DEVELOPMENT OF A MULTI-CHANNEL CORROSION SURVEYOR FOR NON DESTRUCTIVE TESTING OF RCC STRUCTURES

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ABSTRACT

This paper deals with the design and development of a PIC micro-controller based Muhi-channel corrosion surveyor for RCC structures. Electrical potential between the reinforcing steel and a reference electrode is named as half-cell. Based on the half-cell potential values, one can identify the area that is affected by corrosion. The developed system measures the half-cell potential at 4 locations and temperature at a single point simultaneously. This system has been developed according to the ASTM C876-80 standard, the basis of which is that the corrosion potential of the rebar will shift in the negative direction if the surface changes from the passive to the active state.

1. INTRODUCTION

The ability to assess the severity of corrosion in existing concrete structures for maintenance and inspection scheduling and the use of corrosion data for predicting the remaining service life is becoming increasingly important. There are a number of electrochemical techniques for measuring the severity of rebar corrosion, such as Linear Polarisation Resistance method, OCP measurement, Galvanic Pulse Technique, Electrical Resistance Probe technique, Impedance method and Noise measurement. These measurements can be performed completely non-destructively on the actual reinforcing steel or on separate probes that are embedded in the concrete structure, preferably at different depths of cover. Perhaps the simplest assessment technique for rebar corrosion damage is the measurement of the corrosion potential (or rest potential, half cell potential). A measurement procedure is described in the ASTM C876-80 standard [1], the basis of which is that the corrosion potential of the rebar will shift in the negative direction if the surface changes from the passive to the active state. Rebar corrosion rates can change considerably with time. Such variations are the result of fluctuations in temperature, humidity, degree of aeration, micro structural changes in the concrete, the development of cracks in structures etc. In this paper, a rapid, cost-effective, non-destructive multi channel concrete corrosion surveyor using PIC micro controller for measuring the half-cell potential along with probability of corrosion rate and temperature measurement are described.

2. PRINCIPLE OF MEASUREMENT

Half-cell Potential Measurement:

One can measure the potential difference between a standard portable half-cell, normally a copper/copper sulphate ($Cu/CuSO_4$) standard reference electrode placed on the surface of the concrete with the steel reinforcement underneath. Fig.1 illustrates the basics for such a measurement, also called half-cell potential measurement. The reference electrode is connected to the positive end of the high input impedance voltmeter and the steel reinforcement to the negative end [2]. This potential indicates the corrosion of the rebar [3,4].

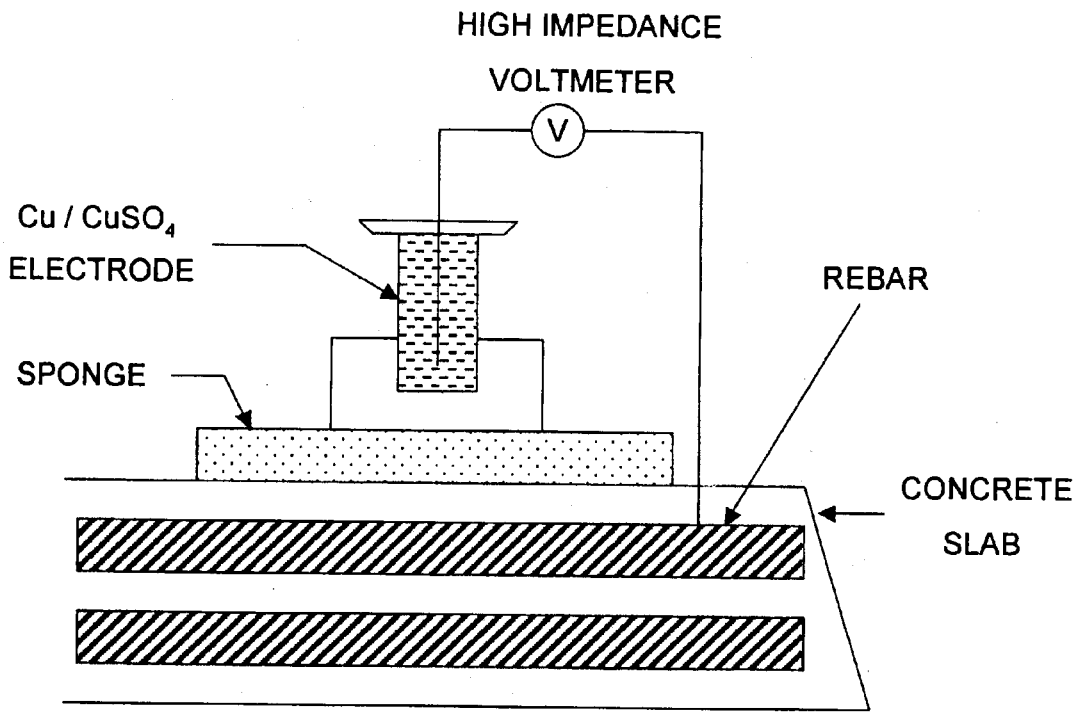

Fig. 1 : Half-Cell Potential Measurement

Temperature Measurement:

For temperature measurement, one classic sensor is AD590 (metal can or ceramic flat-pack) [5], a two-terminal device that converts temperature to current. The output current of the sensor is one microampere per Kelvin, and is linear, so that calculations by software are very easy. The current can be converted to voltage by a simple resistor at the measuring end, for standard analog to digital converters. The value of the resistor can be trimmed to calibrate the sensor. Often only this single-point calibration is necessary. The AD590 can be used to measure from -55°C to 150°C. Any DC voltage from +4 volts to +30 volts will operate the device.

3. HARDWARE

Fig.2 shows the complete block diagram of the multi-channel concrete corrosion surveyor using PIC micro controller (16F877A). The block diagram mainly consists of the $Cu/CuSO_4$ Electrodes, Voltage Followers, Uni-polar Generators (UPG), Temperature Sensor, Current to Voltage converter, PIC Micro controller 16F877A [6] and Display unit.

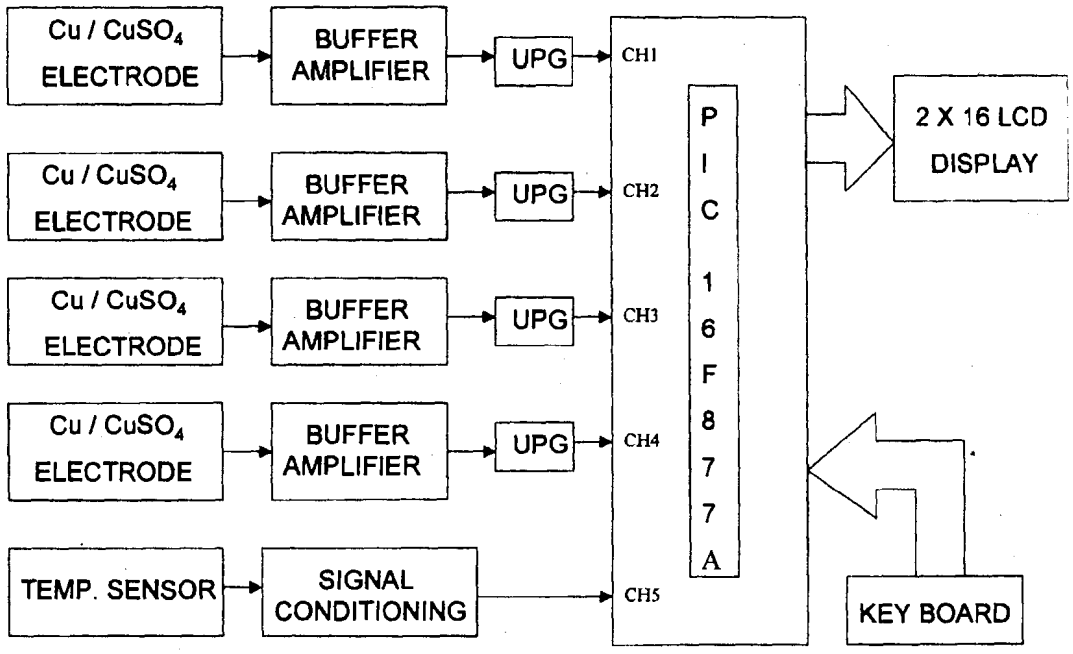

Fig. 2 : Block diagram of concrete corrosion surveyor

The potential difference between the copper/copper sulphate ($Cu/CuSO_4$) reference electrode placed on the surface of the concrete and the steel rebar is fed to a high input impedance voltage follower (CA3140). The I/O lines of the micro controller allow only the positive inputs. Hence the voltage follower output is fed to the I/O lines through *UPG* (OP-07). The half-cell potential measurement is made using the first four channels of the A/D converter. Similarly for temperature measurement the sensor output is being current that is fed to a current to voltage converter with a gain of 10 and connected to the fifth channel. The PIC 16F877A is an on-board micro controller that sequences the half-cell potential measurements and temperature measurements. It also controls data acquisition I/O lines and performs all necessary calculations for corrosion measurements.

The PIC micro controller 16F877 A is a 40 pin device and having a high performance RISC CPU, 33 I/O lines, up to 8K x 14 words of FLASH Program Memory, 368 x 8 bytes of Data Memory (RAM) 256 x 8 bytes of EEPROM Data Memory, and 10 bit multi-channel Analog to Digital Converter. It has only 35 instructions and easily programmable. The output of the micro controller is interfaced with a 2 x 16 alphanumeric LCD.

SPECIFICATIONS

No. of Channels used	:	5
OCP Measurement	:	4 Channels
OCP Range	:	0 to ± 1.25V
Corrosion status	:	Low, Medium and High
Temperature Measurement	:	1 Channel
Temperature Range	:	0 to 100°C
Display	:	2 x 16 LCD
Power	:	±9V

SOFTWARE

Fig.3 shows the various steps involved for the overall system software. The software for PIC micro controller 16F877 A is programmed in assembly language.

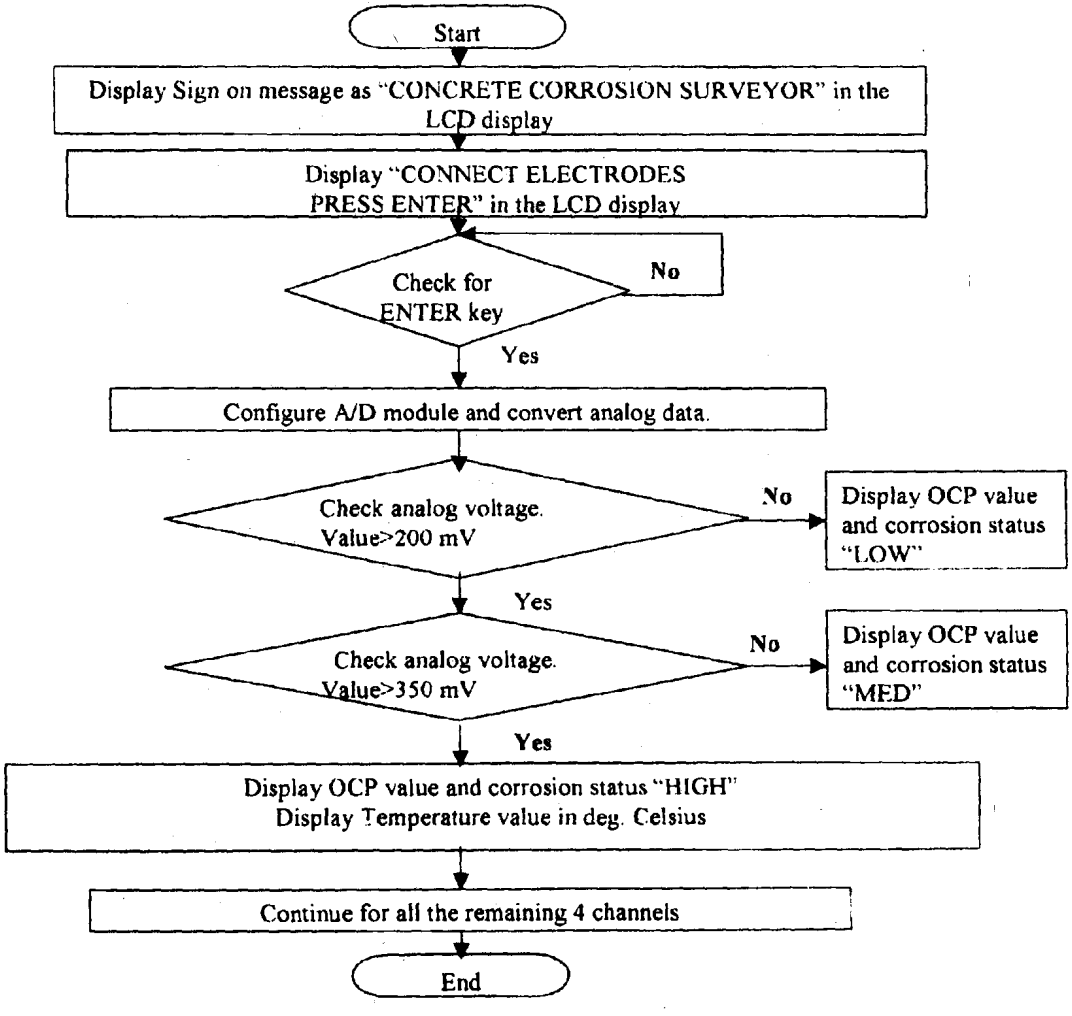

Fig. 3 : Flow chart of 5-Channel concrete corrosion surveyor

The LCD displays have a standard ASCII set of characters plus Japanese, Greek and mathematical symbols. For an 8-bit data bus, the display requires a +5V supply plus 11 I/O lines (3 control lines and 8 data lines). The 3 control lines are Enable (E), Read/Write (R/W) and Register Select (RS). The 'E' line allows access to the display through R/W and RS lines. When this line is low the LCD is disabled and ignores signals from W/R and RS. When 'E' line is high, the LCD checks the state of the two control lines and responds accordingly. The R/W line determines the direction of data between the LCD and micro controller. When it is low, data is written to the LCD. When it is high, data is read from the LCD. With the help of RS line, the LCD interrupts the type of data on data lines. When it is low, an instruction is being written to the LCD. When it is high, a character is being written.

After execution of the program the system shows a sign on message "CONCRETE CORROSION SURVEYOR" followed by "CONNECT ELECTRODES, PRESS ENTER" message. As soon as Enter key is pressed, the display gives the result as follows:

CHI : -180mV; LOW

TEMP : 28.5°C

The first line of the display shows the Channel number, half-cell potential data and the corrosion status and the second line shows the temperature data. The display shows the corrosion status as MED (medium) and HIGH, if the measured open circuit potential is in between -200 mV and -350 mV and less than -350 mV.

RESULTS AND CONCLUSION

The PIC micro controller based multi-channel corrosion surveyor is designed and constructed. The OCP versus corrosion status as per ASTM C876-80 standard is presented in table 1. The ASTM standard states that the probability of corrosion is less than 5% if the potential is greater than -200mV, whereas the potential values less than -350mV indicate a high probability (>90%) that corrosion is active. Values between the upper and lower limits indicate areas where the corrosion activity is uncertain.

Table 1. OCP versus Corrosion Status as per ASTM Standards

OCP Value	Corrosion status
Greater than -200mV	Probability of corrosion is < 5%
Between -200mV and -350 mV	Probability of corrosion is < 50%
< -350mV	Probability of corrosion is < 90%

The results obtained by the instrument developed are tabulated in table 2.

The developed Multi-channel corrosion surveyor is highly useful for detecting the condition of mild steel reinforcement, non-destructively, in the existing RCC structures and bridges located in coastal areas.

Table 2. Experimental Values of OCP

RCC Slab Size of 5 ft x 5 ft Points are marked at an interval of 1 ft x 1 ft				
364	186	245	261	301
368	331	222	242	239
103	161	301	235	273
258	186	245	261	301
259	239	194	152	184
178	290	287	122	267
All the OCP values are positive because the slab was cast just 6 months earlier.				

Since this instrument consists of four channels for half-cell potential measurements, it is easy to cover large areas of corrosion surveys within a very short span of time. The fifth channel provides the information on the temperature of the concrete surrounding it.

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