MONITORING OF CORROSION OF PRESTRESSING STEEL CABLES IN PRESTRESSED CONCRETE BRIDGES

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There are many instances wherein prestressing steel in prestressed concrete has suffered severe corrosion leading to premature deterioration of bridges. Till date no reliable non-destructive test is available to monitor the condition of prestressing steel encased in cement grout and high strength concrete. Attempts have been made to monitor the corrosion of prestressing steel cables by measurement of electrical resistance of the cables using accessible cable ends as terminal points. In this paper, some typical results obtained on some coastal bridges are presented. The limitations of the method are also pointed out.

Key words: Prestressing cable, Electrical resistance, Percentage reduction in diameter, Progress of corrosion.

INTRODUCTION

Electrical resistance is an important parameter of any metallic material and in the case of prestressing cables, the resistance R of a cable of length L is given by the equation.

$$R = \rho L/A \qquad \text{.........} \quad (1)$$

Where ρ = resistivity of the material and

A = cross sectional area of the cable

From the equation (1) it is clear that the resistance of a known length of a cable depends only on the cross sectional area of the cable, the resistivity being constant for the particular material. This fact could be exploited to monitor corrosion of the cables as the area of cross section reduces due to corrosion, thus giving a higher resistance value than the original value. The technique made use of to measure the resistance of cables is four probe technique where the contact resistance is eliminated and the resistance of the connecting wires is not included in the measurements.

THE INSTRUMENT

An instrument has been developed in our laboratory for the specific purpose of cable resistance measurement. It is a portable instrument powered by three eveready cells of 9V rating, the type number being 216. The instrument consists of a constant current source, a difference amplifier

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and an LCD display unit. Precision integrated circuits have been used in building up of the instrument. The constant current source has extremely high long term stability and temperature stability in the operating range of 0°C to 70°C. The difference amplifier has a fixed adjusted gain and a very high signal to noise ratio The LCD unit has been calibrated to display directly the resistance in milliohms.

Measurement :

The instrument consists of four probes in a line. The outer two probes are current probes, the inner being the voltage probes. To make a measurement the accessible two ends of the cable are opened and cleaned thoroughly with emery paper to remove the rust and to ensure the good electrical contact. The two current probes are connected to the two ends of the cable in order to drive the constant current through the cable. The voltage drop across the cable is sensed through the two voltage probes which is the input to the difference amplifier. The resistance of the cable is directly displayed on the meter in milliohms.

RESULTS AND DISCUSSIONS

Eventhough the technique looks very simple, lot of care should be taken while making the measurements. The cleaning of cable ends is very important to obtain correct readings. The interpretation of the results also is very difficult because of some uncertainities involved in measurement in actual bridge site. Some typical cable resistance values obtained in some of the coastal bridges are presented.

In bridge 'A' which is a new bridge, the cable referred should have a theoritical resistance value of 14.2 milliohm. The measurement of its resistance was made just after prestressing. The measured value was found to be 14.7 milliohm which is in good agreement with the theoritical value.

In bridge 'B' which is worst affected, the cable 1 has a theoritical resistance of 33.9 milliohm and after 16 years of laying the bridge, a value of 43 milliohm was measured. The cable 2 which has a theoritical value of 35.8 milliohm showed a value of 70 milliohm after 16 years of ageing. It was possible to measure the diameters of both the cables at the visible portion in between the ends. The diameter of the cable 1 was found to be 6mm instead of 7mm and the diameter of the cable 2 was found to be 4.7mm instead of 7mm. It could be seen that both observed and measured values agree satisfactorily. The observation of the actual diameter of wires in the cables is not possible in most of the bridges.

Table I illustrates the progress of corrosion in cables with time measured in the bridge 'C'. The cable 1 which has a theoretical resistance value of 3.7 milliohms showed a value of 7.8 milliohms after 11 years of ageing and 10.3 milliohms after 15 years of ageing. These values correspond to 31% and 40% of reduction in diameter, which means that the corrosion in this cable has progressed from 31 to 40% over a period of 4 years. The cable 2, which has a theoretical resistance value of 3.7 milliohms showed a value of 8.8 milliohms and 12 milliohms respectively after 11 and 15 years. These values correspond to 35% and 45% respectively, meaning that the corrosion in this particular cable has progressed from 35 to 45% over 4 years The cable 3 which has 3.4 milliohms as theoretical resistance, showed 13.5 milliohms and 18.4 milliohms respectively after 11 years to 15 years corresponding to 50% and 57% of reduction in diameter. This means that the progress of corrosion in this cables is from 50 to 57% over 4 years.

TABLE I

BRIDGE C (WORST AFFECTED)

Cable No.	Resistivity Theoritical value (milliohms)	Resistivity Measured value (milliohms)	% reduction in diameter	Ageing in years
1	3.7	7.8	31	11
1	3.7	10.3	40	15
2	3.7	8.8	35	11
2	3.7	12.0	45	15
3	3.4	13.5	50	11
3	3.4	18.4	57	15

Limitations :

This technique of resistance measurement of cables to minitor corrosion is not without limitations. It needs caution to interpret the results because the situation is complex inside the concrete. There may be some short circuits contact resistance problems at the anchoring ends which may contribute towards some uncertainities in measurement. Prestressing cables may also be touching each other in some portions. Since bunch of wires along with sheath are involved in they measurements they may introduce some uncertain factors in theoritical calculations. The results of the technique are based on the assumption that the wires have undergone uniform corrosion throughout their length which neednot be true. It is to be emphasized that since it is not possible to identify and isolate the individual wires and all the wires and cable sheath may be shortcircuited the measured resistance values represent the overall condition of the prestressing system.

CONCLUSION

It is shown that the electrical resistance measurements on prestressing wires with all its limitations may be useful for monitoring corrosion of prestressing cables in a nondestructive way. The only requirement is that both the ends of the wires are to be made accessible for electrical contact. This is normally possible only in the case of cables anchored at the deck slab

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