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NOVEL RESISTANCE PROBE CORROSION MONITOR FOR CONCRETE REINFORCEMENT

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ABSTRACT

Corrosion monitors using resistance probe as described in literature are not suitable when they are to be used for monitoring of corrosion in reinforcements. The monitor described herein is of the direct digital display type. Along with the special type of probe, this is a valuable instrument for monitoring of corrosion of reinforcements embedded in concrete. With suitable probes this can be used in other types of corrosion studies also. The instrument being portable is quite useful for field applications.

INTRODUCTION

The alkaline nature of cement concrete provides a protective environment around steel rods under normal conditions. But when a reinforced concrete cement (RCC) structure is exposed to saline atmosphere, corrosion of the steel rebars leads to premature failure of the same. In view of this, it becomes necessary to monitor the corrosion of steel rebars in RCC structures so that it helps in taking suitable preventive measures. In the laboratory, weight loss on mild steel coupons embedded in cement mortar or concrete and subjected to various corrosive environments for

Instruments based on resistance probes reported or those available are invariably of the null type resulting in subjective errors [1]. When large number of readings are to be taken on probes distributed over a large structure, it becomes rather cumbersome. The resistance probes already reported in literature are not suitable for use in reinforced concrete structures due to the requirements of strength and ruggedness. Hence a special type of probe has been developed after making extensive studies on various types and configurations of resistance probes [2]. In order to display the percentage reduction in diameter directly, a resistance probe corrosion monitor (R.P. Monitor) has been developed.

EXPERIMENTAL

The resistance of a wire of uniform cross-section is (i) directly proportional to the length and nature of metal and (ii) inversely proportional to the cross-sectional area. The probe designed has equal lengths of wire of 2 mm diameter. One section is protected from the environment while the other section is exposed to the same environment as that of the reinforcement. If d_p and d_e are the diameters of the protected and exposed elements respectively, then the resistance of the protected portion,

$$R_p = k/d_p^2$$

and the resistance of the exposed portion,

$$R_e = k/d_e^2$$

$$\frac{R_p}{R_e} = \frac{d_e^2}{d_p^2} \quad \text{and} \quad d_e/d_p = \sqrt{\frac{R_p}{R_e}}$$

$$\text{(i.e.)}\ 1 - \frac{d_e}{d_p} = 1 - \sqrt{\frac{R_p}{R_e}}$$

Percentage reduction in diameter $= 100\left(1 - \frac{d_e}{d_p}\right)$ or

$$100\left(1 - \sqrt{\frac{R_p}{R_e}}\right)$$

Thus by measuring the resistance R_p and R_e, the percentage reduction in diameter can be obtained. Figure 1 shows the probe

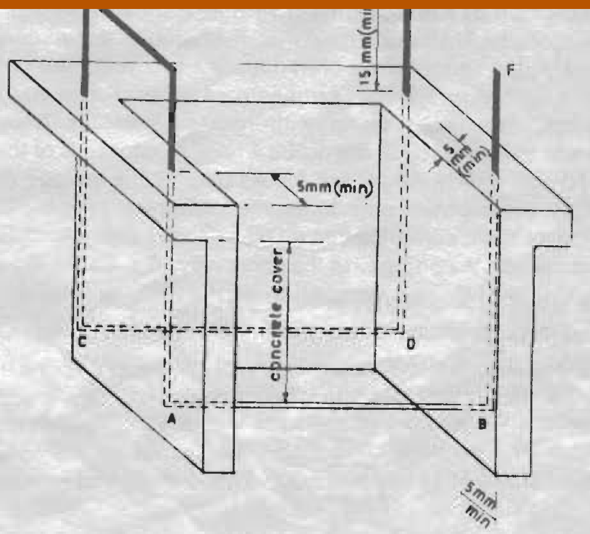

Fig. 1 : Resistance probe

exposed to the corrosive environment. It has no bent portions exposed to the environment so that the corrosion is uniform throughout the section. Moreover, care has been taken to make the cover thickness the same for both the protected portion and the exposed portion. The dimensions of the steel wire used have been optimised after making studies on its utility in concrete environments. Figure 2 shows the relation between the weight loss and the voltage drop across the wire in alkaline medium with chloride [2].

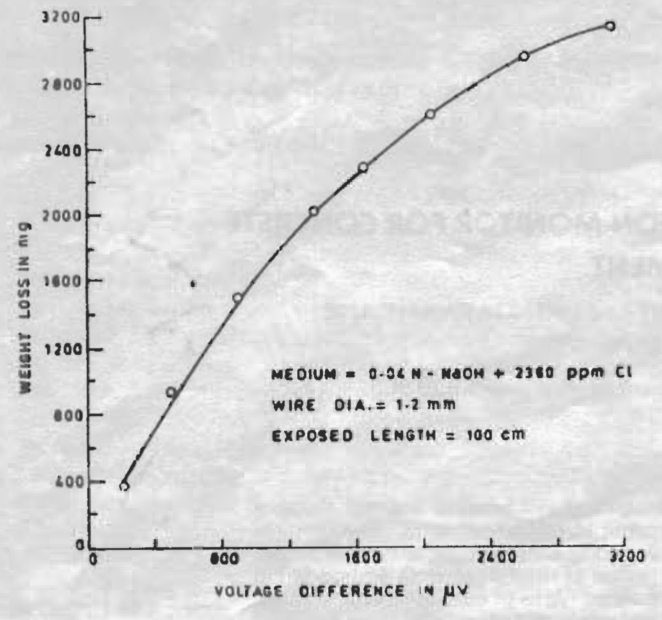

Fig. 2 : Relation between the weight loss and voltage drop across the wire in alkaline medium with chloride.

While designing the metering instrument, the following points were taken care of :

i) Passage of direct current results in instabilities and errors due to magneto resistive effects. Hence alternating current has been used.

ii) Time taken per measurement should be minimum. For this direct digital display of the percentage reduction in diameter has been achieved.

Description of the instrument : Figure 3 shows the circuit schematic of the instrument. A_1 is the square wave generator generating a square wave of frequency 1 kilocycle. The output of this is limited to 5.1 volts by means of zener diodes A_1 and Z_2. These zener diodes along with resistor R ensure a constant current to flow through the probe whose resistance is of the order of 10 milli ohms. Amplifiers A_2, A_3 amplify the voltage drop V_e across the exposed portion of the resistance probe AB. The output of this is converted into a D.C. voltage by rectifier constituted by amplifiers A_4 and A_5. In the same way, IC's A_6, A_7, A_8 and A_9 produce a D.C. voltage proportional to the voltage drop V_p across CD', the protected portion of the resistance probe. Outputs of A_5 and A_9 are fed to the inputs of the square root extraction cum divider circuit A_{10}. This being a specially developed circuit gives the square root of the ratio V_p, to V_e on pressing the set switch S_1. Amplifier A_{11} scales the output of this to give an output equal to $\left(1 - \sqrt{\frac{V_p}{V_e}}\right) 100$. This is displayed by the digital panel meter consisting of IC 12 and the liquid crystal display. The circuit can resolve a resistance change of 10 micro ohms. Small changes in the current passing through the probe equally affects the drop across the protected and the exposed portions which hence does not reflect on the output of the square root cum divider circuit.

The photograph of the instrument is shown in Figure 4. The instrument is powered by dry cells. The Integrated Circuits used are of the CMOS type and the amplifiers are of the micropower type having high stability. This ensures long battery life and high stability.

The unit was used in the laboratory for collecting data under accelerated conditions. Table I shows results obtained with the corrosion monitor compared with that of digital calipers.

Table II shows the performance of the instrument when the probe was immersed in 5N HCl. There is good agreement between the readings given by the instrument and that of Digital Caliper.

The resistance probe type monitor has the following advantages :

i) rapid determination of corrosion rates at any given time without disturbing the system;

ii) simplicity of measurement; and

iii) possibility of continuous monitoring of corrosion rates.

Using suitable probes, it can be put into the following applications [3-7] also :

i) Atmospheric corrosion
ii) Bacterial corrosion
iii) Corrosion under paints and coatings
iv) Corrosion of lead cable sheaths laid in wood conduits
v) Corrosion of steel in molten sulfur and
vi) Corrosion inhibitor evaluation of various media.

Table I : Comparison of percentage reduction in diameter measured by R.P. Monitor with Digital Caliper for mild steel in NaCl

Length of the exposed element : 50 mm
Initial diameter of the exposed element : 2 mm
Medium : Salt spray test with 5% NaCl solution (aerated) in Salt Fog Chamber

No.	Test duration in hours	% reduction in diameter	
		As displayed by R.P. Monitor	Actual as per Digital Caliper
1	100	1.0	1.2
2	500	5.6	6.0

Table II : Comparison of percentage reduction in diameter measured by R.P. Monitor with Digital Caliper for mild steel in HCl

Length of the exposed element : 50 mm
Initial diameter of the exposed element : 2.096 mm
Medium : 5N HCl

No.	Immersion time (hours)	% reduction in diameter	
		As displayed by R.P. Monitor	Actual as per Digital Caliper
1.	1	1.90	1.95
2.	2	2.50	2.67
3.	3	4.60	3.87
4.	5	6.20	6.96
5.	22	29.10	28.57
6.	23	29.60	29.86
7.	24	31.30	30.84
8.	25	33.30	33.68
9.	26	34.60	35.12
10.	27	35.90	37.02

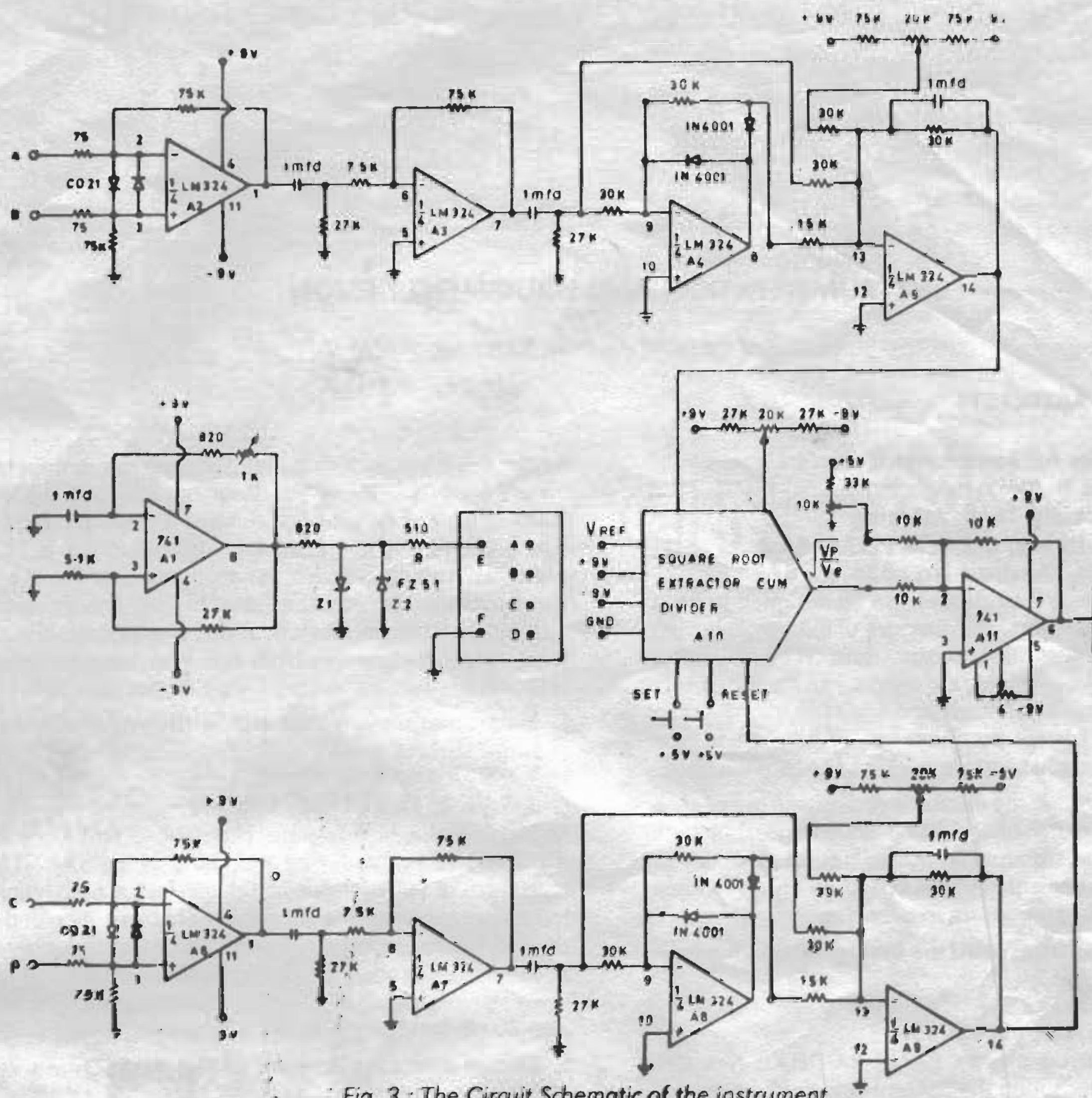

Fig. 3 : The Circuit Schematic of the instrument.

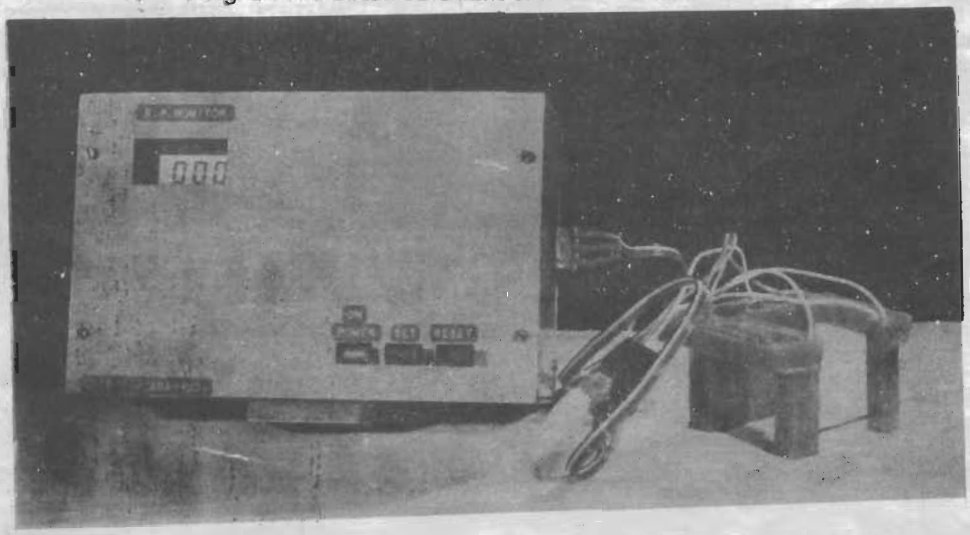

Fig. 4 : Digital Panel Meter

CONCLUSION

A direct reading Digital Corrosion Monitor has been found to be quite useful in monitoring corrosion of reinforcements in concrete structures.

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