold plates pressed on the rusted steel. For wetting the rust layer, 50μl pure water was dropped on the rusted steel before pressing the gold plates.

Results

Fig.1 shows a weight change of the rusted steel during adsorption of water vapor from the humidified air at RH = 80 %.. The weight increase is almost proportional to thickness of the rust layer. From the transient of weight gain, it is seen that the wetting of the rust layer is completed in 0.5 h.

The water adsorption induces a decrease of impedance of the rust layer, or an increase of conductance. Fig.2 shows a impedance diagram of a rust layer under dry and wet conditions. The impedance is plotted in the form of the Bode plot. The rust layer was formed on a weathering steel during exposure for 17 y on Oomina-sawa bridge which locates in mountain area. In the dry condition, the rust indicates high impedance, however, in the wet condition, the impedance decreases about 2 decades.

Fig.3 shows an equivalent circuit for the impedance under the wet condition. The impedance at frequencies lower than 10Hz is related to the double layer capacitance of the gold electrode pressed onto the rust layer. The impedance correspondent to the rust layer appears only in the frequency region higher than 100 Hz, in which the impedance response of R_f, C_f, and R_s can be seen.

The responses in the frequency region higher than 100 Hz are compared among the weathering steels exposed in various environments as a function of environmental factor. For example, the R_f value was found to decrease with increase of amount of air born NaCl particles.

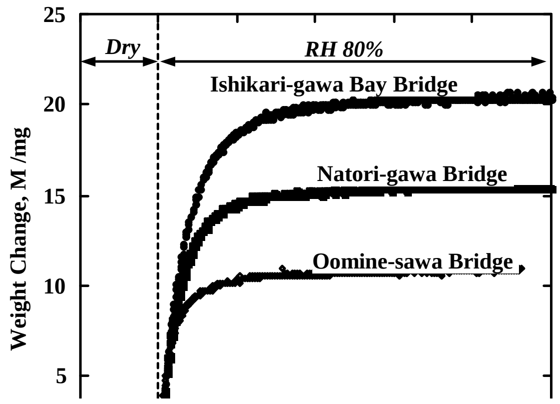

Fig. 1 Transient of amount of water adsorbed in the rusted weathering steel in humidified air at RH 80 %

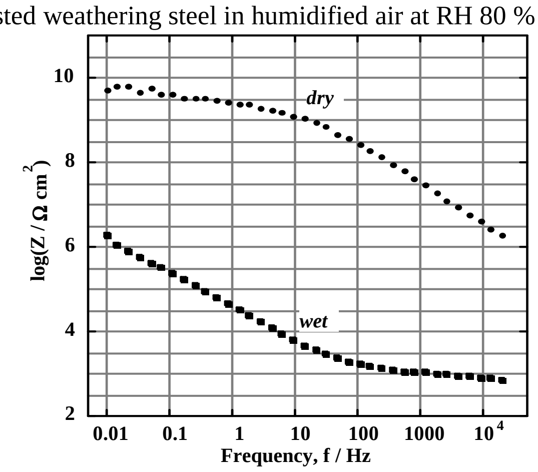

Fig. 2 Impedance diagram of the rust layer on a weathering steel under dry and wet conditions. The steel was exposed for 17 y on Oonine-sawa brighe in mountain area.

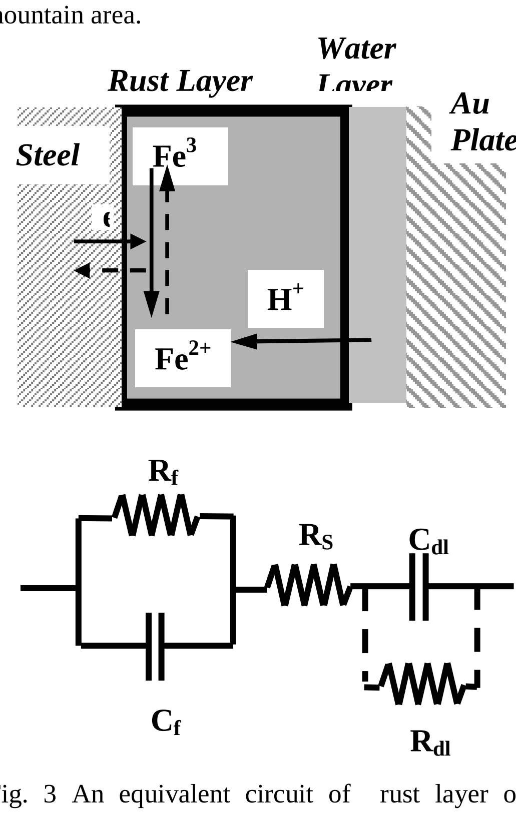

Fig. 3 An equivalent circuit of rust layer on weathering steel under wet condition. R_f and C_f are redox response of Fe^{2+}/Fe^{3+} in the rust layer, R_s solution resistance in the layer, and C_{dl} double layer capacitance on gold electrode.