Electrical resistivity of concrete in relation to corrosion of reinforcement

Salman Saleh Al-Abdul-Hadi

Civil Engineering

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Abstract

The present work develops data related to the effect of commonly occuring concrete mix and environmental parameters on the electrical resistivity characteristics of concrete. An attempt has been made to correlate this data with the process of rebar corrosion in concrete. The specific variables included in thisstudy are the w/c ratio, chloride content, age of concrete, aggregates, wetting and drying process, temperature and pozzolan admixture. Concrete samples from field structures have been cored and fully analyzed to study the resistivity-rebar corrosion relationship after long exposures in the local environment.

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by

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A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

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This thesis, written by Salman Saleh Al-Abdul-Hadi under the direction of his Thesis Committee, and approved by all its members, has been presented to and accepted by the Dean of the College of Graduate Studies, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN CIVIL ENGINEERING.

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ABSTRACT

The present work develops data related to the effect of commonly occuring concrete mix and environmental parameters on the electrical resistivity characteristics of concrete. An attempt has been made to correlate this data with the process of rebar corrosion in concrete. The specific variables included in this study are the w/c ratio, chloride content, age of concrete, aggregates, wetting and drying process, temperature and pozzolan admixture. Concrete samples from field structures have been cored and fully analyzed to study the resistivity - rebar corrosion relationship after long exposures in the local environment.

Chapter 1

BACKGROUND TO CONCRETE RESISTIVITY STUDIES

1.1 INTRODUCTION

Studies on the performance of concrete in the Gulf area provide a unique opportunity to evaluate parameters bearing directly on the durability characteristics of concrete construction in an aggressive service environment. Due to intense growth in the development programs there has been an unprecedented demand for concrete buildings of all kinds and the local construction industry, beset by an inadequate infrastructure, shortages of suitable materials, equipment, skilled manpower and inadequate specifications and construction practices has succeeded only in producing structures which are showing an alarming degree of deterioration within a short span of 10 to 15 years.[1,2,3] The deterioration is accentuated by the geomorphic and climatic environmental conditions which are characterized by reactive and marginal aggregates, high temperature-humidity regimes and severe ground and ambient salinity.

Condition surveys[1] carried out on framed structures located in Khobar-Dhahran-Dammam habitations show an alarming condition of structures constructed

15-20 years hence. Corrosion of reinforcement is the number one durability problem followed by sulphate attack, salt weathering, early age cracking and aggregate-cement reactivity.

An attempt is being made at UPM to focus research on concrete durability problems in the environment of Eastern Saudi Arabia with special reference to deterioration resulting from rebar corrosion and associated concrete spalling.

Corrosion of reinforcement in the local conditions is primarily an electro-chemical reaction involving in interactive effect of chloride salts, water and oxygen on the reinforcement. Corrosion cells are formed on the steel surface due to non-uniformities in the metallurgical structure of steel or in the environment provided by the hardened cement paste surrounding the reinforcement. The process involves the flow of electrical charges through an ionically conducting electrolyte which is available in the form of liquid and moisture present in hardened cement pores.

Clearly, the property of concrete related to the conductance of electrical charges is a directly related parameter in the electrochemical corrosion process on rebars. This was rather dramatically shown by Stratfull[4,5] in a

report on the deterioration of San Mateo-Hayward Bridge near San Francisco due to rebar corrosion and concrete spalling. It was noted that the amount of concrete cracking as a result of rebar corrosion in the San Mateo-Hayward Bridge varied with the specific electrical resistance of concrete.

Unfortunately comparatively little work has been undertaken on the electrical properties of concretes and the literature is meagre. No attempt has so far been made to systematically study the effect of concrete resistivity on the extent of corrosion while eliminating the overshadowing effect of the other directly related parameters.

The lack of effort at data development is probably due to a variety of problems involved in such an investigation. The characteristics of cement paste alter to an enormous degree throughout the hydration and the resulting hardening and subsequent drying process. The relative importance of many electrical characteristics affecting the ease or otherwise of current flow vary considerably with the age and the degree of humidity in concrete. Furthermore, the electrical properties may vary throughout the specimen of concrete because: firstly, concrete is itself a heterogeneous material, secondly, stratification

occurs during placing and thirdly, subsequent drying out takes place preferentially from the exposed surfaces resulting in a humidity gradient from the center to the outside. Finally, there are problems of instrumentation in such a study.

The primary objective of the present study is to develop data on concrete resistivity characteristic in an attempt to elucidate its sensitivity with respect to rebar corrosion process. This necessitates a broad understanding of the implications of rebar corrosion and its mechanism. These are discussed in the following section of this chapter.

1.2 THE REBAR CORROSION PROBLEM AND THE MECHANISM OF STEEL CORROSION IN CONCRETE

1.2.1 Rebar Corrosion Problem

Professor F. Tamas of the Hungarian Academy of Sciences has described concrete as "the most noble material on earth"[6]. The following statement is quite true in respect of corrosion of reinforcement also. High quality concrete, properly placed, compacted and cured provides an alkaline environment of pH 12-14 at the steel concrete interface that will normally prevent corrosion of embedded steel. However, reports from the field abound with evidence of serious problems due to rebar corrosion in concrete

structures both in terms of the frequency of occurence and the magnitude of the resulting damage. Generally speaking, coastal structures everywhere in the world are subjected to noticeable rebar corrosion due to their exposure to marine atmosphere characterized by wind, spray and rain charged with sea salts. The effect is intensified in hot, humid, sub-tropical climatic environments. Several feedback reports based on studies of coastal structures in Africa, Japan, South Pacific and other parts of the USA confirm this.[7,8,9] The results of a survey[10] carried out in the U.K. by the British Building Research Station on the durability of concrete indicate that corrosion of reinforcement is the number one offender. Figg[11,12] reporting on the basis of British experience states: "The rusting of reinforcement in concrete is the single most important cause of poor durability of structural concrete. The costs of corrosion in the construction industry are of the order of £700 million per year, and of this a significant proportion is due to corrosion of steel reinforcement."[13]

The corrosion of reinforcement and the subsequent spalling of concrete as a major concrete performance problem in the United States was dramatically illustrated in recent years following the adoption of the "bare pavement"

policy by various highway agencies. The matter achieved national prominence as the "Bridge Deck Problem"[14,15] with its consequent heavy impact on the maintenance and construction budgets of the state highway agencies. The genesis of the problem is as follows: With the placement of fresh concrete subsidence, shrinkage and thermal stresses cause small tension cracks to occur over the reinforcing bars. These provide paths of ingress for water and deicing salts (sodium and calcium chlorides) to the reinforcement. Subsequent corrosion of the reinforcing bars generates forces of sufficient magnitude to cause the spalling or delamination of the concrete on bridge decks. In 1973 the reported annual cost of bridge deck repairs in the USA was $70 million; by 1975 that figure increased to $200 million per year. A yet another disturbing feature is the early age at which deterioration begins to appear. A Pennsylvania State University Survey[16] shows that nearly one fourth of the 249 bridges surveyed showed reinforcement corrosion and concrete spalling within four years of their construction.

Another area in which corrosion of steel poses a serious threat is prestressed concrete construction. Corrosion of prestressed reinforcement is considerably more

serious than that of normal reinforcement because of much smaller size of the wire used and also because of the more significant role prestressed steel plays in the stability of structures. Several features of prestressed concrete structures have been reported due to the corrosion of the prestressing cables[17-22] initiated mainly by the salt contaminated environment.

Concrete construction on the Gulf Coast is continually exposed to ground and atmosphere charged with salts. Aided by capillary action and high humidity conditions, the salt contaminated ground water and the salt-laden airborne moisture and dew find an easy ingress in the exposed concrete matrix. This supply would be in addition to an already substantive base salt content already present in the concrete through the mix water and the salt contaminated aggregates. Profuse cracking of concrete in the Gulf area due to a large number of factors such as high plastic and drying shrinkage, large and rapid temperature swings, salt crystallisation, cement-aggregate reactivity as well as the extreme Gulf climatic conditions intensify the chemical reactions involved in the corrosion process thereby accentuating the resulting physical deterioration.

A close examination of the case histories and circumstances reported in the foregoing discussion reveals two common denominators: firstly, the aggressive salt environment characterized by the presence of chloride ions most of the time; secondly, some kind of weakness in concrete which can be broadly identified as its absorptive capacity to facilitate the ingress of salt-laden moisture.

1.2.2 Mechanism of Steel Corrosion in Concrete

Steel is passivated against corrosion if embedded in an alkaline environment corresponding to a pH range[23] of 10 to 13. The hydrated cement medium around the rebars in concrete provides just such an environment (pH > 12.5).[24] At this pH a protective insoluble film of gamma ferric oxide forms on rebar surface effectively inhibiting the corrosion process. Such a protective environment, however, may be disrupted by two specific reactions. Firstly, when atmospheric carbon dioxide gets a possible ingress into the concrete matrix and its penetrating front advances so deeply as to intercept the steel reinforcement. Carbon dioxide reacts with the alkaline medium and neutralizes it by forming carbonates thereby damaging the quality of the protective environment. Such deep and disrupted carbonation is however, usually discounted in normal concretes.[25,26]

The second and more usual way in which the passivating film is disrupted is through attack by aggressive anions; chloride ion being a specific destroyer of the protective ferric oxide film is particularly effective in cancelling the alkaline passivity against corrosion. As soon as the passivity is destroyed corrosion cells, also called galvanic cells, form along the rebar surface generating rusting. As the products of corrosion occupy a volume about fifteen times that of original metal, tensile pressures are set up in concrete far beyond its capacity to withstand resulting in cracking and profuse spalling.

The current state of knowledge on corrosion of rebars in concrete has evolved rapidly over the past 30 years and there is unanimity that corrosion of steel in concrete takes place through an electrochemical process; i.e. a process involving chemical reaction as well as a *flow of electricity*. Further, the flow of electricity mentioned is mostly an internally generated process through electric cells, called galvanic cells.

1.2.21 Galvanic Cells

The *galvanic cells* are generated in various ways but to be practically operative they all essentially

require:

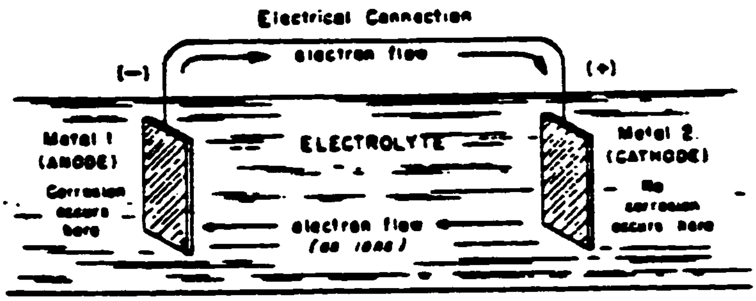
Firstly, two dissimilar electrodes electrically connected by a conductor;

Secondly, presence of an electrolyte whose ions can conduct electricity; and

Thirdly, presence of an electrical potential between the two electrodes.

A simple galvanic cell incorporating the above prerequisites is shown in Figure 1.1. Figure 1.2 shows a simulated model of a galvanic cell in concrete with the aforesaid essential features marked on the diagram itself and elucidated below:

* *Two zones* A and C on the rebar act as *electrodes* (anode and cathode respectively). These electrodes are connected by the bar length AC acting as a *conductor*.
* *Water* and *moisture* with *dissolved salts* within the pores of concrete matrix act as an *electrolyte*.
* A *differential electrical potential* between cathode and anode may arise from almost any conceivable heterogenity of the system, that is, any asymmetry of the metal, or the environment, or both. Specifically, an



A: Simple Galvanic Cell with different metals

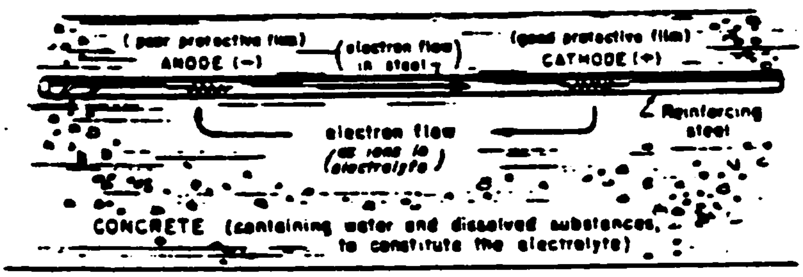


Fig:1.1: B: Simple galvanic cell in concrete - Galvanic corrosion cells.

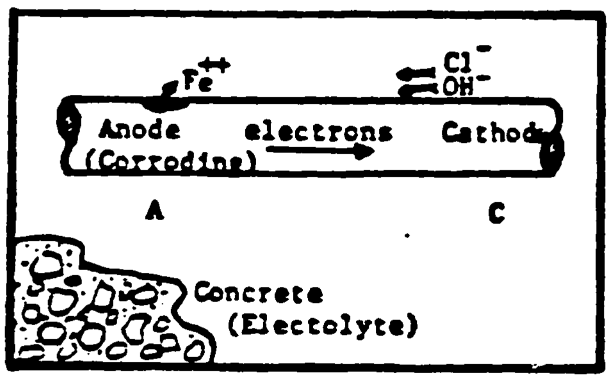


Fig: 1.2: Schematic diagram of the corrosion cell.

electrical potential may be caused due to differential aeration, differential ion concentration, differential concrete environment, or differential surface properties of steel.

1.2.22 Chemical Reactions

Corrosion is aptly defined as the destruction of a metal due to interaction with its environment. Table 1.1 is the electromotive force series. All metals listed above hydrogen are electronegative with reference to the standard hydrogen electrode because on immersion in an electrolyte they have a tendency, in proportion to their upward position in the series, to release ions into solution leaving a residual negative charge on the metal. This process of oxidation, when it takes place in an uncontrolled manner as a result of reaction with the environment, gives rise to corrosion.

Dissolution of the metal occurs at the anode where the corrosion current enters the electrolyte and flows to the cathode. The general reaction which occurs at the anode is the dissolution of metal as ions and is referred to as the primary stage of the corrosion reaction.

$$Fe \longrightarrow Fe^{++} + 2e^{-}$$ (1) Oxidation, or reaction at the anode; metal dissolves.

Table: 1.1: Electromotive-Force Series ($77^{\circ}F$)

Element	Electrode Reaction	Standard Electrode Potential, v*
(Active end)		
Sodium	$Na \rightarrow Na^{+} + e$	−2.712
Magnesium	$Mg \rightarrow Mg^{++} + 2e$	−2.34
Beryllium	$Be \rightarrow Be^{++} + 2e$	−1.70
Aluminum	$Al \rightarrow Al^{+++} + 3e$	−1.67
Manganese	$Mn \rightarrow Mn^{++} + 2e$	−1.05
Zinc	$Zn \rightarrow Zn^{++} + 2e$	−0.762
Chromium	$Cr \rightarrow Cr^{+++} + 3e$	−0.71
Iron	$Fe \rightarrow Fe^{+++} + 3e$	−0.44
Cadmium	$Cd \rightarrow Cd^{++} + 2e$	−0.402
Cobalt	$Co \rightarrow Co^{++} + 2e$	−0.277
Nickel	$Ni \rightarrow Ni^{++} + 2e$	−0.250
Tin	$Sn \rightarrow Sn^{++} + 2e$	−0.136
Lead	$Pb \rightarrow Pb^{++} + 2e$	−0.126
Hydrogen	$H \rightarrow 2H^{+} + 2e$	0.000 (reference)
Copper	$Cu \rightarrow Cu^{++} + 2e$	+0.345
Copper	$Cu \rightarrow Cu^{+} + e$	+0.522
Silver	$Ag \rightarrow Ag^{+} + e$	+0.800
Platinum	$Pt \rightarrow Pt^{++} + 2e$	+1.2
Gold	$Au \rightarrow Au^{+++} + 3e$	+1.42
(Noble end)		

*There are two schools of thought on the plus versus the minus sign on these voltages: the main thing to keep in mind is that the more active (the more minus in this table), the more the metal tends to oxidize (lose electrons or corrode).

The cathodic reaction for the electrochemical process is:

$$H_2O + \frac{1}{2} O_2 \longrightarrow 2O\overline{H} \quad (2)$$

The flow diagram showing the basic chemical reactions in the corrosion cell is shown in Figure 1.3. As the iron corrodes, it is converted to hydrated form of iron oxide which occupies a volume approximately fifteen times that of the steel corroded. This expansion places the surrounding concrete in tension causing cracking and spalling (Plates 1.1, 1.2). Discoloration of the concrete results from the leaching of the corrosion products (Plate 1.3).

1.3 SIGNIFICANCE OF CONCRETE RESISTIVITY CHARACTERISTICS IN REBAR CORROSION PROCESS

One of the very important parameters controlling the amount of metal or alloy electrochemically dissolved at the anode is the magnitude of the corrosion-current. If the effective electromotive force (EMF) driving a corrosion cell is E (Volts), the corrosion-current depends upon the value of E/R, where R is the cell or circuit resistance in ohms. Anything which increases E or decreases R will increase the corrosion current and thereby the corrosion damage.

The resistance of an electrolyte, or any other material is directly proportional to the length and inversely propor-

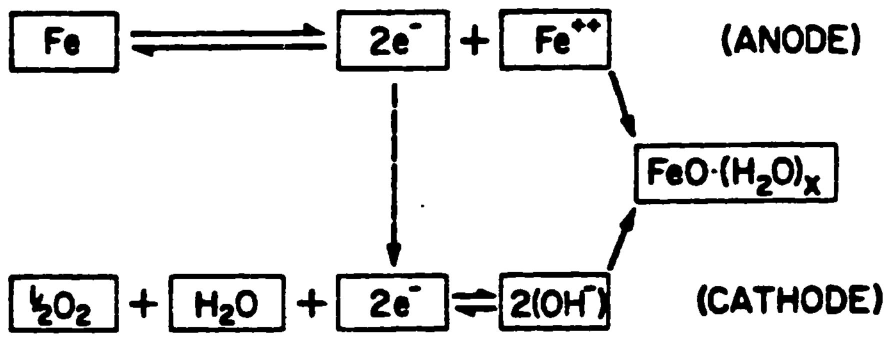


Fig: 1.3: Flow diagram showing the basic chemical reactions in the corrosion cell.

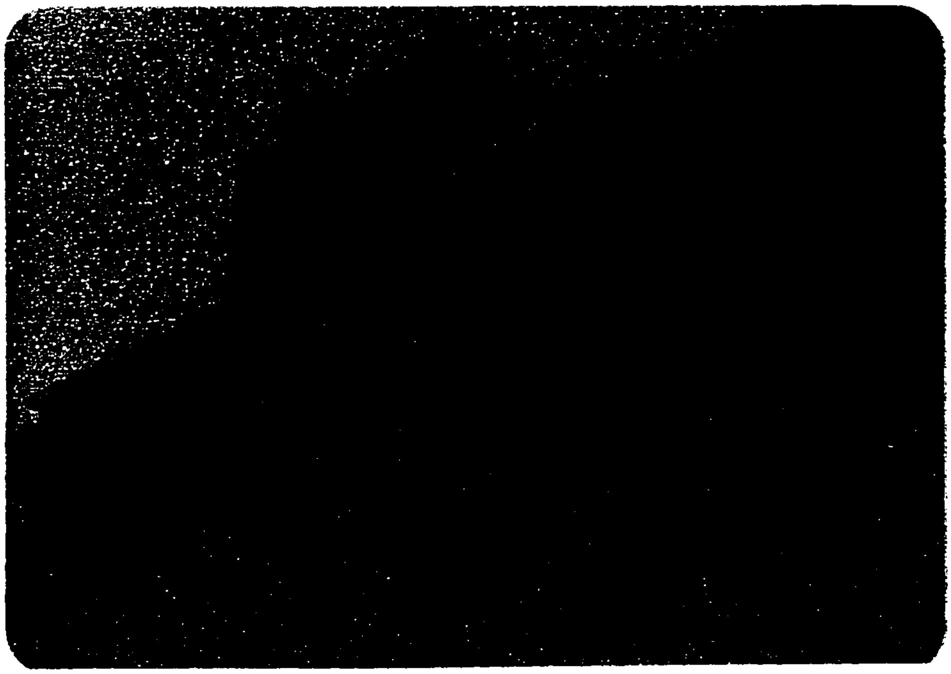


Plate: 1.1: Cracking and Spalling of concrete in a building in Dammam due to rebar corrosion.

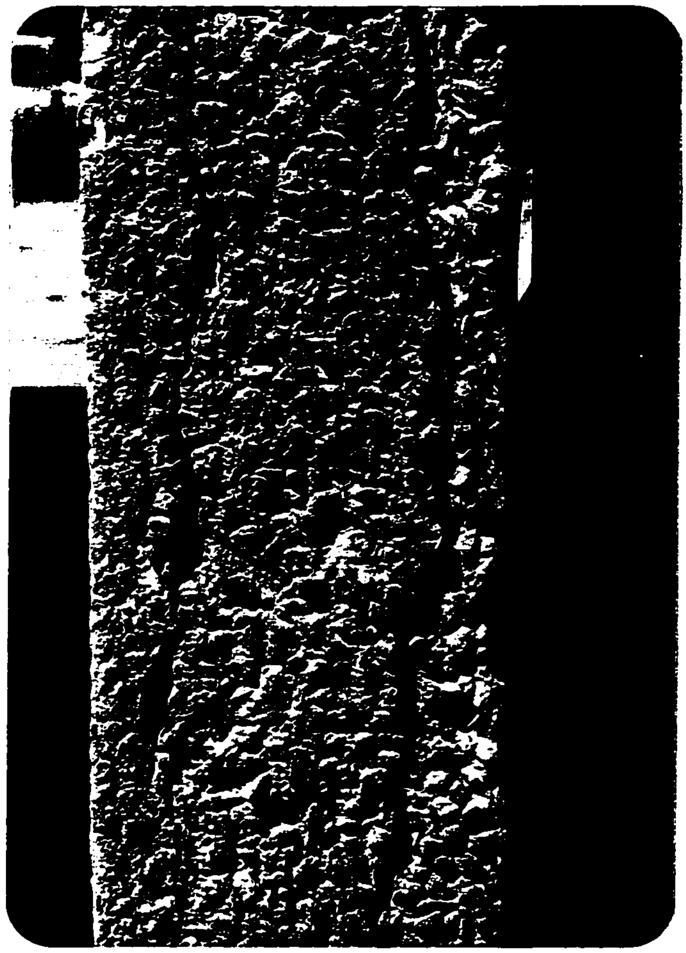


Plate: 1.2: Cracking and Spalling of concrete column in a building in Dhahran due to rebar corrosion.

Plate: 1.3: Rust stains signifying the onset of rebar corrosion in the canopy of Al-Khobar building.

tional to the cross-sectional area. Thus:

$$R = \rho \frac{L}{A}$$

where:

R is resistance in ohms,
ρ is resistivity in ohm-cm,
L is length in cm, and
A is cross-sectional area in sq.cm.

Resistivity is a fundamental property of a particular material which characterizes that material almost as completely as its density. It is essentially constant for a given material under constant conditions and is given by:

$$\rho = \frac{RA}{L} \text{ ohm-cm}$$

The significance of the resistivity concept in the corrosion mechanism can easily be understood from the fact that corrosion engineers usually identify corrosive environment in terms of its resistivity data. For example, it is generally understood that steel is specially susceptible to corrosion in soils having resistivities less than 10,000 ohm-cm. As the resistivity of the soil decreases, the magnitude of the corrosion damage increases. Even galvanized steel has been frequently reported to corrode in environments of low-resistivity soils. In sand containing sea water (ρ = 60 to 100 ohm-cm) steel pipes reportedly failed totally in times as short as five years.[27]

Scanning through whatever meagre literature exists on concrete resistivity characteristics indicates that the concrete resistivity may vary from in excess of 100,000 ohm-cm to as low as 100 ohm-cm. The figure of 100,000 ohm-cm is for dry concrete which could for all practical purposes be classified as an insulator (compare with 17×10^{-7} ohm-cm for copper and 97×10^{-7} ohm-cm for iron). Concretes buried in moist soil are reported to have resistivities in the range of 3,000 to 8,000 ohm-cm.[28] Lewis and Copenhagen[29] however, have reported that in coastal atmosphere where sea salt and moisture can penetrate the concrete, resistivities as low as 100 ohm-cm have been observed. This emphasizes the significance of moisture and salts in the conductance of electrical charges through the concrete mass. The volume of evaporable water in a typical cement paste varies from about 60 percent at the time of mixing to about 20 percent after full hydration.[30] This water contains ions derived from the water-soluble conductive compounds that have dissolved out of the cement powder. These are primarily Na^+, K^+, Ca^{++}, SO^- and OH^- and their concentrations vary with time. Nikkanen[31] has suggested that the conduction of electricity through moist concrete would be essentially electrolyte i.e. by means of ions in the evaporable water in

cement paste. Tests by Hammond and Robson[32] and Monfore[33] support this view.

1.4 MECHANISM OF CONDUCTION THROUGH CONCRETE

Concrete is a composite di-phasic material consisting of aggregates of various sizes in a matrix of portland cement paste. Make-up of typical concrete is shown in Figure 1.4. In Table 1.2 are listed the resistivities of typical aggregates used in concrete. The average value of the electrical resistivity of limestone aggregate is of the order of 1×10^5 ohm-cm whilst those of moist concrete and cement paste are in the range of 2500-4500 ohm-cm and 1000-1500 ohm-cm respectively. It is therefore seen that the resistivities of the aggregate are several orders of magnitude higher than that of either concrete or cement paste. This fact will result obviously in a very high proportion of current being conducted through the paste which offers the path of least resistance.

In general, however, the conduction of electrical current through concrete can occur through three possible paths as shown in Figure 1.4:

(a) through the aggregate and paste in series
(b) through the aggregate particles in contact with each other
(c) through the paste itself.

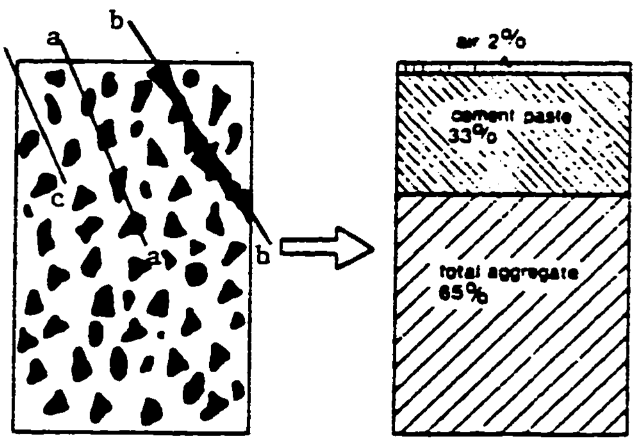


Fig: 1.4: Make-up of Concrete and Possible Paths
of electrical conduction through concrete.

TABLE 1.2: RESISTIVITIES OF TYPICAL AGGREGATES USED IN CONCRETE

Type of Rock	Range of resistivity (Ω m)
Granite	5×10^3-1×10^6
Marble	2.9×10^3
Gabbro	1×10^5-1.4×10^7
Limestone	3×10^2-1.5×10^3
Diorite	1×10^4
Quartz-porphyrite	3.4×10^2
Serpentine	5.3×10^2-2×10^4
Slate	6.4×10^2-6.5×10^4
Hornblende	3×10^4- 1.0×10^6
Sandstone	1.8×10^2-4×10^3
Syenite	1×10^6
Gneiss	2×10^5
Conglomerate	2×10^3-1.3×10^4
Quartz	3.14×10^4-1.2×10^{12}

The most important and significant path of electrical current is through the paste. As discussed in the last section the major vehicle of conduction through paste are the conductive ions present in evaporable water, although a much lesser contribution by means of electronic conduction through the compounds of cement hydration cannot be ruled out. Models of structure of cement paste are shown in Figures 1.5 and 1.6. The conduction of electric current through the cement paste can be visualized as having two components: One is ionic conductivity through the free evaporable water shown in Figure 1.6 as capillary water; this will depend upon ionic concentration, temperature and the type of ions present in solution. The other is by the movement of electrons through the gel, gel water and unreacted cement particles. Since approximately 40 percent (by volume) of water is bound to varying degrees within the products of hydration, this path could contribute to conduction through the paste. Wyllie and Gregory[34] have suggested that even physically immobile water can conduct electricity.

Thus, the electrical conductivity of the paste depends upon the changes which both solid and solution phase (i.e. evaporable water) undergo. These changes are closely linked

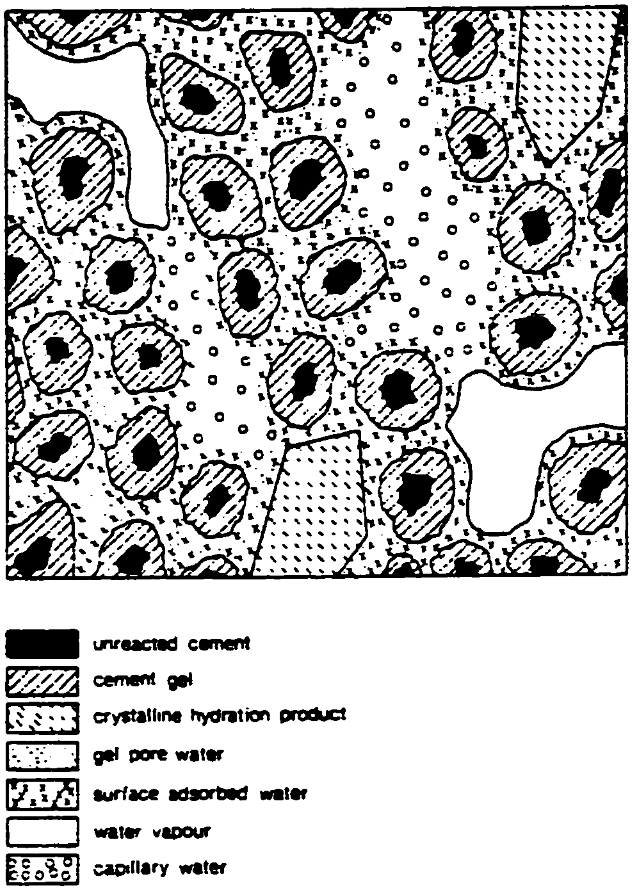


Fig: 1.5: Diagrammatic representation of hardened cement paste.

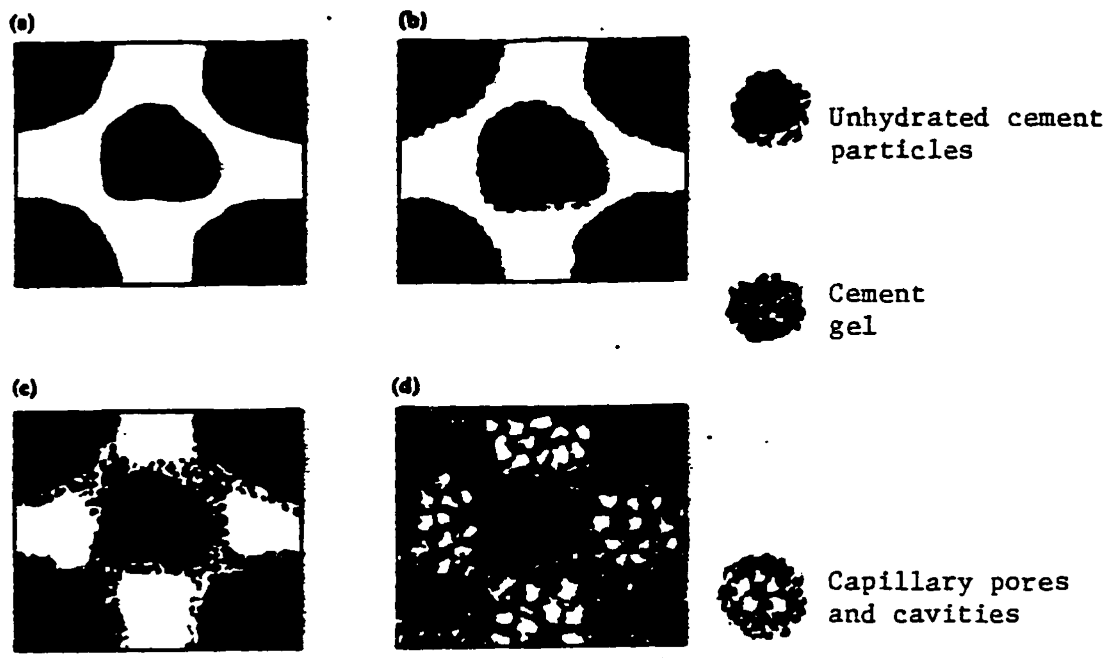


Fig: 1.6: Diagrammatic representation of the hydration process and formation of cement gel.

to each other, since the composition and concentration of ions in the evaporable water depend upon the soluble compounds within the cement particles and residual water available; whilst the composition and structure of the solid phase depend upon the amount of water, both adsorbed and chemically combined, within the cement compounds during the hydration process. Hence, it is clear that the two factors mentioned above, which conduct nearly all the current through concrete, are virtually inseparable, as the paste itself is in a constant state of change.

1.5 OBJECTIVES OF THE PRESENT STUDY

The three most significant factors which affect corrosion in the Gulf region are: high chloride contents in concrete, high temperature-humidity regimes and the generally inferior and absorptive quality of concrete resulting from faulty particles. It was therefore decided to include these parameters in some manner in an attempt to study their effect on concrete resistivity characteristics. Also, corrosion has been reported to be considerably enhanced at concrete locations subject to constant cycles of wetting and drying. Also, pozzolan admixtures offer distinct advantages for use in the Gulf area in terms of their well recognized effects in reducing concrete permeability and in mitigating cement-

aggregate reactivity damage. However, recently evidence[35] has appeared to the effect that the addition of pozzolans increase corrosive action on rebars. Hence the effect of wetting and drying cycles and the addition of pozzolan admixtures have also been included in the present investigations. Thus the overall objective format is to study the effect of the following parameters on concrete resistivity properties:

Firstly, the effect of concrete quality expressed in terms of w/c ratio, age and water absorption characteristics;

Secondly, the effect of chloride quantum;

Thirdly, the effect of wetting and drying cycles;

Fourthly, the effect of various quantities of pozzolan admixtures;

Fifthly, the effect of temperature;

Sixthly, the effect of drying concrete in order to confirm conduction mechanism through the ionic process, and

Finally, an investigation has been carried out on cores obtained from field structures to evaluate a possible relationship between resistivity of concrete and the extent of rebar corrosion.

The details of the experimental program are presented in Table 1.3.

TABLE: 1.3: DETAILS OF EXPERIMENTAL PROGRAMME

Series No.	Mix No.	W/C Ratio	Cement Content Lb/cu.yd.	Coarse Aggregate /total Aggregate Ratio	Chloride Content Lb/cu.yd.	Pozzolan % by weight of cement	PROGRAM OBJECTIVES
1	1	0.35	-	-	Nil	Nil	Studies related to cement paste for comparison with concrete - Effect of W/C ratio and age on resistivity properties
	2	0.45	-	-	Nil	Nil	
	3	0.50	-	-	Nil	Nil	
	4	0.65	-	-	Nil	Nil	
2	5	0.35	680.00	0.620	Nil	Nil	Studies related to the effect of W/C ratio, age, water absorption and temperature on concrete resistivity characteristics.
	6	0.45	680.00	0.620	Nil	Nil	
	7	0.50	680.00	0.620	Nil	Nil	
	8	0.55	680.00	0.620	Nil	Nil	
	9	0.65	680.00	0.620	Nil	Nil	
3	10	0.45	680.00	0.620	30.0	Nil	Studies related to the effect of chloride content, w/c ratio, age absorption characteristics and wetting/drying cycles on concrete resistivities properties.
	11	0.50	680.00	0.620	4.0	Nil	
	12	0.50	680.00	0.620	8.0	Nil	
	13	0.50	680.00	0.620	16.0	Nil	
	14	0.50	680.00	0.620	30.0	Nil	
	15	0.50	680.00	0.620	60.0	Nil	
	16	0.65	680.00	0.620	30.0	Nil	

Continued...

DETAILS OF EXPERIMENTAL PROGRAMME

Series No.	Mix No.	W/C Ratio	Cement Content Lb/cu.yd.	Coarse Aggregate /total Aggregate Ratio	Chloride Content Lb/cu.yd.	Pozzolan % by weight of cement	PROGRAM OBJECTIVES
4	17	0.35	680.00	0.620	Nil	10.0	Studies related to the effect of pozzolan, W/C ratio, age on concrete resistivity properties.
	18	0.35	680.00	0.620	Nil	25.0	
	19	0.45	680.00	0.620	Nil	10.0	
	20	0.45	680.00	0.620	Nil	25.0	
	21	0.55	680.00	0.620	Nil	10.0	
	22	0.55	680.00	0.620	Nil	25.0	
	23	0.65	680.00	0.620	Nil	10.0	
	24	0.65	680.00	0.620	Nil	25.0	
5	Details in Table 3.12						Studies on cores obtained from field structures to evaluate a possible relationship between resistivity of concrete and corrosion of rebars.

Chapter 2

METHODOLOGY OF INVESTIGATIONS

2.1 MATERIALS MIX DESIGN AND CONCRETE MAKING

2.1.1 Concrete Materials

Ordinary portland cement Type I was used throughout the investigation. The coarse aggregate used for various mixes was crushed limestone procured from local quarries in Dhahran. Specific gravity and absorption of coarse and fine aggregates were determined in accordance with ASTM tests C-127 and C-128 respectively. Angularity data for coarse aggregate was obtained using Hughes Method.[36] Data related to the specific gravity, 24-hour absorption and angularity for the coarse aggregate are given in Table 2.1. Coarse aggregate gradings have been chosen in accordance with ASTM C-33. 3/4" maximum size of aggregate was adopted. Grading curves corresponding to the lower and upper ASTM limits were plotted and a grading curve lying between the two limits was established. Coarse aggregate grading used for all mixes corresponds to this curve. This grading is specified in Table 2.2 and is graphically shown in Figure 2.1.

Table: 2.1: Physical Properties of Coarse Aggregate

24 hour Absorption %	Specific Gravity			Angularity
	Bulk Specific Gravity	Bulk Specific Gravity S.S.D.	Apparent Specific Gravity	
4.10	2.33	2.42	2.57	1.20

Table: 2.2: Grading of Coarse Aggregate

Sieve	Percentage Passing	Cumulative Percentage	Percentage Retained
3/4"	95	5	5
3/8"	38	62	57
# 4	5	95	33
# 8	0	100	5

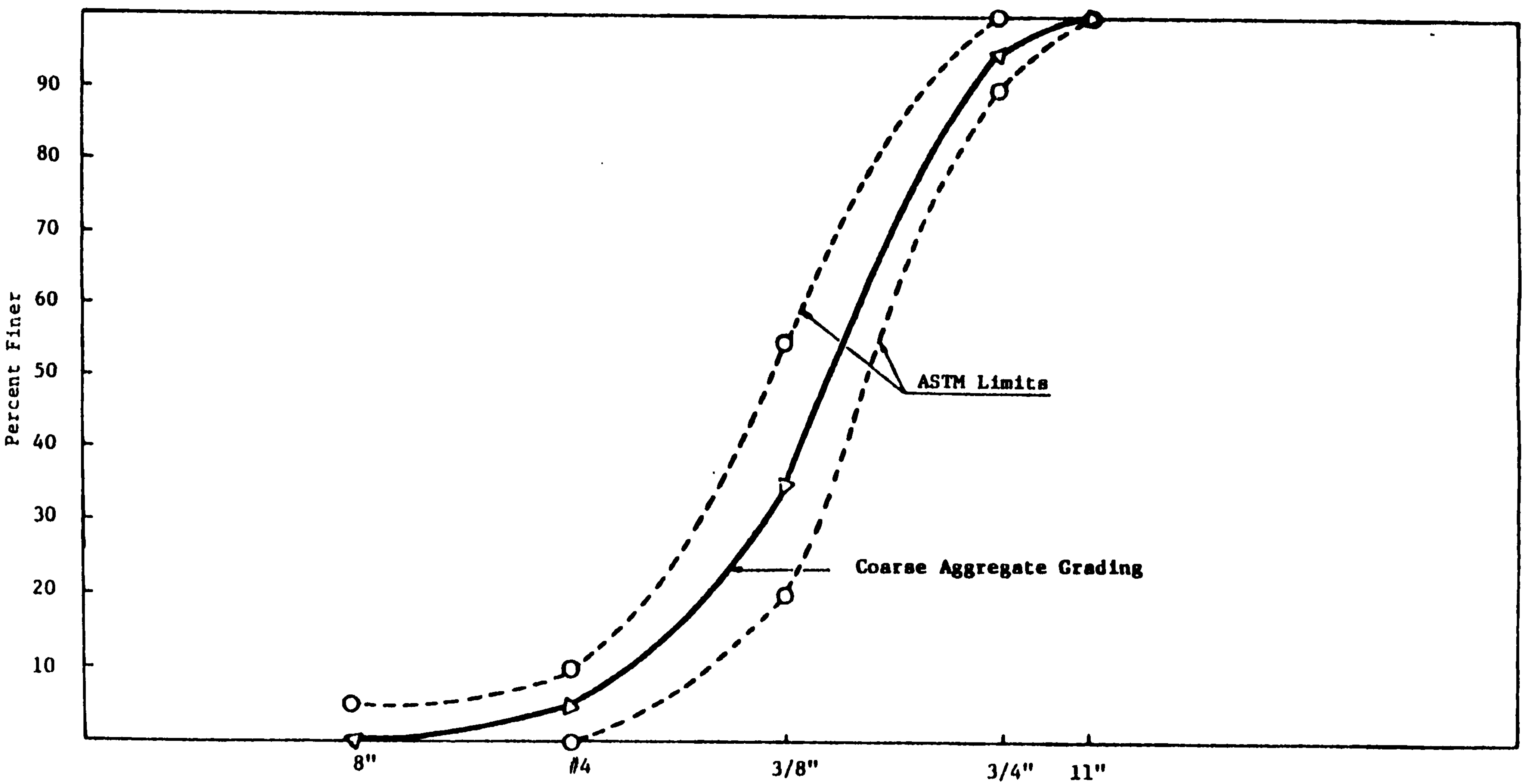


Fig: 2.1: Coarse aggregate grading

Beach sands being the primary source of fine aggregate supplies in Eastern Saudi Arabia, Half-Moon Beach sand was used for all the mixes. Data pertaining to the specific gravity, absorption and angularity are shown in Table 2.3. Typical sieve analysis of the sand is shown in Table 2.4 and is plotted in Figure 2.2. The combined grading of the coarse and fine aggregates is shown in Figure 2.3.

Sweet water was used for mixing concrete.

2.1.2 Pozzolan Admixture

The pozzolan used was a West German fly ash. Two values of cement replacement corresponding to 10 and 25 percents by weight of cement were adopted. An analysis of the pozzolan used is shown in Table 2.5.

2.1.3 Chlorides

Chlorides were inducted through sodium and calcium chloride salts in one series of concrete mixes in quantities varying from 4 to 60 lb/cu.yd. to investigate the influence of chloride contamination on concrete resistivity properties. In a previous investigation[37] an analysis of the concrete samples cored from field structures showed chloride contents as high as 12 percent around the rebars. Sodium/calcium salts were thoroughly dissolved in the mix

Table: 2.3: Physical Properties of Fine Aggregate (Half-Moon Beach Sand)

24 hour Absorption %	Specific Gravity	Angularity
0.227	2.700	1.033

Table: 2.4: Sieve Analysis of Half-Moon Beach sand used in the mix.

Sieve Size	Percentage Retained	Cumulative Percentage Retained	Percentage Passing
9.5 mm	0	0	100
4.75 mm	0	0	100
2.36 mm	0	0	100
1.18 mm	.04	.04	99.96
600 μm	3.8	3.84	96.16
300 μm	34.794	38.634	61.366
150 μm	39.460	78.094	21.906
75 μm	20.938	99.032	.968

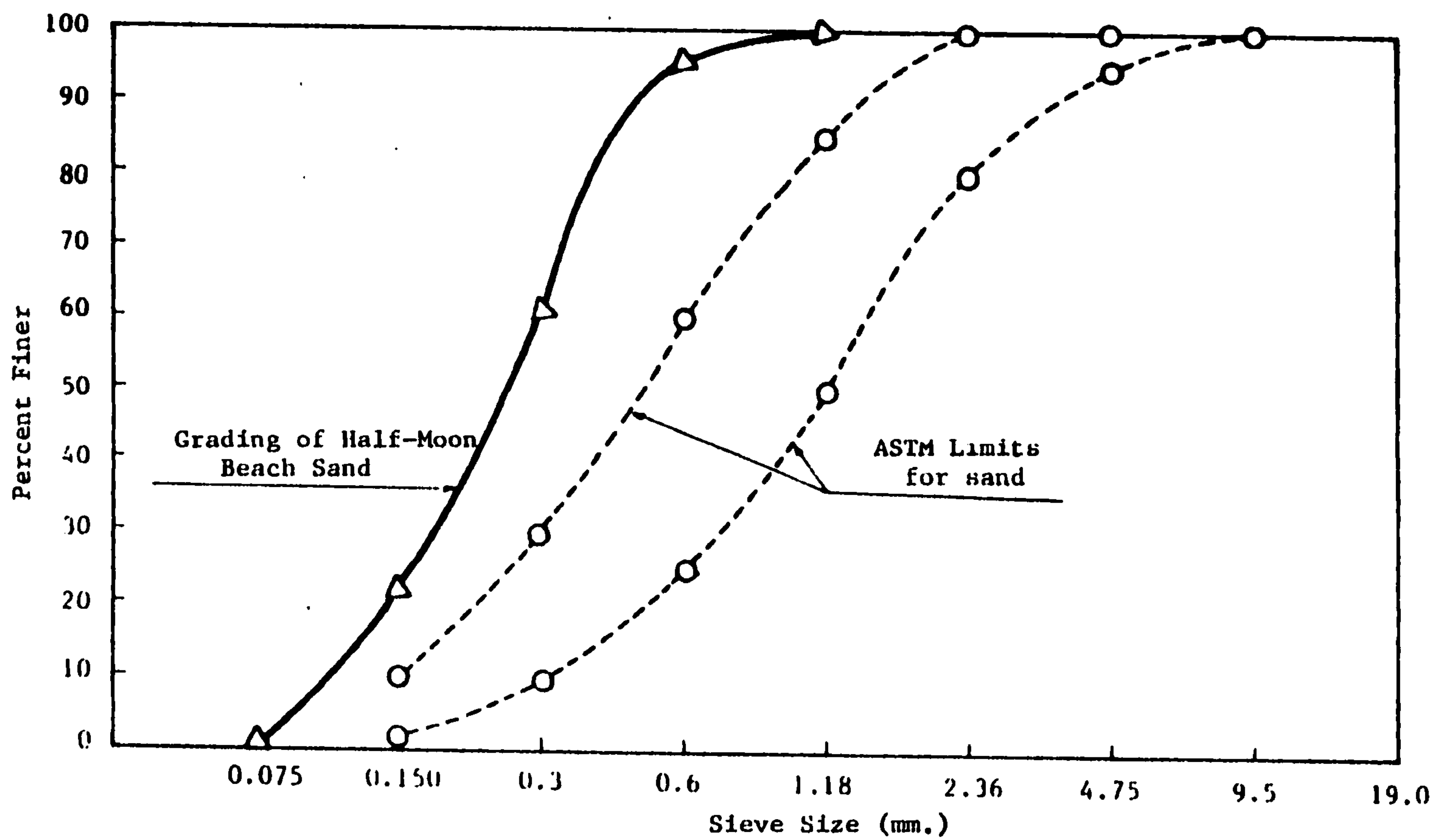


Fig: 2.2: Grading of the Fine Aggregate (Half-Moon Beach Sand)

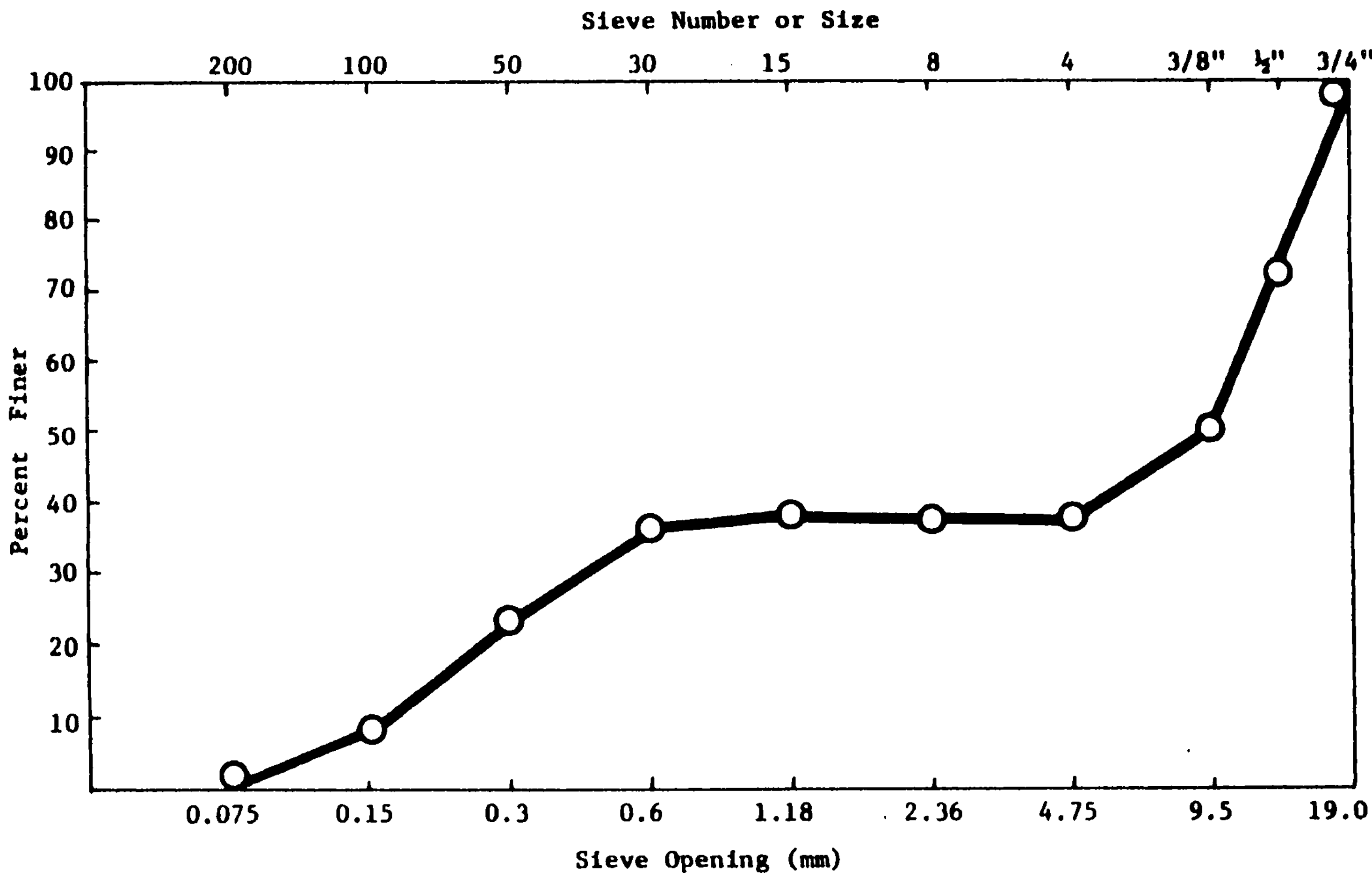


Fig: 2.3: Combined Aggregate Grading for Fine to Coarse Aggregate Ratio: 0.61.

Table: 2.5: Physical and Chemical Analysis of Pozzolan

Physical Analysis		
Physical Properties		ASTM C-618 Specification
Specific Gravity:	2.40	-
Fineness: % retained 0.045 min:	23% by wt.	Max 34%
Drying Shrinkage of Mortar bars:	0.01% by wt.	Max .03%
Soundness Autoclave expansion:	0.06%	Max 0.8%
Pozzolanic activity index with portland cement	:78.6%	Min 75%
Water requirement, Percentage of control	:96%	Max 105%
Pozzolanic activity index with Lime	:1900 psi	Min 800 psi
Specific Surface	:406 m^2/kg.	-

Chemical Analysis		
Constituents	% by Weight	ASTM C-618 Specifications
Silica (SiO_2)	40.50	
Aluminum Oxide (AL_2O_3)	31.38	Min 70%
Ferric Oxide (Fe_2O_3)	2.00	
Insoluble Residue	1.28	-
Calcium Oxide (CaO)	14.36	-
Magnesium Oxide (MgO)	0.81	Max 5%
Sulphur Trioxide (SO_3)	1.51	Max 5%
Loss on ingition	6.24	Max 12%
Undetermined	1.92	-

water to ensure a uniform distribution of chlorides in the mix of the hardened cement paste.

2.1.4 Concrete Mix

The mix used is shown in Table 2.6 in terms of the Cement/Aggregate and Fine Aggregate/Coarse Aggregate ratios. The quantities listed are for one cubic yard of concrete. The quantity of water was adjusted in each mix according to the adopted value of the w/c ratio. In the test series related to the pozzolan admixture, cement quantities were decreased corresponding to 10 percent and 25 percent of pozzolan used as cement replacement. The mix used corresponds to a Cement/Aggregate ratio of 0.234 and Fine Aggregate/Coarse Aggregate ratio of 0.61. All materials were batched by weight.

2.1.5 Casting and Curing of Concrete Samples

Constituent materials were mixed in a one tonne electrically operated mixer. 6 x 6 x 12 inch concrete blocks were cast in specially manufactured wooden moulds. The concrete was vibration-compacted in three layers, each layer being vibrated by a needle vibrator. The concrete samples were left in air at room temperature for 24 hours; thereafter the specimens were demoulded and cured in water

Table: 2.6: Mix Details Used

Water Cement Ratio	Quantities of Ingredients of 1 cu.yd. of concrete				Cement/Aggregate Ratio	Fine Aggregate / Coarse Aggregate Ratio
	Weight of Water Lb.	Weight of Cement Lb.	Weight of Coarse Aggregate Lb.	Weight of Fine Aggregate Lb.		
Variable	Variable according to W/C Ratio.	680	1800	1100	0.234	0.61

at room temperature till the age of 28 days. Plate 2.1 shows some of the concrete blocks used in this investigation.

2.2 CORED SAMPLES FROM FIELD STRUCTURES

In view of the significance of the field studies, cored concrete samples were selected and used from amongst those approximately hundred cores which were obtained in a previous investigation from ten deteriorated concrete buildings located in Dhahran-Dammam-Khobar areas. These concrete framed building structures were 22-27 years old and were in various states of concrete cracking and spalling as a result of rebar corrosion. Typical sampled buildings are shown in Plates 2.2, 2.3. Cores were extracted from interesting regions of exposed slabs from the viewpoint of corrosion deterioration. A gasoline driven core drilling machine (Plate 2.4) with a 3 inch diameter diamond bit was used to extract the cores. Plates 2.5, 2.6 show the cored areas and Plate 2.7 shows a typical core. Plate 2.8 shows the cores tested for resistivity properties with embedded pure copper pins for use as electrodes.

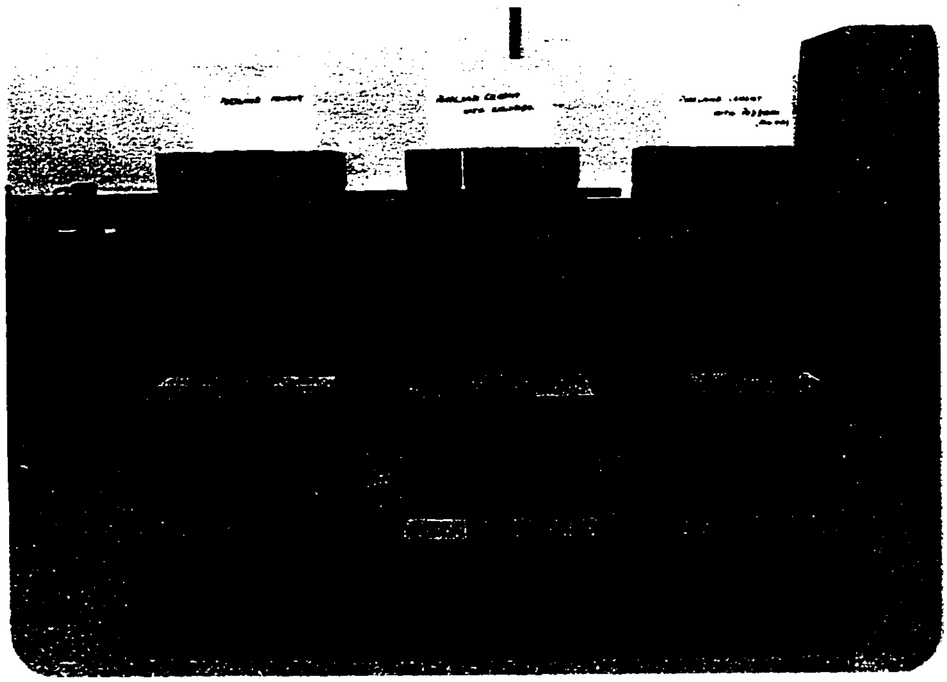


Plate: 2.1: Concrete samples used for data development on concrete resistivity characteristics.

Plate: 2.2: Typical field structure from which cores were obtained.

Plate: 2.3: Typical field structure from which cores were obtained.

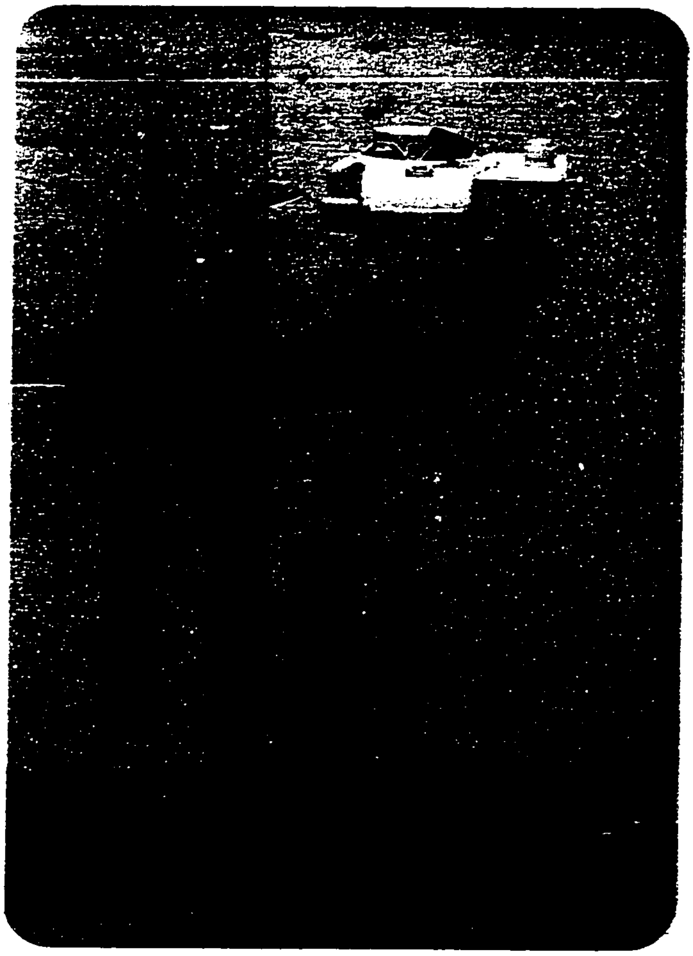


Plate: 2.4: Gasoline Core Drilling Machine

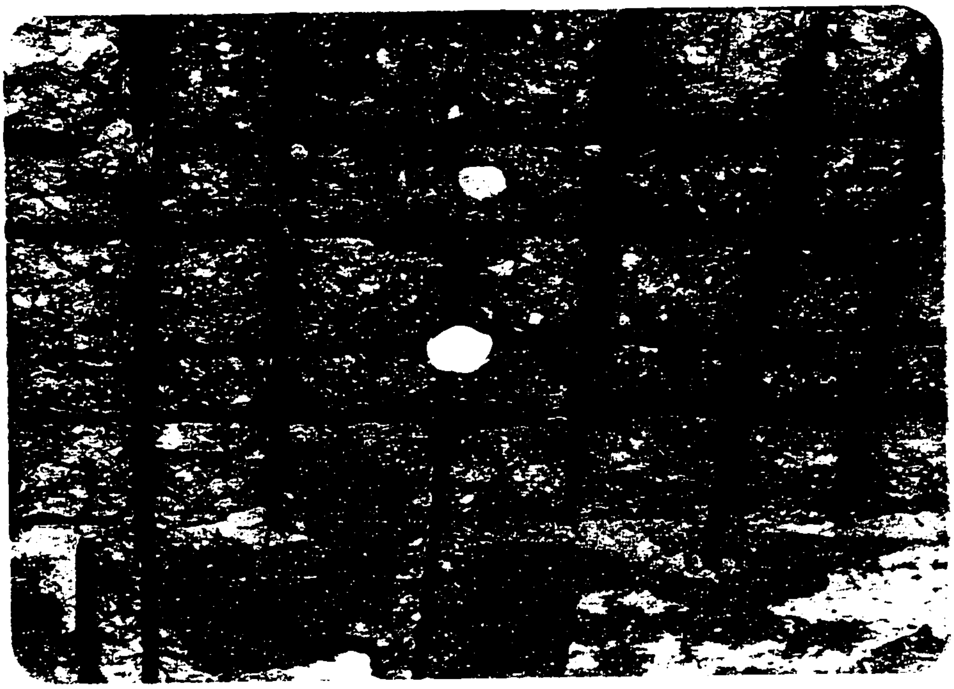


Plate: 2.5: Typical Cored area

Plate: 2.6: Typical Cored area.

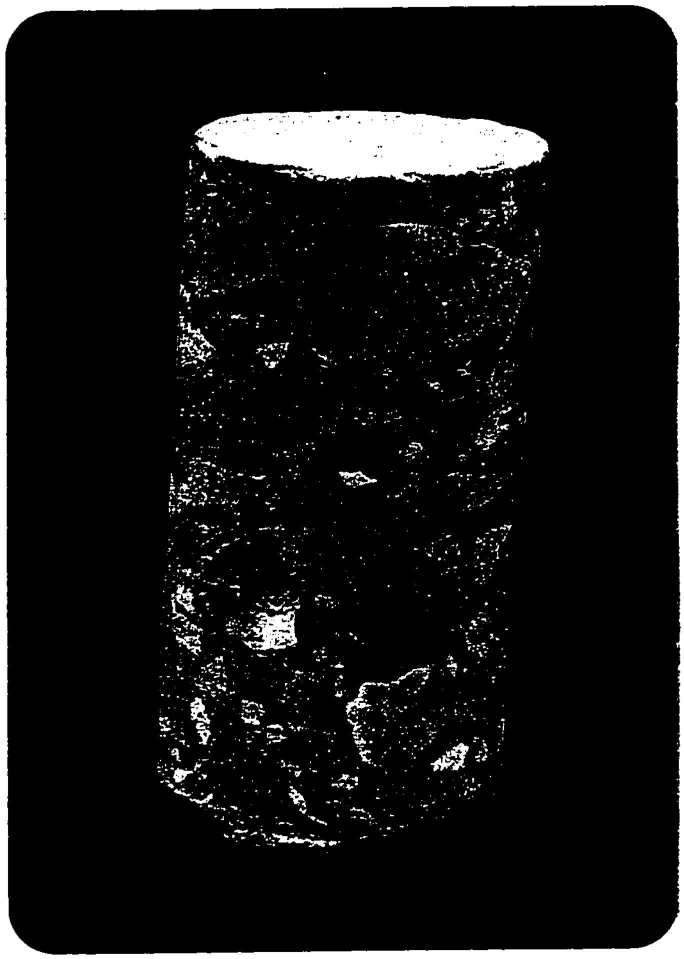


Plate: 2.7: A typical core

Plate: 2.8: Typical cores from field structures used for developing data on concrete resistivity.

2.3 LOSS OF METAL DETERMINATION FOR REINFORCEMENT

Steel bars removed from the cores were cut off neatly at the two opposite faces in the machine shop to obtain exact lengths. These bars were labelled with steel markers and their original diameter identified. The bar length which varied in size were then dipped in concentrated hydrochloric acid for approximately 15-20 minutes. Subsequently these bars were washed with water and then dried. These were then weighed and the percent loss was calculated as:

$$\%\ \text{loss} = (\text{original wt/inch} - \frac{\text{weight of the bar}}{\text{length of the bar}}) \times 100$$

2.4 WATER ABSORPTION DETERMINATION

The absorptive capacity of concrete was determined by first drying the specimens in an oven for 8 days at 250°F. The dry weight of the specimen was then obtained. Thereafter the specimen was submerged in water for 60 days after which period it was weighed again. The water gain was calculated by subtracting the previous weight reading from the later one. The percent absorption was obtained in terms of the dry weight of the specimen.

2.5 WETTING AND DRYING CYCLES

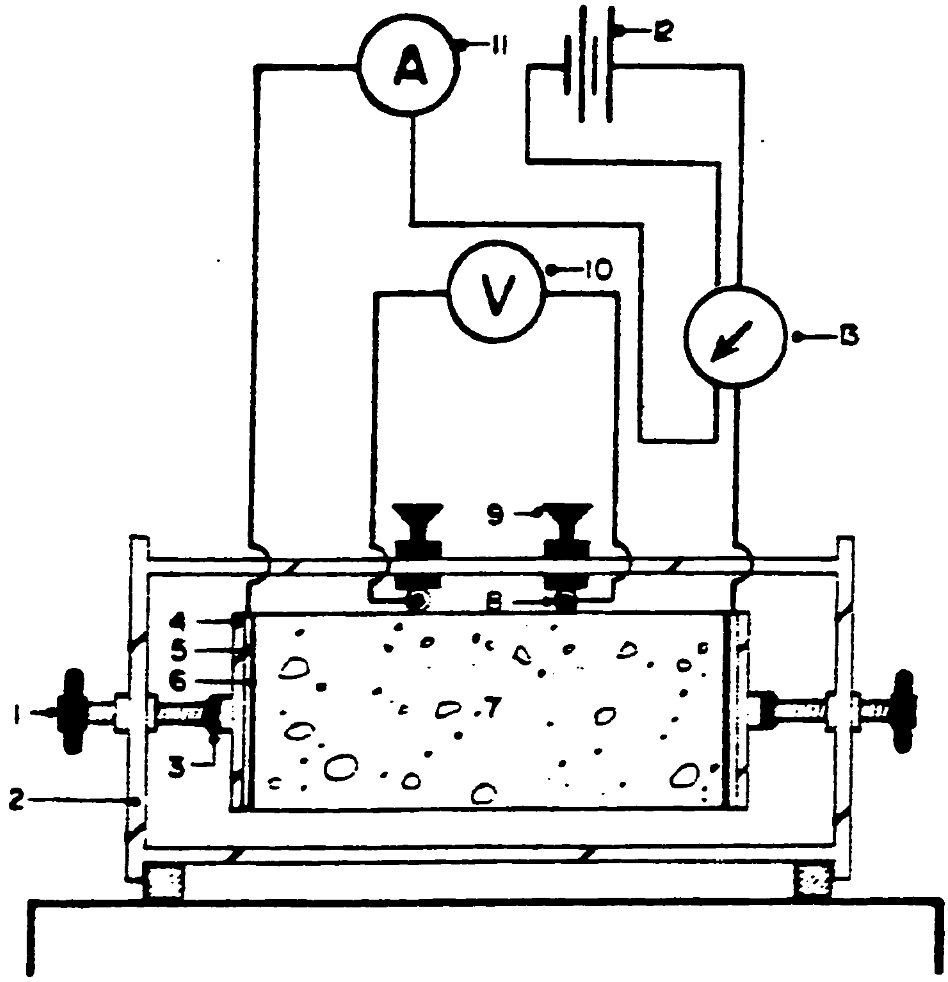
The wetting/drying cycle consisted of 24 hours of oven drying at 250°F, 24 hours of cooling at room temperature and 24 hours of submergence in water.

2.6 HEATING TREATMENT OF SPECIMENS FOR TEMPERATURE EFFECT

The effect of temperature on resistivity properties was determined by heating specimens in water bath for 24 hours at pre-determined temperatures of 20°C, 40°C, 60°C and 80°C. The resistivity measurements were obtained immediately after the specimen was removed from the water bath.

2.7 INSTRUMENTATION FOR RESISTIVITY MEASUREMENTS

To facilitate electrical resistivity measurements on concrete blocks and cores a special apparatus was fabricated in the UPM Research Workshop. This apparatus is shown schematically in Figure 2.4 and Plates 2.9 and 2.10. The resistivity measurement apparatus consists of a steel frame with end plates made of copper and covered with a cloth pad which was wetted with water before the concrete block was gripped by the end plates. The copper plate-wet cloth combination was used to ensure a uniform distribution of



1. Screw for gripping the block
2. Steel frame
3. Insulator
4. Steel plate
5. Copper plate
6. Cloth pad
7. Concrete block
8. Copper sulphate half-cell
9. Screw for positioning copper sulphate half-cell
10. Voltmeter
11. Ammeter
12. d-c power supply
13. Current reversing switch

Fig: 2.4: Resistivity Measurement Apparatus and the adopted electric circuit.

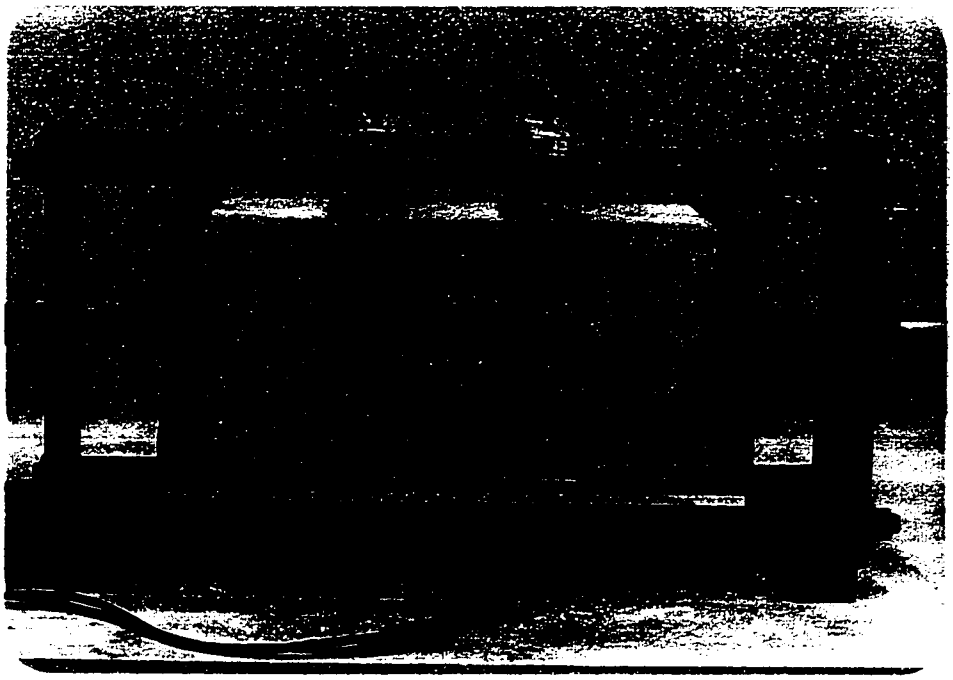


Plate: 2.9: Close-up of concrete block showing wet pads covering copper plate on opposite faces and the positioning of the electrodes.

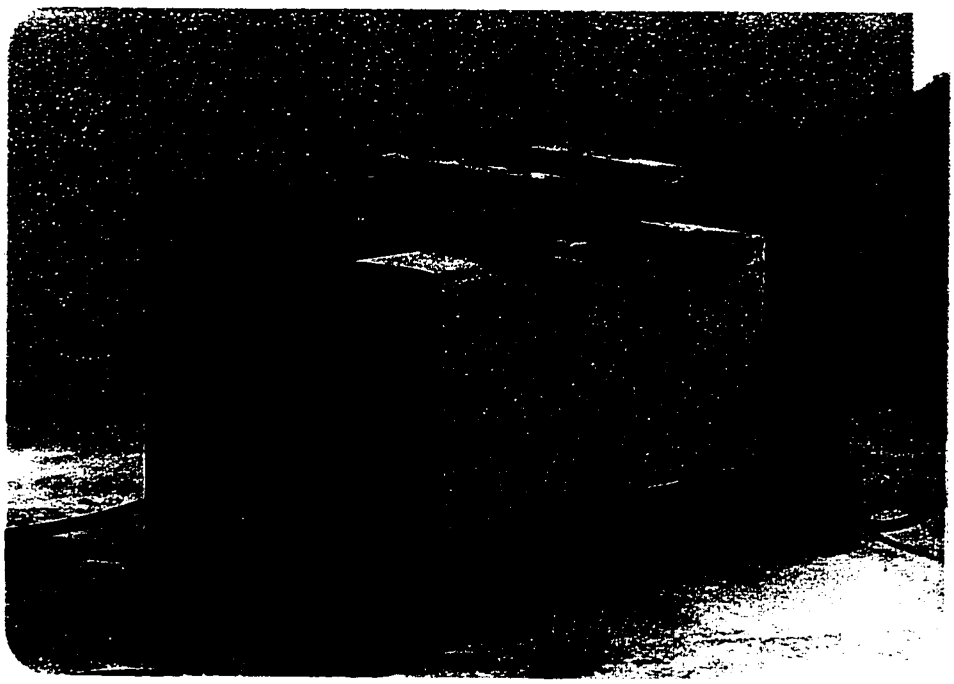


Plate: 2.10: Concrete specimen in the resistivity measuring apparatus showing positioning of electrodes for measuring voltage drop.

current density across the cross section of the test specimen. The screws at the two ends are used for tightening the block in place between the two end plates. The voltage drop is measured on the surface of the block while the current is flowing. Two copper sulphate half-cells were used at specific third point locations across the width of the concrete block and at right angles to the current flow. The copper sulphate half cells were constructed by using chemically pure copper rods which were encased in a cloth sheath. The cloth was wetted with a solution of copper sulphate just prior to each voltage measurement (Plate 2.10).

The electrical instrumentation consisted of d-c power supply of 600 volts capacity, and very precise voltmeter and ammeter connected as shown in Figure 2.4 and Plate 2.11. A current reversal switch was also used as each resistivity measurement was an average of two resistance values which were obtained after the direction of current flow was reversed.

The potential electrodes are located in the central third of the equipment (Plate 2.9) to avoid errors due to possible polarization phenomena at the electrode-concrete interface. Figure 2.5 is a schematic of the equation used

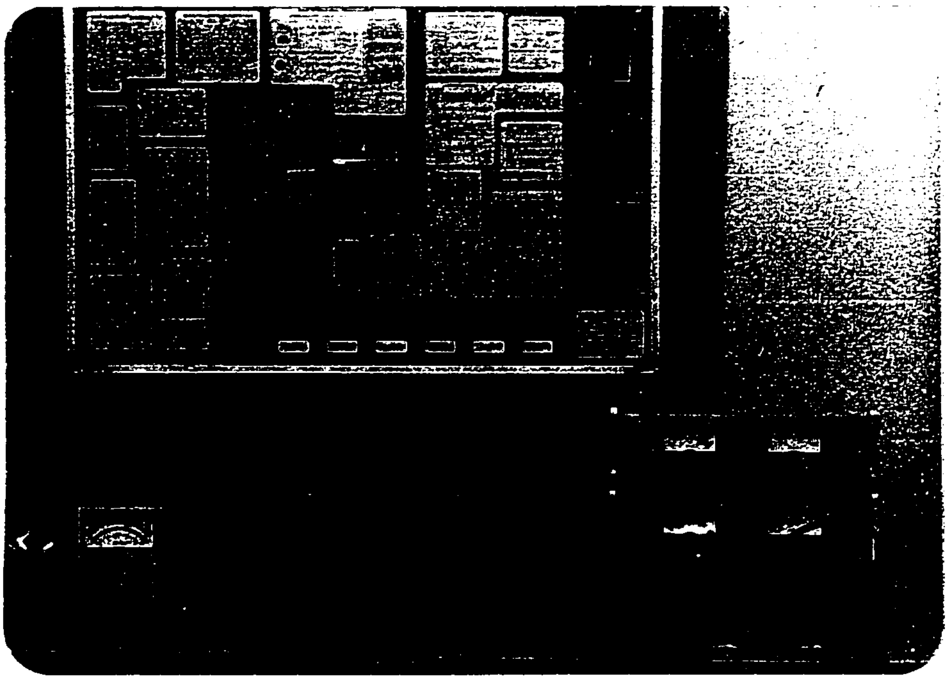
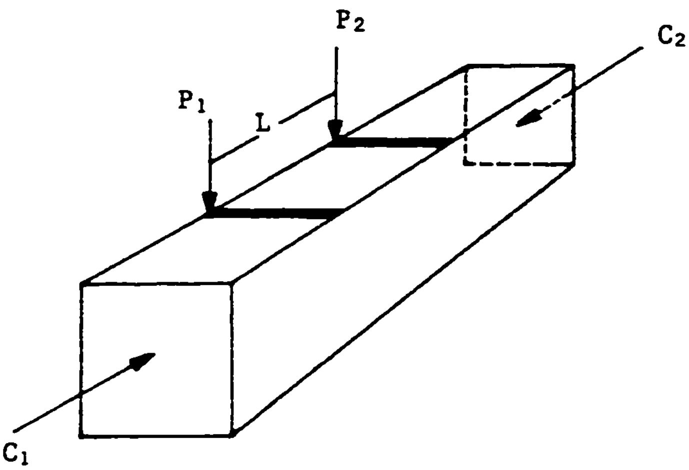


Plate: 2.11: Instrumentation for measuring resistivity of concrete.



$$\rho = \frac{RA}{L}$$

ρ = Resistivity, ohm-centimeter

R = Resistance in ohms

A = Cross sectional area - centimeters

L = Length in centimeters

C_1 and C_2 = Current electrodes

P_1 and P_2 = Potential electrode

Fig: 2.5: Equation for measuring resistivity of a concrete block.

for calculating the resistivity of the concrete test specimens.

Plate 2.12 shows a concrete core in position for measurements in the resistivity apparatus.

Subsequently an integrated and a highly compact electrical instrument was used for resistivity measurements. This apparatus, commercially available as Nilsson 400, is shown in Plate 2.13. The instrument is a 4 terminal, null balancing ohm meter. It measures resistance directly from 0.01 ohm to 1.1 megohms. The unit generates a low voltage 97 Hz square wave current between the C_1 and C_2 binding posts (Figure 2.6). The detector, whose input is connected between the P_1 and P_2 binding posts is only sensitive to 97 Hz, and so is not affected by stray A-C and D-C currents. This is a very strong feature of the apparatus when used in resistivity measurements; the apparatus is totally insensitive to any spurious potentials or stray currents. The detector senses the voltage drop between the P_1 and P_2 binding posts, compares it to internal standard resistors, and indicates a difference on the null detector. When the null detector is balanced, using the range switch and the dial, the resistance in ohms between P_1 and P_2 is the dial reading multiplied by the range switch position. The arrangement

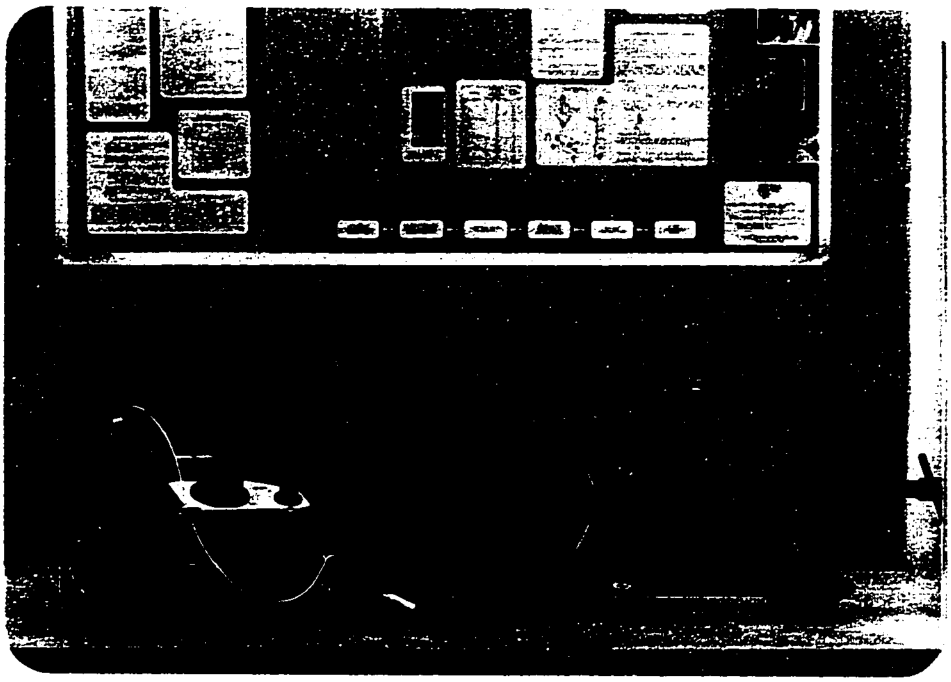


Plate: 2.12: Instrumentation for measuring resistivity of concrete cores drilled from field structures.

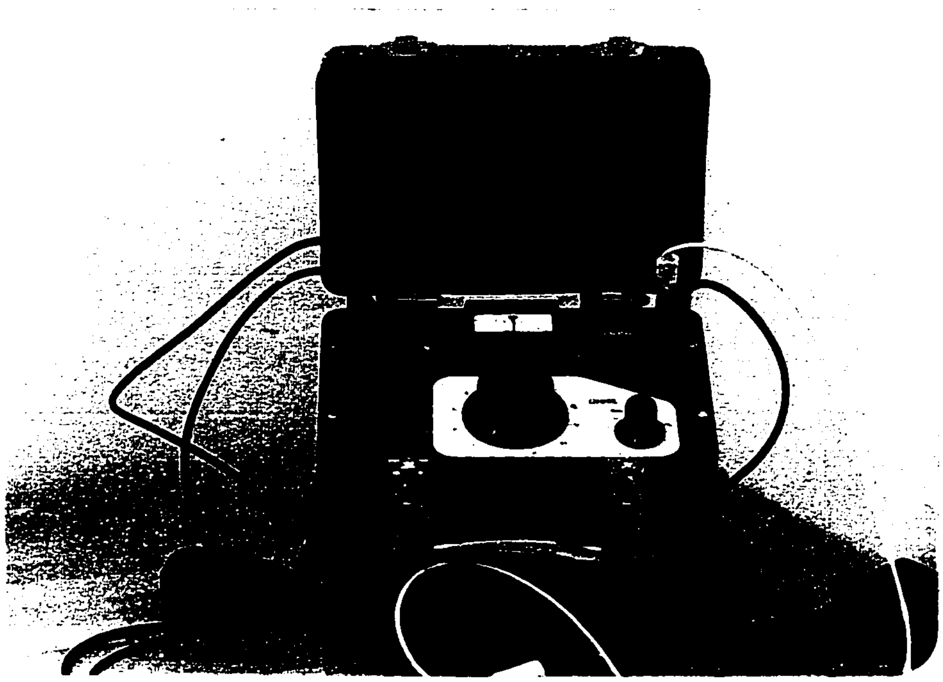


Plate: 2.13: Nilsson used for concrete resistivity measurement.

used for the concrete blocks is shown in Figure 2.6.

For concrete cores, it was thought best to insert pure copper pins using small amounts of cement paste and to directly connect the pins to the P_1 and P_2 binding posts for voltage drop measurements. This arrangement is shown in Figure 2.7.

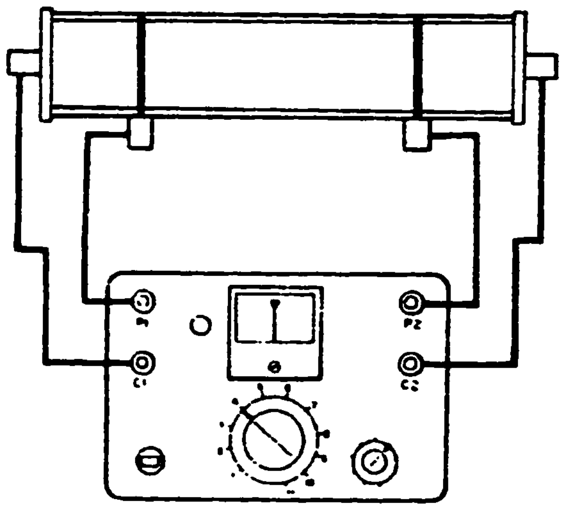


Fig: 2.6: Instrumentation using Nilson 400 for Resistivity measurement on concrete blocks.

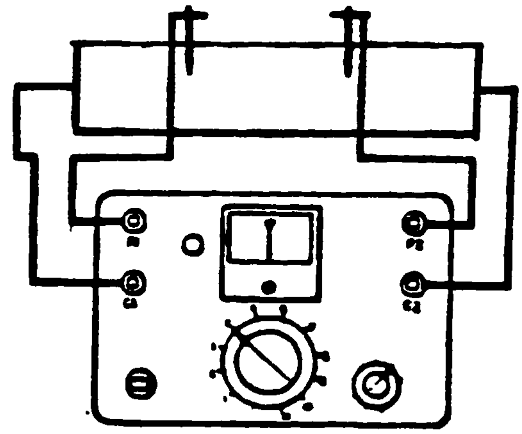


Fig: 2.7: Instrumentation using Nilson 400 for Resistivity measurement on concrete cores.

Chapter 3

RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Mix Characteristics and Resistivity of Cement Paste and Concrete

The concrete resistivity data for the neat cement pastes and concrete of W/C ratios 0.35, 0.45, 0.50 and 0.65 after 28 days of moist curing is listed in Tables 3.1, 3.2 and plotted in Figure 3.1. The plots show that for both cement paste and concrete the resistivity falls sharply with an increase in the W/C ratio. The paste and concrete resistivities at the W/C ratio of 0.35 are respectively 7.14 and 1.67 times the corresponding values at W/C ratio of 0.65. Also, the differential in the resistivities of the concrete and the paste is a function of the W/C ratio. The resistivity of concrete is 4.15 to 1.70 times that of the cement paste for W/C ratio of 0.65 and 0.40 respectively. However, for W/C ratio below 0.40 this difference sharply converges till the resistivities of the paste and concrete are almost equalized for a value of 0.35.

Figure 3.1 clearly shows the effect of the mix water. The mix water varies from 28.52 gallon/cu yd to

TABLE 3.1: CEMENT PASTE RESISTIVITY DATA

Effect of w/c Ratio

Moist Curing Time (Days)	RESISTIVITY (ohm-cm) Water-Cement Ratio			
	0.35	0.45	0.50	0.65
7	2745.00	645.08	480.38	491.81
14	4346.25	1132.31	834.94	686.25
21	5032.50	1509.75	1120.88	754.88
28	5718.75	1932.94	1418.25	800.63

TABLE 3.2: CONCRETE RESISTIVITY DATA

Effect of w/c Ratio and Age

W/C Ratio	RESISTIVITY (ohm-cm) Moist Curing Time (Days)			
	7	14	21	28
0.35	3289.77	4300.96	5036.46	5551.42
0.45	2881.68	3147.37	3677.73	4100.35
0.50	2574.01	3115.92	3594.99	4032.06
0.55	2434.92	3090.87	3409.87	3854.67
0.65	2366.19	2835.93	3109.17	3322.94

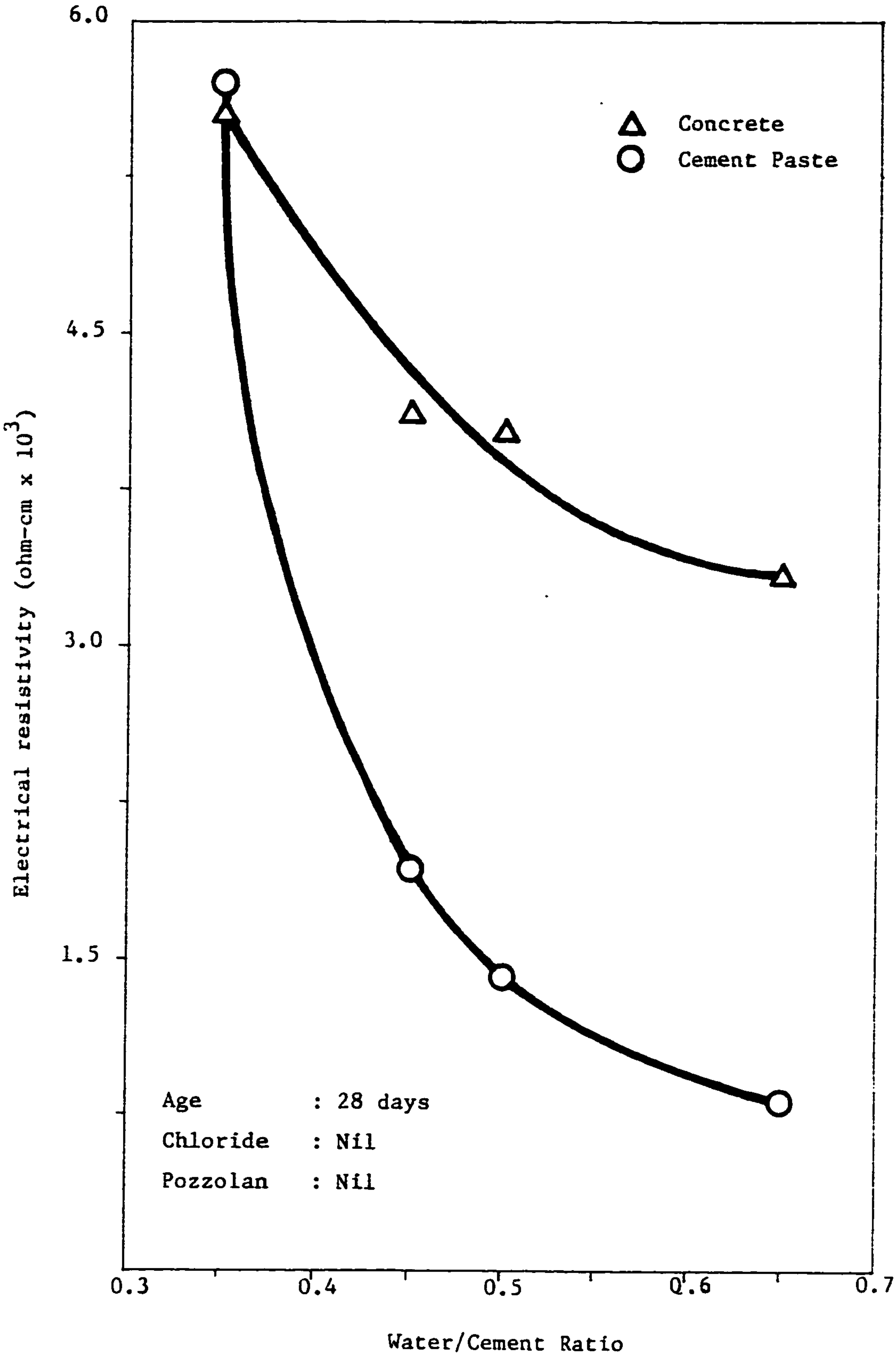


Fig: 3.1: Relationship between electrical resistivity and W/C Ratio of Concrete and Cement Paste.

52.97 gallon/cu yd respectively for W/C ratio of 0.35 and 0.65. With an increase in the mix water resistivity falls sharply for both concrete and paste.

Figure 3.2 and Table 3.1 show a similar trend of resistivity variation with W/C ratio for different ages of cement paste. Figure 3.3 and Tables 3.2, 3.3 show the corresponding data for concretes of different ages.

Figure 3.4 and Table 3.4 show the concrete resistivity variation with W/C ratio after 14 days of exposure to the environment subsequent to 28-days of moist curing. It is seen that the trend of variation is similar to that shown in Figure 3.1, although the resistivity values for the same W/C ratios are higher on an average by 30.48 per cent due to the loss of evaporable water and more advanced hydration entailing a further consumption of mix water.

3.1.2 Chlorides and Concrete Resistivity

The effect of chlorides on concrete resistivity is shown in Table 3.5 and Figure 3.5. This data has been developed for chloride contents varying from 4 lb per cu.yd. to 60 lb per cu.yd. in a concrete of 0.50 W/C ratio. It is seen that chloride contents upto about 10 lb per cu.yd. have little effect on resistivity values.

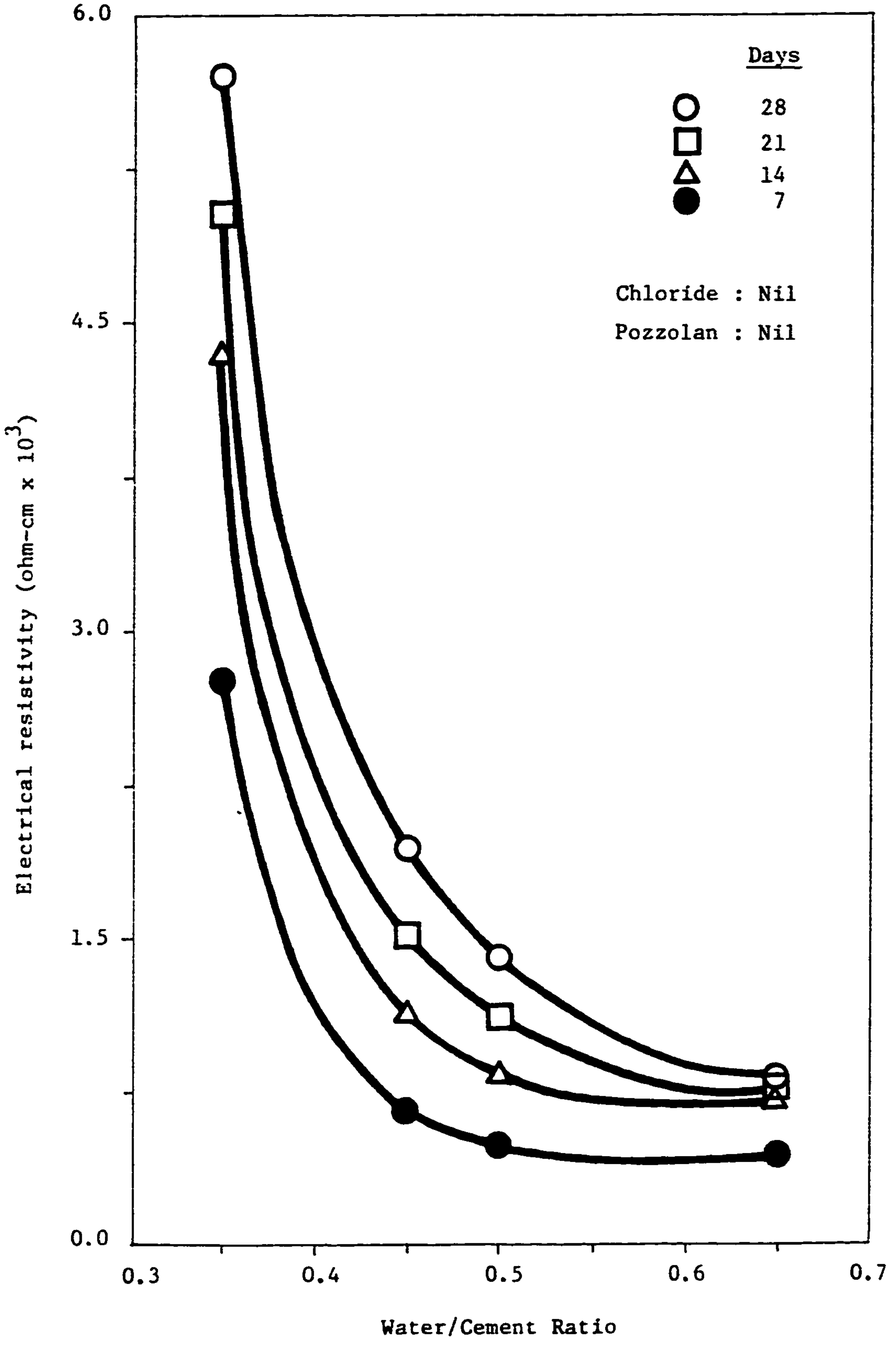


Fig: 3.2: Relationship between electrical resistivity and w/c ratio of cement pastes of different ages.

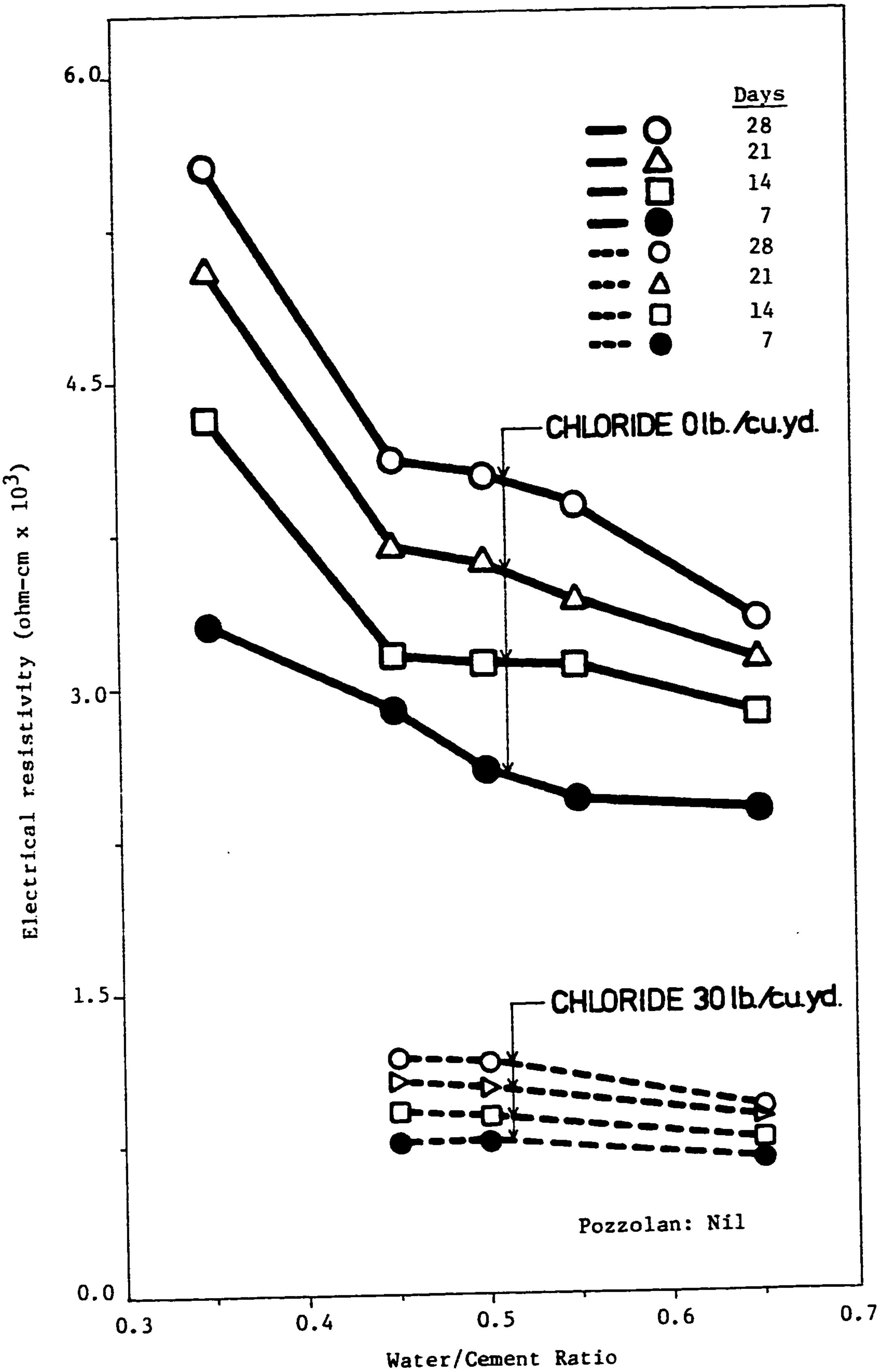


Fig: 3.3: Relationship between electrical resistivity and water/cement ratio of concretes of different ages.

TABLE 3.3: CONCRETE* RESISTIVITY DATA

Effect of w/c Ratio and Age

Moist Curing Time (Days)	RESISTIVITY (ohm-cm)		
	Water-Cement Ratio		
	0.45	0.50	0.65
7	751.33	750.65	647.25
14	892.81	876.46	743.33
21	1051.68	1019.77	860.79
28	1153.89	1130.37	908.60

*contains 30 lb/cu yd of chloride.

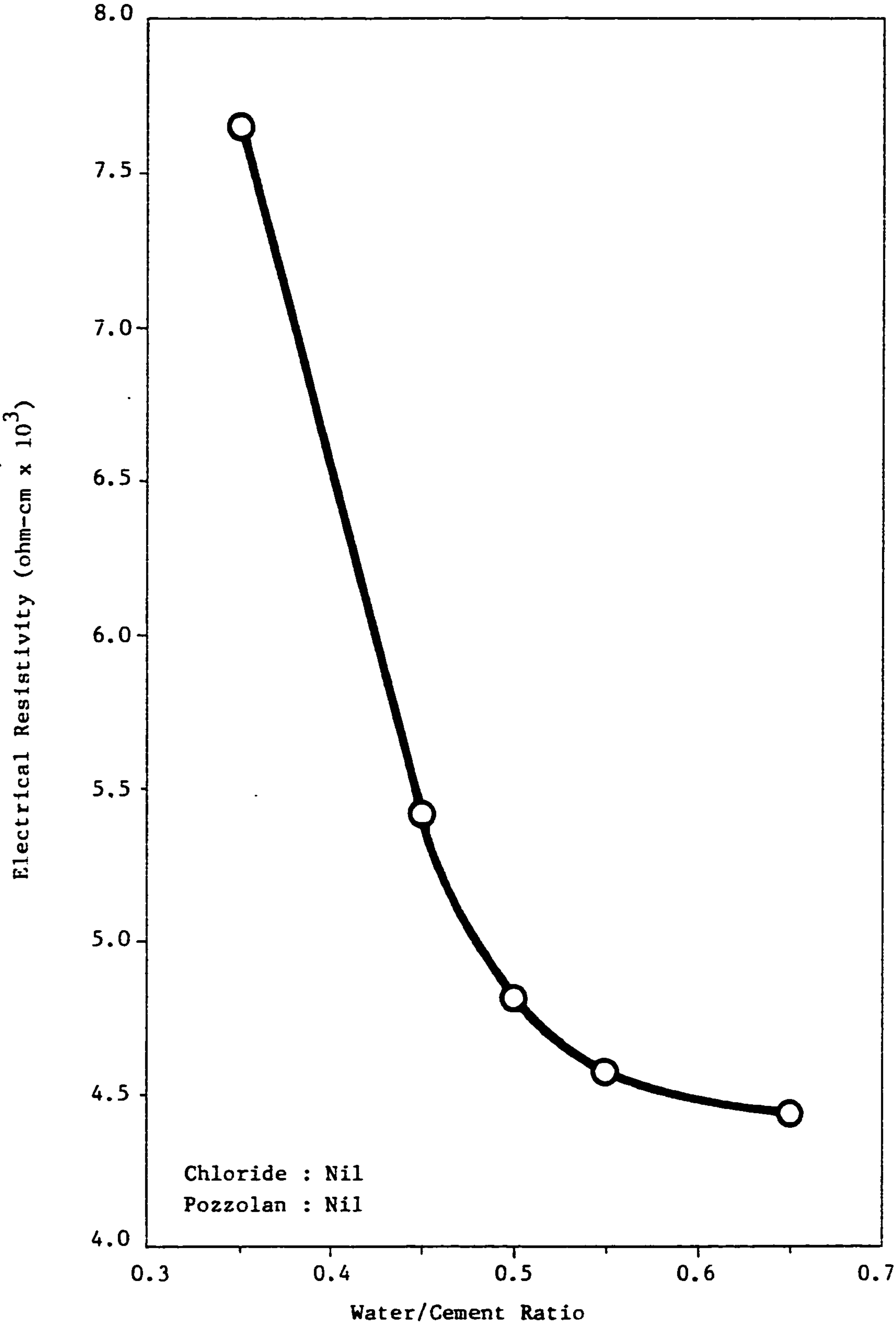


Fig: 3.4: Relationship between electrical resistivity and water/cement ratio of concrete exposed for 14-days after 28 days of moist curing.

TABLE 3.4: CONCRETE* RESISTIVITY DATA

Effect of Water-Cement Ratio

Water-Cement Ratio	Resistivity (Ohm-cm)
0.35	7653.53
0.45	5407.88
0.50	4806.27
0.55	4572.71
0.65	4418.53

* Exposed for 14 days to the environment subsequent to 28 days of moist curing

TABLE 3.5: CONCRETE* RESISTIVITY DATA

Effect of Chloride

Chloride Content (lb/cu.yd.)	Resistivity (ohm-cm)
4	6171.07
8	6238.24
16	6312.13
30	4715.91
60	2877.67

* Exposed for 14 days to the environment subsequent to 28 days of moist curing.

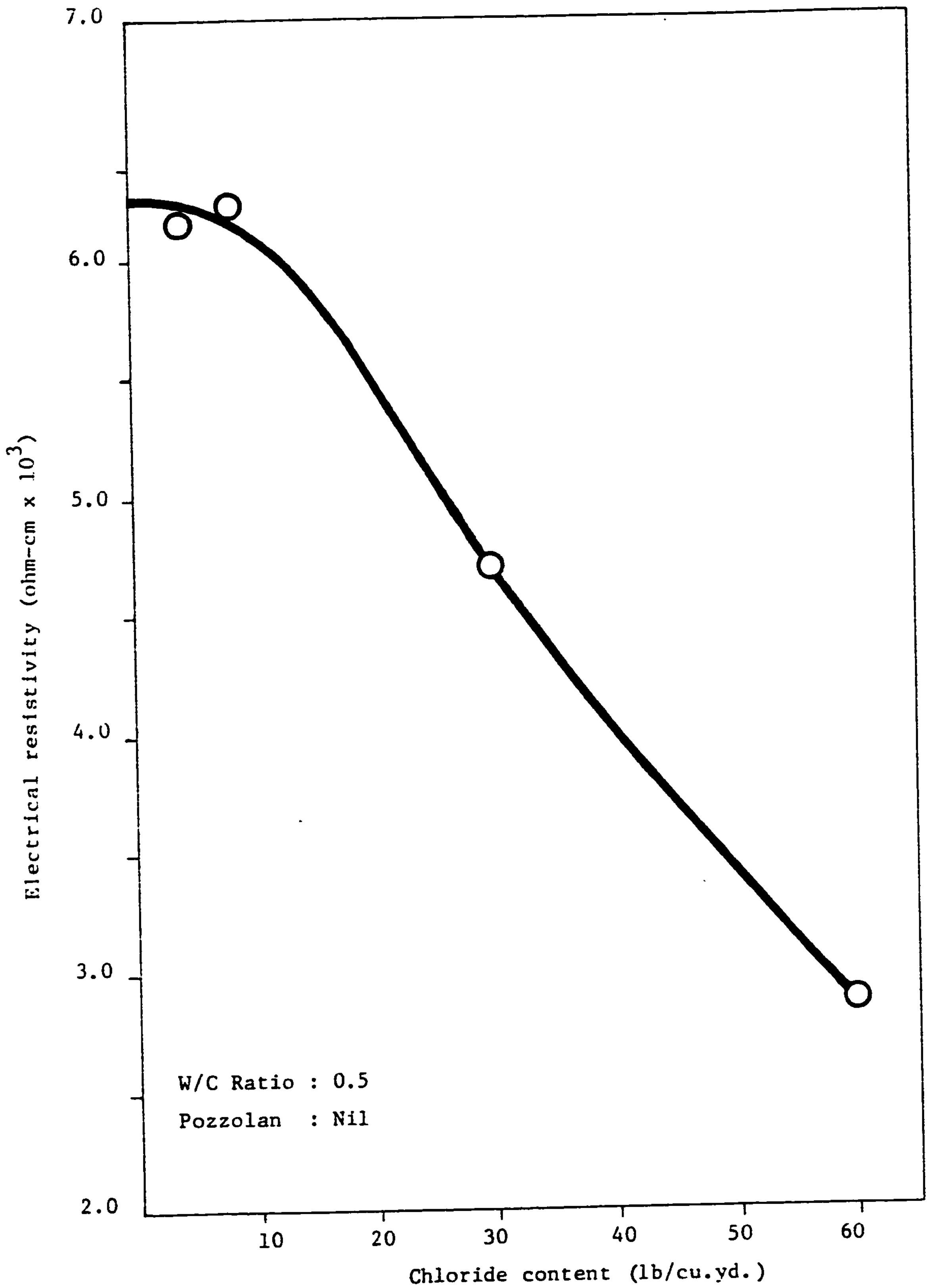


Fig: 3.5: Relationship between electrical resistivity and Chloride content (14 days of exposure after 28-days of moist curing).

However, as the chloride contamination further increases the resistivity values decrease sharply. For chlorides around 30 lb per cu.yd. the resistivity value is 75.60% of the value for 8 lb/cu.yd. and is further reduced to 46.13% for a chloride inclusion of 60 lb/cu.yd. A similar trend is observed in Figure 3.6 and Table 3.6 which show resistivity variations with chlorides in a 0.5 W/C ratio concrete at different ages. A marked decrease in the resistivity value of 30 lb/cu.yd. chloride concrete independent of W/C ratio and age is shown in Figures 3.3 and 3.7. It is seen that for W/C ratios in the range of 0.45 to 0.65 the resistivity values are on an average 27.84% for the 30 lb chloride concrete compared to those for uncontaminated concrete.

3.1.3 Absorptive Characteristics and Concrete Resistivity

The data concerning relationship between the mix characteristics and the absorptive capacity of concrete is listed in Table 3.7 and is plotted in Figure 3.8. As expected, the absorptive capacity of concrete increases sharply with W/C ratio, the capacity for 0.65 W/C ratio being 1.5 times that for 0.45 at all ages. Concrete reaches more than 85% saturation after two days of soaking in water and the additional water absorption for a continued 60 days of further submergence is almost negligible.

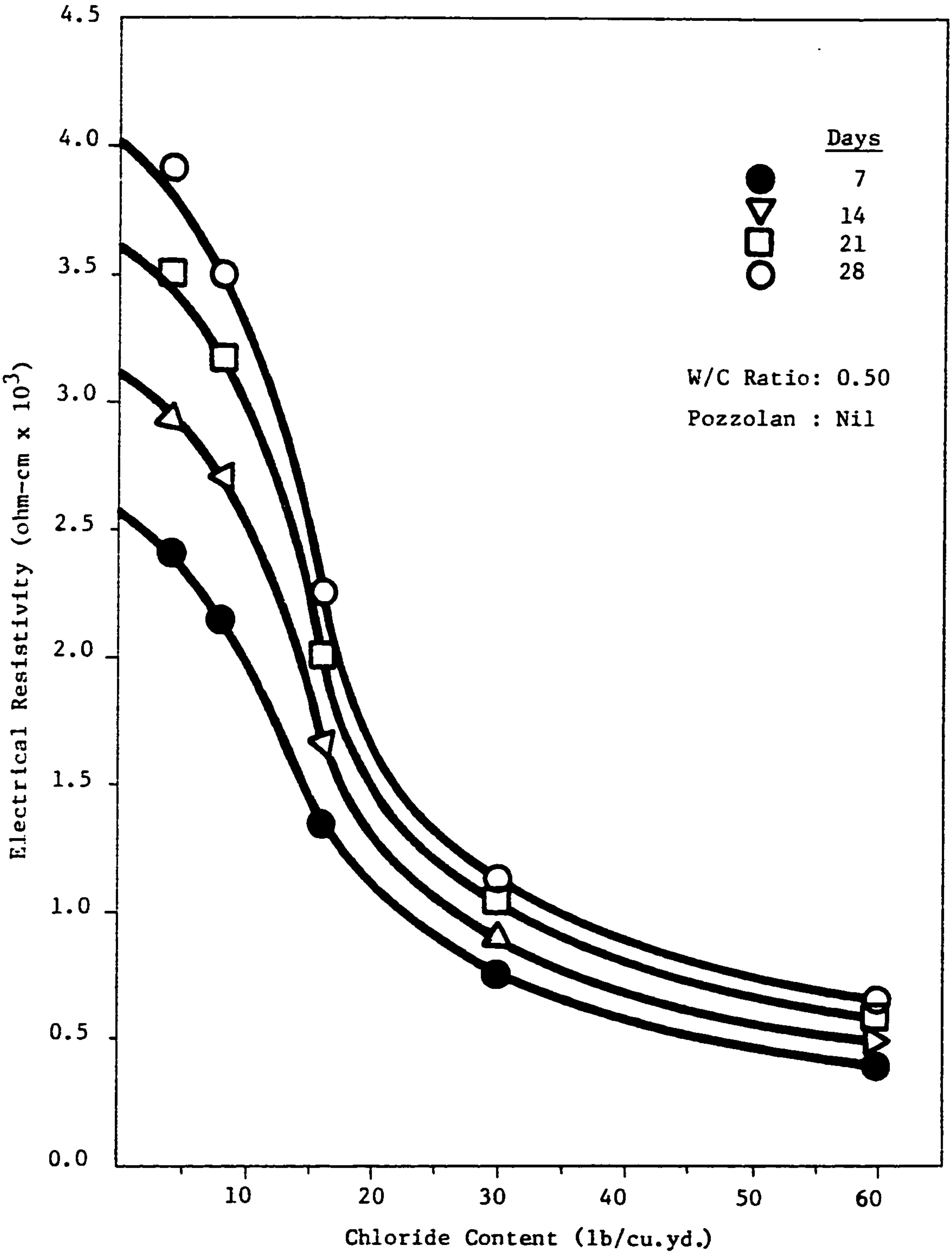


Fig: 3.6: Relationship between electrical resistivity and chloride content.

TABLE 3.6: CONCRETE RESISTIVITY DATA

Effect of Chloride and Age

Chloride Content	Resistivity (ohm-cm) Moist Curing Time (Days)			
(lb/cu.yd.)	7	14	21	28
0	2574.01	3115.92	3594.99	4032.06
4	2404.05	2935.21	3490.38	3894.70
8	2129.55	2688.27	3164.07	3503.08
16	1351.46	1650.55	1992.87	2257.65
30	750.65	876.46	1019.77	1130.37
60	391.85	490.67	586.29	654.80

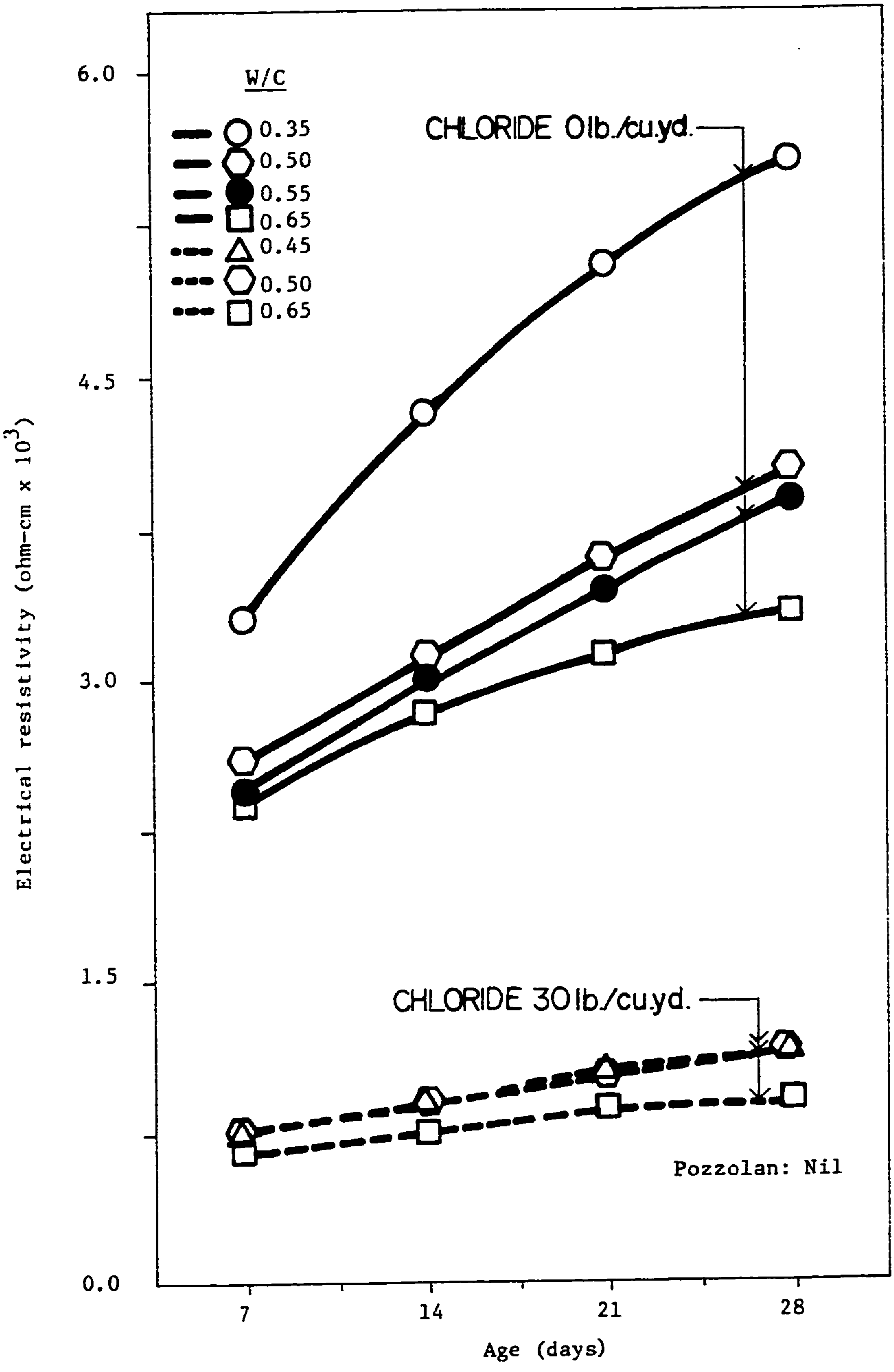


Fig: 3.7: Relationship between electrical resistivity and age of concrete for different w/c ratio.

TABLE 3.7: CONCRETE*RESISTIVITY/ABSORPTION DATA

Effect of Water Cement Ratio and Age

Age	WATER-CEMENT RATIO					
	0.45		0.50		0.65	
(Days)	Resistivity (ohm-cm)	Absorption (% dry weight)	Resistivity (ohm-cm)	Absorption (% dry weight)	Resistivity (ohm-cm)	Absorption (% dry weight)
8	-	5.09	-	5.32	-	7.71
21	1310.51	5.17	970.13	5.35	810.46	7.78
32	-	5.21	-	5.38	-	7.83
55	-	5.27	-	5.40	-	7.86

*contains 30 lb/cu yd of chloride.

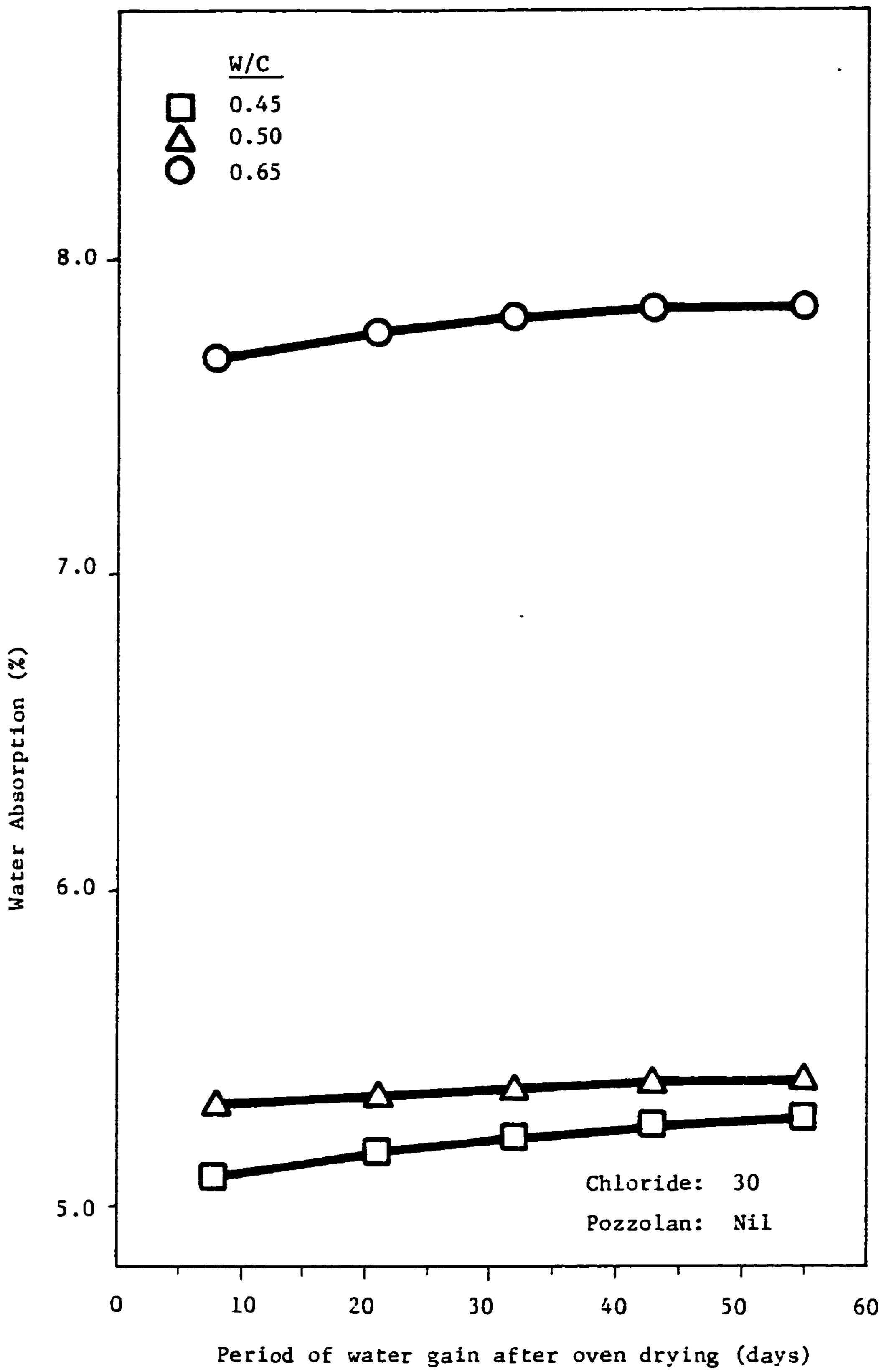


Fig: 3.8: Relationship between water absorption and w/c Ratio of concrete.

Figure 3.9 and Table 3.8 show another interesting feature related to the absorptive capacity of concrete. The data shows that concrete with greater chloride content absorbs more water. Although the increase in absorption is only about 4.94%, the trend typically shown in Figure 3.9 has been observed so consistently in this investigation that it seemed worth noticing and mentioning.

Figure 3.10 shows the relationship between the resistivity of concrete and its absorptive capacity. It is seen from this plot that concrete resistivity is a strong function of the absorptive capacity. The resistivity for an absorption 7.78 (W/C = 0.65) being 61.84% of that for a value of 5.17 (W/C = 0.45).

3.1.4 Age of Concrete and its Resistivity

The relationship between the age of concrete and its resistivity is shown in Tables 3.1, 3.2, 3.6 and Figures 3.11 and 3.12 for concretes of 0.35 to 0.65 W/C ratios. Figure 3.11 corresponds to chloride free concrete while Figure 3.12 is for chloride contaminated concretes in the range of 4 to 60 lb/cu.yd. Data related to both chloride free and chloride contaminated concretes shows similar trend; the resistivity increases with age which signifies the progress in the hydration of cement. It

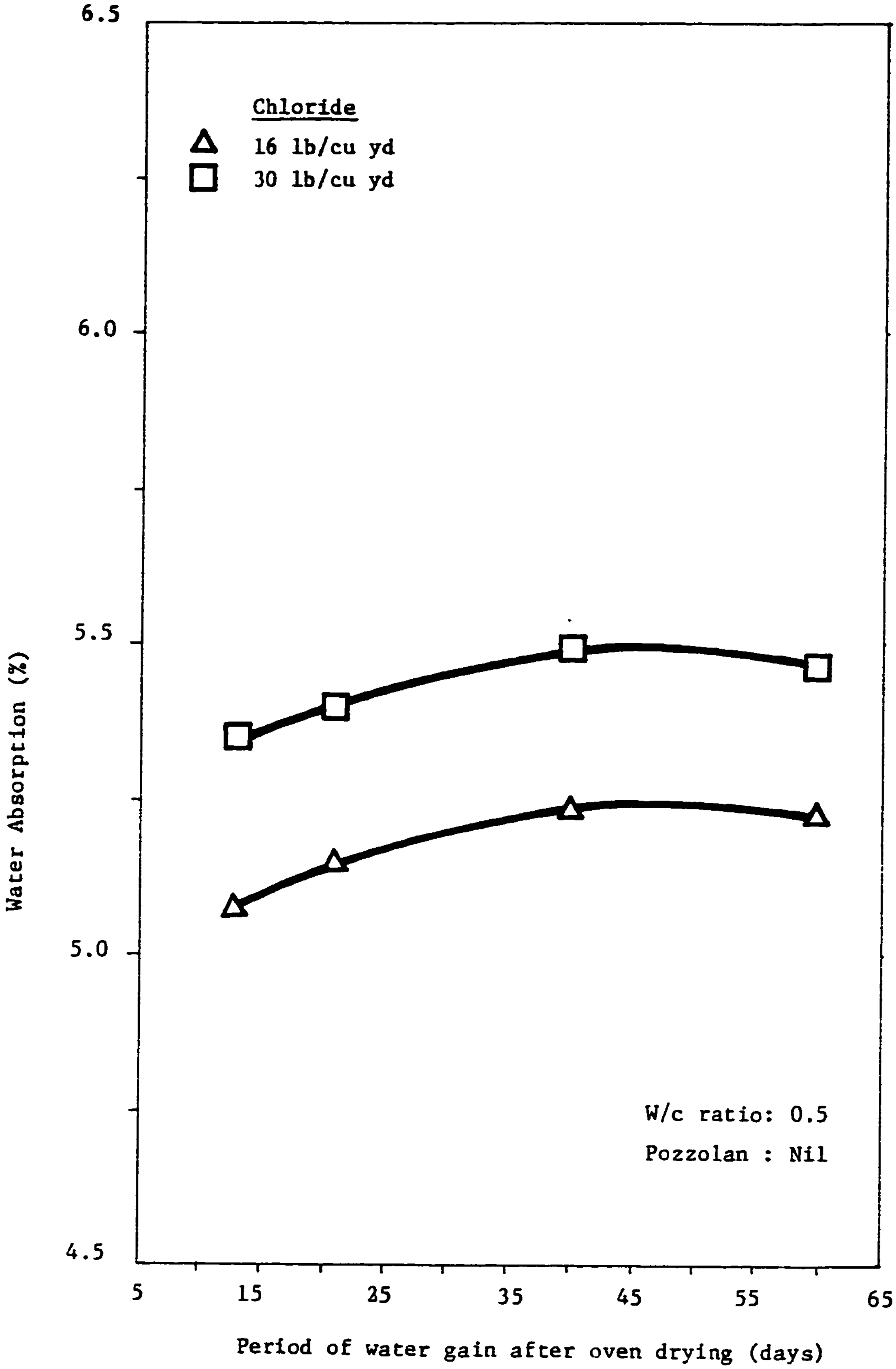


Fig: 3.9: Relationship between water absorption with time and chloride content for concrete.

TABLE 3.8: CONCRETE ABSORPTION DATA

Effect of Chloride Content & Age

AGE (days)	CHLORIDE CONTENT (lb/cu.yd) 16	
	16	30
	Absorption (% dry weight)	Absorption (% dry weight)
13	5.07	5.35
21	5.14	5.39
40	5.23	5.49
60	5.22	5.45

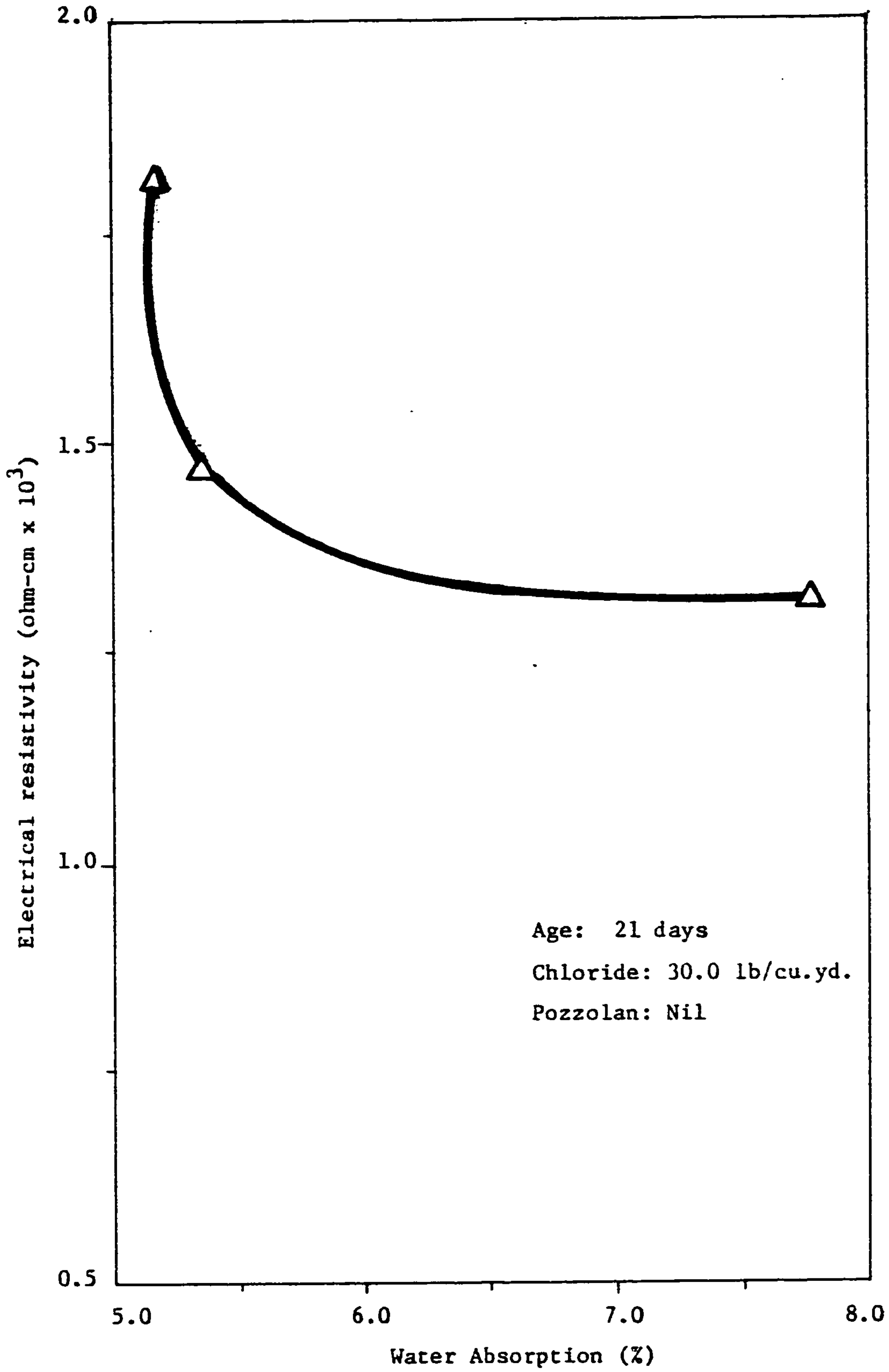


Fig: 3.10: Relationship between electrical resistivity and water absorption for concrete.

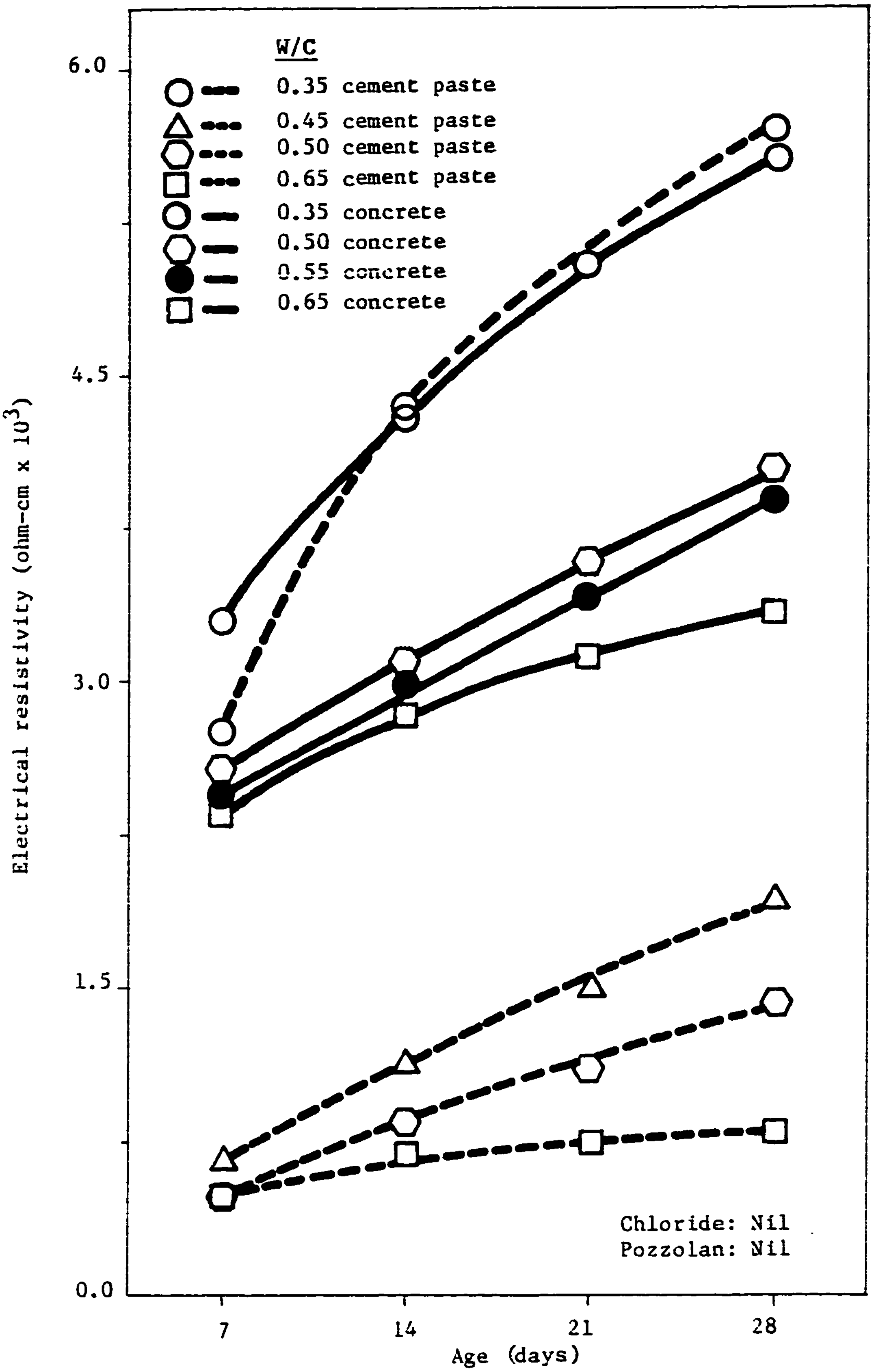


Fig: 3.11: Relationship between electrical resistivity and age of concrete and cement paste for different w/c ratios.

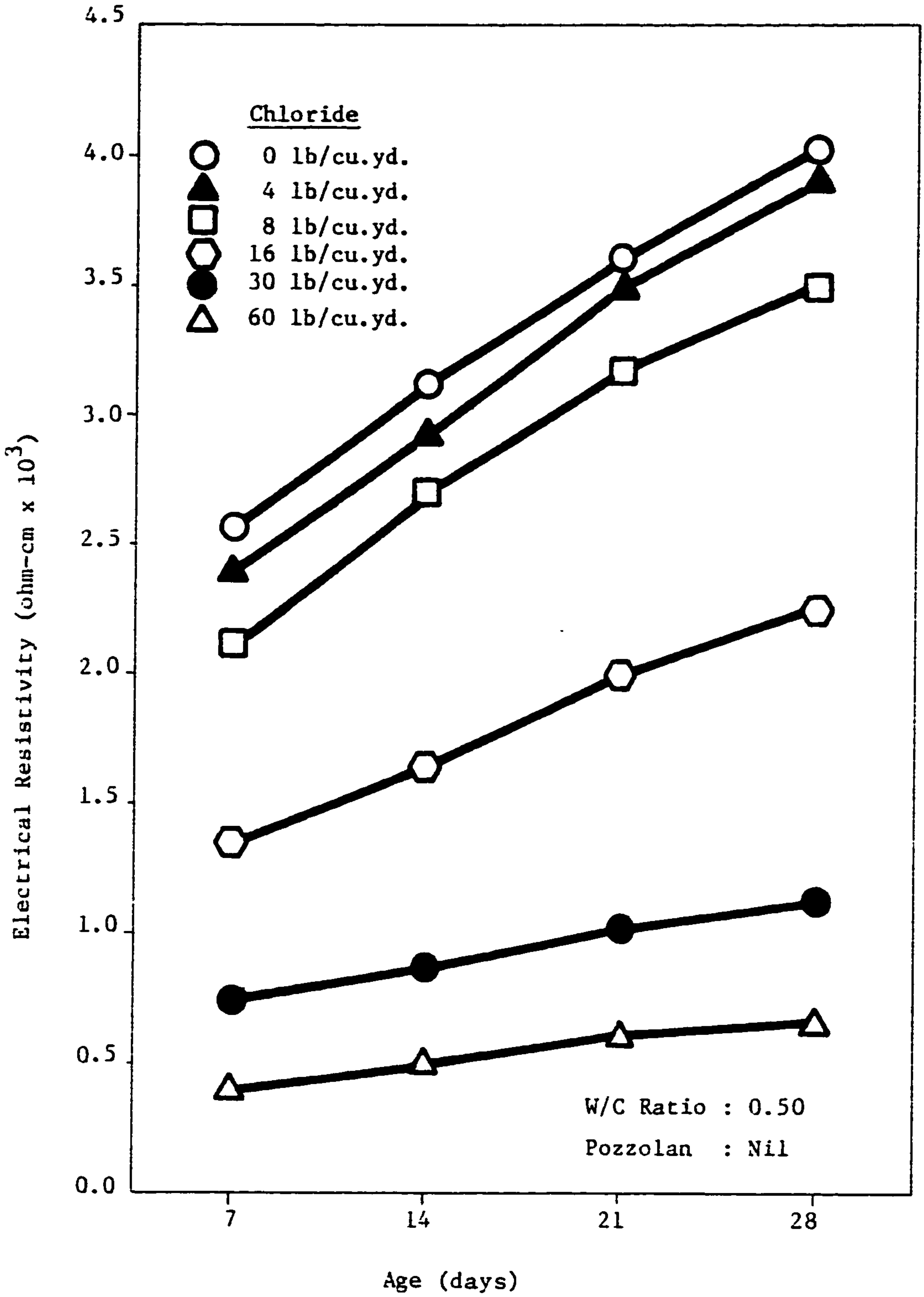


Fig: 3.12: Relationship between electrical resistivity and age of concrete with different chloride contents.

is observed that the increase in the value becomes more gradual and flatter with an increase in the W/C ratio and chloride content. The increase in resistivity from an age of 7 days to 28 days for 0.35 W/C ratio is 68.75% whereas the corresponding value for 0.65 W/C ratio is 40.43%. Also, the increase for chloride free concrete is 56.65% the corresponding value for 30 lb chloride concrete being 50.59%.

The effect of age on the resistivity of the paste is also shown in Figure 3.11 for cement pastes of W/C ratios 0.35, 0.45, 0.50 and 0.65. It is seen that the variations with age for paste and concrete are qualitatively very similar. The values for the paste resistivity are much smaller compared to concretes of corresponding W/C ratios except for a W/C ratio of 0.35. It was observed that for a W/C ratio of 0.35 the resistivity values for the cement paste and concrete were almost the same. This abnormal equality can be ascribed to the high resistances in ionic conduction for a 0.35 W/C ratio paste due to significant short supplies of evaporable pore water in the matrix of the cement paste due to its consumption in the hydration process. This phenomenon is further discussed in sections 3.2.1 and 3.2.3.

3.1.5 Cement Substitution by Pozzolan and Resistivity Characteristics

Pozzolan is one of the most potentially useful admixture for producing quality concrete in the aggressive environment of the Gulf area. It drastically reduces permeability producing dense concrete and effectively counters disruptive expansions due to cement-aggregate reactivity and sulphate attack. 10 and 25 per cent of cement in concretes of W/C ratios 0.35, 0.45, 0.55, 0.65 were substituted by fly ash to investigate the effect of pozzolan addition on concrete resistivity. The data is plotted in Figures 3.13 through 3.17. It is seen from Figure 3.13 and Table 3.9 that for pozzolan concrete a trend similar to that for ordinary portland cement concrete is obtainable; higher W/C ratio values result in a reduction of the resistivity. Data in Figure 3.14 thru 3.17 shows that for each of the W/C ratio investigated the resistivity value increases with an increase in the cement substitution by pozzolan. For 25% cement substitution the increases in resistivity for W/C ratios of 0.35, 0.45, 0.55 and 0.65 are 186.64, 217.26, 209.20 and 233.35 per cents respectively.

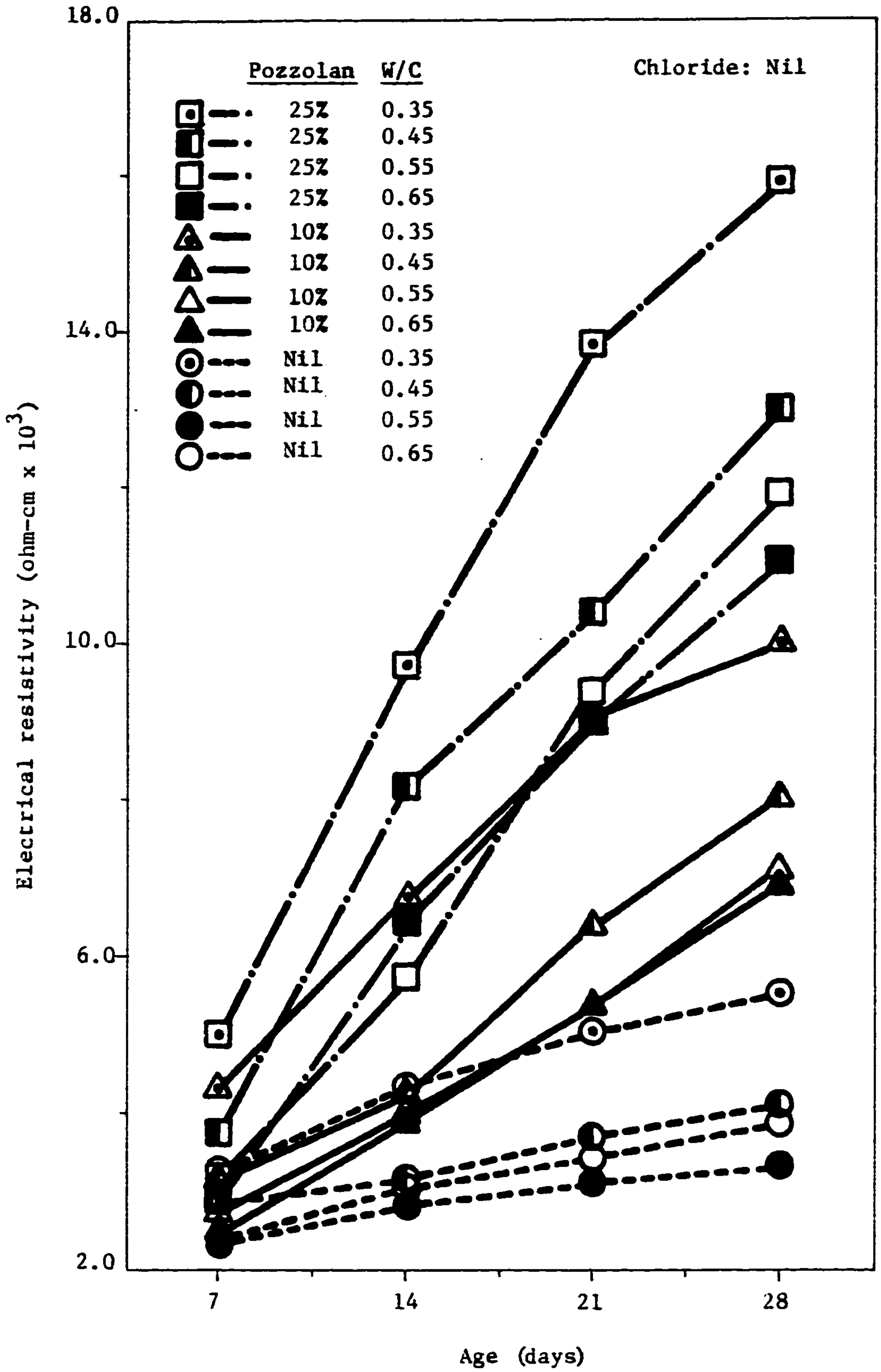


Fig: 3.13: Relationship between electrical resistivity and age of concrete with different w/c ratios and pozzolan contents.

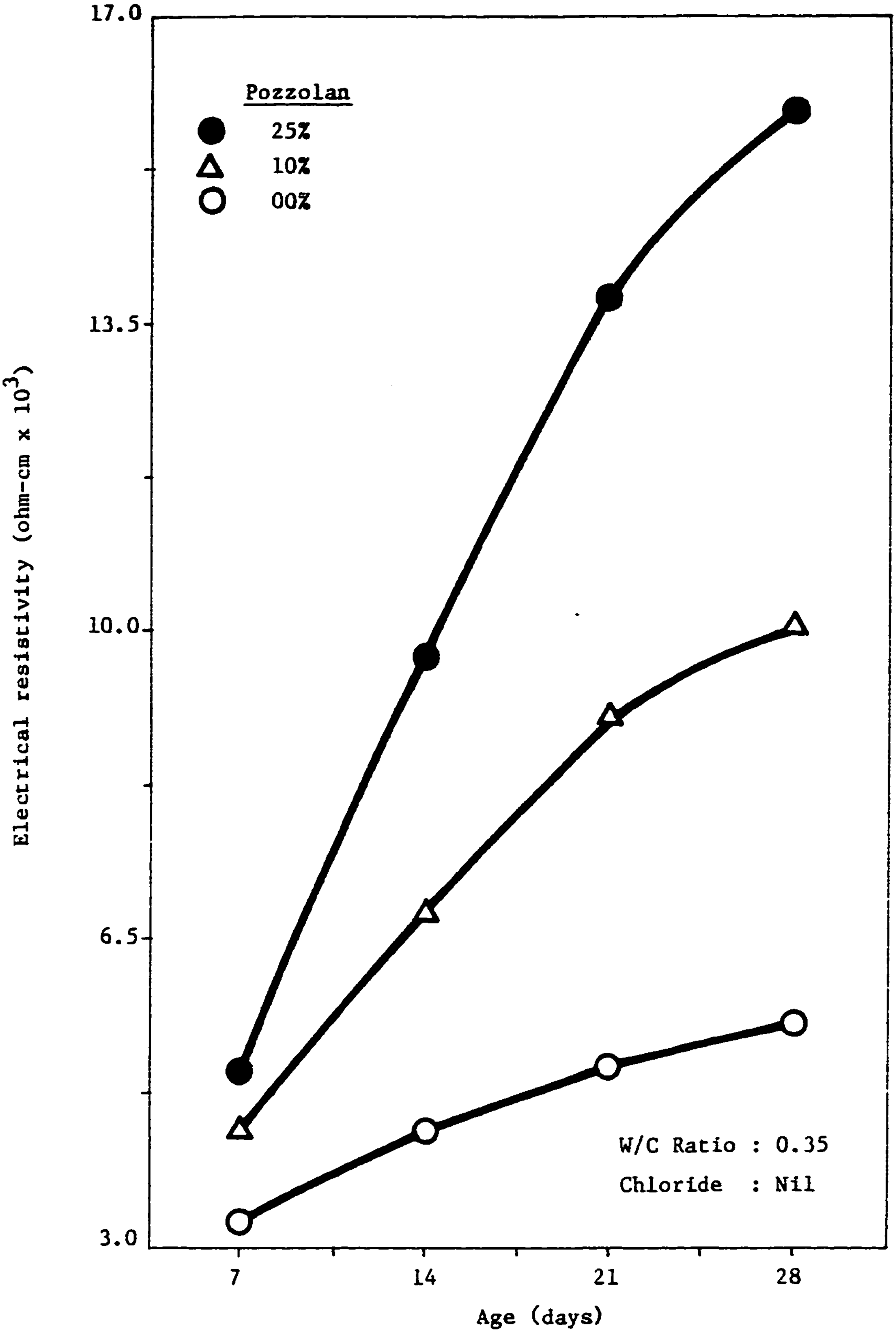


Fig:3.14:Relationship between electrical resistivity and age of concrete with different pozzolan contents.

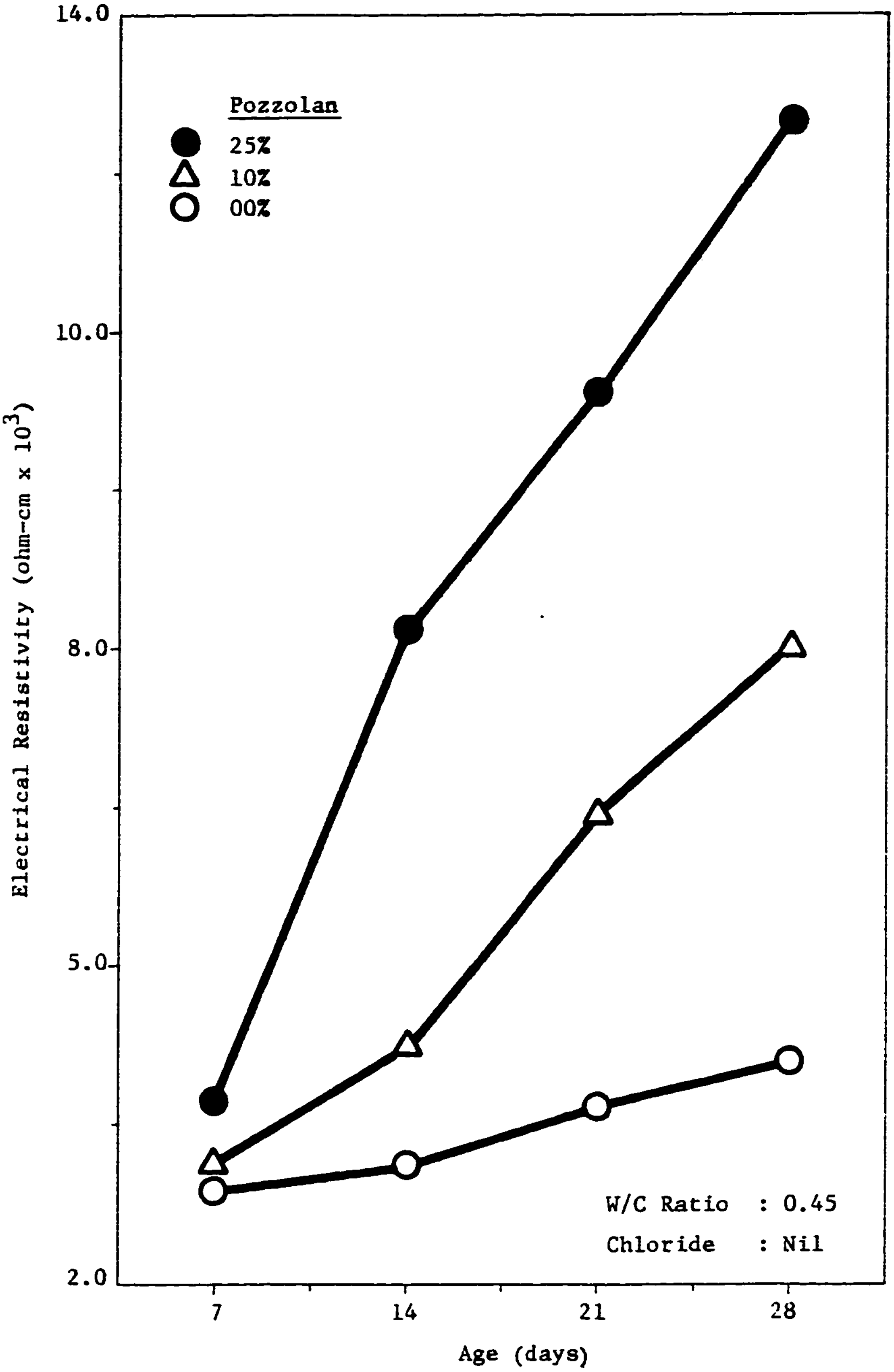


Fig: 3.15: Relationship between electrical resistivity and age of concrete with different pozzolan contents.

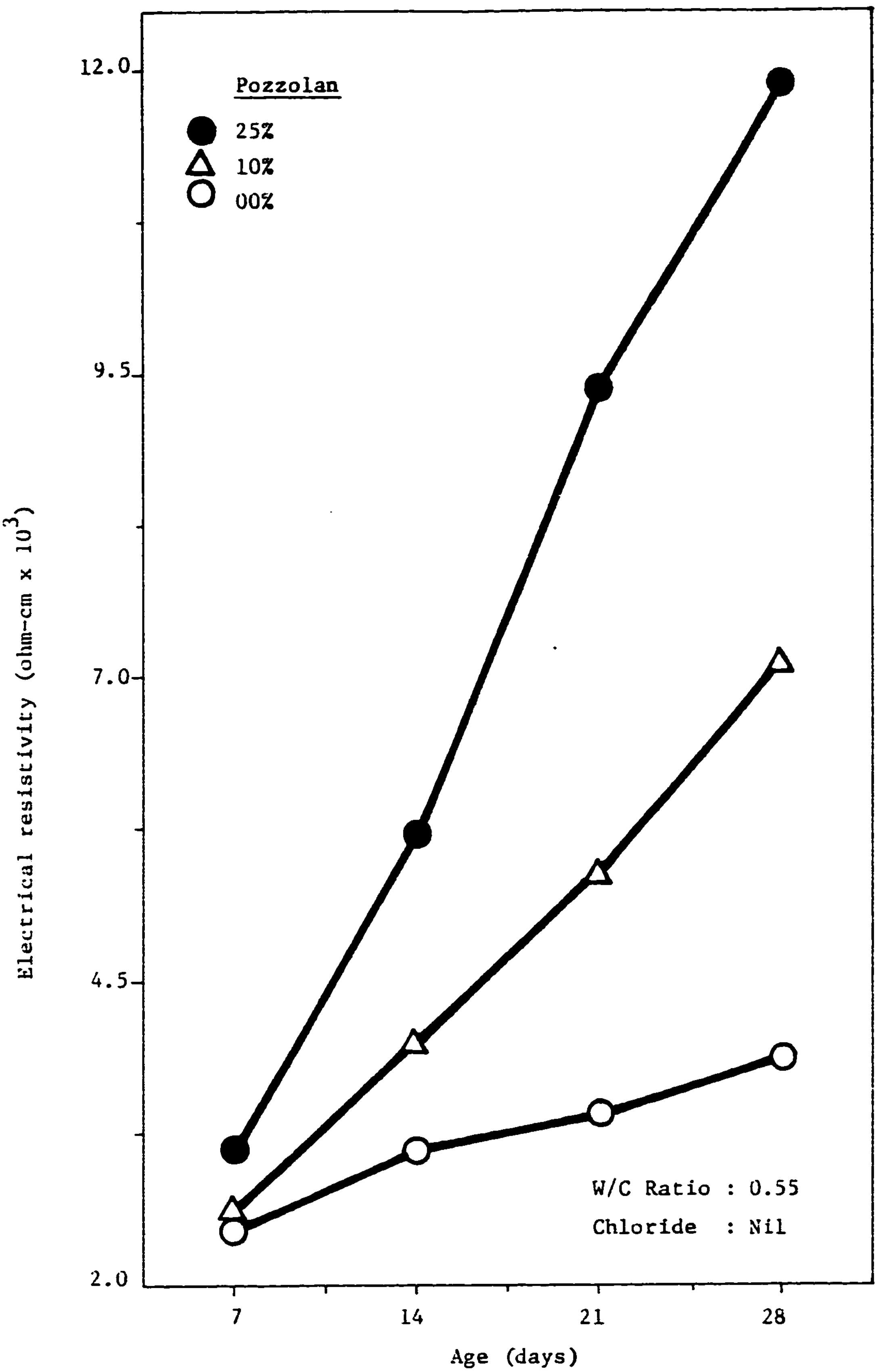


Fig:3.16: Relationship between electrical resistivity and age of concrete with different pozzolan contents.

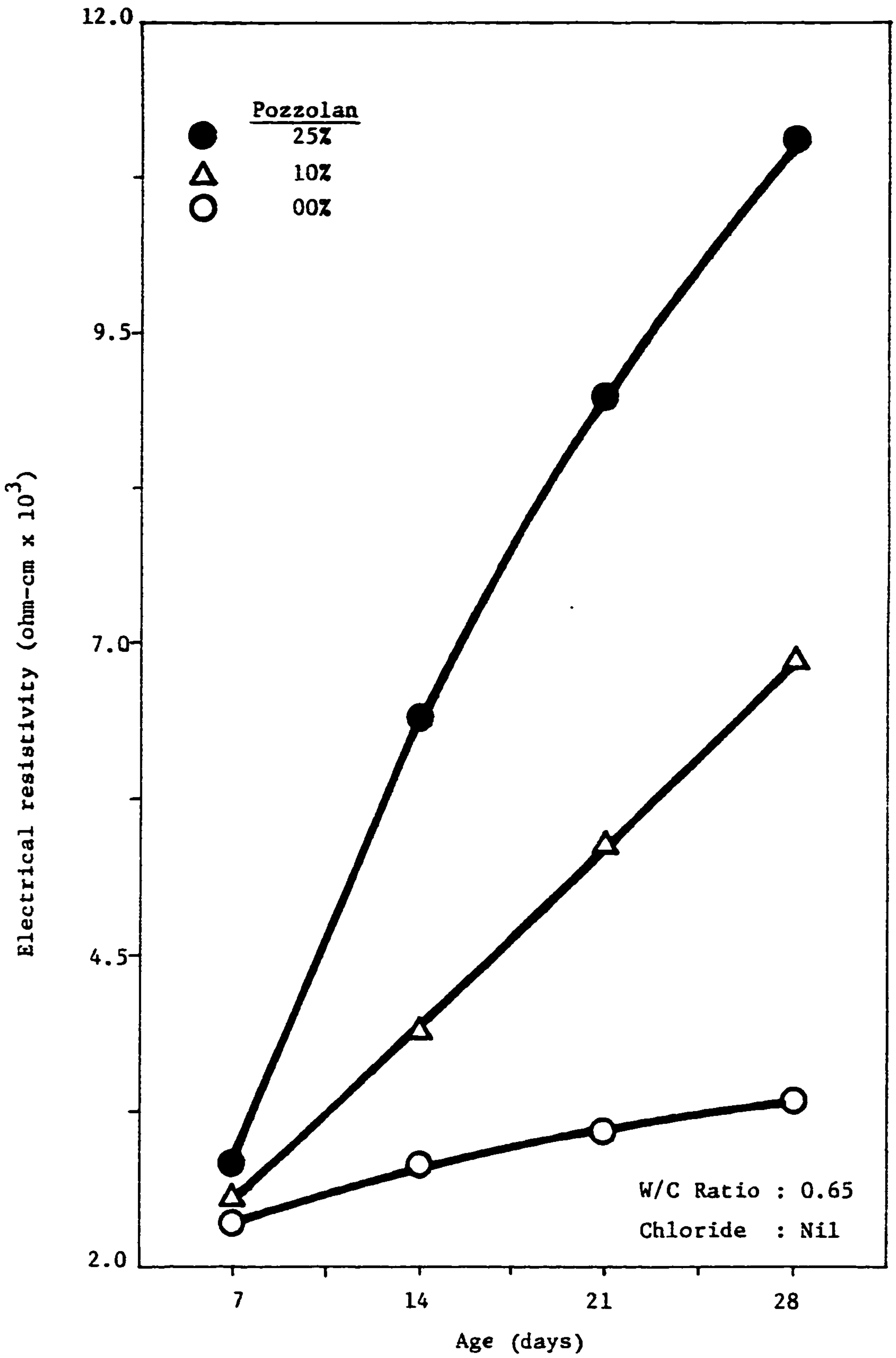


Fig: 3.17: Relationship between electrical resistivity and age of concrete with different pozzolan contents.

TABLE 3.9: CONCRETE RESISTIVITY DATA

Effect of w/c Ratio, Age and Fly Ash Content

Moist Curing Time (days)	Fly Ash % by weight of cement	RESISTIVITY (ohm-cm) WATER-CEMENT RATIO			
		0.35	0.45	0.55	0.65
7	0	3289.77	2881.68	2434.92	2366.17
	10	4351.97	3126.67	2615.41	2535.58
	25	5000.82	3734.12	3111.23	2835.47
14	0	4300.96	3147.37	3090.87	2835.93
	10	6763.11	4254.75	4003.58	3897.10
	25	9707.69	8167.86	5718.87	6430.05
21	0	5036.46	3677.73	3409.87	3109.17
	10	9029.68	6430.16	5398.84	5378.71
	25	13831.48	10425.40	9377.95	9877.07
28	0	5551.42	4100.35	3854.67	3322.94
	10	10041.10	8038.05	7138.83	6867.76
	25	15912.42	13008.55	11918.68	11076.87

3.1.6 Effect of Temperature on Resistivity

The effect of temperature for a 0.5 W/C ratio concrete is shown in Figure 3.18 and Table 3.10. The range investigated is from 20°C to 80°C. Rise in the temperature of moist concrete causes a drastic reduction in the resistivity value. The value at 80°C is only 46.51% of the value at 20°C.

3.1.7 Effect of Wetting/Drying Cycles

Severe corrosion and concrete spalling in field structures have been reported at locations where continuous drying/wetting cycles occur. The effects of 20 drying/wetting cycles on water absorption and resistivity are shown in Figure 3.19 and Table 3.11 for 16 and 30 lb chloride concretes of 0.5 W/C ratio. It is seen that these cycles increase the absorptive capacity of concrete probably due to the development of the micro-cracking and minute fissures in the structure of the paste. For the 16 lb chloride concrete the resistivity increases upto certain cycles and then decreases sharply. For the 30 lb chloride it is more or less stable upto ten cycles and then shows a sharp decreasing trend.

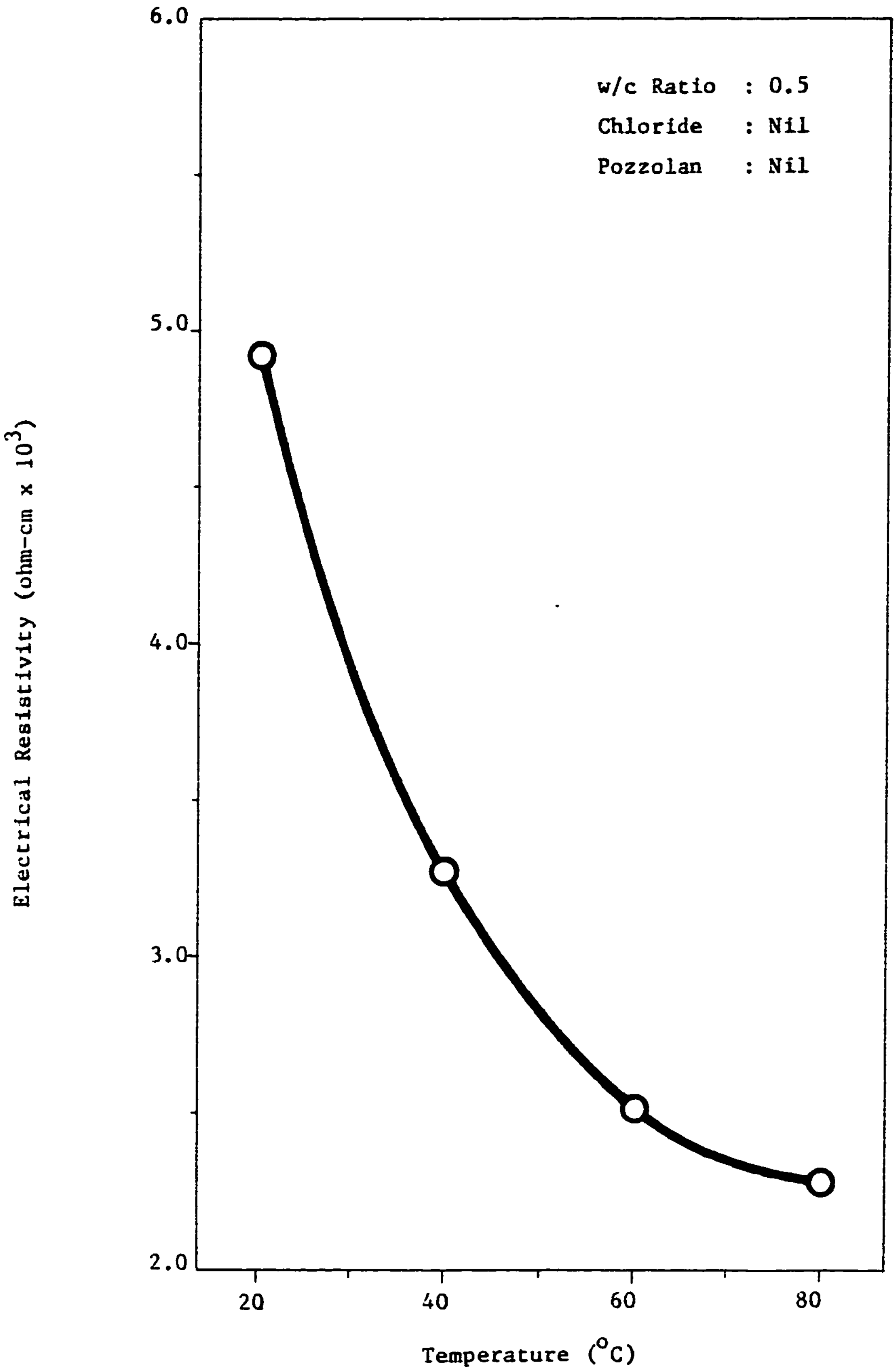


Fig:3.18:Relationship between electrical resistivity of concrete and temperature.

TABLE 3.10: CONCRETE RESISTIVITY DATA

Effect of Temperature

W/C Ratio : 0.5

Chloride Content : 0.0 lb/cu.yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectiona area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Temperature (^oC)	Resistance (R) (Ohm)	Resistivity (ρ=RA/L) (Ohm-cm)
20	215	4918.12
40	143	3271.12
60	110	2516.25
80	100	2287.50

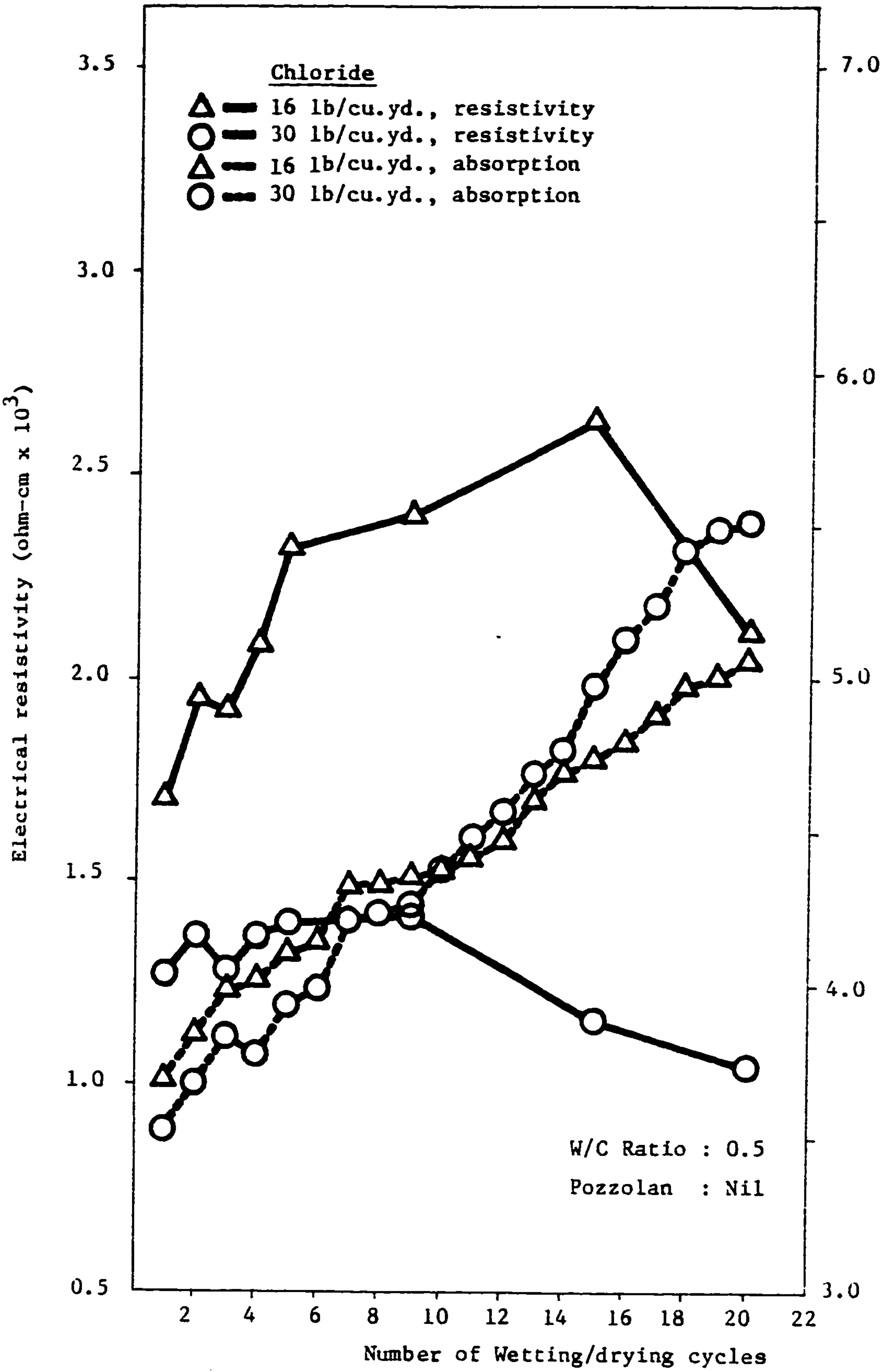


Fig: 3.19: Relationship between electrical resistivity, water absorption and wetting/drying cycles.

TABLE 3,11: CONCRETE RESISTIVITY/WATER ABSORPTION DATA

Effect of Chloride and Wetting/Drying Cycles

Number of Cycles	CHLORIDE CONTENT 16 lb/cu.yd. RESISTIVITY x 10^3 (ohm-cm) Dry Condition	16 lb/cu.yd. RESISTIVITY x 10^3 (ohm-cm) Moist Condition	16 lb/cu.yd. WATER ABSORPTION (% dry weight)	30 lb/cu.yd. RESISTIVITY x 10^3 (ohm-cm) Dry Condition	30 lb/cu.yd. RESISTIVITY x 10^3 (ohm-cm) Moist Condition	30 lb/cu.yd. WATER ABSORPTION (% dry weight)
1	28.793	1.720	3.693	6.902	1.281	3.528
2	-	1.947	3.843	8.555	1.372	3.690
3	49.085	1.924	4.000	19.120	1.289	3.828
4	78.438	2.087	4.024	13.615	1.372	3.765
5	-	2.327	4.116	-	1.402	3.938
6	-	-	4.153	30.283	-	4.000
7	-	-	4.326	-	-	4.221
8	-	-	4.317	-	-	4.244
9	131.183	2.403	4.360	-	1.424	4.262
10	-	-	4.372	-	-	4.382
11	-	-	4.424	-	-	4.483
12	-	-	4.473	-	-	4.575
13	-	-	4.606	-	-	4.689
14	-	-	4.646	-	-	4.766
15	-	2.626	4.732	32.610	1.165	4.979
16	-	-	4.801	-	-	5.134
17	-	-	4.883	-	-	5.240
18	-	-	4.985	-	-	5.418
19	-	-	5.013	-	-	5.488
20	4.012×10^3	2.114	5.055	138.994	1.048	5.514

3.1.8 Effect of Drying

Effect of concrete drying is shown in Figure 3.20 where for each drying/wetting cycle firm and dotted plots indicate the values of concrete resistivity in dry and wet conditions respectively. It is seen that in dry state the resistivity values are far higher than the corresponding values for the same concrete in the moist state. After a few cycles in the case of 16 lb chloride concrete and after about 14 cycles for the 30 lb chloride concrete the resistivity mounts to very high values of the order of 4.012×10^6 and 138.994×10^3 respectively (not shown in Figure 3.20). Also, it is noticed that at least in the initial stages of observation, even in the dry state, a high chloride concrete shows a comparatively smaller resistivity values than a low chloride concrete. This may suggest some sort of chloride effect, per se, in lowering the resistivity values.

3.1.9 Results of Field Studies

The loss of metal for reinforcement embedded in concrete is controlled by four primary parameters: quality of concrete, chloride content, cover to reinforcement and resistivity characteristics. To study the effect of any one of these four parameters, it is essential to hold the remaining three reasonably constant. Data related to about

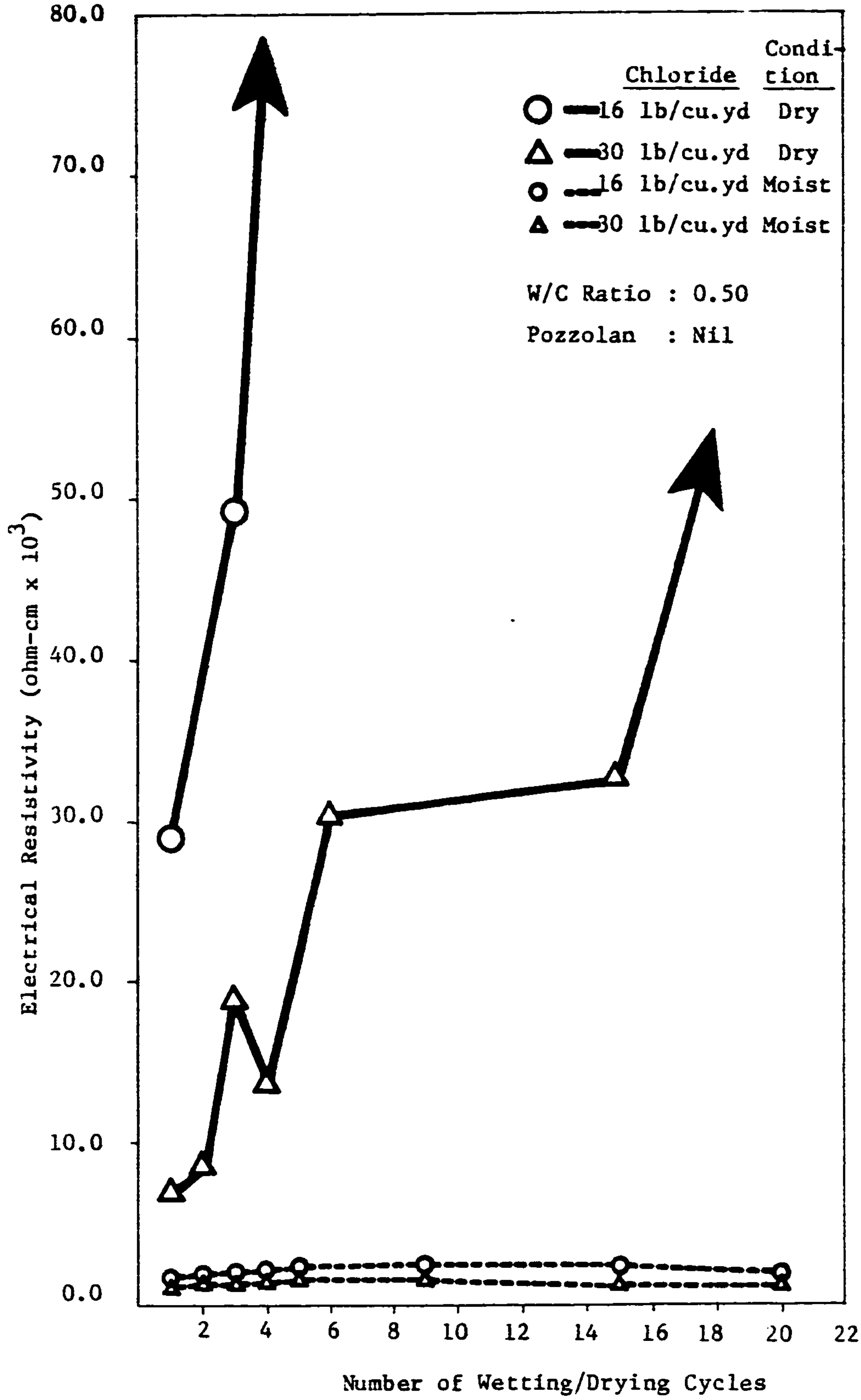


Fig: 3.20: Relationship between electrical resistivity and wetting/drying cycles.

100 cores obtained from field structures in a previous investigation was carefully studied to select a number of cores for resistivity studies which fulfilled the aforesaid condition. Fortunately six such cores were available where the quality of concrete, chloride contamination and cover were reasonably constant in the following range:

Quality of concrete: Absorption : 3.85% - 4.30%
Pulse Velocity: 10,500 to 12,500 ft/sec.

Chloride content: 6 - 8 lb/cu yd.

Cover to reinforcement: 0.65 - 0.85 inches.

Resistivity data was developed for these cores in the moist condition and is shown in Table 3.12 and Figure 3.21. It is seen from this plot that resistivity has a marked effect on the extent of metal loss. For a moist-conditioned resistivity measurement the loss of metal in about 20 years is about 10% if the moist-resistivity values are in the range of 15000 ohm-cm. The loss of metal increases sharply to 80% for a moist-resistivity value of around 7000 ohm-cm.

TABLE 3.12: DATA ON CORROSION OF BARS AND CONCRETE RESISTIVITY VALUES*

Core No.	Concrete Resistivity (Ohm-cm)	Loss of Metal %
1 - 4	14755.00	11.60
1 - 3	15635.81	12.20
3 - 2	14076.34	22.40
5 - 2	12728.00	38.80
5 - 1	12286.15	34.62
3 - 1	7855.04	72.85

*All samples listed in Column 1 fell in the following range with respect to cover, absorption and chloride content:

Cover : 0.65 to 0.85 inches

Absorption: 3.85% to 4.30%

Pulse Velocity: 10,500 to 12,500 ft/sec.

Chloride: 6 to 8 lb/cu yd.

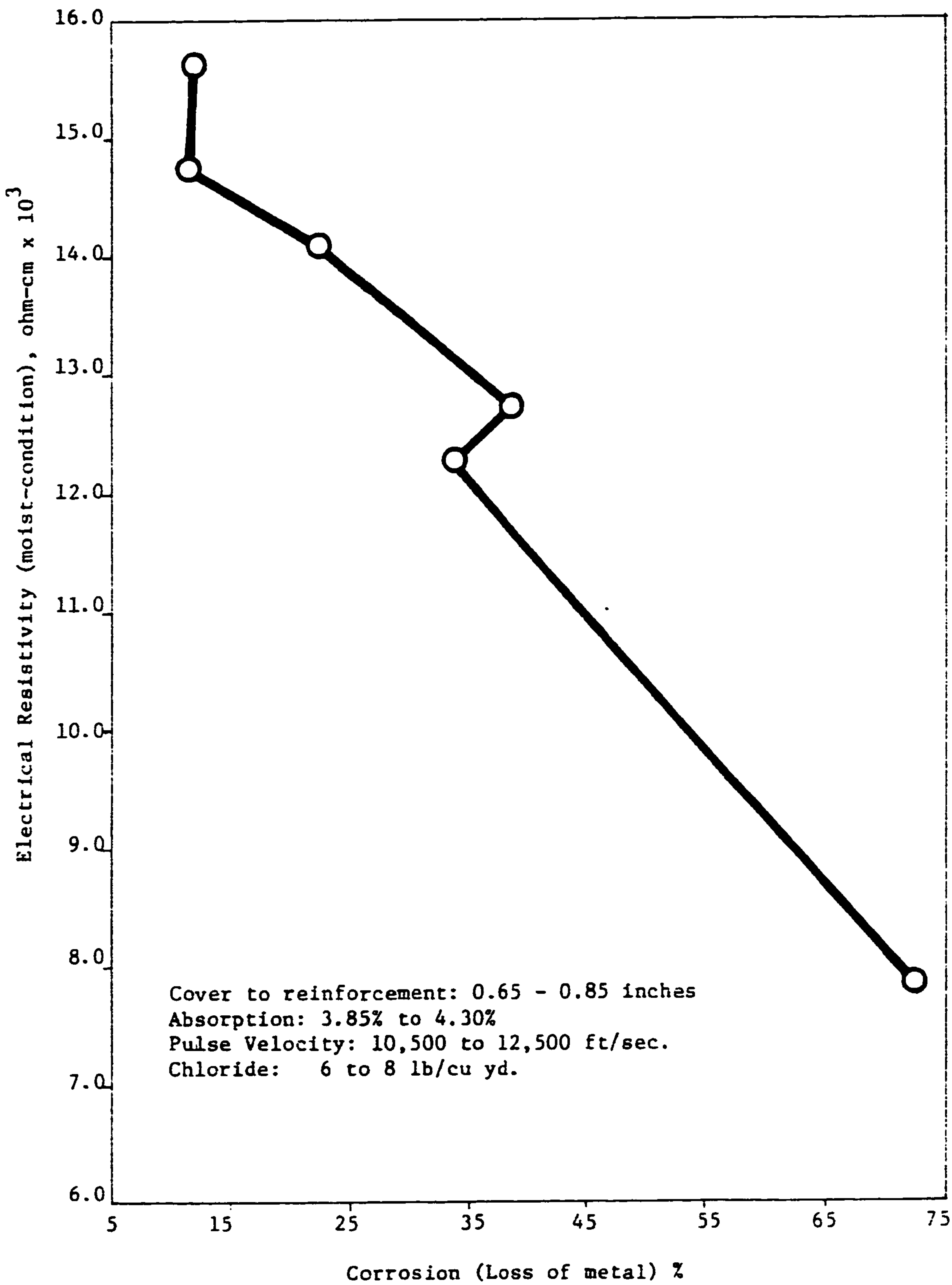


Fig: 3.21: Relationship between electrical resistivity and loss of metal.

3.2 DISCUSSION

3.2.1 Concrete Quality and Resistivity

For properly compacted and well cured concrete, W/C ratio is the predominant parameter controlling its strength and quality in general. For far too long, however, strength has been regarded a most reliable index of concrete quality and its durability characteristics as well. This may be so in many cases and in normal circumstances of environment but the total identification is now being challenged for several reasons. It is now generally recognized that strength can only be an indirect measure of durability and performance and that other parameters which govern the ease of movement of liquids and gases through the concrete would provide a better assessment of its durability. This is specially true for concretes in the Gulf region when the operative mechanisms of the two most effective causal factors contributing to concrete deterioration viz sulphate attack and rebar corrosion, are heavily dependent on the absorptive and moisture transmission characteristics of concrete. Hence data on electrical resistivity has been developed for W/C ratio in conjunction with concrete absorptive characteristics as representative of concrete quality.

Several field investigations connected with the corrosion deterioration of reinforced concrete structures have heavily emphasized the significance of W/C ratio and the absorptive characteristics of concrete. Tyler,[38] in a report based on 15 to 17 years long studies on reinforced concrete piles exposed to sea water, has reported the heavy dependence of concrete durability on the W/C ratio of the concrete mixes used. Concrete made from mixes with a W/C ratio of 5 gal per bag of cement performed best, and concrete with a W/C ratio of about 7 gal per bag performed poorest. Spalling of concrete in the San Mateo-Hayward Bridge due to corrosion of reinforcing steel resulting from exposure to a marine atmosphere was carefully studied by Tremper, Beaton and Stratfull.[4,5] Main factor contributing to the distress was a W/C ratio as high as 7.5 gal per bag resulting in a highly absorptive concrete liberally uptaking chlorides and water. Wakerman, Dockweiler, Stover and Whiteneck[39] have described the experience of the Los Angeles Harbour Department in using concrete in marine environment. From their experience and the experience of others, they concluded that concrete used in reinforced concrete structures, exposed to the action of sea water or marine environment should be dense, impervious, relatively non-absorbent. Laboratory tests carried out by Stark[40] at the Portland Cement Association's laboratory also show

clearly the effect of W/C ratio on rebar corrosion in Figure 3.22. Concrete slabs 12" x 12" x 6" of varying W/C ratio having steel embedded at depth of 0.5 inch were subjected to a cycle consisting of 4 days ponding with a 3.5% Nacl solution followed by 10 days drying at 50% R.H. Those slabs prepared at a ratio of 0.60 exhibit active corrosion much more rapidly than those prepared at ratios of 0.45 or 0.35. Similar laboratory results have been reported by Clear[41] after comprehensive testing at FHWA.

Based on evidence from these studies, W/C ratio appears to be the primary mix design parameter in determining the degree of protection offered to steel by the concrete. The explanation for this is the two-fold cumulatively adverse interactive effect of increased W/C ratio on corrosion mechanism. Firstly, permeability of concrete to liquids is a strong function of W/C ratio (Figure 3.23). The permeability of concrete is determined by the permeability of the paste phase which can be reduced to extremely low values at W/C ratios below 0.40 (Figure 3.23). The application of this concept is easily seen in Figure 3.8 which shows a relationship between W/C ratio and absorptive characteristics of concrete. The highly absorptive concrete in addition to readily uptaking and transmitting deleterious ions such as chlorides can easily imbibe evaporable water or moisture

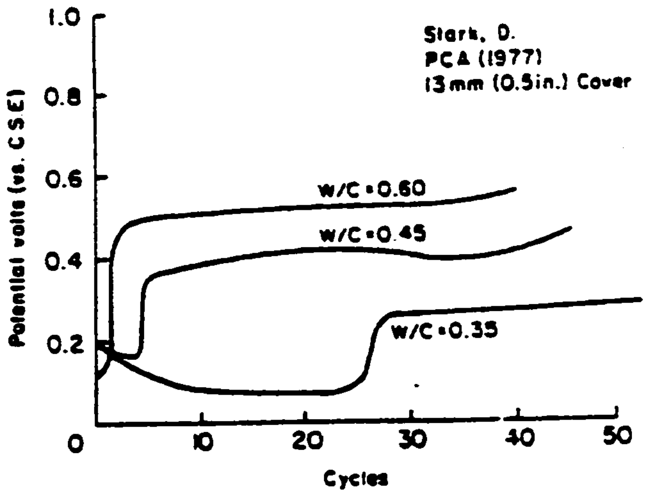


Fig:3.22: Potential vs time for various w/c ratios at 13mm (0.5 inch) cover.

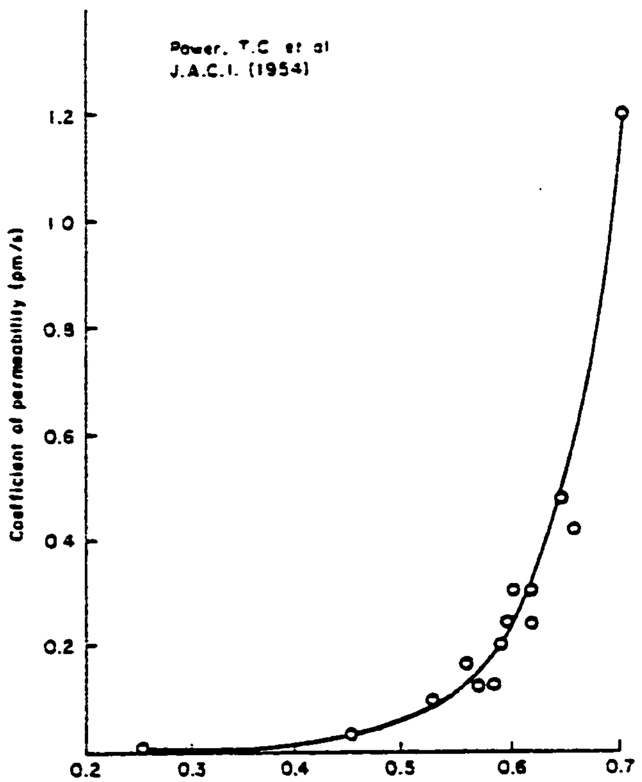


Fig: 3.23: Permeability of mature cement pastes as influenced by w/c ratio.

from its environment thereby producing excellent conditions for the ionic conduction of electric charges necessary for effective operation of corrosion cells. Figure 3.10 shows how increased water absorption effectively reduces the electrical resistivity of concrete thereby facilitating the flow of electric current within the corrosion cells. A reduction in the W/C ratio will reduce permeability and moisture absorption thereby creating physical segmentation and blockade resulting in the retardation of the progress of ionic conduction in concrete matrix thereby increasing the electrical resistivity of the concrete. This effect is clearly shown in Figures 3.1 through 3.4 where reduction in W/C ratio is shown to result in a drastic increase in the concrete resistivity value.

The second important effect of the W/C ratio is in terms of the relative amount of initial mix water contained in the concrete. Increase in W/C ratio implies an increase in the quantity of mixing water. In this investigation the mix water was 238, 306, 340, 374, 442 lb cu.yd. respectively for 0.35, 0.45, 0.50, 0.55, and 0.65 W/C concretes. An increased initial supply implies liberal availability even after its consumption in the cement hydration process. This facilitates ionic conduction thereby reducing resistivity.

This concept is also clearly shown in Figures 3.1 through 3.4. The above mentioned field tests by Tyler[38] conclusively show that with other factors constant, corrosion of steel is more severe in a concrete made with the greater amount of mix water.

Although the resistivity of the paste is generally substantially smaller than the resistivity of the concretes of similar W/C ratios mainly due to path blocking effect by aggregates,it is seen from Figure 3.1 that the differential reduces sharply with reduction in the W/C ratio till the resistivity values are found to be the same for paste and concrete at a W/C ratio of 0.35. This appears to be entirely due to the fact that with reduction in W/C ratio the non-availability of pore water in the paste or concrete mortar matrix for ionic conduction becomes a controlling factor in determining concrete resistivity levels.

From the standpoint of the flow of electric current in a corrosion cell, it therefore seems that under equal conditions, the metal loss of the steel will be more rapid in the concrete having a high W/C ratio because of its lower electrical resistance due to greater initial mix water and greater absorption capacity.

3.2.2 Chlorides and Concrete Resistivity

There is a general agreement in the literature that the presence of chlorides in concrete initiate and accelerate corrosion.[42,43,44] Chlorides act in a number of direct and indirect ways which are cumulatively deleterious in respect of corrosion mechanism. Their presence depresses pH value of the current pore fluid,[45,46] destroys the passivating film,[47] helps in setting up differential salt concentration type corrosion cells and increases the porosity of the cement paste. However, an additional influence in enhancing corrosion rate is bound to be the fact that their presence is conducive to increased ionic activity.[48,49] Chloride salts being strong electrolytes, increase the electrical conductance of concrete. The effect of electrical resistivity on the corrosion process and the resulting deterioration was shwon by the results of field investigation at San Mateo-Hayward Bridge.[4,5] These observations showed that the corrosion deterioration of concrete is almost a direct function of concrete resistivity.

Another way in which the presence of chlorides may lower the concrete resistivity value is by increasing the porosity of cement paste which may enhance the ingress of moisture and water in regions where corrosion cells occur exist. Porosity and pore size distribution changes which

occur in the structure of the hydrated cement with chloride addition are well documented.[50,51,52,53] Figure 3.24 compares the pore size characteristics of hydrated cement formed at a W/C ratio of 0.5 and hydrated for 7 days, with that containing 2% $CaCl_2$. The substantial increase in the porosity of $CaCl_2$ treated samples is due to the existence of a greater amount of smaller pores of size 10-50 Å.[54]

There is very little data related to the effect of chlorides on concrete resistivity. The only such study is due to Stratfull who reported somewhat reduced resistivity due to chloride concentrations upto 10 lb/cu.yd. Many studies indicate concrete chloride concentrations much higher than 10 lb/cu.yd. for corrosion affected concrete. In an investigation on California Bridge decks, Spellman and Stratfull[55] have reported values upto 12.5 lb/cu.yd. and in another investigation on submerged reinforced concrete piling values upto 34 lb/cu.yd. were observed.[56] In a previous investigation[37] at UPM cracked concrete of a Dhahran structure was found to contain chlorides in excess of 50 lb/cu.yd. Figure 3.25 shows the chloride profile for a typical concrete core obtained from the Eastern Province. The chloride concentration varies from about 1.5 lb/cu.yd. to 15 lb/cu yd.

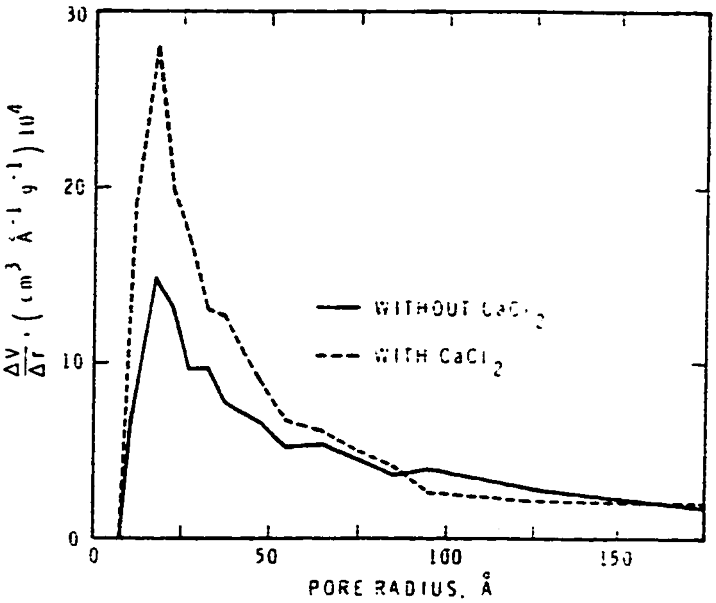


Fig: 3.24: Pore-size distribution curves for portland cement paste hydrated for 7 days.

Chloride concentration as % of mortar around the bar

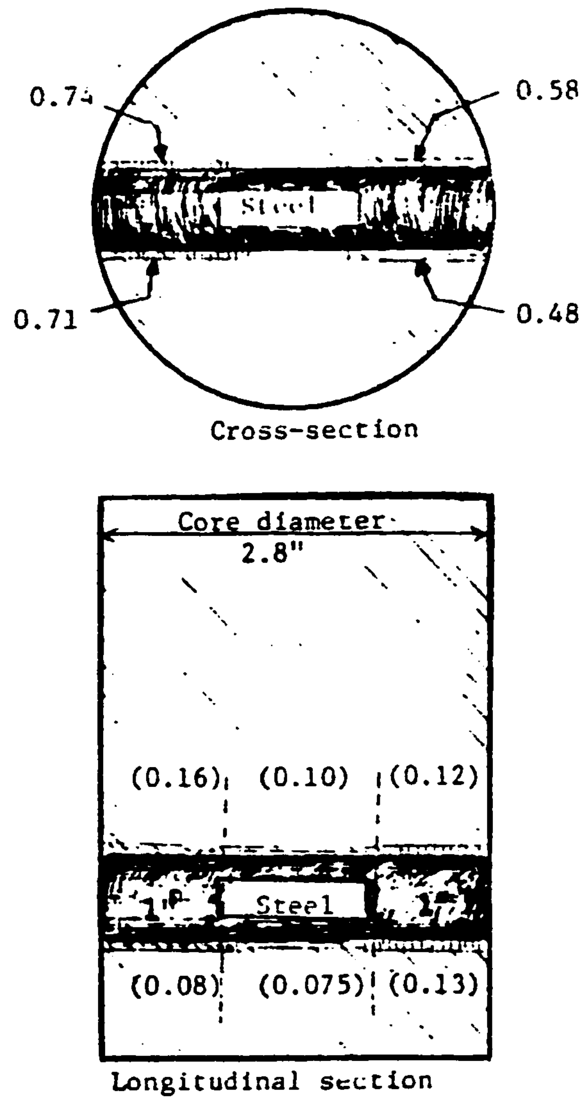


Fig. 3.25 : Variation of chloride

In view of these reports of the clear possibility of heavy local chloride concentrations, chloride contamination from 4 to 60 lb/cu.yd. were studied in an effort to develop related concrete resistivity data. The effect of chloride contamination on concrete resistivity is shown in Figures 3.5 through 3.7 and also in Figures 3.3. It is seen that irrespective of W/C ratio and age the resistivity decreases when values exceed contamination level of around 10 lb/cu.yd. The resistivity value for 60 lb/cu.yd. concrete is about one-third the value for 16 lb/cu.yd. However, it must be appreciated that the data developed in this investigation pertains to the action of chlorides in conjunction with water as all the measurements were made on moist concrete.

The effect of chlorides on water absorption is shown in Figure 3.9 where water absorption is about 4.94% more for a 30 lb chloride concrete as compared to a 16 lb chloride. concrete. This is possibly due to the increased porosity resulting from additional chlorides.

This discussion entails an accelerated corrosion cell activity due to a reduction in concrete resistivity in isolated areas around the reinforcement where mortar is rich in chlorides and the porous texture of concrete allows the ingress and transmission of moisture. This would

usually result in pitting type of corrosive action on rebars. This type of corrosion has been frequently noticed in this region and typical examples from local structures are shown in plates 3.1 and 3.2.

3.2.3 Effect of Age on Concrete Resistivity

The resistivity variations with age are shown in Figures 3.11 through 3.17 for concretes of different W/C ratios and for concretes containing different amounts of chlorides and pozzolan. All the curves show a similar trend - an increase in the resistivity with age, the rate of increase becoming more gradual with time. Although not shown explicitly in the aforesaid plots which have been terminated at 28 days, the resistivity values were found to become fairly stable, around 90% of the 120 days value at 35 days. The increase is much sharper during the first 28 days; the average value of 28-days being about 1.55 the value at 7-days for the chloride free concrete (Figure 3.11).

Since conduction can be regarded as essentially electrolytic in nature, with conduction taking place through the cement paste, the observed increase in resistivity with age is probably due to the reduced amount of evaporable water within the cement paste - this reduction being caused

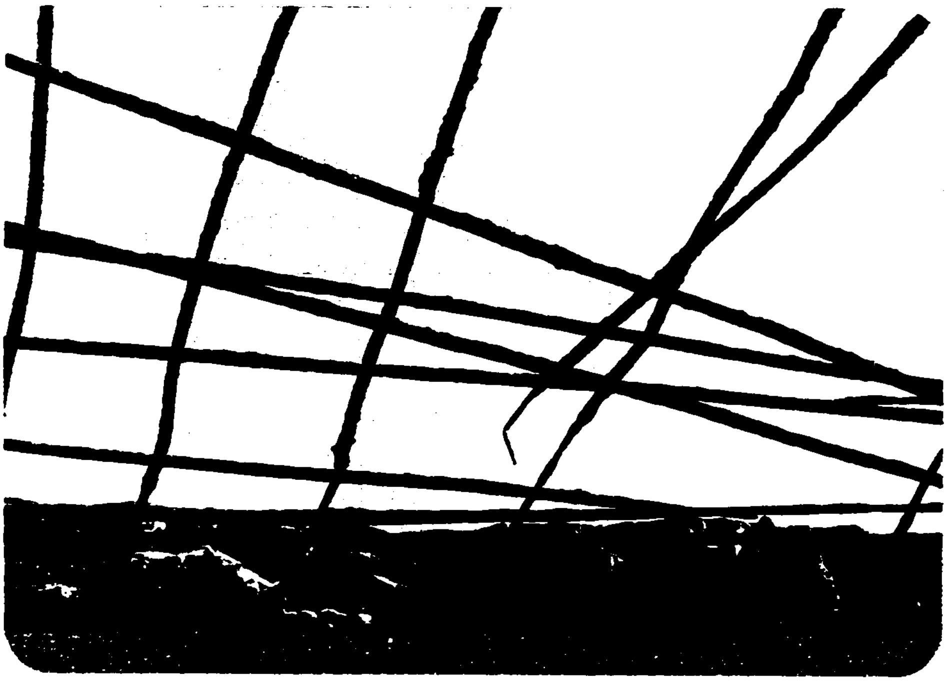


Plate 3.1: Corrosion Pitting on rebars

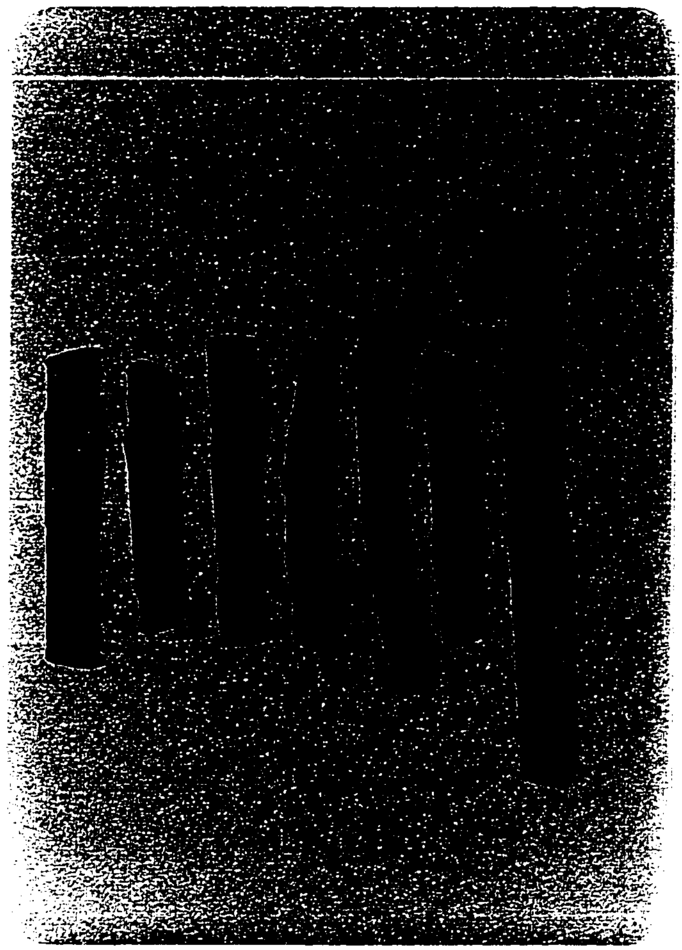


Plate 3.2: Pitting Corrosion of Steel embedded in Concrete.

by consumption due to 0.35 cement paste and cement quality continuing hydration process. After about 30 to 40 days the rate of hydration decreases. Hence after this period the amount of evaporable water within the cement paste changes little with increasing time. From an electrical point of view, this will mean a leveling off in the resistivity, an implication which is borne out by the experimental data developed in this investigation.

Another indication of a direct link between the progress of hydration and the increase in the resistivity is available by a comparison of the rate of strength development with age shown in Figure 3.26 and Table 3.13 to that of resistivity growth with age shown in Figure 3.11. It is observed that the average ratio of 28-day to 7-day strength is 1.45 whereas the average ratio of 28-day to 7-day resistivity is a close 1.55.

It is seen that the addition of high dosage of chloride reduces the ratio of 28-day to 7-day resistivity (Figure 3.12) whereas an opposite effect is obtainable with the addition of pozzolan. This indicates the deleterious effect of chlorides and the beneficial effect of pozzolans from the point of view of corrosion.

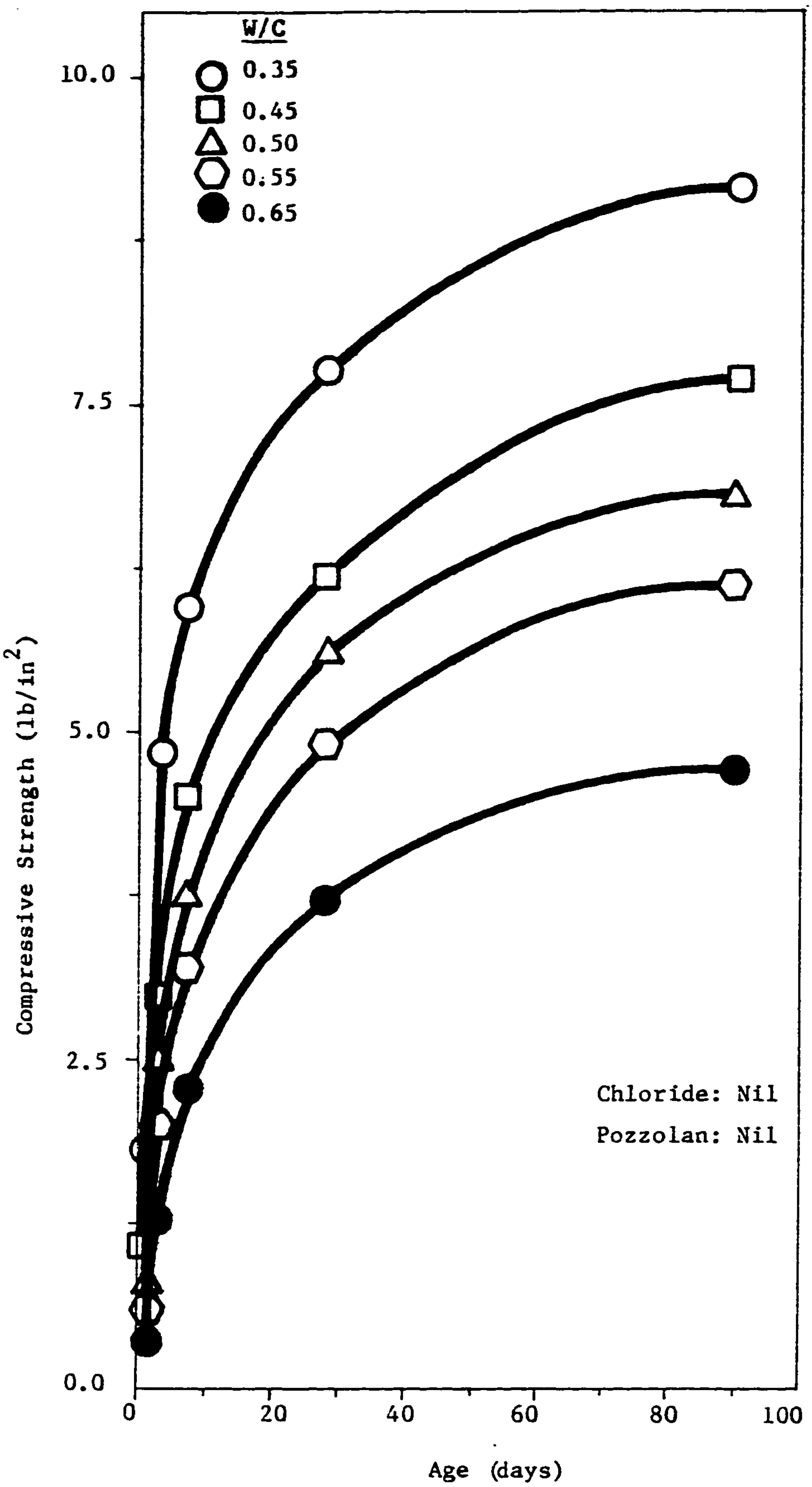


Fig: 3.26 Relationship between compressive strength and age of concrete for different w/c ratios.

TABLE 3.13: CONCRETE COMPRESSIVE STRENGTH DATA

Effect of w/c Ratio and Age

AGE (Days)	Compressive Strength (lb/in^2) Water-Cement Ratio				
	0.35	0.45	0.50	0.55	0.65
1	1800.00	1100.00	800.00	660.00	350.00
3	4400.00	3000.00	2500.00	2000.00	1300.00
7	5960.00	4500.00	3750.00	3200.00	2300.00
28	7750.00	6400.00	5600.00	4900.00	3760.00
91	9150.00	7700.00	6820.00	6120.00	4700.00

3.2.4 Effect of Temperature on Concrete Resistivity

Since the resistivity of electrolytes decreases with increasing temperature, the resistivity of moist concrete would also be expected to decrease with increasing temperature. Measurements of the resistivity of a 0.5 W/C ratio concrete over the temperature range from 20°C to 80°C are shown in Figure 3.18. For this specific range, an average increase in temperature of one degree C caused an average decrease in resistivity of about one per cent.

The application of the concept is seen in Figure 3.27 which shows the effect of temperature on the corrosion of crevice coupons mounted on vehicles during a winter season (November-April) in Winnipeg. The corrosion rates of those crevice coupons that were mounted on vehicles and were periodically housed in heated garages were approximately triple the corrosion rates of those mounted on vehicles left in the open or in unheated garages.

This provides an indication of accelerated reinforcement corrosion in the hot-humid climate of the Eastern Saudi Arabia.

3.2.5 Effect of Drying

The effect of drying concrete in the oven at 121°C even for 24 hours is to remove a substantial portion of the

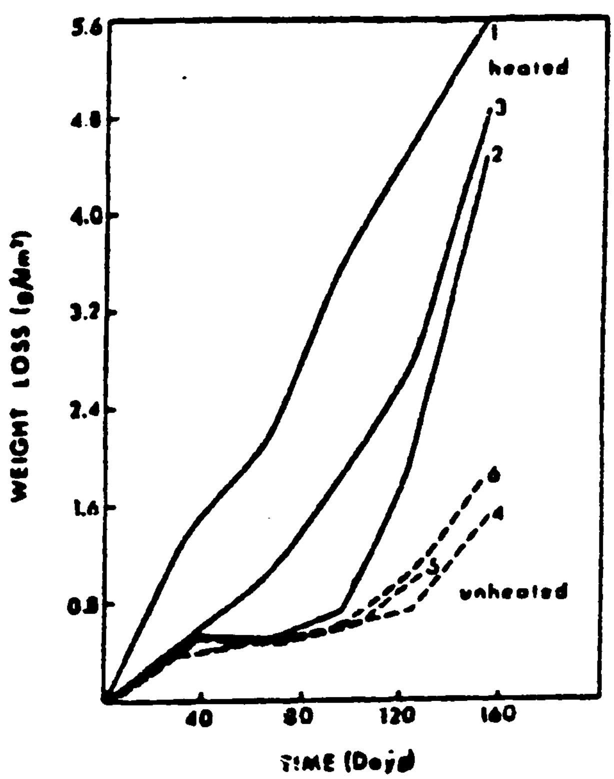


Fig:3.27 : Comparative corrosion rates of crevice specimens attached to vehicles stored in heated garages vs unheated garages

evaporable water from the concrete matrix. The result of this process on concrete resistivity values is shown in Figure 3.20. For a 16 lb chloride concrete the value increased from 6312.13 to 49.085 x 10^3 after 3 cycles - an increase of 7.78 times. For the 30 lb chloride concrete also the value increased from 4715.91 to 32.61 x 10^3 after 15 cycles - an increase of 6.92 times. These increased values place dried concretes in the class with electrical insulators. These results tend to confirm that the conduction through concrete is essentially an electrolytic process wherein it takes place by means of ions in the evaporable water in the cement paste matrix, the principal ions being Ca^{++}, Na^{+}, K^{+}, $O\overline{H}$, and $S\overline{O}_4$. With drying, as the evaporable water is driven out, the ionic conductivity through the free evaporable water is stifled thereby indicating a phenomenal rise in the value of resistivity.

3.2.6 Effect of Cement Substitution by Pozzolan

Pozzolan as a cement substitution admixture is already familiar to concrete technologists for its multipronged beneficial effects in the production of high quality, dense concrete. It drastically reduces permeability (Figure 3.28), disruptive cracking due to cement-aggregate reactivity (Figure 3.29), lowers heat of hydration, improves workability

and enhances resistance to sulphate attack. All these good attributes are directly relevant to the production of quality concrete in the high chloride-sulphate environment of the Gulf Coast. However, there is one feature in relation to which there does not exist sufficient and satisfactory evidence. This concerns its performance with respect to corrosion inhibition. Several investigations suggest that fly ash concrete does not decrease the corrosion protection of steel reinforcing when compared with normal concrete.[58,59,60] In fact studies by Larson et al[61,62] indicate that corrosion protection is increased by the inclusion of fly ash in concrete.

Inspite of these reports concern continues in this respect because of two counts. Firstly, pozzolans react with the calcium hydroxide of the cement paste and this may have the effect of reducing the alkaline environment of concrete which provides the most effective barrier against rebar corrosion. The presence of sulphur or chloride compounds may also contribute to enhance corrosion tendency. But what really is more significant is the presence of carbon in fly ash which is considered highly potential in reducing the resistivity of the concrete containing pozzolans.

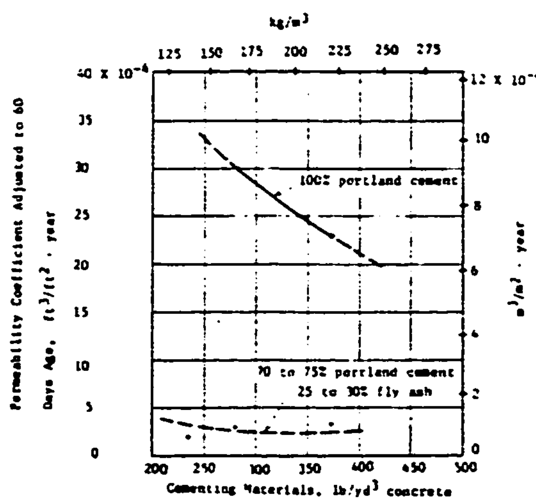


Fig:3.28: Permeability of concrete with and without pozzolan.

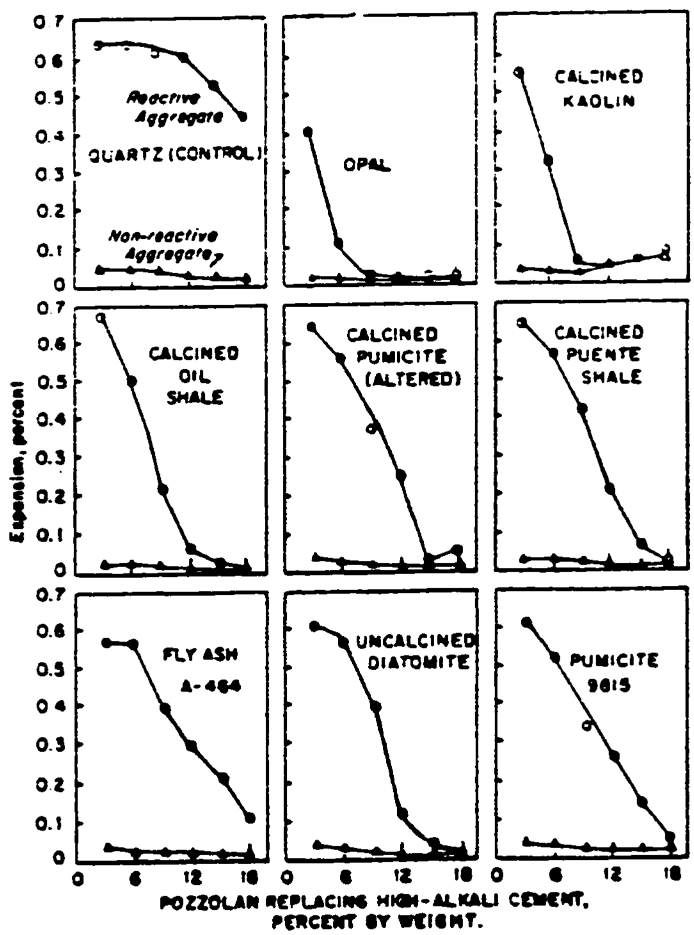


Fig:3.29: *Effect of small proportions of pozzolans on chemical reactivity in mortar bars: expansion after 15 months storage. (Note: 1.2 mortar in 25 by 25 by 278-mm (1 by 1 by 11¼-in.) bars sealed moist at 100°F.)*

The results of this study show that the addition of pozzolans actually increase resistivity. For example the value of 0.45 W/C concrete was about twice with 10% pozzolan substitution and was more than tripled for 25% substitution. Similar results may be ascribed to reduced permeability causing segmentation and blockade thereby making ionic conduction less efficient.

3.2.7 Studies on samples from field structures

The marked effect of resistivity on corrosion is clearly seen in Figure 3.21 where the loss of metal is plotted against resistivity for more or less constant values of cover, chlorides and concrete quality. The results show that given sufficient chlorides, resistivity plays a key role in determining loss of metal. A value of 15000 ohm-cm for moist concrete reduces corrosion to acceptable limits and the resulting loss of metal after about 20 years of exposure is not more than 15%. Reduced values of resistivity for moist concrete in the range of 6000 ohm-cm may cause upto 80% loss of metal. These field results indicate concrete resistivity as a controlling factor in the corrosion process.

Chapter 4

CONCLUSIONS

1. Given sufficient chlorides, field data shows that resistivity of concrete has a controlling effect on corrosion of reinforcement.

   Values of 15000 ohm-cm for moist concrete reduce loss of metal to less than 10% after 20 years of exposure; a reduction in resistivity value to 7000 ohm-cm may enhance the corresponding value of 80% loss of metal.

2. Concrete Resistivity decreases markedly with increase in w/c ratio. Mixes with high w/c will therefore result in increased corrosion of rebars.

   W/c ratio is observed to be the primary mix design parameter affecting the concrete resistivity values. Concrete resistivity for a w/c ratio of 0.35 is 1.67 times the value for a w/c ratio of 0.65. This controlling effect can be ascribed to the relative presence of initial mix water, evaporable water and the resulting pore structure determining the permeability, segmentation and the absorptive characteristics of concrete.

3. There is strong effect of chloride presence on concrete in decreasing the resistivity values. Chlorides content beyond

10 lb/cu yd causes sharp decrease in the resistivity value of concrete. Chloride contents in excess of 10 lb cu/yd will therefore enhance corrosion of steel reinforcement.

The value for 60 lb/cu yd chloride contamination is about one-third the value for 16 lb/cu yd chloride concrete. This effect may be attributed to increased ionic activity/ conductance due to chloride salts being strong electrolytes and due to their effect in increasing porosity and absorptive capacity of concrete.

4. Increase in temperature causes sharp decrease in the resistivity value of concrete. Concrete structures in the Gulf Area are therefore prone to accelerated corrosion during the Summer months.

   The values at 40^{o}C and 60^{o}C being about 66 and 51 per cent of the value at 20^{o}C. For the specific range investigated (20^{o}C - 80^{o}C) there was about 1 per cent average decrease in the resistivity value for an average increase of 1 degree C.

5. Resistivity increases with age along the same profile as the strength. For uncontaminated concrete, irrespective of w/c values, the ratio of 28-day to 7-day resistivity value being 1.53; the corresponding value for strength is 1.47. This increase is attributed to a reduction in ionic activity/ conductance due to a reduction in the amount of evaporable

water as a result of continued hydration. The resistivity value at 35 days is around 90% of the value of 120 days.

6. Exclusion of evaporable water through drying increases concrete resistivity.

   The effect of oven drying concrete specimens at 120°C is to remove a substantial portion of the evaporable water. In certain cases this results in a 2000 times increase in the resistivity of dry concrete compared to the same concrete in the moist state. This observation tends to confirm the electrolytic nature of the conduction process. With the elimination of the evaporable water the ionic conductivity is stifled and concrete resistivity values of the order of 4.012×10^6 are obtainable which place dried concrete in the class with electrical insulators.

7. Wetting/drying cycles increase the absorption capacity of concrete and decrease resistivity. This will enhance corrosion of reinforcement.

8. The addition of pozzolan as admixture increases the concrete resistivity values markedly and is likely to decrease corrosion of rebars. 25% substitution of cement by pozzolans triple the resistivity values for w/c ratios studied in the range of 0.35 to 0.65.

9. The resistivity value for the paste is found to be generally significantly lower than that of concrete of similar w/c ratio. However, the differential sharply converges for w/c ratio values smaller than 0.40 and the resistivity values of paste and concrete are found to be about equal for a w/c ratio of 0.35.

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APPENDIX "A"

TABLE : A-1: CEMENT PASTE RESISTIVITY DATA

Effect of w/c Ratio

Chloride Content : 0.0 lb/cu.yd.

Specimen Material Specifications : Ordinary Portland Cement Paste

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop, measurement, (L) = 10.17 cm

Moist Curing Time (Days)	Water-Cement Ratio							
	0.35		0.45		0.50		0.65	
	Resistance	Resistivity (ohm-cm)	Resistance	Resistivity (ohm-cm)	Resistance	Resistivity (ohm-cm)	Resistance	Resistivity (ohm-cm)
7	120.00	2745.00	28.20	645.08	21.00	480.38	21.50	491.81
14	190.00	4346.25	49.50	1132.31	36.50	834.94	30.00	686.25
21	220.00	5032.50	66.00	1509.75	49.00	1120.88	33.00	754.88
28	250.00	5718.75	84.50	1932.94	62.00	1418.25	35.00	800.63

TABLE: A-2: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35 Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	8.4800	0.0567	8.5800	0.0580	8.5300	0.0574	148.61
I	2	80	22.5000	0.1500	22.5000	0.1500	22.5000	0.1500	150.00
	3	120	33.5000	0.2267	33.5000	0.2283	33.5000	0.2275	147.25
							Average Resistance ($\overline{R}_1$) =		148.62
	1	30	7.9500	0.0575	8.3000	0.0590	8.1250	0.0583	139.37
II	2	80	21.2000	0.1517	21.0000	0.1500	21.1000	0.1509	139.83
	3	105	27.5000	0.2033	28.1000	0.2000	27.8000	0.2017	137.83
							Average Resistance ($\overline{R}_2$) =		139.01

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3289.77$ Ohms-cm

TABLE: A-3: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	:	0.35
Chloride Content	:	0.0 lb/cu yd.
Specimen Material Specifications	:	Ordinary Portland Cement Concrete
Age	:	14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.9500	0.0538	10.3000	0.0550	10.1250	0.0544	186.12
I	2	80	26.1000	0.1367	26.4000	0.1383	26.2500	0.1375	190.91
	3	120	39.8000	0.2133	40.2000	0.2167	40.0000	0.2150	186.05
							Average Resistance ($\overline{R}_1$)	=	187.69
	1	30	9.9000	0.0533	10.0000	0.0533	9.9500	0.0533	186.68
II	2	80	26.0000	0.1367	26.0500	0.1367	26.0250	0.1367	190.38
	3	120	39.6000	0.2117	40.0000	0.2117	39.8000	0.2117	188.00
							Average Resistance ($\overline{R}_2$)	=	188.35

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 4300.96 Ohms-cm

TABLE: A-4: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.3500	0.0433	9.2200	0.0423	9.285	0.0428	216.94
I	2	80	24.6000	0.1133	24.5000	0.1133	24.5500	0.1133	216.68
	3	150	46.0000	0.2100	46.2000	0.2083	46.1000	0.2092	220.36
							Average Resistance ($\overline{R}_1$) =		217.99
	1	30	9.4500	0.0422	9.6000	0.0433	9.5250	0.0428	222.55
II	2	80	25.0000	0.1100	24.5000	0.1100	24.7500	0.1100	225.00
	3	150	46.8000	0.2067	46.2000	0.2167	46.5000	0.2117	219.65
							Average Resistance ($\overline{R}_2$) =		222.40

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 5036.46 Ohms-cm

TABLE: A-5: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	10	9.4000	0.0397	9.6200	0.0400	9.5100	0.0399	238.35
I	2	80	25.0000	0.1033	25.1500	0.1050	25.0750	0.1042	240.64
	3	150	46.5000	0.1950	45.5000	0.2000	46.0000	0.1975	232.91
							Average Resistance $(\overline{R}_1)$ =		237.30
	1	30	9.9000	0.0400	9.5800	0.0397	9.7400	0.0399	244.11
II	2	80	25.6000	0.1000	25.5000	0.1000	25.5500	0.1000	255.50
	3	150	48.0000	0.1967	47.0000	0.1917	47.5000	0.1942	244.59
							Average Resistance $(\overline{R}_2)$ =		248.07

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 5551.42$ Ohms-cm

TABLE: A-6: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.3500	0.0753	9.4000	0.0750	9.3750	0.0752	124.67
	2	60	18.4000	0.1483	19.000	0.1500	18.7000	0.1492	125.34
	3	90	27.4000	0.2200	28.5000	0.2200	27.9500	0.2200	127.05
							Average Resistance ($\overline{R}_1$)	=	125.69
II	1	30	9.3500	0.0760	9.4000	0.0750	9.3750	0.0755	124.17
	2	60	18.5000	0.1479	18.9000	0.1467	18.7000	0.1467	127.47
	3	90	27.0000	0.2167	28.3000	0.2183	27.6500	0.2175	127.13
							Average Resistance ($\overline{R}_2$)	=	126.26

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2881.68$ Ohms-cm

TABLE: A-7: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	8.6100	0.0637	8.6000	0.0657	8.6050	0.0647	133.00
I	2	60	17.5000	0.1267	17.5000	0.1300	17.5000	0.1284	136.29
	3	100	29.2500	0.2100	29.0000	0.2133	29.1250	0.2117	137.58
							Average Resistance ($\overline{R}_1$)	=	135.62
	1	30	9.0000	0.0647	8.7300	0.0638	8.8650	0.0643	137.87
II	2	60	17.8000	0.1267	17.5000	0.1267	17.6500	0.1267	139.31
	3	100	29.5000	0.2067	29.0000	0.2067	29.2500	0.2067	141.51
							Average Resistance ($\overline{R}_2$)	=	139.56

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3147.37$ Ohms-cm

TABLE: A-8: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
	1	30	9.7000	0.0603	9.8500	0.0617	9.7750	0.0610	160.25
I	2	60	19.1000	0.1167	19.5000	0.1183	19.3000	0.1175	164.26
	3	100	31.5000	0.1917	32.0000	0.1983	31.7500	0.1950	162.82
							Average Resistance ($\overline{R}_1$) =		162.44
	1	30	9.6300	0.0617	9.7000	0.0617	9.6650	0.0617	156.65
II	2	60	18.8000	0.1167	19.2000	0.1183	19.0000	0.1175	161.70
	3	100	31.0000	0.1950	31.8000	0.2000	31.4000	0.1975	158.99
							Average Resistance ($\overline{R}_2$) =		159.11

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3677.73$ Ohms-cm

TABLE: A-9: CONCRETE RESISTIVITY DATA

Effect of ·/C Ratio

W/C Ratio : 0.45 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.3000	0.0523	9.1000	0.5170	9.2000	0.0520	176.92
	2	60	18.7000	0.1033	18.4000	0.1033	18.5500	0.1033	179.57
	3	120	38.8000	0.2083	37.0000	0.2117	37.9000	0.2100	180.48
							Average Resistance $(\overline{R}_1)$ =		178.99
II	1	30	9.3200	0.0520	9.4200	0.0530	9.3700	0.0525	178.48
	2	60	18.8000	0.1033	18.5000	0.1033	18.6500	0.1033	180.54
	3	120	38.0000	0.2133	38.0000	0.2100	38.0000	0.2117	179.50
							Average Resistance $(\overline{R}_2)$ =		179.51

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 4100.35$ Ohms-cm

TABLE: A-10: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.5

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.1000	0.0827	9.0000	0.0830	9.0500	0.0829	109.17
	2	60	18.3000	0.1633	18.2500	0.1667	18.2750	0.1650	110.76
	3	80	24.5000	0.2167	24.0000	0.2167	24.2500	0.2167	111.91
								Average Resistance ($\overline{R}_1$) =	110.61
II	1	30	9.2500	0.0823	9.4500	0.0847	9.3500	0.0835	111.98
	2	60	18.6000	0.1583	18.5000	0.1633	18.5500	0.1608	115.36
	3	85	26.3000	0.2217	26.1000	0.2300	26.2000	0.2259	115.98
								Average Resistance ($\overline{R}_2$) =	114.44

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 2574.01 Ohms-cm

TABLE: A-11: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.5

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.5000	0.0770	10.7500	0.0792	10.6250	0.0781	136.04
I	2	60	20.9000	0.1500	21.1000	0.1500	21.0000	0.1500	140.00
	3	90	31.0000	0.2200	31.0000	0.2200	31.0000	0.2200	140.91
							Average Resistance ($\overline{R}_1$) =		138.98
	1	30	10.0000	0.0767	9.7000	0.0737	9.8500	0.0752	130.98
II	2	60	19.4000	0.1450	19.3000	0.1417	19.35	0.1434	134.94
	3	90	29.0000	0.2167	28.8000	0.2133	28.9000	0.215	134.42
							Average Resistance ($\overline{R}_2$) =		133.45

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3115.92$ Ohms-cm

TABLE: A-12: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.5

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.5000	0.0617	9.4500	0.0613	9.4750	0.0615	154.07
	2	60	19.2000	0.1200	19.0000	0.1200	19.1000	0.1200	159.17
	3	100	32.0000	0.2050	31.5000	0.2000	31.7500	0.2025	156.79
							Average Resistance ($\overline{R}_1$) =		156.68
II	1	30	9.4000	0.0600	9.4000	0.0600	9.4000	0.0600	156.67
	2	60	19.2000	0.1200	18.8000	0.1183	19.0000	0.1192	159.40
	3	100	31.0000	0.1967	31.0000	0.1938	31.0000	0.1975	156.960
							Average Resistance ($\overline{R}_2$) =		157.68

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3594.99$ Ohms-cm

TABLE: A-13: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.5

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.9000	0.0558	9.5500	0.0542	9.7250	0.0550	176.82
I	2	60	19.6000	0.1100	19.1500	0.1083	19.3750	0.1092	177.43
	3	100	32.5000	0.1817	31.6000	0.1800	32.05	0.1809	177.27
						Average Resistance ($\overline{R}_1$) =			177.17
	1	30	9.2500	0.0528	9.3000	0.0533	9.2750	0.0531	174.67
II	2	60	18.6000	0.1050	18.8500	0.1067	18.725	0.1059	176.82
	3	100	31.2000	0.1750	30.6000	0.1783	30.8500	0.1767	174.59
						Average Resistance ($\overline{R}_2$) =			175.36

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 4032.06 Ohms-cm

TABLE: A-14: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.0000	0.0837	8.7000	0.0832	8.8500	0.0835	105.99
	2	60	18.0000	0.1667	17.5000	0.1667	17.7500	0.1667	106.48
	3	80	23.9000	0.2200	23.4000	0.2200	23.6500	0.2200	107.50
							Average Resistance $(\overline{R}_1)$ =		106.66
II	1	30	8.9000	0.08330	8.6500	0.0853	8.7750	0.0843	104.09
	2	60	17.6000	0.1633	17.2000	0.1617	17.4000	0.1625	107.08
	3	80	23.5000	0.2167	23.1000	0.2167	23.3000	0.2167	107.52
							Average Resistance $(\overline{R}_2)$ =		106.23

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2434.92$ Ohms-cm

TABLE: A-15: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.5000	0.0723	10.0000	0.0750	9.7500	0.0737	132.29
	2	60	19.0500	0.1400	19.0500	0.1400	19.0500	0.1400	136.07
	3	95	29.8000	0.2200	30.0000	0.2250	29.9000	0.2225	134.38
							Average Resistance ($\overline{R}_1$)	=	134.25
II	1	30	10.0000	0.0742	9.7500	0.0717	9.8750	0.0730	135.27
	2	60	18.9000	0.1383	19.2000	0.1367	19.0500	0.1375	138.55
	3	95	28.6000	0.2200	30.0000	0.2167	29.3000	0.2184	134.16
							Average Resistance ($\overline{R}_2$)	=	135.99

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3090.87$ Ohms-cm

TABLE: A-16: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	:	0.55
Chloride Content	:	0.0 lb/cu yd.
Specimen Material Specifications	:	Ordinary Portland Cement Concrete
Age	:	21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.5500	0.0653	9.5000	0.0650	9.5250	0.0652	146.09
I	2	60	19.0000	0.1300	19.0000	0.1300	19.0000	0.1300	146.15
	3	100	32.0000	0.2167	31.0000	0.2117	31.5000	0.2142	147.06
							Average Resistance $(\overline{R}_1)$	=	146.43
	1	30	9.5200	0.0630	9.8000	0.6250	9.6600	0.0640	150.94
II	2	60	19.1000	0.1250	19.0000	0.1250	19.0500	0.1250	152.40
	3	100	31.5000	0.2050	32.0000	0.2133	31.7500	0.2092	151.77
							Average Resistance $(\overline{R}_2)$	=	151.70

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3409.87$ Ohms-cm

TABLE: A-17: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.0500	0.0530	9.3500	0.0553	9.2000	0.0542	169.74
	2	60	18.5000	0.1083	18.0000	0.1057	18.2500	0.1070	170.56
	3	100	31.0000	0.1767	30.0000	0.1800	30.5000	0.1784	170.96
							Average Resistance ($\overline{R}_1$) =		170.42
II	1	30	9.2000	0.0555	8.7900	0.0533	8.9950	0.0544	165.40
	2	60	18.0000	0.1053	18.0000	0.1083	18.0000	0.1068	168.50
	3	100	29.6000	0.1783	29.3000	0.1767	29.4500	0.1775	165.90
							Average Resistance ($\overline{R}_2$) =		166.60

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3854.67$ Ohms-cm

TABLE: A-18: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	20	5.9500	0.0600	5.9500	0.0595	5.9500	0.0598	99.50
	2	50	14.6000	0.1467	14.6500	0.1467	14.6250	0.1467	99.69
	3	75	22.0000	0.2167	22.0000	0.2167	22.0000	0.2167	101.52
							Average Resistance ($\overline{R}_1$) =		100.24
II	1	20	5.9000	0.0567	6.0500	0.0575	5.9750	0.0571	104.64
	2	50	15.2000	0.1400	15.2500	0.1400	15.2250	0.1400	108.75
	3	80	24.1000	0.2267	24.2000	0.2267	24.1500	0.2267	106.53
							Average Resistance ($\overline{R}_2$) =		106.64

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2366.19$ Ohms-cm

TABLE: A-19: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.1500	0.0770	9.1200	0.0768	9.1350	0.0769	118.79
I	2	60	18.5000	0.1533	18.5000	0.1533	18.5000	0.1533	120.68
	3	90	27.6500	0.2300	27.8000	0.2300	27.7250	0.2300	120.54
							Average Resistance ($\overline{R}_1$)	=	120.00
	1	30	9.5000	0.0760	9.4200	0.0743	9.4600	0.0752	125.80
II	2	60	18.7000	0.1467	19.0000	0.1467	18.8500	0.1467	128.44
	3	90	28.4000	0.2200	28.6000	0.2200	28.5000	0.2200	129.55
							Average Resistance ($\overline{R}_2$)	=	127.95

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2835.93$ Ohms-cm

TABLE: A-20: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.6300	0.0738	9.7000	0.0737	9.6650	0.0738	130.96
	2	60	19.2000	0.1450	19.2500	0.1450	19.2250	0.1450	132.58
	3	90	28.9000	0.2167	28.9000	0.2150	28.9000	0.2159	133.86
							Average Resistance $(\overline{R}_1)$ =		132.47
II	1	30	9.7000	0.0718	9.8000	0.0710	9.7500	0.0714	136.56
	2	60	19.1500	0.1367	19.4500	0.1367	19.3000	0.1367	141.19
	3	90	28.55	0.2033	29.0000	0.2067	28.7750	0.2050	140.37
							Average Resistance $(\overline{R}_2)$ =		139.37

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3109.17$ Ohms-cm

TABLE: A-21: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	8.9500	0.0648	9.3500	0.0648	9.1500	0.0648	141.20
	2	60	18.1000	0.1317	18.3000	0.1317	18.2000	0.1317	138.19
	3	100	29.5000	0.2133	30.5000	0.2167	30.0000	0.2150	139.54
							Average Resistance ($\overline{R}_1$)	=	139.64
II	1	30	9.3500	0.0633	9.4000	0.0618	9.3750	0.0626	149.76
	2	60	18.5000	0.1217	18.6500	0.1217	18.5750	0.1217	152.63
	3	100	30	0.2033	31.1000	0.2033	30.5500	0.2033	150.27

Average Resistance ($\overline{R}_2$) = 150.89

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 3322.94 Ohms-cm

TABLE:A-22: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
I	1	10	2.7500	0.0847	2.7150	0.0832	2.7325	0.0840	32.53
	2	15	4.2000	0.13000	4.2500	0.1250	4.2250	0.1275	33.14
	3	25	7.2000	0.2133	7.1000	0.2133	7.1500	0.2133	33.52
							Average Resistance ($\overline{R}_1$)	=	33.06
II	1	10	2.8500	0.0867	2.8500	0.0880	2.8500	0.0874	32.61
	2	15	4.3000	0.1333	4.2500	0.1300	4.2750	0.1317	32.46
	3	25	7.1200	0.2167	7.1000	0.2167	7.1100	0.2167	32.81
							Average Resistance ($\overline{R}_2$)	=	32.63

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 751.33$ Ohms-cm

TABLE: A-23: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	3.0500	0.0817	3.3000	0.0872	3.1750	0.0845	37.57
	2	20	6.0200	0.1533	6.0500	0.1567	6.0350	0.1550	38.94
	3	25	7.5000	0.1933	7.5500	0.1967	7.5250	0.1950	38.59
							Average Resistance ($\overline{R}_1$)	=	38.37
II	1	10	3.2800	0.0845	3.3500	0.0860	3.3150	0.0853	38.86
	2	20	6.4200	0.1600	6.7000	0.1683	6.5600	0.1642	39.95
	3	25	8.0000	0.2000	8.1000	0.2000	8.0500	0.2000	40.25
							Average Resistance ($\overline{R}_2$)	=	39.69

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 892.81$ Ohms-cm

TABLE: A-24: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.7600	0.0613	2.8000	0.0623	2.7800	0.0618	44.98
	2	20	5.6600	0.1250	5.6600	0.1233	5.6600	0.1242	45.57
	3	30	8.5000	0.1850	8.5000	0.1850	8.5000	0.1850	45.57
							Average Resistance $(\overline{R}_1)$	=	45.37
II	1	10	2.9400	0.0637	2.9200	0.0637	2.9300	0.0637	46.00
	2	20	5.9900	0.1300	5.9000	0.1267	5.9450	0.1284	46.30
	3	30	8.9000	0.1867	8.8300	0.1883	9.9650	0.1875	47.28
							Average Resistance $(\overline{R}_2)$	=	46.58

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 1051.68$ Ohms-cm

TABLE: A-25: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

W/C Ratio : 0.45

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.8600	0.0567	2.8100	0.0557	2.8350	0.0562	50.45
	2	20	5.5500	0.1117	5.700	0.1133	5.6250	0.1125	50.00
	3	30	8.42	0.1667	8.6500	0.1700	8.5350	0.1684	50.68
							Average Resistance $(\overline{R_1})$ =		50.38
II	1	10	2.8400	0.0560	2.8050	0.0560	2.8225	0.0560	50.40
	2	20	5.8000	0.1133	5.7500	0.1167	5.7750	0.1150	50.22
	3	30	8.7000	0.1700	8.6500	0.1700	8.6750	0.1700	51.03
							Average Resistance $(\overline{R_2})$ =		50.55

Average Resistivity, $\overline{\rho} = \frac{(\overline{R_1} + \overline{R_2})A}{2L} = 1153.89$ Ohms-cm

TABLE: A-26: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.8600	0.1033	2.8500	0.1000	2.8550	0.1017	28.07
	2	15	4.3500	0.1533	4.2500	0.1533	4.3000	0.1533	28.05
	3	20	5.7000	0.2033	5.7000	0.2033	5.7000	0.2033	28.04
							Average Resistance ($\overline{R}_1$)	=	28.05
II	1	10	2.9000	0.1000	2.8500	0.1000	2.8750	0.1000	28.75
	2	15	4.3000	0.1500	4.2500	0.1500	4.2750	0.1500	28.50
	3	20	5.7000	0.2000	5.6500	0.2000	5.6750	0.2000	28.38
							Average Resistance ($\overline{R}_2$)	=	28.54

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 647.25$ Ohms-cm

TABLE: A-27: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
I	1	10	3.0000	0.6950	3.0500	0.0963	3.0250	0.0957	31.61
	2	15	9.6000	0.1400	4.6500	0.1433	4.6250	0.1417	32.64
	3	20	6.0200	0.1850	6.1000	0.1867	6.0600	0.1859	32.60
							Average Resistance ($\bar{R}_1$) =		32.28
II	1	10	3.2000	0.1000	3.1500	0.0987	3.1750	0.0994	31.94
	2	15	4.9000	0.1500	5.0500	0.1517	4.9750	0.1509	32.97
	3	20	6.6000	0.2000	6.3500	0.1900	6.4750	0.1950	33.21
							Average Resistance ($\bar{R}_2$) =		32.71

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L} = 743.33$ Ohms-cm

TABLE: A-28: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.6600	0.0720	2.6600	0.0700	2.6600	0.0710	37.47
	2	20	5.5500	0.1500	5.5000	0.1500	5.5250	0.1500	36.83
	3	30	8.4500	0.2250	8.4000	0.2217	8.4250	0.2234	37.72
							Average Resistance ($\overline{R}_1$) =		37.34
II	1	10	2.8300	0.0757	2.8000	0.0747	2.8150	0.0752	37.44
	2	20	5.7200	0.1500	5.7000	0.1517	5.7100	0.1509	37.84
	3	30	8.6200	0.2250	8.5000	0.2200	8.5600	0.2225	38.47
							Average Resistance ($\overline{R}_2$) =		37.92

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L}$ = 860.79 Ohms-cm

TABLE: A-29: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
I	1	10	2.7000	0.0677	2.7500	0.0683	2.7250	0.0680	40.07
	2	20	5.5500	0.1367	5.7500	0.1417	5.6500	0.1392	40.59
	3	30	8.4000	0.2067	8.5000	0.2067	8.4500	0.2067	40.88
							Average Resistance ($\overline{R}_1$)	=	40.51
II	1	10	2.6000	0.0647	2.6700	0.0817	2.6350	0.0732	36.00
	2	20	5.4000	0.1333	5.4000	0.1333	5.4000	0.1333	40.51
	3	30	8.1000	0.2000	8.1500	0.2033	8.1250	0.2017	40.28
							Average Resistance ($\overline{R}_2$)	=	38.93

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 908.60 Ohms-cm

TABLE: A-30: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
		Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
1	40	11.1000	0.0347	11.7600	0.0363	11.5800	0.0355	326.20
2	70	20.2500	0.0633	20.4000	0.0617	20.3250	0.0625	325.20
3	100	30.5000	0.0875	30.5000	0.0903	30.5000	0.0889	343.08
4	150	46.0000	0.1333	46.5000	0.1367	46.2500	0.1350	342.59
5	210	64.4000	0.1900	64.4000	0.1917	64.5000	0.1909	337.87
6	255	76.1000	0.2333	78.0000	0.2300	77.0500	0.2317	332.54

Average Resistance $(\overline{R}_1)$ = 334.58

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 7653.52 Ohms-cm

TABLE: A-31: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
		Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
1	30	8.7000	0.0383	9.0000	0.0408	8.8500	0.0396	223.49
2	40	11.25000	0.0492	11.4000	0.0505	11.3250	0.0499	226.95
3	70	20.1000	0.0873	20.4000	0.0883	20.2500	0.0878	230.64
4	100	30.1000	0.1250	30.1000	0.1233	30.1000	0.1242	242.35
5	150	46.1000	0.1717	46.5000	0.1917	46.3000	0.1817	254.82
6	180	55.0000	0.2333	55.5000	0.2267	55.2500	0.2300	240.22

Average Resistance ($\overline{R}_1$) = 236.41

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 5407.88 Ohms-cm

TABLE: A-32: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.5

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
		Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
1	30	8.7000	0.0437	9.0000	0.0450	8.8500	0.0444	199.32
2	40	11.4000	0.0542	11.4300	0.0550	11.4150	0.0546	209.07
3	70	20.2500	0.0973	19.9200	0.0925	20.0850	0.0949	211.64
4	100	28.5300	0.1367	28.8300	0.1400	28.6800	0.1384	207.23
5	150	45.8000	0.2100	45.5000	0.2067	45.6500	0.2084	219.05
6	162	49.4000	0.2267	49.2000	0.2333	49.3000	0.2300	214.35

Average Resistance $(\overline{R}_1)$ = 210.11

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 4806.27 Ohms-cm

TABLE: A-33: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
1	30	8.5500	0.0433	8.7000	0.0458	8.6250	0.0446	193.39
2	40	11.4000	0.0583	11.4000	0.0580	11.4000	0.0582	195.88
3	70	20.1000	0.1000	20.1000	0.1033	20.1000	0.1017	197.64
4	100	30.2000	0.1467	30.2000	0.1467	30.2000	0.1467	205.86
5	120	37.0000	0.1817	37.2000	0.1833	37.1000	0.1825	203.29
6	150	46.0000	0.2267	46.2000	0.2267	46.1000	0.2267	203.35

Average Resistance ($\overline{R}_1$) = 199.90

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 4572.71 Ohms-cm

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TABLE: A-36: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 8.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
		Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
1	30	8.8000	0.0317	8.7300	0.0313	8.7650	0.0315	278.25
2	40	11.1000	0.0417	11.1000	0.0427	11.1000	0.0422	263.03
3	70	19.5600	0.0740	19.5000	0.0733	19.5300	0.0737	264.99
4	100	29.5000	0.1100	29.5000	0.1067	29.5000	0.1084	272.14
5	150	45.0000	0.1633	45.0000	0.1633	45.0000	0.1633	275.57
6	210	63.0000	0.2250	62.6000	0.2200	62.8000	0.2225	282.25

Average Resistance ($\overline{R}_1$) = 272.71

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 6238.24 Ohms-cm

TABLE: A-37: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
1	40	10.8600	0.0410	10.9200	0.0420	10.8900	0.0415	262.41
2	70	19.2000	0.0725	19.0500	0.0717	19.1250	0.0721	265.26
3	100	27.7500	0.1033	27.9600	0.1033	27.8550	0.1033	269.65
4	150	45.0000	0.1567	44.8000	0.1533	44.9000	0.1550	289.68
5	180	54.0000	0.1867	54.0000	0.1900	54.0000	0.1884	286.62
6	210	63.0000	0.2250	63.0000	0.2217	63.0000	0.2234	282.01

Average Resistance ($\overline{R}_1$) = 275.94

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 6312.13 Ohms-cm

TABLE: A-38: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
1	40	12.0000	0.0573	11.5000	0.0570	11.7500	0.0572	205.42
2	70	20.0000	0.0967	20.4000	0.1000	20.2000	0.0984	205.29
3	100	28.7000	0.1400	28.4000	0.1383	28.5500	0.1392	205.10
4	120	34.3000	0.1667	34.7000	0.1700	34.5000	0.1684	204.87
5	150	42.5000	0.2067	42.5000	0.2050	42.5000	0.2059	206.41
6	165	46.4000	0.2200	47.0000	0.2250	46.7000	0.2225	209.89

Average Resistance ($\overline{R}_1$) = 206.16

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 4715.91 Ohms-cm

TABLE: A-39: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 60.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
		Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
1	20	5.5700	0.0427	5.9500	0.0458	5.7600	0.0443	130.02
2	40	10.8600	0.0892	11.1000	0.0900	10.9800	0.0896	122.55
3	50	13.7100	0.1100	14.0400	0.1133	13.8750	0.1117	124.22
4	70	19.2000	0.1533	19.2000	0.1533	19.2000	0.1533	125.25
5	90	24.5400	0.1967	24.7500	0.2000	24.6450	0.1984	124.22
6	100	27.4500	0.2217	29.1000	0.2183	28.2750	0.2200	128.52

Average Resistance $(\overline{R}_1)$ = 125.80

Average Resistivity, $\overline{\rho} = \frac{\overline{R}_1 A}{L}$ = 2877.67 Ohms-cm

TABLE: A-40: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 4 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
	1	20	6.2000	0.0617	6.0000	0.0597	6.1000	0.0607	100.49
I	2	50	15.3500	0.1500	15.2500	0.1500	15.3000	0.1500	102.00
	3	75	22.8000	0.2200	22.8000	0.2200	22.8000	0.2200	103.64
							Average Resistance ($\bar{R}_1$)	=	102.04
	1	20	6.1000	0.0573	6.2000	0.0587	6.1500	0.0580	106.04
II	2	50	15.5000	0.1383	15.1000	0.1417	15.3000	0.14	109.29
	3	80	24.6000	0.2217	24.5000	0.2283	24.55	0.2250	109.11
							Average Resistance ($\bar{R}_2$)	=	108.15

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L}$ = 2404.05 Ohms-cm

TABLE: A-41: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 4 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.5000	0.081	10.4000	0.0800	10.4500	0.0805	129.81
I	2	60	20.5000	0.1533	20.6000	0.1550	20.5500	0.1542	133.27
	3	85	29.0000	0.2167	29.0000	0.2183	29.0000	0.2175	133.33
							Average Resistance ($\overline{R}_1$) =		132.148
	1	30	9.8000	0.0793	9.5000	0.0773	9.6500	0.07830	123.24
II	2	60	19.2000	0.1533	19.2000	0.1500	19.2000	0.1517	126.57
	3	90	26.6500	0.2250	28.6000	0.2217	27.6250	0.2234	123.66
							Average Resistance ($\overline{R}_2$) =		124.49

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2935.21$ Ohms-cm

TABLE: A-42: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 4 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.8500	0.0660	9.6000	0.0640	9.7250	0.0650	149.62
I	2	60	19.1000	0.1250	19.3000	0.1283	19.2000	0.1267	151.54
	3	100	31.8000	0.2133	32.0000	0.2100	31.9000	0.2117	150.69
								Average Resistance $(\overline{R}_1)$ =	150.62
	1	30	9.5000	0.062	9.8500	0.0645	9.6750	0.0633	152.84
II	2	60	19.2000	0.1233	19.1000	0.1233	19.1500	0.1233	155.31
	3	100	32.0000	0.2033	32.0000	0.2083	32.0000	0.2058	155.49
								Average Resistance $(\overline{R}_2)$ =	154.55

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3490.38$ Ohms-cm

TABLE: A-43: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 4 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.6000	0.0568	9.5000	0.0570	9.5500	0.0569	167.84
I	2	60	19.1000	0.1133	18.9000	0.1133	19.0000	0.1133	167.70
	3	100	32.0000	0.1867	31.0000	0.1867	31.5000	0.1867	168.72
							Average Resistance ($\overline{R}_1$) =		168.09
	1	30	9.5000	0.0555	9.5000	0.0550	9.5000	0.0553	171.79
II	2	60	18.7000	0.1083	19.0000	0.1083	18.8500	0.1083	174.05
	3	100	30.5000	0.1833	31.8000	0.1800	31.1500	0.1817	171.44
							Average Resistance ($\overline{R}_2$) =		172.43

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3894.70$ Ohms-cm

TABLE: A-44: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 8 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	20	6.2000	0.0638	6.3000	0.0663	6.2500	0.0651	96.01
	2	50	15.5000	0.1550	15.1000	0.1550	15.3000	0.1550	98.71
	3	70	21.6000	0.2167	21.4000	0.2167	21.5000	0.2167	99.22
								Average Resistance $(\overline{R}_1)$ =	97.98
II	1	20	5.5000	0.0627	5.5000	0.0632	5.5000	0.0630	87.30
	2	50	14.1000	0.1567	14.0000	0.1600	14.0500	0.1584	88.70
	3	70	19.5000	0.2200	19.5000	0.2200	19.5000	0.2200	88.64
								Average Resistance $(\overline{R}_2)$ =	88.21

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2129.55$ Ohms-cm

TABLE: A-45: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 8 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.2000	0.0867	10.0000	0.0850	10.1000	0.0859	117.58
I	2	60	19.6000	0.1667	19.9000	0.1650	19.7500	0.1659	119.05
	3	80	26.0000	0.2183	26.5000	0.2167	26.2500	0.2175	120.69
								Average Resistance ($\overline{R}_1$) =	119.11
	1	30	9.9000	0.0890	10.1000	0.0880	10.0000	0.0885	112.99
II	2	60	19.5000	0.1667	19.6000	0.1667	19.5500	0.1667	117.28
	3	80	25.9000	0.2200	25.8000	0.2200	25.8500	0.2200	117.50
								Average Resistance ($\overline{R}_2$) =	115.93

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2688.27$ Ohms-cm

TABLE: A-46: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 8 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.0200	0.0670	9.4000	0.0700	9.2100	0.0685	134.45
	2	60	18.4500	0.1333	18.3500	0.1350	18.4000	0.1342	137.11
	3	100	30.2000	0.2200	30.2000	0.2250	30.2000	0.2225	135.73
								Average Resistance ($\overline{R}_1$) =	135.76
II	1	30	9.5800	0.0683	9.5500	0.0680	9.5650	0.0682	140.25
	2	60	19.3000	0.1367	19.1000	0.1350	19.2000	0.1359	141.28
	3	100	32.0000	0.2267	31.5000	0.2233	31.7500	0.2250	141.11
								Average Resistance ($\overline{R}_2$) =	140.88

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3164.07$ Ohms-cm

TABLE: A-47: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio	: 0.5	**Cross sectional area of specimen, (A)**	= 232.56 cm^2
Chloride Content	: 8 lb/cu yd.	**Length for voltage drop measurement, (L)**	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete		
Age	: 28 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.0000	0.0595	9.0500	0.0600	9.0250	0.0598	150.92
I	2	60	18.1500	0.1183	18.1500	0.1200	18.1500	0.1192	152.27
	3	100	30.0000	0.1950	30.0000	0.2000	30.0000	0.1975	151.90
							Average Resistance ($\overline{R}_1$)	=	151.70
	1	30	9.4000	0.0617	9.5000	0.0613	9.4500	0.0615	153.66
II	2	60	18.4000	0.1200	19.0000	0.1200	18.7000	0.1200	155.83
	3	100	30.0000	0.2000	31.7000	0.2000	30.8500	0.2000	154.25
							Average Resistance ($\overline{R}_2$)	=	154.58

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3503.08$ **Ohms-cm**

TABLE: A-48: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 16 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	20	6.0200	0.1000	6.1000	0.1000	6.0600	0.1000	60.60
	2	30	9.0800	0.1500	9.1000	0.1500	9.0900	0.1500	60.60
	3	45	13.0000	0.2250	13.5000	0.2250	13.5000	0.2250	60.00
							Average Resistance ($\overline{R}_1$) =		60.40
II	1	20	5.7000	0.1000	5.7000	0.1000	5.7000	0.1000	57.00
	2	30	8.5000	0.1467	8.5500	0.1467	8.5250	0.1467	58.11
	3	45	12.6500	0.2183	12.7500	0.2183	12.7000	0.2183	58.18
							Average Resistance ($\overline{R}_2$) =		57.76

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 1351.46$ Ohms-cm

TABLE: A-49: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 16 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
	1	20	6.1500	0.0883	6.4500	0.0920	6.3000	0.0902	69.85
I	2	40	12.3000	0.1717	12.5000	0.1750	12.4000	0.1734	71.51
	3	50	15.1500	0.2133	15.1000	0.2133	15.1000	0.2133	70.79
							Average Resistance ($\overline{R}_1$)	=	70.72
	1	20	6.3200	0.0860	6.5500	0.0903	6.4350	0.0882	72.96
II	2	40	12.2000	0.1667	12.3000	0.1667	12.2500	0.1667	73.49
	3	50	15.3000	0.2050	15.3000	0.02067	15.3000	0.2059	74.31
							Average Resistance ($\overline{R}_2$)	=	73.59

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 1650.55$ Ohms-cm

TABLE: A-50: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 16 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	20	6.1100	0.0708	6.4200	0.0750	6.2650	0.0729	85.94
	2	40	12.5000	0.1433	12.4000	0.1433	12.4500	0.1433	86.88
	3	60	18.6000	0.2133	18.6000	0.2133	18.6000	0.2133	87.20
							Average Resistance ($\overline{R}_1$) =		86.67
II	1	20	6.2200	0.0717	6.0000	0.0687	6.1100	0.0702	87.04
	2	40	12.0000	0.1367	12.5000	0.1417	12.2500	0.1392	88.01
	3	60	18.0000	0.2050	18.1000	0.2067	18.0500	0.2059	87.66
							Average Resistance ($\overline{R}_2$) =		87.57

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 1992.87$ Ohms-cm

TABLE: A-51: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio	: 0.5	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 16 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete		
Age	: 28 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	20	5.7200	0.0593	5.7000	0.0603	5.7100	0.0598	95.49
	2	40	11.8000	0.1217	11.5000	0.1210	11.6500	0.1214	96.96
	3	70	20.2500	0.2117	20.5000	0.2167	20.3750	0.2142	95.12
								Average Resistance ($\overline{R}_1$) =	95.86
II	1	20	6.1000	0.0607	6.1000	0.0600	6.1000	0.0604	100.99
	2	40	11.9000	0.1183	12.1000	0.1167	12.0000	0.1175	102.13
	3	70	20.8000	0.2083	21.1500	0.2050	20.9750	0.2067	101.48
								Average Resistance ($\overline{R}_2$) =	101.53

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2257.65$ Ohms-cm

TABLE: A-52: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	10	2.7600	0.0820	2.8250	0.0850	0.7925	0.0835	33.44
I	2	20	5.7400	0.1667	5.7600	0.1667	5.7500	0.1667	34.49
	3	25	7.2000	0.2083	7.2200	0.2117	7.2100	0.2100	34.33
							Average Resistance ($\overline{R}_1$) =		34.09
	1	10	2.900	0.0900	2.7800	0.0892	2.8400	0.0896	31.70
II	2	20	5.6000	0.1783	5.6100	0.1800	5.6050	0.1792	31.28
	3	25	7.0300	0.2233	7.1000	0.2233	7.0650	0.2233	31.64
							Average Resistance ($\overline{R}_2$) =		31.54

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 750.65$ Ohms-cm

TABLE: A-53: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
I	1	10	3.3500	0.0847	3.1000	0.07980	3.2250	0.0823	39.19
	2	20	6.2000	0.1583	6.2000	0.1533	6.2000	0.1558	39.80
	3	30	9.1200	0.2233	9.2000	0.2300	9.1600	0.2267	40.41
							Average Resistance ($\overline{R}_1$)	=	39.80
II	1	10	2.9500	0.0807	2.9800	0.0813	2.9650	0.0810	36.61
	2	20	5.8500	0.1533	5.7500	0.1583	5.8000	0.1558	36.23
	3	25	7.3000	0.1933	7.3800	0.1967	7.3400	0.1950	37.64
							Average Resistance ($\overline{R}_2$)	=	36.83

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 876.46$ Ohms-cm

TABLE: A-54: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.7250	0.0613	2.9000	0.0650	2.8125	0.0632	44.50
	2	20	5.9500	0.1333	5.5500	0.1233	5.7500	0.1283	44.82
	3	35	9.800	0.2167	9.8000	0.2167	9.8000	0.2167	45.22
							Average Resistance ($\overline{R}_1$)	=	44.85
II	1	10	2.7900	0.0630	2.7600	0.0627	2.7750	0.0629	44.12
	2	20	5.7000	0.1300	5.6500	0.1267	5.6750	0.1284	44.20
	3	35	10.000	0.2250	10.0000	0.2233	10.0000	0.2242	44.60
							Average Resistance ($\overline{R}_2$)	=	44.31

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 1019.77$ Ohms-cm

TABLE: A-55: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 30 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.7000	0.5270	2.8650	0.0572	2.7825	0.0550	50.59
	2	20	5.6000	0.1083	5.6500	0.1133	5.6250	0.1108	50.77
	3	40	11.2500	0.2182	11.5000	0.2300	11.3750	0.2242	50.74
								Average Resistance ($\overline{R}_1$) =	50.70
II	1	10	2.5400	0.0530	2.5500	0.0530	2.5450	0.0530	48.02
	2	20	5.3000	0.1100	5.2200	0.1083	5.2600	0.1092	48.17
	3	40	10.8000	0.2217	10.5000	0.22	10.6500	0.2209	48.21
								Average Resistance ($\overline{R}_2$) =	48.13

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 1130.37$ Ohms-cm

TABLE: A-56: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 60 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	6	1.4300	0.0817	1.4000	0.0805	1.4150	0.0811	17.45
	2	12	3.0500	0.1700	3.0000	0.1700	3.0250	0.1700	17.79
	3	15	3.8000	0.2133	3.7500	0.2117	3.7750	0.2125	17.77
							Average Resistance ($\overline{R}_1$) =		17.67
II	1	6	1.3500	0.0823	1.3300	0.0793	1.3400	0.0808	16.58
	2	12	2.7900	0.1733	2.8800	0.1833	2.8350	0.1783	15.9
	3	15	3.8000	0.2133	3.5800	0.2133	3.6900	0.2133	17.30
							Average Resistance ($\overline{R}_2$) =		16.59

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 391.85$ Ohms-cm

TABLE: A-57: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio : 0.5

Chloride Content : 60 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	6	1.4300	0.0650	1.4500	0.0653	1.4400	0.0652	22.09
I	2	10	2.9200	0.1300	2.9000	0.1300	2.9100	0.1300	22.39
	3	15	4.2500	0.1883	4.2500	0.1883	4.2500	0.1883	22.57
							Average Resistance $(\overline{R}_1)$	=	22.35
	1	6	1.6000	0.0800	1.6800	0.0818	1.6400	0.0809	20.27
II	2	10	2.6000	0.1333	2.8800	0.1350	2.7400	0.1342	20.42
	3	15	4.2000	0.2000	4.2500	0.2033	4.2250	0.2017	20.95
							Average Resistance $(\overline{R}_2)$	=	20.55

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 490.67 Ohms-cm

TABLE: A-58: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio	: 0.5	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 60 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete		
Age	: 21 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	10	2.5600	0.0967	2.6600	0.1000	2.6100	0.0984	26.52
I	2	15	3.9800	0.1500	3.8000	0.1433	3.8900	0.1467	26.52
	3	20	5.3500	0.2000	5.2500	0.2000	5.3000	0.2000	26.50
							Average Resistance ($\overline{R}_1$)	=	26.51
	1	10	2.5750	0.1033	2.7000	0.1067	2.6375	0.1050	25.12
II	2	15	3.9000	0.1600	4.1000	0.1667	4.0000	0.1634	24.48
	3	20	5.3000	0.2167	5.5000	0.2217	5.4000	0.2192	24.64
							Average Resistance ($\overline{R}_2$)	=	24.75

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 586.29$ Ohms-cm

TABLE: A-59: CONCRETE RESISTIVITY DATA

Effect of Chloride

W/C Ratio	: 0.5	**Cross sectional area of specimen, (A)**	= 232.56 cm^2
Chloride Content	: 60 lb/cu yd.	**Length for voltage drop measurement, (L)**	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete		
Age	: 28 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	10	2.3600	0.0807	2.4600	0.0833	2.4100	0.0820	29.39
	2	15	3.7200	0.1283	3.7400	0.1283	3.7300	0.1283	29.07
	3	20	5.0500	0.1717	4.9000	0.1667	4.9750	0.1692	29.40
							Average Resistance ($\overline{R}_1$)	=	29.29
II	1	10	2.5000	0.0902	2.6000	0.0923	2.5500	0.0913	27.93
	2	15	3.8000	0.1383	3.9900	0.1400	3.8950	0.1392	27.98
	3	20	5.2000	0.1867	5.2000	0.1850	5.2000	0.1859	27.97
							Average Resistance ($\overline{R}_2$)	=	27.96

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 654.80 **Ohms-cm**

TABLE: A-60: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 30.00 lb/cu.yd.

Specimen Material Specifications : Oridnary Portland Cement Concrete

Period of moist curing after oven drying : 21 days

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Moist weight of specimen = 17.966 kg

Observation	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
		Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
1	10	2.2750	0.0388	2.2500	0.0387	2.2625	0.0388	58.31
2	20	4.5700	0.0808	4.5500	0.0800	4.5600	0.0804	56.72
3	30	7.0500	0.1217	7.0500	0.1217	7.0500	0.1217	57.93
4	40	9.4000	0.1667	9.4000	0.1633	9.4000	0.1650	56.97
5	45	11.6000	0.2033	11.6500	0.2067	11.6250	0.2050	56.71
6	50	12.9000	0.2267	12.9000	0.2250	12.9000	0.2259	57.11

Average Resistance $(\overline{R})$ = 57.29

Average Resistivity, $\overline{\rho} = \frac{\overline{R}A}{L}$ = 1310.51 Ohms-cm

TABLE: A-61: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu.yd.

Specimen Material Specifications : Oridnary Portland Cement Concrete

Period of moist curing after oven drying : 21 days

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Moist weight of specimen = 18.055 kg

Observation	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
1	10	1.8500	0.0433	1.8400	0.0433	1.8450	0.0433	42.61
2	20	3.7200	0.0892	3.7500	0.0900	3.7350	0.0896	41.69
3	30	5.8000	0.1367	5.8000	0.1367	5.8000	0.1367	42.43
4	40	7.7000	0.1800	7.7500	0.1817	7.7250	0.1809	42.70
5	50	9.6500	0.2267	9.6000	0.2250	9.6250	0.2259	42.61
6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R})$ = 42.41

Average Resistivity, $\bar{\rho} = \frac{\bar{R}A}{L}$ = 970.13 Ohms-cm

TABLE: A-62: CON' 'ETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 30.00 lb/cu.yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Period of moist curing after oven drying : 21 days

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Moist weight of specimen = 17.562 kg

Observation	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
1	10	1.7100	0.0483	1.8500	0.0520	1.7800	0.0502	35.46
2	20	3.5300	0.1000	3.6100	0.1033	3.5700	0.1017	35.10
3	30	5.3500	0.1500	5.4000	0.1500	0.5375	0.1500	35.83
4	40	7.0500	0.2000	7.0800	0.2000	6.0650	0.2000	35.33
5	45	7.8500	0.2217	7.8000	0.2200	7.8250	0.2209	35.42
6	-	-	-	-	-	-	-	-

Average Resistance $(\overline{R})$ = 35.43

Average Resistivity, $\overline{\rho} = \frac{\overline{R}A}{L}$ = 810.46 Ohms-cm

TABLE: A-63: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan(Fly Ash)

Age : 7 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.5000	0.0528	9.0000	0.0513	9.2500	0.0521	177.54
	2	80	24.7000	0.1333	24.5000	0.1333	24.6000	0.1333	184.55
	3	120	37.5000	0.2033	36.5000	0.2033	37.0000	0.2033	182.00
							Average Resistance ($\overline{R}_1$) =		181.36
II	1	30	10.0000	0.0500	9.8000	0.0500	9.9000	0.0500	198.00
	2	80	27.0000	0.1333	26.5000	0.1333	26.7500	0.1333	200.68
	3	120	40.0000	0.2000	39.5000	0.2000	39.7500	0.2000	198.75
							Average Resistance ($\overline{R}_2$) =		199.14

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 4351.97$ Ohms-cm

TABLE: A-64: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzlan (Fly Ash)

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	10.2000	0.0363	10.0000	0.0357	10.1000	0.0360	280.00
	2	90	29.4000	0.1033	29.5000	0.1017	29.4500	0.1025	287.32
	3	180	59.1000	0.2067	59.5000	0.2083	59.3000	0.2075	285.78
							Average Resistance ($\overline{R}_1$)	=	284.55
II	1	30	10.8500	0.0357	11.0000	0.0363	10.9250	0.0360	303.47
	2	90	31.2000	0.1017	31.5000	0.1017	31.3500	0.1017	308.360
	3	180	64.0000	0.2067	64.0000	0.2083	64.0000	0.2075	308.44

Average Resistance ($\overline{R}_2$) = 306.76

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{L} = 6763.11$ Ohms-cm

TABLE: A-65: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan(Fly Ash)

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
I	1	30	10.0000	0.0253	9.6500	0.0250	9.8250	0.0252	389.88
	2	100	32.5000	0.0813	31.0000	0.0817	31.7500	0.0815	389.57
	3	270	86.3000	0.2250	85.5000	0.2200	85.9000	0.2225	386.08
							Average Resistance ($\bar{R}_1$)	=	388.51
II	1	30	9.9200	0.0247	10.0000	0.0250	9.9600	0.0249	400.00
	2	100	32.5000	0.0800	32.0000	0.0808	32.2500	0.0804	401.12
	3	270	88.5000	0.2167	87.0000	0.2200	87/75	0.2184	401.79
							Average Resistance ($\bar{R}_2$)	=	400.79

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L}$ = 9029.69 Ohms-cm

TABLE: A-66: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan(Fly Ash)

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.5000	0.0220	9.3700	0.0217	9.4350	0.0219	430.82
I	2	100	31.0000	0.0717	30.0000	0.0722	30.5000	0.0720	423.61
	3	300	93.0000	0.2217	92.5000	0.2150	92.7500	0.2184	424.68
							Average Resistance ($\overline{R}_1$)	=	426.37
	1	30	10.1000	0.0217	10.0500	0.0223	10.0750	0.0220	457.96
II	2	100	33.2000	0.0733	32.2000	0.0727	32.7000	0.0730	447.95
	3	300	100.0000	0.2167	96.0000	0.2200	98.0000	0.2184	448.72
							Average Resistance ($\overline{R}_2$)	=	451.54

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 10041.10 Ohms-cm

TABLE: A-67: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.5000	0.0443	9.5000	0.0450	9.5000	0.0479	212.53
I	2	80	25.6000	0.1167	25.6000	0.1167	25.6000	0.1167	219.37
	3	150	48.2000	0.2200	48.2000	0.2200	48.2000	0.2200	219.09
							Average Resistance ($\overline{R}_1$) =		217.00
	1	30	10.0000	0.0455	9.6500	0.0450	9.8250	0.0453	216.89
II	2	80	26.5000	0.1167	26.1000	0.12000	26.3000	0.1189	222.13
	3	150	50.0000	0.2233	49.0000	0.2233	49.5000	0.2233	221.68
							Average Resistance ($\overline{R}_2$) =		220.23

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 5000.82$ Ohms-cm

TABLE: A-68: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.5000	0.0250	10.5000	0.0250	10.5000	0.0250	420.00
I	2	150	52.0000	0.1200	52.0000	0.1217	52.0000	0.1209	430.11
	3	270	92.5000	0.2167	92.2000	0.2200	92.3500	0.2184	422.85
							Average Resistance ($\overline{R}_1$)	=	424.32
	1	30	11.0000	0.0258	10.6500	0.0252	10.8250	0.0255	424.51
II	2	150	53.0000	0.1250	52.8000	0.1233	52.9000	0.1242	425.93
	3	270	93.5000	0.2233	94.0000	0.2200	93.7500	0.2217	422.87
							Average Resistance ($\overline{R}_2$)	=	424.44

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 9707.69$ Ohms-cm

TABLE: A-69: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.35 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)

Age : 21 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.2000	0.0167	10.8000	0.0168	10.5000	0.0168	625.00
I	2	180	62.0000	0.1000	63.0000	0.1000	62.5000	0.1000	625.00
	3	360	123.00	0.2017	125.0000	0.2067	124.0000	0.2042	607.25
							Average Resistance ($\overline{R}_1$) =		619.08
	1	30	10.4000	0.0173	10.2000	0.0173	10.3000	0.0173	595.38
II	2	180	61.3000	0.1033	61.0000	0.1033	61.1500	0.1033	591.97
	3	360	124.0000	0.2067	121.0000	0.2133	122.5000	0.2100	583.33
							Average Resistance ($\overline{R}_2$) =		590.23

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 13831.48$ Ohms-cm

TABLE: A-70: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	:	0.35
Chloride Content	:	0.0 lb/cu yd.
Specimen Material Specifications	:	Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)
Age	:	28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
	1	30	10.2500	0.0140	10.0000	0.0142	10.1250	0.01410	718.09
I	2	150	49.8000	0.0687	49.2000	0.0697	49.5000	0.06920	715.32
	3	420	140.0000	0.1867	136.0000	0.2067	138.0000	0.1967	701.58
							Average Resistance ($\bar{R}_1$)	=	711.66
	1	30	10.0000	0.0150	10.1000	0.0147	10.0500	0.0149	674.50
II	2	150	49.0000	0.0713	49.9000	0.0717	49.4500	0.0715	691.61
	3	420	136.0000	0.2167	141.0000	0.1950	138.50000	0.2059	672.66
							Average Resistance ($\bar{R}_2$)	=	679.59

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L} = 15912.42$ Ohms-cm

TABLE: A-71: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 7 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.1000	0.0675	9.3200	0.0677	9.2100	0.0676	136.24
I	2	60	17.7000	0.1333	18.5000	0.1333	18.1000	0.1333	135.78
	3	100	29.0000	0.2183	31.0000	0.2200	30.0000	0.2192	136.86
							Average Resistance ($\overline{R}_1$)	=	136.29
	1	30	9.0000	0.0667	9.2000	0.0673	9.1000	0.0670	135.82
II	2	60	18.0000	0.1333	18.4000	0.1333	18.2000	0.1333	136.53
	3	100	30.0000	0.2167	30.2000	0.2167	30.1000	0.2167	138.90
							Average Resistance ($\overline{R}_2$)	=	137.08

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 3126.67 Ohms-cm

TABLE: A-72: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
I	1	30	8.2000	0.0447	8.1200	0.0450	8.1600	0.0449	181.74
	2	80	22.6000	0.1167	22.0000	0.1200	22.3000	0.1184	188.35
	3	150	40.0000	0.2250	40.2000	0.2200	40.1000	0.2225	180.23
							Average Resistance ($\overline{R}_1$)	=	183.44
II	1	30	8.8000	0.0450	8.8000	0.0467	8.8000	0.0459	191.72
	2	80	22.7500	0.1167	22.7000	0.1200	22.7250	0.1184	191.93
	3	150	40.2000	0.2200	40.8000	0.2250	40.5000	0.2225	182.02
							Average Resistance ($\overline{R}_2$)	=	188.56

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 4254.75$ Ohms-cm

TABLE: A-73: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	10.5000	0.0377	10.3000	0.0360	10.4000	0.0369	281.84
	2	100	33.0000	0.1167	33.0000	0.1167	33.0000	0.1167	282.78
	3	180	61.0000	0.2167	61.0000	0.2133	61.0000	0.2150	283.72
							Average Resistance ($\overline{R}_1$)	=	282.78
II	1	30	9.9500	0.0358	10.3000	0.0367	10.1250	0.0363	278.93
	2	100	32.0000	0.1150	32.5000	0.1167	32.2500	0.1159	278.26
	3	180	59.0000	0.2100	60.0000	0.2133	59.5000	0.2117	281.06
							Average Resistance ($\overline{R}_2$)	=	279.42

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 6430.16 Ohms-cm

TABLE: A-74: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
I	1	30	9.5000	0.0275	9.4000	0.0268	9.4500	0.0272	347.43
	2	150	46.5000	0.1350	46.0000	0.1367	46.2500	0.1359	340.32
	3	240	72.5000	0.2183	71.0000	0.2167	71.7000	0.2175	329.66
							Average Resistance ($\bar{R}_1$)	=	339.14
II	1	30	9.8500	0.0273	10.5000	0.0288	10.1750	0.0281	362.10
	2	150	51.5000	0.1433	51.0000	0.1367	51.2500	0.1400	366.07
	3	240	81.0000	0.2233	81.0000	0.2233	81.0000	0.2233	362.74
							Average Resistance ($\bar{R}_2$)	=	363.64

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L} = 8038.05$ Ohms-cm

TABLE: A-75: CONCRETF RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
I	1	40	12.0000	0.0720	12.2000	0.0720	12.1000	0.0720	168.06
	2	80	24.0000	0.1433	24.0000	0.1417	24.0000	0.1425	168.42
	3	120	36.0000	0.2167	36.0000	0.2167	36.0000	0.2167	166.13
							Average Resistance ($\overline{R}_1$) =		167.54
II	1	40	11.0000	0.0712	11.6000	0.0717	11.3000	0.0715	158.04
	2	80	21.6000	0.1400	23.5000	0.1417	22.5500	0.1409	160.04
	3	120	32.0000	0.2150	36.0000	0.2133	34.0000	0.2142	158.73
							Average Resistance ($\overline{R}_2$) =		158.94

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 3734.12 Ohms-cm

TABLE: A-76: CONCRETF RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	: 0.45	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 0.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)		
Age	: 14 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.0000	0.0270	9.6000	0.0270	9.8000	0.0270	362.96
I	2	100	33.0000	0.0908	32.0000	0.0908	32.5000	0.0908	357.93
	3	240	77.6000	0.2167	78.6000	0.2183	78.1000	0.2175	359.08
						Average Resistance ($\overline{R}_1$)	=		359.99
	1	30	10.0000	0.0270	9.9000	0.0275	9.9500	0.0273	364.47
II	2	100	31.5000	0.0900	31.0000	0.0900	31.2500	0.0900	347.22
	3	240	77.0000	0.2167	75.0000	0.2167	76.0000	0.2167	350.72
						Average Resistance ($\overline{R}_2$)	=		354.14

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 8167.86 Ohms-cm

TABLE: A-77: CONCRETF RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	10.1500	0.2300	10.6000	0.0237	10.3750	0.0234	443.38
	2	150	50.6500	0.1133	51.5000	0.1133	51.0750	0.1133	450.79
	3	270	92.5000	0.2033	93.5000	0.2117	93.0000	0.2075	448.19
							Average Resistance $(\overline{R}_1)$	=	447.45
II	1	30	11.0000	0.0240	10.6500	0.0230	10.8250	0.0235	460.64
	2	150	53.0000	0.1150	53.0000	0.1133	53.0000	0.1142	464.10
	3	270	96.2000	0.2083	96.2000	0.2033	96.2000	0.2058	467.44
							Average Resistance $(\overline{R}_2)$	=	464.06

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 10425.40 Ohms-cm

TABLE: A-78: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.45 | Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. | Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)

Age : 28 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.5000	0.0182	10.2000	0.0178	10.3500	0.0180	575.00
I	2	180	60.8000	0.1033	60.0000	0.1033	60.4000	0.1033	584.71
	3	360	120.0000	0.2100	120.0000	0.2100	120.0000	0.2000	571.43
							Average Resistance ($\overline{R}_1$) =		577.05
	1	30	10.5000	0.0183	10.0000	0.0183	10.2500	0.0183	560.11
II	2	180	61.3000	0.1083	60.5000	0.1083	60.9000	0.1083	562.33
	3	360	122.0000	0.2167	120.0000	0.2167	121.0000	0.2167	558.48
							Average Resistance ($\overline{R}_2$) =		560.31

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 13008.55 Ohms-cm

TABLE: A-79: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	8.7000	0.0790	8.8500	0.0807	8.7750	0.0799	109.83
I	2	60	17.6500	0.1533	17.4000	0.1550	15.5250	0.1542	113.65
	3	85	25.0000	0.2183	25.4000	0.2167	25.2000	0.2175	115.86
							Average Resistance ($\overline{R}_1$) =		113.11
	1	30	8.9200	0.0763	8.8500	0.0783	8.8850	0.0773	114.94
II	2	60	17.5000	0.1500	17.5000	0.1517	17.5000	0.1509	115.97
	3	85	25	0.2117	24.2000	0.2133	24.6000	0.2125	115.77
							Average Resistance ($\overline{R}_2$) =		115.56

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 2615.41 Ohms-cm

TABLE: A-80: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 14 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.1000	0.0550	9.4000	0.0572	9.2500	0.0561	164.88
I	2	80	23.8000	0.1433	24.0000	0.1433	23.9000	0.1433	166.78
	3	120	33.8000	0.2183	35.8000	0.2217	34.8000	0.2200	158.18
							Average Resistance ($\overline{R}_1$) =		163.28
	1	30	9.8500	0.0532	10.2000	0.0555	10.0250	0.0544	184.28
II	2	80	26.0000	0.1367	26.0000	0.1367	26.0000	0.1367	190.20
	3	120	39.9000	0.2133	40.0000	0.2167	39.9500	0.2150	185.81
							Average Resistance ($\overline{R}_2$) =		186.76

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 4003.58 Ohms-cm

TABLE: A-81: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 21 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.4000	0.0413	9.3600	0.0408	9.3800	0.0411	228.22
	2	80	25.0000	0.1067	25.0000	0.1067	25.0000	0.1067	234.30
	3	150	47.0000	0.2067	47.0000	0.2033	47.0000	0.2050	229.27
							Average Resistance ($\overline{R}_1$) =		230.60
II	1	30	9.5500	0.0400	9.9000	0.0412	9.7250	0.0406	239.53
	2	80	25.6000	0.1050	25.6000	0.1050	25.6000	0.1050	243.81
	3	150	48.2000	0.2000	49.0000	0.2033	48.6000	0.2017	240.95
							Average Resistance ($\overline{R}_2$) =		241.43

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 5398.84$ Ohms-cm

TABLE: A-82: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzolan (Fly Ash)

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.4200	0.0297	9.5000	0.0302	9.4600	0.0300	315.33
	2	100	31.5000	0.1000	30.0000	0.0983	30.7500	0.0992	309.98
	3	210	65.5000	0.2117	65.0000	0.2150	65.2500	0.2134	305.76
							Average Resistance ($\overline{R}_1$) =		310.36
II	1	30	9.4000	0.0300	9.2000	0.0288	9.3000	0.0294	316.33
	2	100	30.0000	0.0967	30.8000	0.0973	30.4000	0.0970	313.40
	3	210	64.5000	0.2100	65.4000	0.2067	64.9500	0.2084	311.66
							Average Resistance ($\overline{R}_2$) =		313.80

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 7138.83 Ohms-cm

TABLE: A-83: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	: 0.55	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 0.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)		
Age	: 7 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	8.4000	0.0630	8.5500	0.0633	8.4750	0.0632	134.10
I	2	60	17.3500	0.1233	17.1500	0.1267	17.2500	0.1250	138.00
	3	100	28.0000	0.2067	28.0000	0.2067	28.0000	0.2066	135.46
							Average Resistance ($\overline{R}_1$)	=	135.85
	1	30	8.6100	0.0627	8.6300	0.0648	8.6200	0.0638	135.11
II	2	60	17.0000	0.1217	17.0000	0.1250	17.0000	0.1234	137.76
	3	100	28.4000	0.2033	27.0000	0.2050	27.7000	0.2042	135.65
							Average Resistance ($\overline{R}_2$)	=	136.17

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 3111.23$ Ohms-cm

TABLE: A-84: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd.

Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)

Age : 14 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.3000	0.0360	9.1500	0.0343	9.2250	0.0352	262.07
I	2	80	23.6000	0.0917	23.0000	0.0908	23.3000	0.0913	255.20
	3	195	52.5000	0.2250	53.0000	0.2200	52.7500	0.2225	237.08
							Average Resistance ($\overline{R}_1$) =		251.45
	1	30	9.3000	0.0350	8.3000	0.0337	8.8000	0.0344	255.81
II	2	80	23.7500	0.0897	20.5000	0.0892	22.1250	0.0895	247.21
	3	195	57.0000	0.2167	49.0000	0.2200	53.0000	0.2184	242.67
							Average Resistance ($\overline{R}_2$) =		248.56

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 5718.87 Ohms-cm

TABLE: A-85: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	: 0.55	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 0.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)		
Age	: 21 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.9200	0.0247	10.4000	0.0257	10.1600	0.0252	403.18
I	2	150	50.0000	0.1233	50.0000	0.1233	50.0000	0.1233	405.52
	3	270	89.0000	0.2183	90.0000	0.2267	89.5000	0.2225	402.25
							Average Resistance ($\overline{R}_1$)	=	403.65
	1	30	10.5000	0.0252	10.0000	0.0237	10.2500	0.0245	418.37
II	2	150	51.0000	0.1217	50.5000	0.1217	50.7500	0.1217	417.01
	3	270	90.1000	0.2200	90.5000	0.2167	90.3000	0.2184	413.46
							Average Resistance ($\overline{R}_2$)	=	416.28

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 9377.95$ Ohms-cm

TABLE: A-86: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.55

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan (Fly Ash)

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
	1	30	9.6200	0.0183	9.5200	0.0183	9.5700	0.0183	522.95
I	2	130	48.5000	0.0917	47.5000	0.0920	48.0000	0.0919	522.31
	3	360	118.0000	0.2167	118.0000	0.2267	118.0000	0.2217	532.25
								Average Resistance ($\overline{R}_1$) =	525.84
	1	30	9.4000	0.0183	9.5000	0.0183	9.4500	0.0183	516.39
II	2	150	46.8000	0.0917	47.8000	0.0918	47.3000	0.0918	515.25
	3	360	112.5000	0.2233	115.0000	0.2167	113.75	0.2200	517.05
								Average Resistance ($\overline{R}_2$) =	516.23

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 11918.68 Ohms-cm

TABLE: A-87: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzlan (Fly Ash)

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	20	5.9500	0.0547	5.9500	0.0547	5.9500	0.0547	108.78
I	2	50	14.9000	0.1333	14.9000	0.1333	14.9000	0.1333	111.78
	3	80	23.6000	0.2167	23.7000	0.2167	23.65	0.2167	109.14
								Average Resistance ($\overline{R}_1$) =	109.90
	1	20	6.1500	0.0563	5.8000	0.0522	5.9750	0.0543	110.04
II	2	50	14.9000	0.1333	15.0000	0.1333	14.9500	0.1333	112.15
	3	85	25.0000	0.2217	25.0000	0.2200	25.0000	0.2209	113.17
								Average Resistance ($\overline{R}_2$) =	111.79

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2535.58$ **Ohms-cm**

TABLE: A-88: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzlan (Fly Ash)

Age : 14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.1000	0.0570	9.1000	0.0570	9.1000	0.0570	159.65
I	2	60	18.5000	0.1133	18.2000	0.1133	18.3500	0.1133	161.96
	3	105	32.3000	0.2000	32.3000	0.2000	32.3000	0.2000	161.50
								Average Resistance ($\overline{R}_1$) =	161.04
	1	30	9.8000	0.0550	9.8000	0.0553	9.8000	0.0552	177.54
II	2	60	19.5000	0.1083	19.7000	0.1083	19.6000	0.1083	180.98
	3	105	35.0000	0.1933	34.8000	0.1933	34.9000	0.1933	180.55
								Average Resistance ($\overline{R}_2$) =	179.69

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 3879.10 Ohms-cm

TABLE: A-89: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	: 0.65	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 0.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	: Ordinary Portland Cement Concrete with 10% Pozzlan (Fly Ash)		
Age	: 21 days of moist curing		

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	9.7200	0.0433	10.0000	0.0442	9.8600	0.0438	225.11
I	2	100	31.5000	0.1367	31.5000	0.1367	31.5000	0.1367	230.43
	3	150	48.2000	0.2100	48.7000	0.2133	48.4500	0.2117	228.86
							Average Resistance ($\overline{R}_1$)	=	228.13
	1	30	10.3500	0.0440	10.2500	0.0428	10.3000	0.0434	237.33
II	2	100	33.0000	0.1367	33.2000	0.1350	33.1000	0.1359	243.56
	3	150	50.5000	0.2067	51.0000	0.2067	50.7500	0.2067	245.53
							Average Resistance ($\overline{R}_2$)	=	242.14

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 5378.71 Ohms-cm

TABLE: A-90: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 10% Pozzlan (Fly Ash)

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
I	1	30	9.7200	0.0327	9.5500	0.0322	9.6350	0.0325	296.46
	2	150	48.5000	0.1633	48.2000	0.1650	48.3500	0.1642	294.46
	3	210	67.3000	0.2283	67.1000	0.2250	67.2000	0.2267	296.48
							Average Resistance ($\overline{R}_1$)	=	295.80
II	1	30	9.6000	0.0317	9.8000	0.0318	9.6000	0.0318	301.89
	2	150	48.5000	0.1600	48.5000	0.1600	48.5000	0.1600	303.13
	3	210	68.0000	0.2200	68.5000	0.2217	68.25	0.2209	308.96
							Average Resistance ($\overline{R}_2$)	=	304.66

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 6867.76$ Ohms-cm

TABLE:A-91: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)

Age : 7 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current (Amps)	Voltage Drop (Volts)	Current (Amps)			
I	1	30	8.8000	0.0708	8.6000	0.0693	8.7000	0.0701	124.11
	2	70	20.4000	0.1600	20.4000	0.1600	20.4000	0.1600	127.50
	3	100	28.8000	0.2267	28.6000	0.2217	28.7000	0.2242	128.01
							Average Resistance ($\overline{R}_1$) =		126.54
II	1	30	8.3500	0.0693	8.4500	0.0707	8.4000	0.0700	120.00
	2	70	19.5000	0.1600	19.65	0.1633	19.5750	0.1617	121.06
	3	100	28.0000	0.2250	28.4000	0.2333	28.2000	0.2292	123.04
							Average Resistance ($\overline{R}_2$) =		121.37

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} = 2835.47$ Ohms-cm

TABLE: A-92: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio	:	0.65
Chloride Content	:	0.0 lb/cu yd.
Specimen Material Specifications	:	Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)
Age	:	14 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
	1	30	10.0000	0.0347	10.0000	0.0353	10.000	0.0350	285.70
I	2	100	32.1000	0.1133	32.5000	0.1133	32.300	0.1133	285.08
	3	180	58.5000	0.2050	59.2000	0.2067	58.85	0.2059	285.82
							Average Resistance ($\overline{R}_1$)	=	285.53
	1	30	9.5000	0.0347	9.5000	0.0347	9.5000	0.0347	273.78
II	2	100	31.5000	0.1133	31.5000	0.1133	31.5000	0.1133	278.02
	3	180	57.5000	0.2083	57.5000	0.2050	57.5000	0.2067	278.18
							Average Resistance ($\overline{R}_2$)	=	276.66

Average Resistivity, $\overline{\rho} = \frac{(\overline{R}_1 + \overline{R}_2)A}{2L} =$ 6430.05 Ohms-cm

TABLE: A-93: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65 — Cross sectional area of specimen, (A) = 232.56 cm^2

Chloride Content : 0.0 lb/cu yd. — Length for voltage drop measurement, (L) = 10.17 cm

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)

Age : 21 days of moist curing

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
I	1	30	9.6700	0.0200	9.7000	0.0207	9.6850	0.0204	474.76
	2	150	48.5000	0.1017	47.0000	0.1017	47.7500	0.1017	469.52
	3	300	97.0000	0.2000	95.0000	0.2033	96.0000	0.2017	475.95
							Average Resistance ($\bar{R}_1$)	=	473.41
II	1	30	10.2000	0.0203	9.6500	0.0200	9.9250	0.0202	491.34
	2	150	50.0000	0.1000	50.0000	0.1000	50.0000	0.1000	500.00
	3	300	100.0000	0.2033	100.0000	0.2017	100.0000	0,2025	493.83
							Average Resistance ($\bar{R}_2$)	=	495.06

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L} =$ 11076.87 Ohms-cm

TABLE: A-94: CONCRETE RESISTIVITY DATA

Effect of W/C Ratio

W/C Ratio : 0.65

Chloride Content : 0.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete with 25% Pozzolan(Fly Ash)

Age : 28 days of moist curing

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Specimen No.	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
	1	30	10.1000	0.0255	10.4000	0.0267	10.2500	0.0261	392.72
I	2	150	50.5000	0.1250	50.5000	0.1283	50.5000	0.1267	398.58
	3	255	85.0000	0.2100	85.0000	0.2167	85.0000	0.2134	398.31
							Average Resistance ($\bar{R}_1$)	=	396.54
	1	30	10.4000	0.0272	10.2000	0.0258	10.3000	0.0265	388.68
II	2	150	50.0000	0.1300	50.0000	0.1267	50.0000	0.1284	389.41
	3	255	83.5000	0.2183	83.5000	0.2133	83.5000	0.2158	386.93
							Average Resistance ($\bar{R}_2$)	=	388.34

Average Resistivity, $\bar{\rho} = \frac{(\bar{R}_1 + \bar{R}_2)A}{2L} =$ 8977.07 Ohms-cm

TABLE: A-95: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 1

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.384 kg

Moist Weight of Specimen = 18.026 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	100	17.00	13.33	17.00	13.33	17.00	13.33	1275.32
	2	210	35.50	28.33	36.00	28.67	35.75	28.50	1254.39
	3	255	43.50	35.00	43.00	35.00	43.25	35.00	1235.71
	4	360	61.00	48.83	62.50	50.00	61.75	49.42	1249.49
	5	390	67.00	53.67	66.00	52.00	66.50	52.84	1258.52
	6	420	67.50	52.50	71.00	55.80	69.25	54.15	1278.86

Average Resistance $(\overline{R}_D)$ = 1258.72

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L} = 28.793 \times 10^3$ ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	20	5.70	78.67	5.85	78.33	5.78	78.50	73.63
	2	35	9.99	133.33	10.26	136.67	10.13	135.00	75.04
	3	40	11.70	153.33	11.70	153.33	11.70	153.33	76.31
	4	45	12.90	170.00	13.20	175.00	13.05	172.50	75.65
	5	50	14.16	186.67	14.52	191.67	14.34	189.17	75.81
	6	60	17.40	233.30	17.40	233.30	17.40	233.33	74.58

Average Resistance $(\overline{R}_M)$ = 75.17

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L} = 1.720 \times 10^3$ ohm-cm

TABLE: A-96: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 2

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.342 kg

Moist Weight of Specimen = 18.008 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	15	4.40	50.00	4.80	53.33	4.60	51.67	89.03
	2	20	6.00	70.67	6.10	70.67	6.05	70.67	85.61
	3	30	9.10	103.33	9.35	108.33	9.23	105.83	87.22
	4	40	11.40	140.00	11.55	138.33	11.48	139.17	82.49
	5	50	14.22	170.00	14.46	175.00	14.34	172.50	83.13
	6	65	18.75	225.00	18.36	221.67	18.56	223.34	83.10

Average Resistance ($\bar{R}_M$) = 85.10

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L} = 1.947 \times 10^3$ ohm-cm

TABLE: A-97: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 3

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.330 kg

Moist Weight of Specimen = 18.023 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current x 10^{-3} $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	150	1.14	0.58	1.14	0.56	1.14	0.57	2000.00
	2	201	1.41	0.70	1.65	0.77	1.53	0.74	2067.57
	3	300	1.97	0.94	1.95	0.88	1.96	0.91	2153.85
	4	330	2.16	1.00	2.31	1.08	2.24	1.04	2153.85
	5	420	2.58	1.07	2.55	1.17	2.57	1.12	2294.64
	6	450	2.73	1.20	2.87	1.33	2.80	1.27	2204.72

Average Resistance $(\bar{R}_D)$ = 2145.77

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L} = 49.085 \times 10^3$ ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current x 10^{-3} $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	10	3.00	35.00	3.02	35.33	3.01	35.17	85.58
	2	20	6.14	72.00	6.14	72.00	6.14	72.00	85.28
	3	30	9.30	109.67	8.97	106.67	9.14	108.17	84.50
	4	40	11.70	136.67	11.70	140.83	11.70	138.75	84.32
	5	50	14.70	180.00	14.64	177.50	14.67	178.75	82.07
	6	60	17.70	213.33	17.70	213.35	17.70	213.34	82.97

Average Resistance $(\bar{R}_M)$ = 84.12

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L} = 1.924 \times 10^3$ ohm-cm

TABLE:A-98: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 4

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.320 kg

Moist Weight of Specimen = 18.017 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\bar{V}$) (Volts)	Average Current $\times 10^{-3}$ ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
			Voltage Drop (Volts)	Current $\times 10^{-3}$ (Amps)	Voltage Drop (Volts)	Current $\times 10^{-3}$ (Amps)			
Dry	1	100	0.74	0.21	0.72	0.22	0.73	0.22	3318.18
	2	150	1.09	0.28	1.07	0.30	1.08	0.29	3724.14
	3	210	1.55	0.43	1.50	0.43	1.53	0.43	3558.14
	4	255	1.88	0.53	1.84	0.57	1.86	0.55	3381.82
	5	300	2.26	0.68	2.19	0.65	2.23	0.67	3328.36
	6	330	2.49	0.74	2.46	0.77	2.48	0.76	3263.16

Average Resistance $(\bar{R}_D)$ = 3428.97

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L} = 78.438 \times 10^3$ ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Voltage Drop (Volts)	Current $\times 10^{-3}$ (Amps)	Voltage Drop (Volts)	Current $\times 10^{-3}$ (Amps)	Average Voltage Drop (Volts)	Average Current $\times 10^{-3}$ (Amps)	Average Resistance (Ohms)
Moist	1	10	3.32	37.00	3.00	33.33	3.16	35.17	89.85
	2	20	6.40	70.67	6.20	70.67	6.30	70.67	89.15
	3	30	9.60	105.00	9.30	100.00	9.45	102.50	92.20
	4	40	12.50	133.33	12.20	133.33	12.35	133.33	92.63
	5	50	15.60	168.33	15.20	166.67	15.40	167.50	91.94
	6	60	18.50	200.00	18.50	203.33	18.50	201.67	91.73

Average Resistance $(\bar{R}_M)$ = 91.25

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L} = 2.087 \times 10^3$ ohm-cm

TABLE:A-99: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 5

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.300 kg

Moist Weight of Specimen = 18.012 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_D$) =

Average Resistivity, $\overline{\rho}_D = \frac{\overline{R}_D A}{L}$ = ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	10	3.05	30.33	3.00	30.00	3.03	30.17	100.43
	2	20	6.20	61.50	6.15	61.33	6.18	61.42	100.62
	3	30	9.50	93.33	9.35	92.67	9.43	93.00	101.40
	4	40	13.00	128.33	12.60	125.00	12.80	126.67	101.05
	5	50	15.80	151.67	16.00	155.00	15.90	153.34	103.69
	6	70	22.50	216.67	22.20	216.67	22.35	216.67	103.15

Average Resistance ($\overline{R}_M$) = 101.72

Average Resistivity, $\overline{\rho}_M = \frac{\overline{R}_M A}{L} = 2.327 \times 10^3$ ohm-cm

TABLE: A-100: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 6

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement
Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.290 kg

Moist Weight of Specimen = 18.008 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\overline{R}_D)$ = -

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\overline{R}_M)$ = -

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-101: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 7

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.267 kg

Moist Weight of Specimen = 18.014 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current $\times 10^{-3}$ ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current $\times 10^{-3}$ ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE: A-102: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 8

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.270 kg

Moist Weight of Specimen = 18.016 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_D$) = -

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_M$) = -

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-103: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 9

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement
Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.269 kg

Moist Weight of Specimen = 18.022 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	100	2.42	0.26	2.25	0.30	2.34	0.28	8357.14
	2	150	3.38	0.46	3.38	0.49	3.38	0.48	7041.67
	3	210	3.65	0.72	3.70	0.65	3.68	0.69	5333.33
	4	255	4.75	0.88	4.55	0.92	4.65	0.90	5166.67
	5	300	4.80	1.17	4.95	1.07	4.88	1.12	4357.14
	6	260	6.25	1.38	5.70	1.50	5.98	1.44	4152.78

Average Resistance ($\bar{R}_D$) = 5734.79

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L} = 131.183 \times 10^3$ ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	20	5.55	53.33	5.55	53.33	5.55	53.33	104.07
	2	30	8.44	81.00	8.40	80.33	8.42	80.67	104.38
	3	40	11.25	108.33	11.15	106.67	11.20	107.50	104.19
	4	60	17.15	163.33	17.00	160.00	17.08	161.67	105.65
	5	70	20.85	188.33	20.00	188.33	20.03	188.33	106.36
	6	80	23.10	218.33	22.80	216.67	22.95	217.50	105.52

Average Resistance ($\bar{R}_M$) = 105.03

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L} = 2.403 \times 10^3$ ohm-cm

TABLE: A-104: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 10

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.269 kg

Moist Weight of Specimen = 18.024 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{\bar{R}}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{\bar{R}}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{\bar{R}}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{\bar{R}}_M A}{L}$ = - ohm-cm

TABLE: A-105: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 11

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.270 kg

Moist Weight of Specimen = 18.037 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-106: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 12

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.258 kg

Moist Weight of Specimen = 18.030 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current $\times 10^{-3}$ ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current $\times 10^{-3}$ ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE: A-107: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 13

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.240 kg

Moist Weight of Specimen = 18.034 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_D$) = -

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_M$) = -

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-108: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 14

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.240 kg

Moist Weight of Specimen = 18.041 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\overline{R}_D)$ = -

Average Resistivity, $\overline{\rho}_D = \frac{\overline{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\overline{R}_M)$ = -

Average Resistivity, $\overline{\rho}_M = \frac{\overline{R}_M A}{L}$ = - ohm-cm

TABLE: A-109: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 15

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.222 kg

Moist Weight of Specimen = 18.037 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	10	3.00	0.03	3.00	0.03	3.00	0.03	100.00
	2	30	9.00	0.08	9.00	0.08	9.00	0.08	112.50
	3	50	15.10	0.13	15.20	0.13	15.15	0.13	116.54
	4	70	22.00	0.18	21.50	0.18	21.75	0.18	120.83
	5	80	24.90	0.20	24.90	0.21	24.90	0.21	118.57
	6	90	27.80	0.23	27.50	0.23	27.65	0.23	120.22

Average Resistance ($\bar{R}_M$) = 114.78

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L} = 2.626 \times 10^3$ ohm-cm

TABLE:A-110: CONCRETE RESISTIVITY DATA

Effect of Wet'ing/Drying Cycle

Cycle No: 16

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Ordinary Portland Cement
Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.226 kg

Moist Weight of Specimen = 18.053 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)			
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_D$) = -

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L} =$ - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Average Voltage Drop (Volts)	Average Current (Amps)	Average Resistance (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_M$) = -

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L} =$ - ohm-cm

TABLE: A-111: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 17

W/C Ratio : 0.5	Cross sectional area of specimen, (A) = 232.56 cm^2
Chloride Content : 16.0 lb/cu yd.	Length for voltage drop measurement, (L) = 10.17 cm
Specimen Material Ordinary Portland Cement	Dry Weight of Specimen = 17.223 kg
Specifications : Concrete	Moist Weight of Specimen = 18.064 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Dry:

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Moist:

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE: A-112: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 18

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.212 kg

Moist Weight of Specimen = 18.070 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE: A-113: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 19

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.217 kg

Moist Weight of Specimen = 18.080 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{\bar{R}}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{\bar{R}}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{\bar{R}}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{\bar{R}}_M A}{L}$ = - ohm-cm

TABLE: A-114: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 20

W/C Ratio : 0.5

Chloride Content : 16.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.210 kg

Moist Weight of Specimen = 18.080 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	100	1.00	0.07	3.10	0.07	2.05	0.07	29.29×10^3
	2	180	8.20	0.12	6.50	0.12	7.35	0.12	61.25×10^3
	3	270	15.00	0.17	20.00	0.18	17.50	0.18	97.22×10^3
	4	330	26.10	0.23	26.00	0.22	26.05	0.23	113.26×10^3
	5	390	33.50	0.26	115.00	0.25	79.25	0.26	285.58×10^3
	6	480	148.00	0.31	150.00	0.32	149.00	0.32	465.63×10^3
								Average Resistance ($\overline{R}_D$) =	175.37×10^3
						Average Resistivity, $\overline{\rho}_D = \frac{\overline{R}_D A}{L}$ =	4.012×10^6 ohm-cm		
Moist	1	10	3.09	38.33	2.90	31.67	3.00	35.00	85.71
	2	20	5.92	66.33	5.80	65.00	5.86	65.67	89.23
	3	30	9.20	93.33	8.89	91.67	9.05	92.50	97.84
	4	40	12.10	126.67	12.00	125.00	12.05	125.84	95.76
	5	50	15.20	163.33	15.00	158.33	15.10	160.83	93.89
	6	65	20.00	216.67	19.60	213.33	19.80	215.00	92.10
								Average Resistance ($\overline{R}_M$) =	92.42
						Average Resistivity, $\overline{\rho}_M = \frac{\overline{R}_M A}{L}$ =	2.114×10^3 ohm-cm		

TABLE: A-115: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 1

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.260 kg

Moist Weight of Specimen = 17.869 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	90	17.00	56.67	17.00	57.00	17.00	56.84	299.10
	2	150	28.50	97.00	28.70	97.33	28.60	97.17	294.33
	3	210	40.70	135.00	40.70	135.00	40.70	135.00	301.48
	4	255	50.00	166.67	49.00	163.33	49.50	165.00	300.00
	5	300	59.00	196.67	59.00	190.00	59.00	193.33	305.17
	6	360	67.00	216.67	70.00	225.00	68.50	220.84	310.18

Average Resistance ($\overline{R}_D$) = 301.71

Average Resistivity, $\overline{\rho}_D = \frac{\overline{R}_D A}{L}$ = 6901.61 Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	15	4.65	83.33	4.65	83.33	4.65	83.33	55.80
	2	20	5.85	103.33	6.30	110.00	6.08	106.67	56.99
	3	25	7.55	136.67	7.50	135.00	7.52	135.84	55.36
	4	30	8.76	156.67	9.60	166.67	9.18	161.67	56.78
	5	35	10.44	188.33	10.26	186.67	10.35	187.50	55.20
	6	40	11.70	208.33	12.00	216.67	11.85	212.50	55.76

Average Resistance ($\overline{R}_M$) = 55.98

Average Resistivity, $\overline{\rho}_M = \frac{\overline{R}_M A}{L}$ = 1280.54 Ohms-cm

TABLE: A-116: CONCRETE RESISTIVITY DATA

Effect of Wetring/Drying Cycle

Cycle No: 2

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.209 kg

Moist Weight of Specimen = 17.884 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	150	20.00	52.50	19.00	50.83	19.50	51.67	377.40
	2	255	34.50	92.00	35.00	94.17	34.75	93.08	373.33
	3	330	48.20	126.67	46.30	121.67	47.25	124.17	380.53
	4	384	59.00	153.33	60.20	163.33	59.60	158.33	376.43
	5	420	70.00	186.67	68.00	183.33	69.00	185.00	372.97
	6	450	78.00	213.33	80.00	221.67	79.00	217.50	363.22

Average Resistance ($\bar{R}_D$) = 373.98

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = 8554.79 Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	10	3.00	50.50	3.30	50.50	3.15	50.50	62.38
	2	15	4.85	81.33	4.80	80.50	4.83	80.92	59.69
	3	25	7.80	138.33	8.05	133.33	7.93	130.83	60.61
	4	30	9.50	153.33	9.20	153.33	9.35	153.33	60.98
	5	40	11.70	200.00	11.94	215.00	11.82	207.50	58.37
	6	45	13.35	233.33	13.05	223.33	13.20	228.33	57.81

Average Resistance ($\bar{R}_M$) = 59.97

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = 1371.81 Ohms-cm

TABLE: A-117: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 3

W/C Ratio	: 0.5	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 30.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material	Ordinary Portland Cement	Dry Weight of Specimen	= 17.188 kg
Specifications	: Concrete	Moist Weight of Specimen	= 17.846 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	150	0.54	0.82	0.57	0.87	0.56	0.85	658.82
	2	201	0.69	1.08	0.72	1.08	0.71	1.08	657.40
	3	255	0.86	1.33	0.81	1.17	0.86	1.25	688.00
	4	330	1.13	1.03	1.10	1.07	1.12	1.05	1066.67
	5	420	1.45	1.50	1.38	1.35	1.42	1.43	993.00
	6	450	1.56	1.58	1.56	1.70	1.56	1.64	951.12

Average Resistance ($\overline{R}_D$) = 835.84

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L}$ = 19119.83 Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	10	3.15	56.67	2.90	51.33	3.03	54.00	56.11
	2	20	6.30	108.33	6.03	103.33	6.17	105.83	58.30
	3	25	7.50	133.30	7.45	130.00	7.48	131.65	56.82
	4	30	9.22	160.00	9.00	153.33	9.11	156.67	58.15
	5	35	9.90	185.00	9.99	183.33	9.95	184.17	54.03
	6	40	11.70	213.33	11.40	206.67	11.55	210.00	55.00

Average Resistance ($\overline{R}_M$) = 56.367

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L}$ = 1289.40 Ohms-cm

TABLE: A-118: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 4

W/C Ratio	: 0.5	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 30.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material Specifications	Ordinary Portland Cement : Concrete	Dry Weight of Specimen	= 17.184 kg
		Moist Weight of Specimen	= 17.831 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	100	0.36	0.59	0.32	0.52	0.34	0.56	607.14
	2	150	0.56	0.86	0.56	0.92	0.56	0.89	629.21
	3	210	0.87	1.38	0.79	1.27	0.83	1.33	624.06
	4	255	0.99	1.67	1.01	1.77	1.00	1.72	581.40
	5	300	1.38	2.42	1.20	2.10	1.29	2.26	570.80
	6	330	1.53	2.70	1.53	2.77	1.53	2.74	558.40
								Average Resistance $(\overline{R}_D)$ =	595.17
						Average Resistivity, $\overline{\rho}_D = \frac{\overline{R}_D A}{L}$ = 13614.51 Ohms-cm			
Moist	1	10	3.20	54.00	2.90	48.67	3.05	51.34	59.41
	2	15	4.44	75.00	4.72	80.00	4.58	77.50	59.10
	3	20	6.40	103.33	6.10	100.00	6.25	101.67	61.47
	4	30	9.00	150.00	9.00	150.00	9.00	150.00	60.00
	5	40	12.00	200.00	12.00	200.00	12.00	200.00	60.00
	6	45	13.40	223.33	13.60	226.67	13.50	225.00	60.00
								Average Resistance $(\overline{R}_M)$ =	59.99
						Average Resistivity, $\overline{\rho}_M = \frac{\overline{R}_M A}{L}$ = 1372.27 Ohms-cm			

TABLE: A-119: CONCRETE RESISTIVITY DATA

Effect of Wetring/Drying Cycle

Cycle No: 5

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.165 kg

Moist Weight of Specimen = 17.841 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	10	2.80	46.33	3.02	50.33	2.91	48.33	60.21
	2	20	6.10	100.00	6.00	100.00	6.05	100.00	60.50
	3	30	8.65	143.33	8.70	143.33	8.68	143.33	60.56
	4	35	10.50	170.00	10.20	166.67	10.35	168.33	61.49
	5	40	12.00	190.00	12.00	190.00	12.00	190.00	63.16
	6	45	13.50	216.67	13.50	220.00	13.50	218.33	61.83

Average Resistance ($\bar{R}_M$) = 61.29

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = 1402.00 Ohms-cm

TABLE: A-120: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 6

W/C Ratio	: 0.5
Chloride Content	: 30.0 lb/cu yd.
Specimen Material Specifications	Ordinary Portland Cement : Concrete
Cross sectional area of specimen, (A)	= 232.56 cm^2
Length for voltage drop measurement, (L)	= 10.17 cm
Dry Weight of Specimen	= 17.155 kg
Moist Weight of Specimen	= 17.841 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Dry	1	100	2.60	1.67	2.60	1.70	2.60	1.69	1538.46
	2	150	3.94	2.83	3.80	2.43	3.87	2.63	1471.48
	3	210	5.53	4.00	5.40	3.87	5.47	3.94	1388.32
	4	255	7.12	5.53	7.40	6.00	7.26	5.77	1258.23
	5	300	8.60	7.63	8.20	6.67	8.40	7.15	1174.83
	6	330	10.50	9.30	10.60	9.67	10.55	9.49	1111.70

Average Resistance ($\overline{R}_D$) = 1323.84

Average Resistivity, $\overline{\rho}_D = \frac{\overline{R}_D A}{L}$ = 30282.83 Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\overline{V}$) (Volts)	Average Current x 10^{-3} ($\overline{I}$) (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\overline{R}_M$) = -

Average Resistivity, $\overline{\rho}_M = \frac{\overline{R}_M A}{L}$ = - . Ohms-cm

TABLE: A-121: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 7

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.130 kg

Moist Weight of Specimen = 17.853 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-122: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 8

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.130 kg

Moist Weight of Specimen = 17.857 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current $\times 10^{-3}$ $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current $\times 10^{-3}$ $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-123: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 9

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Specifications : Ordinary Portland Cement Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.128 kg

Moist Weight of Specimen = 17.858 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop $(\overline{V})$ (Volts)	Average Current x 10^{-3} $(\overline{I})$ (Amps)	Average Resistance $\overline{R} = \overline{V}/\overline{I}$ (Ohms)
			Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)			
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\overline{R}_D)$ = -

Average Resistivity, $\overline{\rho}_D = \frac{R_D A}{L}$ = - Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Right: Voltage Drop (Volts)	Right: Current x 10^{-3} (Amps)	Left: Voltage Drop (Volts)	Left: Current x 10^{-3} (Amps)	Average Voltage Drop (Volts)	Average Current x 10^{-3} (Amps)	Average Resistance (Ohms)
Moist	1	10	2.80	45.33	2.60	42.00	2.70	43.67	61.83
	2	20	5.30	86.67	5.37	87.50	5.34	87.09	61.32
	3	30	8.30	133.33	8.40	133.33	8.35	133.33	62.63
	4	40	10.90	173.33	11.00	175.00	10.95	174.17	62.87
	5	45	12.25	198.33	12.49	200.00	12.37	199.17	62.11
	6	50	13.75	220.00	13.90	220.00	13.83	220.00	62.84

Average Resistance $(\overline{R}_M)$ = 62.27

Average Resistivity, $\overline{\rho}_M = \frac{R_M A}{L}$ = 1424.43 Ohms-cm

TABLE: A-124: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 10

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.114 kg

Moist Weight of Specimen = 17.864 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-125: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 11

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm²

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.111 kg

Moist Weight of Specimen = 17.878 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-126: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 12

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.095 kg

Moist Weight of Specimen = 17.877 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop $(\bar{V})$ (Volts)	Average Current x 10^{-1} $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
			Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)			
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Average Voltage Drop (Volts)	Average Current (Amps)	Average Resistance (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-127: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 13

W/C Ratio	: 0.5	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 30.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material	Ordinary Portland Cement	Dry Weight of Specimen	= 17.082 kg
Specifications	: Concrete	Moist Weight of Specimen	= 17.883 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE:A-128: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 14

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.081 kg

Moist Weight of Specimen = 17.895 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current x 10^{-3} $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current x 10^{-3} $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - Ohms-cm

TABLE: A-129: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 15

W/C Ratio	: 0.5	Cross sectional area of specimen, (A)	= 232.56 cm^2
Chloride Content	: 30.0 lb/cu yd.	Length for voltage drop measurement, (L)	= 10.17 cm
Specimen Material	Ordinary Portland Cement	Dry Weight of Specimen	= 17.051 kg
Specifications	: Concrete	Moist Weight of Specimen	= 17.900 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	100	0.04	0.06	0.12	0.06	0.08	0.06	1333.33
	2	150	0.17	0.09	0.08	0.09	0.13	0.09	1444.44
	3	210	0.21	0.13	0.17	0.13	0.19	0.13	1461.54
	4	255	0.27	0.17	0.21	0.16	0.24	0.17	1411.77
	5	300	0.31	0.19	0.25	0.19	0.28	0.19	1473.68
	6	420	0.46	0.28	0.36	0.27	0.40	0.28	1428.57

Average Resistance ($\bar{R}_D$) = 1425.56

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = 32609.67 Ohms-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	10	2.46	47.67	2.44	48.00	2.45	47.83	51.22
	2	20	5.10	100.00	5.10	100.00	5.10	100.00	51.00
	3	30	7.61	150.00	7.63	150.00	7.62	150.00	50.80
	4	40	10.10	200.00	10.50	206.67	10.30	203.33	50.66
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = 50.92

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = 1164.80 Ohms-cm

TABLE: A-130: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 16

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.043 kg

Moist Weight of Specimen = 17.918 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current $\times 10^{-3}$ $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current $\times 10^{-3}$ $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-131: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 17

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.042 kg

Moist Weight of Specimen = 17.935 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current $\times 10^{-3}$ $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_D)$ = -

Average Resistivity, $\bar{\rho}_D = \frac{R_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current $\times 10^{-3}$ (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current $\times 10^{-3}$ (Amps)	Average Voltage Drop $(\bar{V})$ (Volts)	Average Current $\times 10^{-3}$ $(\bar{I})$ (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance $(\bar{R}_M)$ = -

Average Resistivity, $\bar{\rho}_M = \frac{R_M A}{L}$ = - ohm-cm

TABLE: A-132: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 18

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material : Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.016 kg

Moist Weight of Specimen = 17.938 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE: A-133: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 19

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.020 kg

Moist Weight of Specimen = 17.954 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right		Current Flow Reversed to Left		Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
			Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)			
Dry	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_D$) = -

Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = - ohm-cm

Condition	Observation No.	Applied Voltage (Volts)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Voltage Drop (Volts)	Current x 10^{-3} (Amps)	Average Voltage Drop (Volts)	Average Current (Amps)	Average Resistance (Ohms)
Moist	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-

Average Resistance ($\bar{R}_M$) = -

Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = - ohm-cm

TABLE: A-134: CONCRETE RESISTIVITY DATA

Effect of Wetting/Drying Cycle

Cycle No: 20

W/C Ratio : 0.5

Chloride Content : 30.0 lb/cu yd.

Specimen Material Ordinary Portland Cement

Specifications : Concrete

Cross sectional area of specimen, (A) = 232.56 cm^2

Length for voltage drop measurement, (L) = 10.17 cm

Dry Weight of Specimen = 17.010 kg

Moist Weight of Specimen = 17.948 kg

Condition	Observation No.	Applied Voltage (Volts)	Current Flow to Right: Voltage Drop (Volts)	Current Flow to Right: Current x 10^{-3} (Amps)	Current Flow Reversed to Left: Voltage Drop (Volts)	Current Flow Reversed to Left: Current x 10^{-3} (Amps)	Average Voltage Drop ($\bar{V}$) (Volts)	Average Current x 10^{-3} ($\bar{I}$) (Amps)	Average Resistance $\bar{R} = \bar{V}/\bar{I}$ (Ohms)
Dry	1	100	0.48	0.08	0.63	0.08	0.56	0.08	7000.00
	2	150	0.69	0.08	0.52	0.09	0.61	0.09	6777.77
	3	240	0.82	0.14	0.88	0.15	0.85	0.15	5666.67
	4	360	1.20	0.20	1.00	0.20	1.10	0.20	5500.00
	5	420	1.70	0.24	1.15	0.25	1.43	0.25	5720.00
	6	510	1.90	0.28	1.45	0.30	1.68	0.29	5793.10
								Average Resistance ($\bar{R}_D$) =	6076.26
								Average Resistivity, $\bar{\rho}_D = \frac{\bar{R}_D A}{L}$ = 138.99 x 10^3 ohm-cm	
Moist	1	10	2.75	62.00	2.75	62.00	2.75	62.00	44.35
	2	20	5.70	120.00	5.76	120.00	5.73	120.00	47.75
	3	30	8.50	186.67	8.55	186.67	8.53	186.67	45.69
	4	35	10.00	220.00	10.00	220.00	10.00	220.00	45.46
	5	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-
								Average Resistance ($\bar{R}_M$) =	45.81
								Average Resistivity, $\bar{\rho}_M = \frac{\bar{R}_M A}{L}$ = 1047.90 Ohms-cm	

TABLE: A-135 DATA ON CORROSION OF BARS AND CONCRETE RESISTIVITY VALUES

Cover : 0.65 to 0.85 inches

Absorption : 3.85 to 4.30

Chloride Content: 6 to 8 lb/cu.yd.

Core	Loss of Metal (%)	Cross Sectional area of Speciman (A) (cm^2)	Length for Voltage Drop Measurement (L) (cm)	Resistance (Ohm)	Resistivity (ohm-cm)
1-4	11.60	36.32	3.20	1300.00	14755.00
1-3	12.20	37.39	2.75	1150.00	15635.81
3-2	22.40	38.49	3.50	1280.00	14076.34
5-2	38.80	35.26	4.10	1480.00	12728.00
5-1	34.62	14.52	7.80	6600.00	12286.15
3-1	72.85	37.39	5.95	1250.00	7855.04

TABLE: A-136: CONCRETE ABSORPTION DATA
Effect of Chloride Content and Age

W/C Ratio : 0.5

Specimen Material Specifications : Ordinary Portland Cement Concrete.

Age (days)	Chloride Content lb/cu.yd.			
	16		30	
	Dry Weight of Specimen (kg)			
	17.296		17.148	
	Moist Weight of Specimen (kg)	Absorption (% dry weight)	Moist Weight of Specimen (kg)	Absorption (% dry weight)
13	18.173	5.07	18.066	5.35
21	18.185	5.14	18.072	5.39
40	18.200	5.23	18.090	5.49
60	18.198	5.22	18.083	5.45

TABLE: A-137: CONCRETE ABSORPTION DATA
Effect of Water-Cement Ratio

Chloride Content :30.00 lb/cu.yd.

Specimen Material Specifications :Ordinary Portland Cement Concrete

Age (days)	Water-Cement Ratio					
	0.45		0.50		0.65	
	Dry Weight of Specimen (kg)					
	17.083		17.138		16.294	
	Moist Weight of Specimen (kg)	Absorption (% dry weight)	Moist Weight of Specimen (kg)	Absorption (% dry weight)	Moist Weight of Specimen (kg)	Absorption (% dry weight)
8	17.952	5.09	18.040	5.26	17.550	7.71
21	17.966	5.17	18.055	5.35	17.562	7.78
32	17.973	5.21	18.060	5.38	17.569	7.83
55	17.984	5.27	18.063	5.40	17.574	7.86