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EFFECT OF HYDRATION ON THE ELECTRIC PROPERTIES OF CEMENT AND CONCRETE

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ABSTRACT

Through this work, variations of resistivity and dielectric constant of cement paste and concrete, for different water/ cement ratios with time after mixing, are shown. Adding some chemicals (admixtures) with different percentages to retard or to accelerate the chemical process shows changes in the internal temperature behaviour which affects the hydration process.

The components temperatures effects on the mixture temperature and cooling process to control the starting temperature of the mixture to slow down the hydration of the mixture are briefly mentioned.

INTRODUCTION

Over the last few years attention has been drawn to the use of electrical properties of cement paste and concrete as a technique for measuring the degree of hydration, and hence their hardening and strength characteristics. It is possible to change some of the properties of the cement in hand by the use of a suitable additive. Admixtures may be classified according to the purpose for which they are used in concrete. The addition of accelerators to the mix increases the rate of development of strength. This increases the rate of heat libration during the first few hours after mixing; the action of accelerators being probably that of a catalyst in the reactions hydration of C_3S (Tricalcium Silicate) and C_2S (Dicalcium Silicate). The hydration of C_3A (Tricalcium aluminate) is delayed some what, but normal process of hydration of cement is not changed [1].

Hamid [2] used a capacitive moisture probe for the prefabricated concrete industry. It should be pointed out that his system, regardless of however preliminary experimentations in the laboratory have indicated positively, more extensive experimentation and actual adaptation on to existing industrial machinery must be performed before an operating system is produced.

McCarter and Afshar [3] described a preliminary investigation into the electrical properties of cement pastes during the first 24 hours after gauging with water. Khalil and Ward [4] used an isothermal conduction calorimeter to study the effect of sulphate content of cement upon heat evolution of concrete.

In this work, variations of resistivity and dielectric constant of concrete for different water/cement ratios (w/c) with time after mixing are shown. Also the influence of admixtures and frequency on the dielectric properties and on the internal temperature are shown.

2. Experimental Procedure and Results

2.a Procedure

Some investigators [2] have measured the electrical properties of concrete by embedding rod electrodes into the mix. In this case it is difficult to know which area should be used for calculating the electrical properties. To measure these values with an acceptable accuracy, it is essential that the current traverses the full area of the specimen, which can be ensured by using a parallel plate capacitor of the same shape as the surface of the specimen. A parallel plate capacitor is especially designed for this purpose. It consists of an insulating frame supporting two plates, one is stationary and the other is movable. The adjustment should become necessary to correct the parallel adjustment of the plates. RLC Bridge (LEADER) model (LCR. 740) with a range from 0.01 Ω to 11M Ω, for resistance measurements, and from 1 pf to 11,000 μf, for capacitance measurements, was used in this work. Also, a sine-square Audio Generator (HEATHKIT) model (IG. 18) which has a range from zero to 10^5 Hz and automatic voltage compensator (PHONOVOX) were used. The internal temperature was measured by using thermocouple sensor type K(Nickel-Chromium/Nickel-Aluminium) which has a range from $-50^{\circ}C$ to $+1200^{\circ}C$ with ar accuracy of $\pm$ 0.35 % per $50^{\circ}C$. The uncertainty in measurin(is better than $\pm$ 3 %.

Each mixture of concrete in these tests has a constant rati of stone, sand, and ordinary portland cement (OPC) 2:1:1 After addition of water, the mixture was homogenize completely. This stage needs about ten minutes to be achive ed. In this work glucose (as a retarder) and calcium nitra((as an accelerator), with different ratios, dissolved in t! gauging water before addition to the mix were used. T amount added is a fixed percentage, by weight, of cemen

2.b. The Results

2.b.1. Influence of water content on the dielectric consta

Figure (1) shows the behaviour of the dielectric constant (ε) at the setting period (6 hrs) for specimens of 0. cm thickness and different water/cement (w/c), namely 0.4 0.47, and 0.52 respectively. The measurements were perforr at a fixed frequency of 50 KHz. The figure indicates tl the value of the dielectric contant (ε) increases with increase of the water content ratio.

2.b.2 The influence of admixtures on the resistivity (ρ) and the dielectric constant (ε) during the first 36 hrs.

The results are given in Figures (2 and 3) where ρ or plotted versus time up to 36 hrs. after gauging with wa For straighforward comparison the water/cement ratio (was kept constant (at 0.50) as well as frequency of

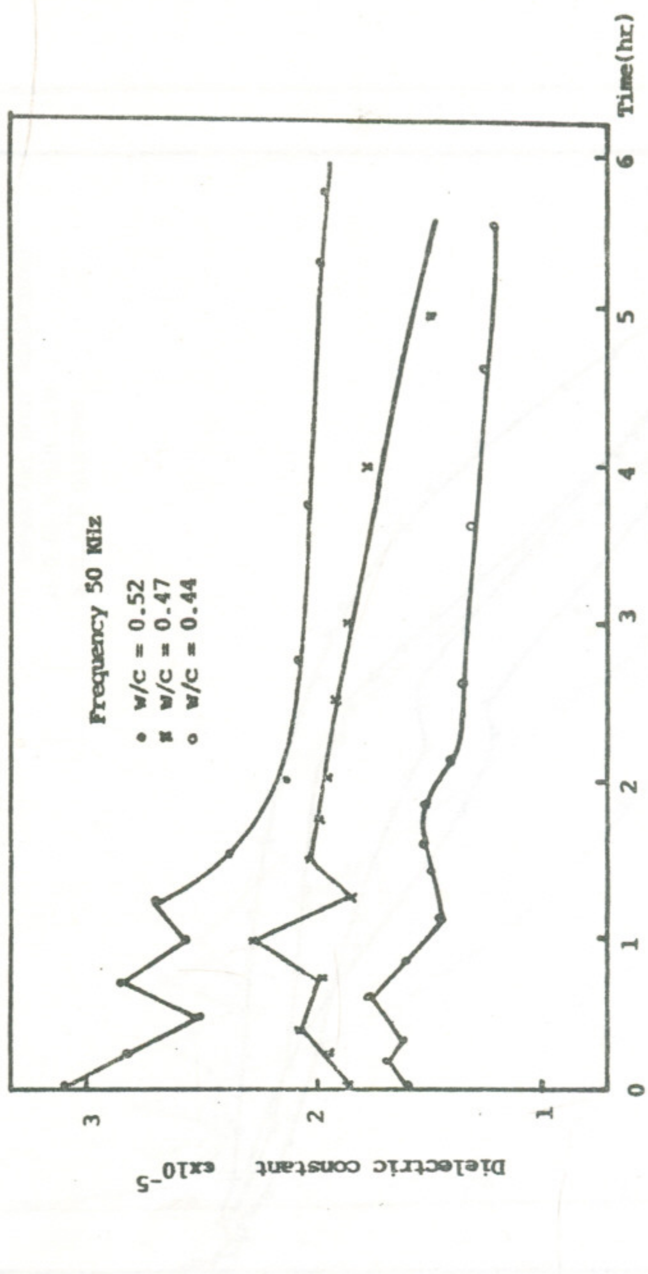

Figure (1) Variation of dielectric constant versus time during the setting period for different water cement ratios (w/c) and frequency 50 KHz.

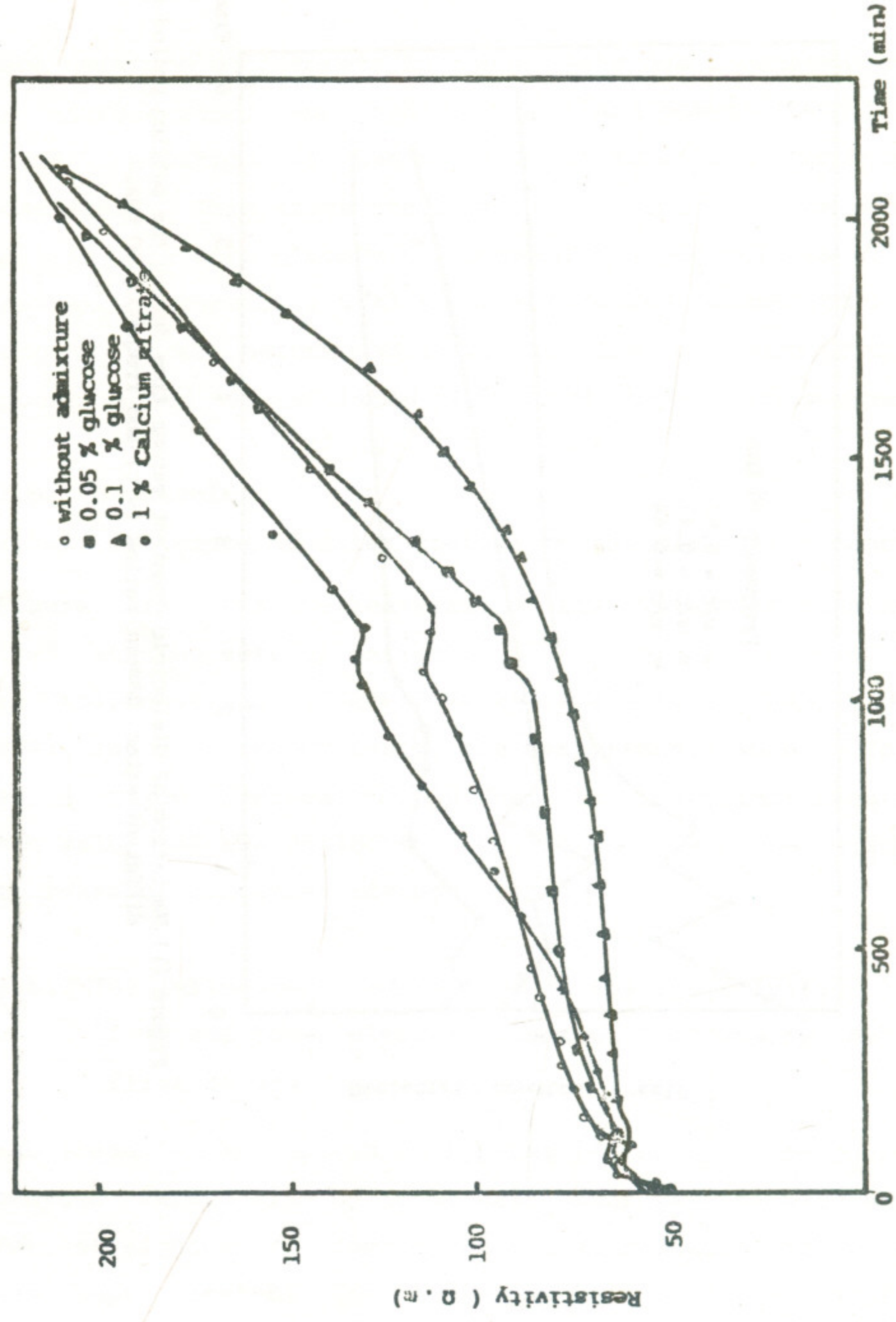

Figure (2) Variation of resistivity during the first 36 hrs. with adding admixture for frequency 10 KHz.

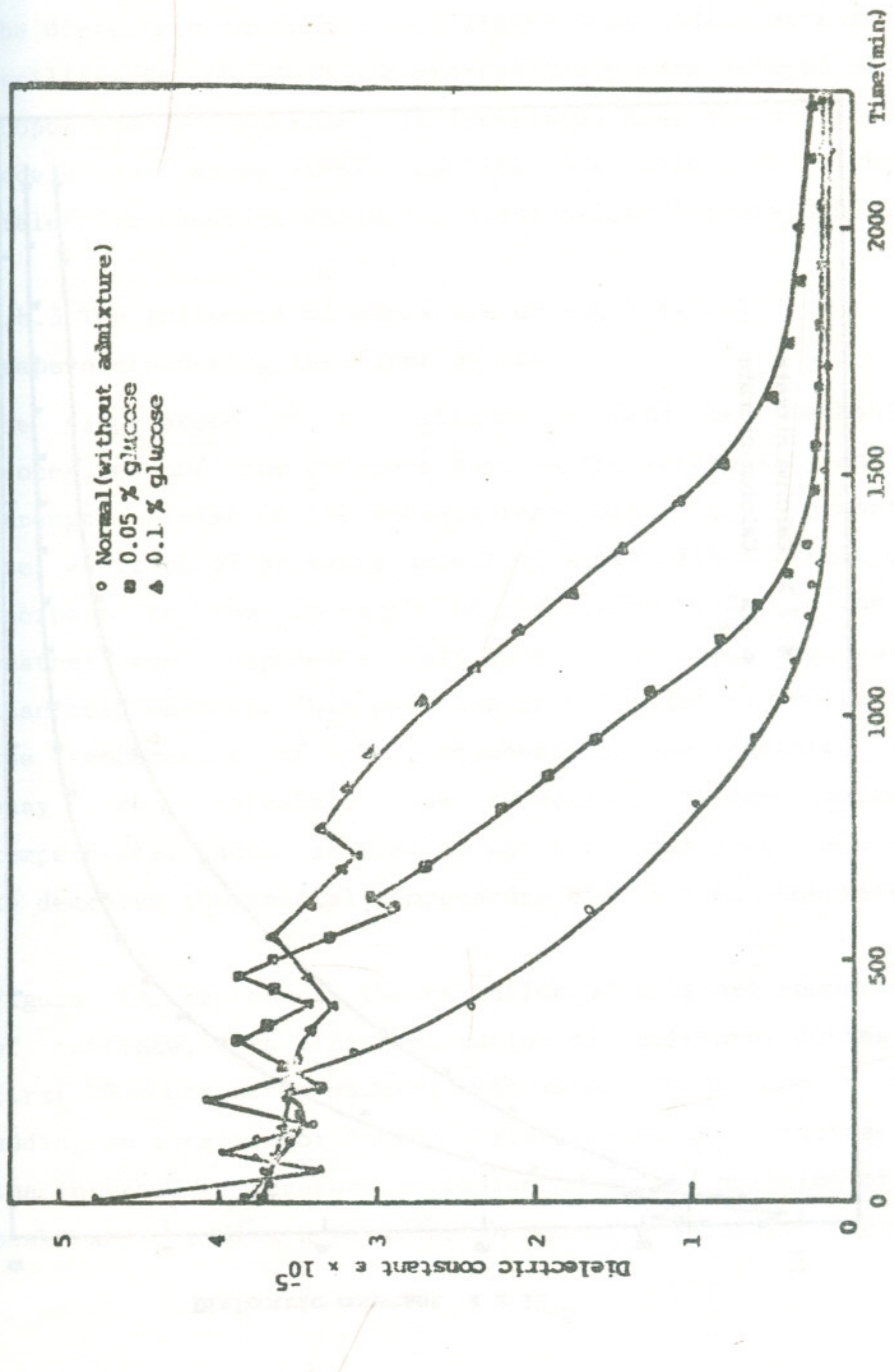

Figure (3-a) Variation of dielectric constant during the first 36 hrs. with adding admixture for frequency 10 kHz.

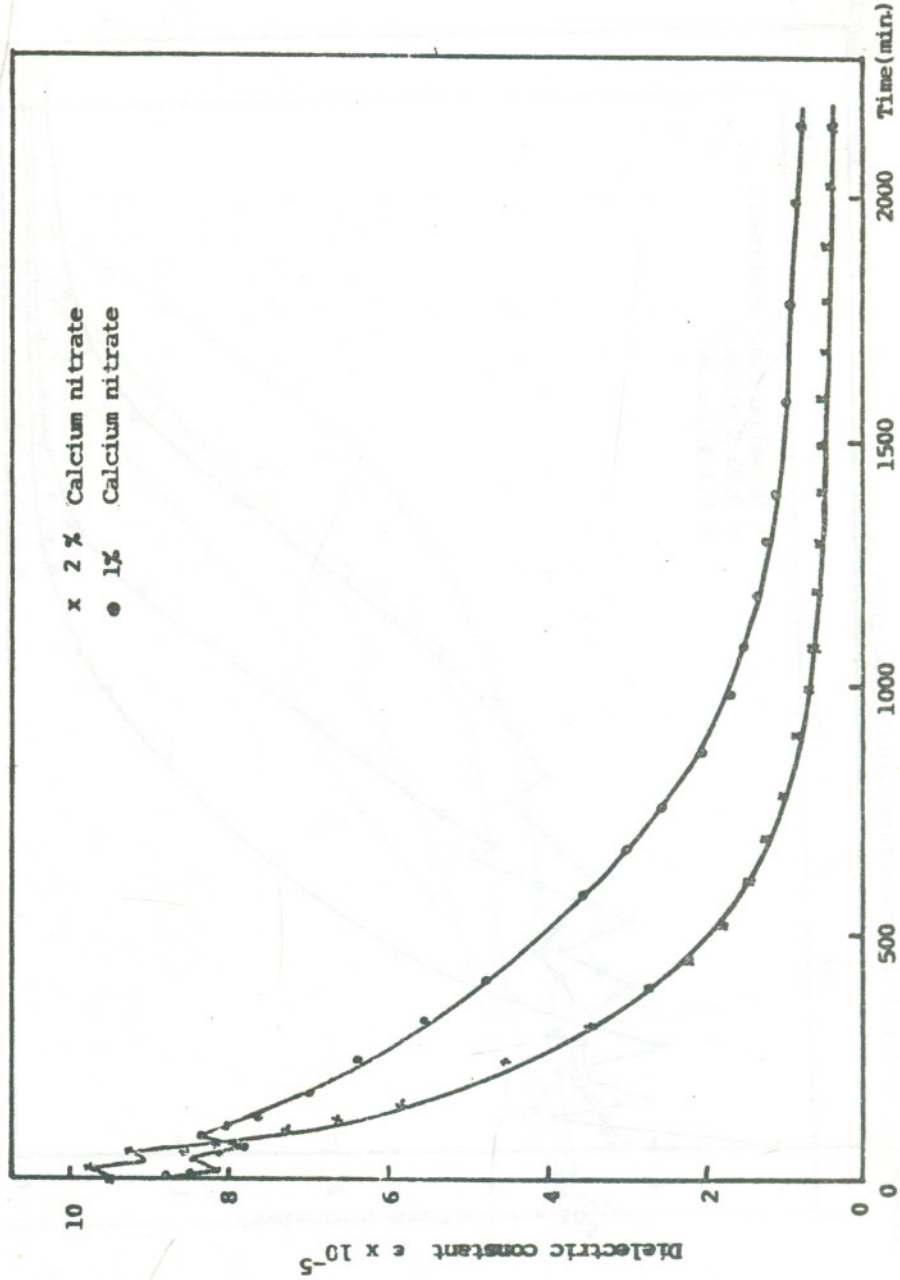

Figure (3-b) Variation of dielectric constant during the first 36 hrs. with adding admixture for frequency 10 KHz.

applied electric field at 10 KHz. Figure (2) shows the influence of the addition of admixtures on the electrical resistivity (ρ), while Figures 3 (a,b) show this effect on the dielectric constant (ε). Figure 3(a) indicates that the oscillations in " ε " are progressively more delayed as the proportion of retarder is increased. Also the addition of accelerator makes these oscillations, associated with the dielectric constant curve, to occur ealier (Figure 3(b)).

2.b.3 The influence of admixture on the internal temperature during the first 36 hrs.

The temperature of the mixture affects the mechanical properties of the concrete such as the workability and the strength. A rise in the ambient temperature would necessiate the addition of an extra amount of water with a result of a decrease in the strength of the concrete. So, in the hot weather the components must be mixed at lower temperature than cold weather. This case can be satisfied by controlling the temperature of the components of the concrete. It is easy to calculate the reduction in any component temperature, such as that of water or aggregate, necessary to decrease the initial temperature of the fresh concrete.

Figure (4) represents the variation of internal temperature of concrete, with different ratios of admixture, during the first 36 hours after gauging with water. The figure shows that, adding an accelerator to the mixture leads to an increase of the internal temperature as indicated by the position of the peak, while adding a retarder an opposite situation occurs.

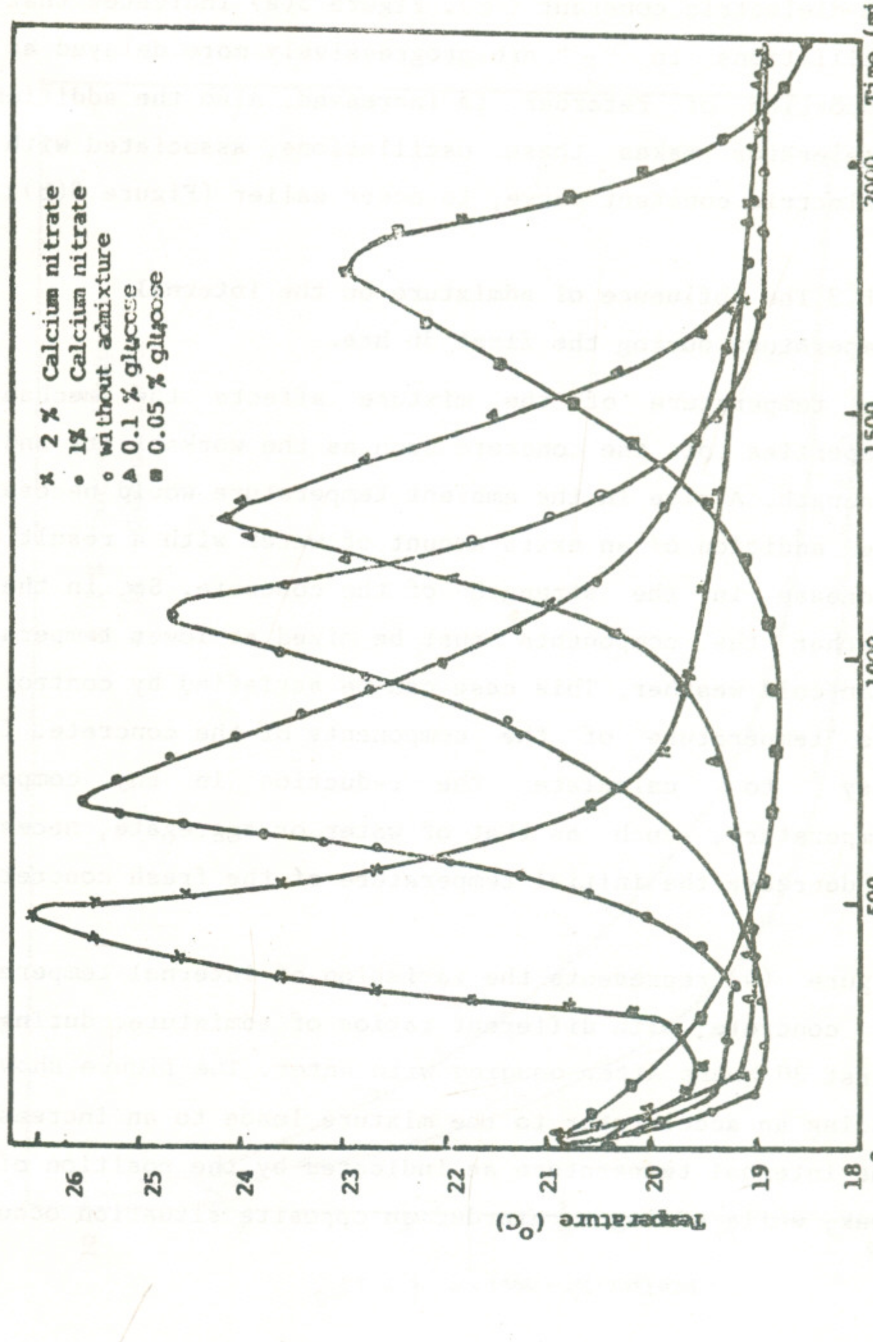

Figure (4) Variation of internal temperature during the first 36 hrs. with adding admixture for frequency 10 KHz.

2.b.4 The infuluence of frequency on the electrical properties:

The electrical properties of concrete especially (ε) is strongly influenced by the frequency of the applied field. The variation of "ρ" and "ε" with time for three frequencies namely 10,50, and 100 KHz respectively are shown in Figure (5). From this figure, the dielectric constant at 10 KHz is about five times that of 50 KHz while the later value is about three times that of 100 KHz. The change in "ρ" with frequency is not noticeable over this range of frequencies (10$\rightarrow$1000 KHz), as the data of "ρ" at frequency of 10 KHz is only shown for clarity.

3. Discussion

As can be seen from the experimental results, there is an initially high dielectric constant and relatively low electrical resistivity of the concrete specimen under test. In this early stage, the concrete specimen is supersaturated with Ca^{++}, HO^{-}, $SO^{--}{}_{4}$, Na^{-} and K^{+} ion. Since the dielectric constant "ε" is proportional to the polarizability (Clausius Mosotii Equation[5]), the high polarizability and low resistivity are then due to the high ionic concentrations and ease of mobility of charges. This explaination is satisfactory from the physical and chemical points of view. Figures (2 and 3) illustrate that, while "ρ" increases steadily with time over the initial period (setting time), there are some oscillations in "ε" within this period. Nearly similar behaviour was reported by McCarter and Afshar[3] for cement paste samples, but disappears in the data reported by whittington et al[6] on

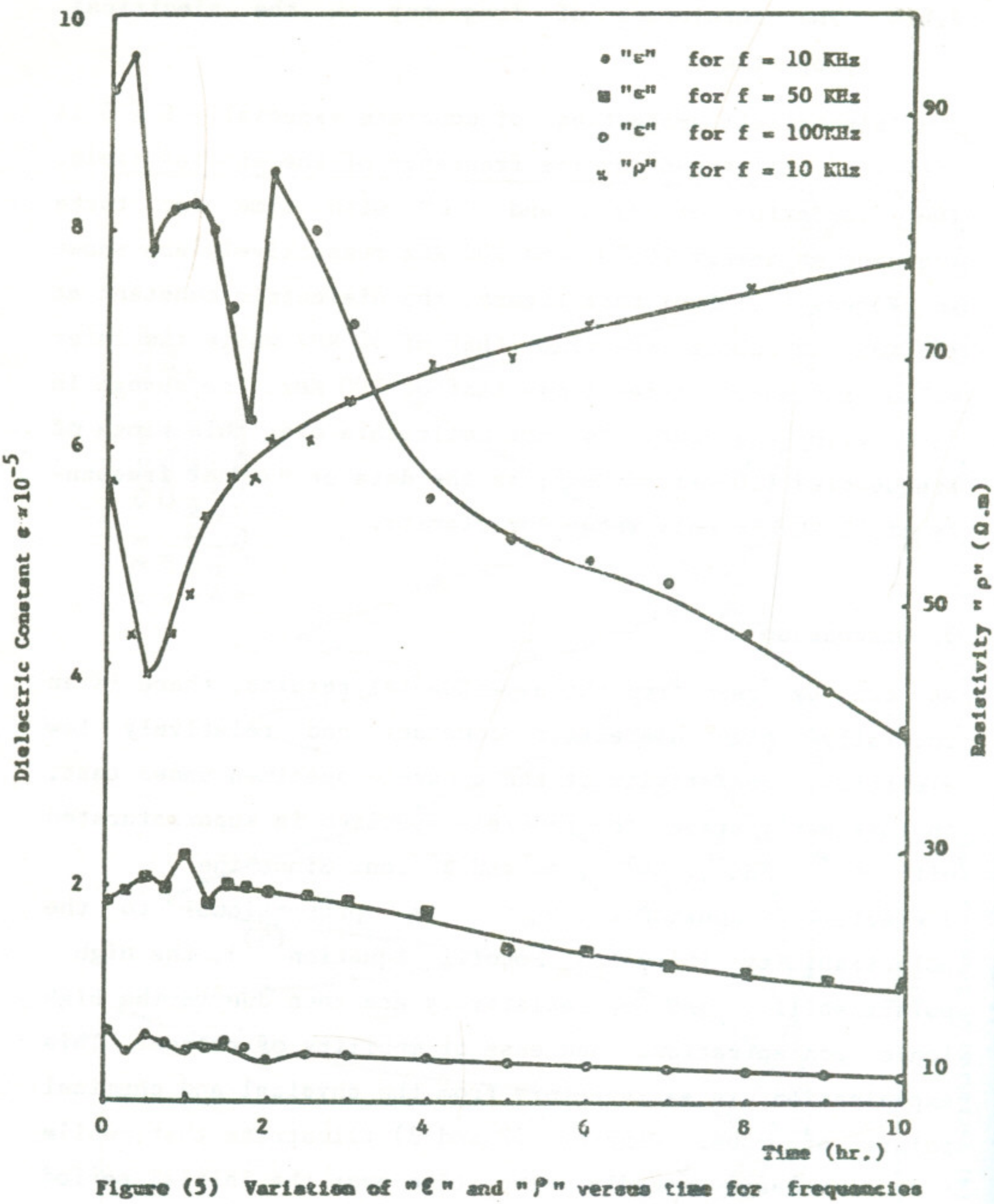

Figure (5) Variation of "ε" and "ρ" versus time for frequencies 10,50, 100 KHz.

concrete. This is not contradiction, since as appeared in Wittington et al data the period between successive data points is about 150 minutes, which may on the average, prevent such oscillations to appear.

In the second stage (after about 5 hrs). "ρ" increases with smaller rate and could signify that ionic concentration pathes through the paste are becoming more tortuous as the gel extends to form a fibrous rigid structure[6]. In the same region, the dielectric constant decreases rapidly.

In the third stage (after about 10 hrs.), "ε" attains an almost constant value, while "ρ" decreases with small rate indicating, perhaps, that the specimen has attained a rigid structure and the period of hardening has started. On comparing the results of 'McCarter and Afshar[3] and Whittington et al[6] with that of the present work the experimental graphs of concrete follow the same trends as those for cement pastes, the only difference being that the curves for concrete are displayed upwards. The resistivity of concrete is four to six times that of respective cement paste, while the dielectric constant of concrete is about 10-15 time that of respective paste.

It is evident from Figures (2 and 3) that the addition of retarding agent (glocose) has the effect of delaying the reaction of C_3S phase and increasing the dormant period (little activity). The peaks in the dielectric constant is prgressively more delayed as the proportion of retarder is increased; the amount of delay is proportional to the quantity of glocose added. When an accelerator (calcium nitrate) is added to the mix, the dormant period is reduced and C_3S hydration oscillations associated with the dielectric constant curve occur earlier. The accelerator has a large effect on the values of the dielectric constant as they are nearly twice that of the control (without any admixture). The resistivity increases with the increase of the amount of accelerator in the mix. These results agree with those obtained by McCarter and Afshar(3) but they used, instead, sugar and calcium chloride as retarder and accelerator respectively.

The internal temperature decreases a little with adding a retarder, while it increases more with adding an accelerator (Figure 4). As soon as contact is initiated between the cement and water, the rate at which heat is evolved, increases abruptly by $\sim 2^{o}C$. This can be attributed to the rapid reaction of C_3A and C_3S compounds. The temperature then increases rapidly till it reaches a maximum (the main peak). This peak is attributed to be due to the hydration of C_3S.

The influence of frequency on the electrical properties of concrete was discussed in detail in a separate paper(7)

To conclude this work, the electrical properties (ε and ρ) are directly related to the rate of hydration of cement paste within the concrete. This is confirmed by the fact that experimental graphs of concrete follow the same trends as those for cement paste(3,6). The electrical properties of concrete are sensitive to the physical and mechanical changes in the mix and could be used as a structure determining technique.

This work can be extended to include investigations on the behaviour of the new inorganic material such as the Macro Defect-Free Cement (MDF) in terms of its mechanical and electrical properties[8] and studying the electrical properties of Glass-Fiber Reinforced Cement (GRC).

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