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Effects of AC Stray Current on Concrete Structures

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ABSTRACT

The purpose of this article is the study of effects of high voltage AC stray current (220 and 380 VAC) on the durability of concrete. In rainy condition, high voltage AC current can leakage into water saturated concrete power pole by creeping AC current through their insulators. In Iran, large budgets are annually spent for replacing degraded concrete power poles with new ones. There is not any research on the above mentioned subject and the history of this research is related to the authors of this paper. Therefore, this study is a new work in the field of concrete.

In this study, the degradation effects and mechanisms of the AC stray current on water saturated concrete were investigated via laboratory tests. They included electrical and electrochemical tests. Based on the results of the tests, AC stray currents can reduce the durability of water saturated concrete by non-distribution current, thermal and shrinkage stress mechanisms. Application of silica fume and reducing w/c ratio increases the resistance of concrete against destructive effects of the AC stray current and increases its durability.

KEYWORDS

Concrete, AC Stray Current, Durability

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1. INTRODUCTION

The formation of galvanic macro cell, carbonation, vibration of concrete pole due to wind force and weight of cable, diffusion of corrosive ions from soil to concrete power pole and its accumulation in near ground level are some of the environmental effects on the degradation of concrete power poles [1], [2]. In addition, the pollution of air can form a deposit layer on the insulations of the concrete power pole. In raining conditions, the layer absorbs water and the surface resistance of insulators is considerably reduced. Thus, a high voltage AC current can creep in the surface of the insulator and exchange between two other phases and the ground. Generally, the grounding system cannot act immediately and does not have suitable low electrical resistance [2]. Meanwhile, if the concrete of the power pole has low quality, then it absorbs high content of rain and its resistivity decreases considerably. Thus, some parts of the fault current can pass through a water saturated concrete power pole [1], [2]. In a special location around Isfahan with polluted air conditions, in rainy conditions, the current creeps through the surface of some insulators and many cracks immediately form on the concrete cover of the power pole and in some cases the concrete cover starts to fall without any corrosion in the rebar. Based on the field study, the AC stray current does not occur in concrete power poles which were manufactured by the centrifugal method and have very low w/c ratio in their mix design. In this method, excess water of the concrete mix is removed before concrete curing. A microscopic study of concrete of the molded pole and centrifugal pole showed that the later had a much denser structure and for this reason the depth of carbonation in the later was much lower than the first [2]. In addition, the centrifugal poles have pre-stress conditions and this reduces their vibration against wind forces and the weight of cables. Vibration has a destructive effect on the concrete cover of concrete poles, especially in their ground level because the force of vibration is concentrated in this location.

In this paper, the effects of AC stray current had been studied by laboratory tests.

2. METHODOLOGY

For studying the mechanism of degradation of the AC stray current, some concrete samples are prepared in water saturated conditions subjected to 220 and 380 VAC stray currents.

According to Figure 2, the AC current in the concrete samples rapidly increased and reached a maximum value and then rapidly reduced to a low level. This phenomenon can be justified by using the electrical model for concrete. In this model, the AC current can pass through two different paths in the concrete including resistor and capacitor paths. The capacitor path is a pore path of concrete and the resistor path is an aggregate and cement paste of concrete [3], [4]. According to the model and Electrochemical Impedance Spectroscopy (EIS) spectra of concrete (**Error! Reference source not found.**), impedance of concrete in the intersection of low and high frequency is minimum. Meanwhile, according to EIS test results, the frequency of this impedance is about 50-60 Hz. Therefore, urban AC power has minimum impedance in water-saturated concrete.

In other words, impedance of the capacitor paths compared to the resistor path is very low and most of the current passes through the capacitor path (pore paths). For this reason, in the first step of current-time curve of Figure 2, serious non-uniform AC current distribution forms in the concrete samples and is cause for creating heat and thermal stress. According to the test results, the thermal stress is high enough to create micro-cracks in concrete and generation heat is cause for evaporation water of concrete.

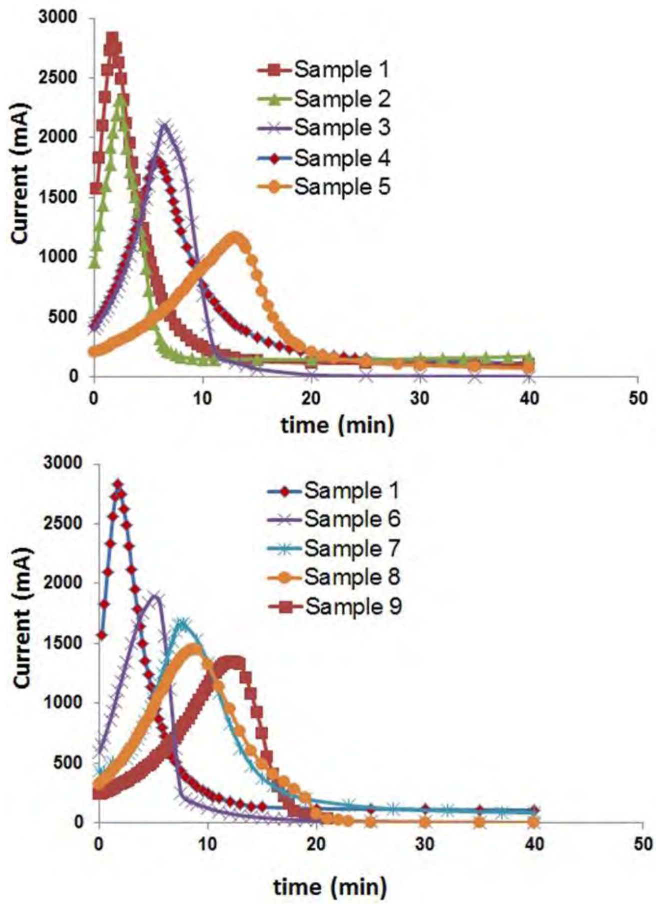

Figure 1: Current-time curve during application of 380 VAC on concrete samples. Curve of sample 1 in part (a) and (b) repeat for comparison.

Therefore, in the first step of curves of figure 1, porosity of concrete increases and current rapidly increases. When water of pores evaporates, the pores paths cannot act as capacitor path and current reduces rapidly. Therefore, the high voltage AC stray current can increase permeability of concrete in a short time and can reduce its durability.

Reducing pores paths by using silica fume or reducing water to cement ratio [5] can be used for increasing impedance of the capacitor path and reducing the AC current through concrete.

3. CONCLUSION

Based on the result tests, the application of silica fume and reducing w/c ratio increases the resistance of concrete against destructive effects of the AC stray current and increases its durability. Therefore, application of new technology for reducing water to cement ratio of the concrete poles considerably increases their durability against destructive effects of AC stray current.

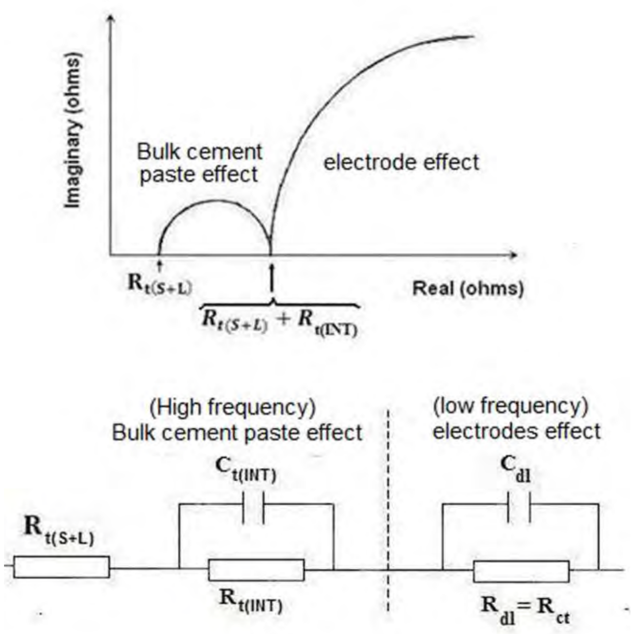

Figure 2: a) Schematic of EIS spectra of concrete, b) Equivalent electrical circuit for concrete [4].

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