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Electrical Conductivity on the Portland Cement by chemical admixture Produced in Najran- Kingdom of Saudi Arabia

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Abstract— Effect of $CaCl_2$ on the electrical conductivity of different cement pastes using blended Portland cement was studied. Various mixes were prepared using a water/cement ratio (W/c) of (0.2,0.3and 0.5)and at different ages of hydration (0.5 hr, 1hr, 4 days ,and 7 days)in the presence and absence of 2% $CaCl_2$ which was 2%.The electrical conductivity was tested by measuring with time for different w/c ratio without and with $CaCl_2$ .The study showed changes in the electrical conductivity reflect the physical and chemical changes in the cement pastes. The results found from the experiments was as follows; increasing of electrical conductivity in the presence of $CaCl_2$ and with higher cement/water content. The increasing of electrical conductivity with $CaCl_2$ because of the formation initial stage of hydration leading to first peak. Later the electrical conductivity increases; reaching a second peak, followed by a decrease in the electrical conductivity . The result in higher w/c ratio shows more rapid increase than the lower w/c ratio In conductivity because the pore structure in OPC cement pastes because the pore structure in OPC cement pastes with higher w/c ratio is more affected by chloride ion which can cause the densification of pore structure . Decreasing of electrical conductivity with the curing time was found, this is because of the chemical reaction products such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) formed bind finer soil particles together resulting.

Key words: Electrical Conductivity, Portland cement, calcium chloride ($CaCl_2$).

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1 INTRODUCTION

The Electrical conductivity is an important parameter to study the hydration of process of cement pastes at early stages.[1,2].Electrical conductivity was used as a method for measuring the effect of additives on effective diffusitives in Portland cement pastes described[3].several studies on the effect of admixtures on the electrical behavior of Portland cement were also investigated[4,5].Harson [6]discussed the factors which control electrical conduction in cement based materials, such as concentration and mobility of ions in the pore solution, porosity and pore size distribution .Morsy [7] studied the effect of temperature on the electrical conductivity of blended cement pastes. cement admixture get decreased due to the hydration reaction and pozzolanic reaction. As a result, the path for the conduction of electrical current becomes more tortuous. Therefore, the electrical resistivity of the water - cement and chemical admixture increased.

As cementitious content is typically known from the batch tickets, the water-cement ratio (w/c) or water-cementitious materials ratio (w/cm) by mass could then be estimated. More recently, Mancio et al. [8] have shown the potential of using measurements of electrical resistivity to estimate w/c of concrete.

Higher the cement content, the higher the hydration compounds formed.
The electrical properties of cement pastes and its effect by the using chemical admixture such as $CaSO_4$ were studied to clarify its physical performance during the hydration process. When an electric field is applied on a material such as cement paste. Some ions are free to drift through the material and discharge at the electrodes producing conduction effect. Other charges, which are, bound the particle surfaces, whilst not free to drift from one electrode to the other, are able to oscillate back and forth under the action of the alternating electric field has a profound influence upon polarization, with a certain polarization mechanism only operative over a particular
frequency band.[9].

Calcium chloride is the most widely used because of its ready availability and low
cost. $CaCl_2$ has long been known to accelerate both the setting and hardening of Portland cement concrete, the effect of strength decreases with time and the final strength can be reduced due to the formation of chloroaluminate hydrates which is responsible for the concrete softening. One of the limitations to the wider use of calcium chloride in reinforced concrete is that if present in larger amounts, it promotes corrosion of the reinforcement, unless suitable precautions are taken (10). The hydration of the system C_3A $CaCl_2$, $CaSO_4S_2H_2O$ shows that the calcium chloride primarily accelerates the reaction between C3A and gypsum. Sulfate reacts first followed by reaction of C_3A and chloride after the gypsum has been used up. $CaCl_2$ appears to stabilize the formation of trisulfoaluminate hydrate (ettringite) $C_3AS3CaSO_4S32H_2O$.After all CaSO4 has been used, conversion of trisulfoaluminate to Monosulfoaluminate $3C_3ASCaSO_4S$ $12H_2O$ occurs (11).

2. EXPERIMENTAL PROGRAM

2.1. Aim of experiments

The aim of this research is to determine the effect of calcium chloride as a chemical admixture on the electrical conductivity of the hardening cement pastes hydrated with the time limited from 0.5 hours to 7 day, and water cement ratios W/C of (0.2,0.3 and 0.5) with and without of calcium chloride as an chemical admixture.

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Materials and methods

2.1. Materials

The type of cement used in the experimentation is OPC Portland cement produced in Najran in the Kingdom of Saudi Arabia , calcium chloride $CaCl_2$. The Chemical composition of the used Portland cement is given in Table 1.

Table 1 : Chemical composition of the used Portland cement

Oxide (%)	(%)
SiO_2	19.81
AlO_3	6.05
Fe_2O_3	3.46
CaO	63.86
MgO	0.81
SO_3	2.16
K_2O	0.08
Ign.loss	**1.48**

2.2. Methods

2-2-1 Specimen Preparation

Curing of Specimens

Different cement pastes were prepared in presence and absence of calcium chloride , with w/c detailed in Table 2 in Mixtures 1, 2, and 3 for the comparative investigation. The w/c was varied as (0.2, 0.35 and 0.5) respectively. After mixing with water each samples were kept in cylinder 2cm diameter, and cured in 100% relative humidity from the first half an hour till 7 days ,and were immersed in distilled water.

2-2-2 Experimental Programs:

Electrical conductivity :

For conductivity measurements, the test cell was coaxial type including concentric inner and outer electrodes mounted on insulated base. The electrode was polished before the experiment and the cell was kept in desiccators at 100% relative humidity during the test period [12]. The measurements began exactly, three minutes after the first contact with water; the cell has been designated to give good contact with cement pastes during the hydration, stiffing and final rigidity and overcome changes in the paste volume during hydration. The electrode was polished before each experiment. Measurements commenced exactly after half an hour ,in the presence and absence of calcium chloride as a chemical admixture ,at at constant temperature 25^0C.The conductivity of the cement pastes were measured using digital conduct meter with accuracy of 0.01ms.

Table 2: The proportion of cement pastes and cement CaCl2:

Type of cement	Cement: water %	$CaCl_2$ content %
Mix 1	0.2	-
Mix 2	0.3	-
Mix 3	0.5	-
Mix 4	0.2	2%
Mix 5	0.3	2%
Mix 6	0.5	2%

3- Results and Discussion:

3-1 Electrical conductivity -Time curves

The electrical conductivity –time curves obtained for the various cement pastes the all figures (1, 2,3,4,5,6,7and 8,) with and without calcium chloride show common characteristics with an initial increase, after mixing with water, followed by a gradual decrease during the initial stage of hydration leading the first peak. Later the electrical conductivity increases, reaching a second peak, followed by a sharp decrease. The increase of electrical conductivity in the initial stage of hydration is due to (OH^-), SO_4-^{2}, Na^+, and $K^{+,}$ but the increase of electrical conductivity in the second peak is due to the ettringite transformation into the monosulphate hydrate, also the osmotic pressure development around cement grains [13].Also the conductivity starts to decrease markedly at the beginning of gel formation due to the reduction of the free water and to diminution and segmentation of the capillary pores, which are the principle pathways for the ionic flow. During the first six hours, the effective length (pathways) decreased; this must mean that the conductivity is increased. At the early stage the ionic concentration increases i.e. the ionic conduction is high. The effective length is decreased and reaching to aminimum at setting time, the ionic conduction paths through the different cement paste samples were becoming more easily and therefore the effective length is decreased [13]. As shown in tables 3 ,4,5,6 without calcium chloride and ,7,8,9,10 with calcium chloride for various age of hydration (0.5 hr, 1hr,4days ,and 7days). The decrease in the conductivity of the stared specimens will result from two sources:

1-A reduction in connected capillary porosity due to a refinement in the pore structure.

2- Changes in ionic concentration within the pore fluid in the different samples of cement paste [12].

3-2 Effect of calcium chloride on electrical conductivity :

The chemical admixture such as chloride calcium is reactive, so it raises the electrical conductivity of the cement paste, as shown from the figures (5 ,6,7 and 8) these figures Illustrate the electrical conductivity of cement pastes with 10 gm of calcium chloride.It is clear that, the electrical conductivity shows an initial stage of hydration leading to first peak. Later the electrical conductivity increases; reaching a second peak, followed by a decrease in the electrical conductivity [11]. So the high values of conductivity would be Indicative of the hydration process and these values increase with increasing of calcium chloride concentration in cement paste in the first stage of hydration and is due to the structure of fresh cement paste.

Table 3 Electrical without calcium chloride conductivity Sm/ Sμ after half an hour(0.5hr)

W/C			Time
0.5	0.3	0.2	(min)
2	27.1	31.0	2
4	21.3	25.9	4
6	17.4	25.9	6
8	17.1	25..9	8
10.	17.0	25.8	10.
12	17.1	25.7	12
14	16.9	25.3	14
2	27.1	31.0	16

Table 4 Electrical without calcium chloride conductivity Sm/ Sμ one hour(1hr)

W/C			Time
0.5	0.3	0.2	(min)
2	14.62	21.6	2
4	14.5	21.0	4
6	13.4	20.9	6
8	12.1	20.8	8
10.	11.0	20.7	10.
12	11.0	20.6	12
14	11.0	20.4	14
16	11.0	20.0	16

Table 5 Electrical without calcium chloride conductivity Sm/ Sμ after (4days)

W/C			Time
0.5	0.3	0.2	(min)
13.9	15.9	15.8	2
13.8	15.8	15.8	4
13.9	15.7	14.9	6
13.5	15.6	14.7	8
13.4	15.5	14.4	10.
13.2	15.3	13.8	12
13.2	15.3	13.7	14
13.1	15.2	13.5	16

Table 6: Electrical without calcium chloride conductivity Sm/ Sμ after 7 (days)

W/C			Time
0.5	0.3	0.2	(min)
13.9	12.9	12.9	2
13.8	12.7	12.8	4
13.9	12.5	12.8	6
13.5	12.4	12.7	8
13.4	12.3	12.7	10.
13.2	12.3	12.7	12
13.2	**12.2**	**12.5**	14
13.1	12.1	12.5	16

3-3 Effect of Water Content on Electrical conductivity

The result in higher w/c ratio shows more rapid increase than the lower w/c ratio In conductivity because the pore structure in OPC cement pastes with higher w/c ratio is more affected by chloride ion which can cause the densification of pore structure. It is clear that, the electrical conductivity shows an initial stage of hydration leading to first peak Later the electrical conductivity increases; reaching a second peak followed by a decrease in the electrical conductivity [14].

3-4 Effect of Curing Time on Electrical conductivity

With the increase in the curing time, following of decreasing of electrical conductivity , because of the chemical reaction products such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) formed bind finer soil particles together resulting.

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Table 7: Electrical with calcium chloride conductivity Sm/ Sμ half an hour(0.5 hr)

W/C			Time (min)
0.5	0.3	0.2	
26.1	83.8	109	2
25.9	84.8	97	4
21.1	31.0	81.2	6
20.7	26.7	63.7	8
17.1	25.9	63.1	10.
16.5	28..5	60.1	12
16.2	25.4	60	14
10.7	25.1	60	16

Table 8: Electrical with calcium chloride conductivity Sm/ Sμ one hour(1 hr)

W/C			Time (min)
0.5	0.3	0.2	
23.1	31.0	31.9	2
22	22.3	22.1	4
21	22.1	22.0	6
20	22.1	21.9	8
19.1	22.0	21.8	10.
18.9	21.9	21.7	12
17.2	21.8	22.6	14
16.7	21.7	22.6	16

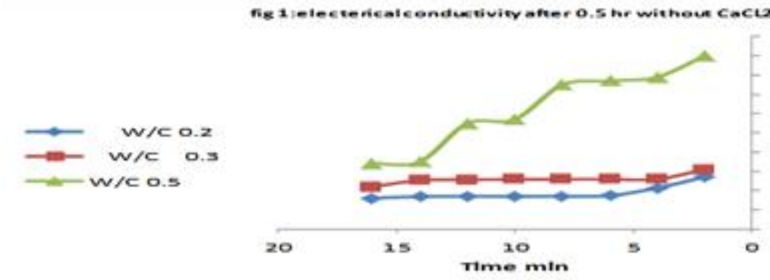
Table 9: Electrical with calcium chloride conductivity Sm/ Sμ 4days

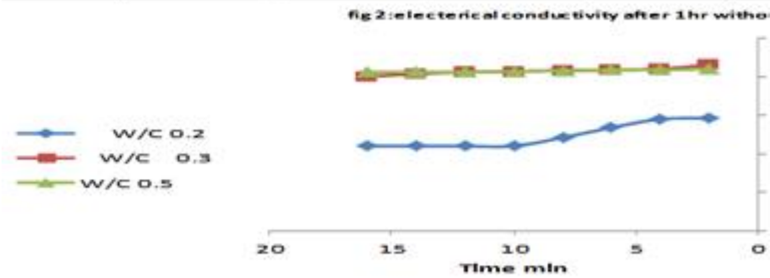
W/C			Time (min)
0.5	0.3	0.2	
26.6	24.2	25.2	2
24.2	16.3	16.3	4
23.9	16.2	16.3	6
17.7	16.2	16.3	8
17.1	16.1	16.2	10.
16.9	16.1	16.2	12
16.8	16.0	16.0	14
16.7	16.0	16.0	15
16.7	16.0	16.0	16

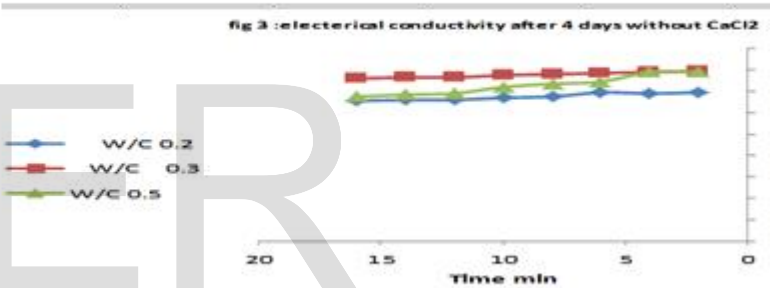
Table 10 Electrical with calcium chloride conductivity Sm/ Sμ 7days

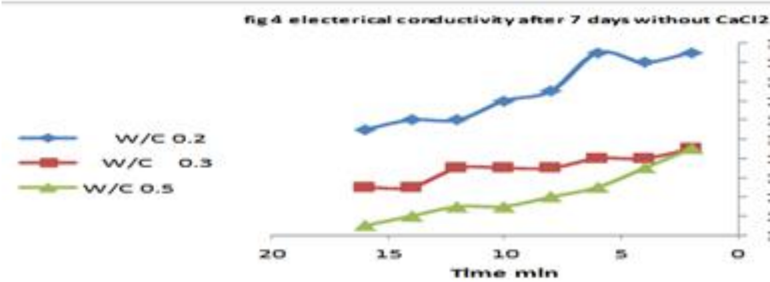
W/C			Time (min)
0.5	0.3	0.2	
24.9	25.2	26.14	2
12.6	17.7	18.3	4
14.4	16.6	17.6	6
14.4	16.5	17.3	8
14.2	15.5	17.2	10.
14.2	15.4	17.1	12
14.0	13.2	13.1	14
14.0	13	13.0	16

❖ . Figures for electrical conductivity after different age of hydrations(0.5hr, 1hr,4 days and 7 days) without CaCl2

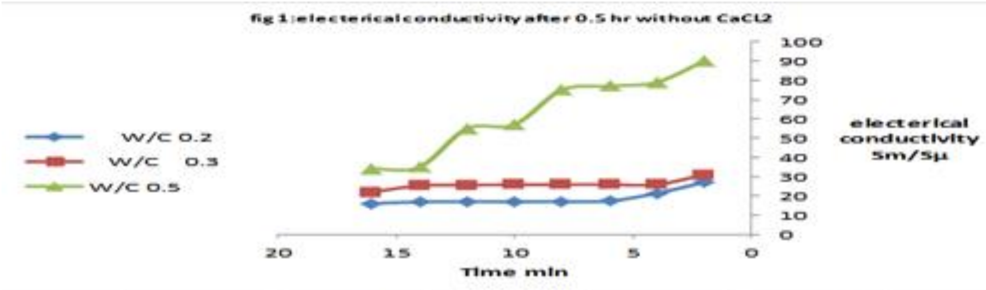


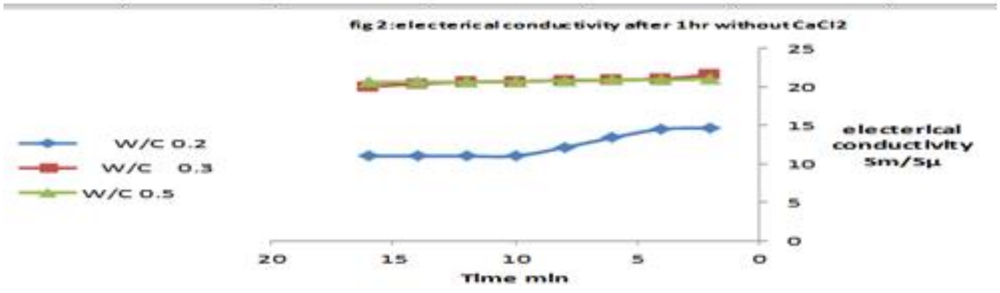


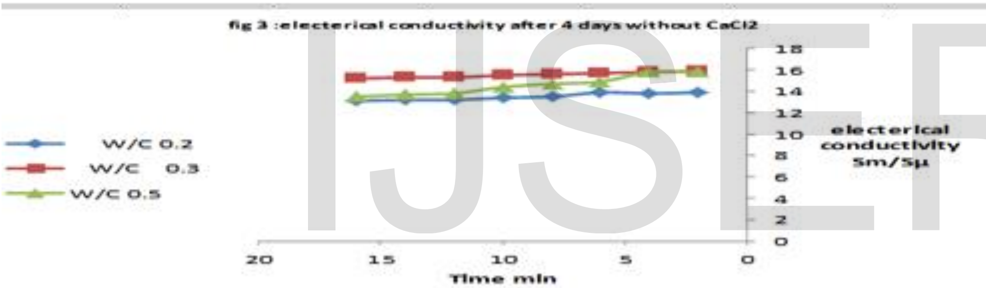


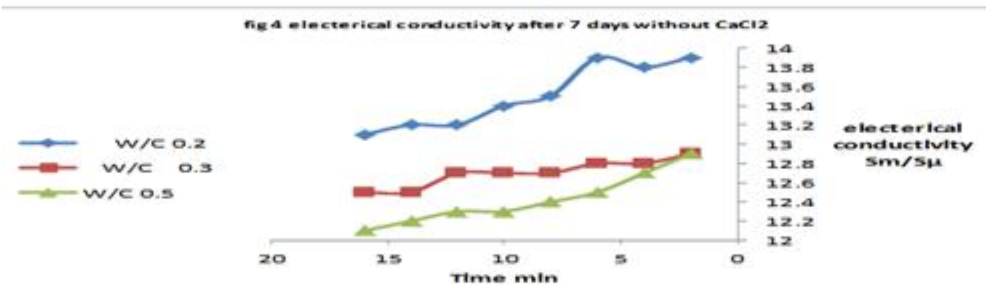


Figures for electrical conductivity after different age of hydrations (0.5hr, 1hr,4 days and 7 days) with $CaCl_2$









Conclusion:

The results found from the experiments could be summarized as follows

- The electrical conductivity increases in the presence of Calcium chloride for the cement pastes for water cement w/c content.
- Higher water cement content higher electrical conductivity.
- Increasing of electrical conductivity increases for the first hours of hydration and gradually decreases with time.
- the increase in the curing time, following of decreasing of electrical conductivity

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