Electrical Curing Application on Cement-based Mortar with Different Stress Intensity

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Abstract. In this study, the effects of different stress intensity on the electrical resistivity of hardening (setting) cement-based mortar were investigated. In experiments, four different mould (5 × 5 × 10 cm, 5 × 5 × 15 cm, 5 × 5 × 20 cm and 5 × 5 × 25 cm) were used. Different combinations of stress intensity (7.5, 15, 22.5 and 30 V) were used on mixtures. The measurements were done at room temperature. Electrical resistivity and setting time of the specimens with and without electric current application were also investigated. Moreover, specific setting hydration temperature was measured by using thermocouple. As a result, electric current application can be used for obtaining to rapid setting time on the mortar with high volume stress intensity.

Keywords: Electrical resistivity · Mortar · Stress intensity · Hydration time

1 Introduction

Concrete's gaining strength at an early time and it's being used immediately are the results of developing industry [1]. In order to reach these results, there are several cure methods and through these methods, the concrete can get early strength. However, the accelerated cure methods which are applied during pouring the concrete is very limited. Depending upon the hydration time, accelerated cure at the buildings in which ready mixed concrete used is important in terms of the project's being carried out in a predicted time since concrete compressive strength reaches the target level in a short time [2]. Moreover, the prediction of the level of strength in an early time is very crucial in terms of building's both performance and economy. Concrete is not conductive but it can show a conductive feature until its final setting time since it includes water. Furthermore, additive minerals in concrete can change in terms of electrical resistivity of concrete. Different methods have been developed to measure electrical conductivity of mortars and various researches and applications which examine cement's micro structure developments have been carried out [3]. In monitoring of the entire hardening process of a cement paste, electrical resistivity can be used as a parameter. The durability and service life of cement-based materials strongly depends on its transport properties [4]. Electrical conductivity process occurs primarily due to

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ion transport through the pore solution in a cement-based system and it is an important parameter to study the hydration process of cement pastes at early stages [4, 5]. During the hydration of cement paste after mixing, calcium (Ca) and hydroxyl (OH) ions go into solution within the first 10 min [6]. Then, little happens except for a slow precipitation of semi-crystalline calcium silicate hydrate gel (C–S–H) while the calcium and hydroxyl ion concentrations continue to rise slowly [7, 8]. The degree of hydration describes the process of hydration, and directly relates to the fraction of the hydration products or porous structure in a hydration system in cement-based materials [9]. The variation of resistivity as function of time can indeed reflect internal changes of the pore solution of cement paste with time [10]. As it is well known, the hydration process in cement paste results in the formation of C–S–H, calcium CH, ettringite and other compounds. During hydration, the capillary pores in hardening cement paste are gradually filled up with hydration products and the solid phases form a rigid microstructure with increasing strength. Then, electrical resistivity of cement paste increases with time [11].

Most of the articles in the literature deal with the electrical resistivity of cement paste. Some work has been published on various aspects of electrical measurement of setting and hardened cement paste. Xiao et al. used electrical resistivity measurement and Marsh cone used it for providing a fast way to evaluate and select suitable superplasticizer in concrete [4]. In another study, Xiao et al. [12] measured the electrical resistivity of the concrete mixes and the pore solution within the mixes by a non-contact electrical resistivity apparatus. They reported that electrical resistivity measurement reflects the hydration kinetics of fresh concrete. Abo El-Enein et al. [13] investigated the electrical conductivity of concrete containing silica fume. The results of their study showed that the electrical resistivity can be used as an indication for the setting characteristics of pastes made with and without silica fume. Tamaás et al. [14] have shown that the time dependence of the electrical response of cement pastes is complex and influenced by a number of variables such as water content, temperature, clinker fineness, gypsum and admixture content. Topçu et al. [4] applied current to cement pastes which have different water/cement ratio (0.40, 0.45, 0.50, 0.55), different mineral admixtures (fly ash, silica fume, and blast furnace slag) and different ratio (0, 10, 20, 30%). As a result, applying electric current can be used for obtaining rapid setting time on the cement paste with high volume mineral admixture [4]. Backe et al. [3] researched the relation between conductivity, porosity, cement chemistry and ion content. According to their theory when porosity increases, conductivity increases too and thus they concluded that it is in relation with hydration degree. As a result, when setting time becomes shorter stripping time becomes shorter too [15]. This research is important for the structures which require rapid repair or fast production such as prefabricate.

2 Experimental Study

In experimental study crushed sand have been used in order to show the impact of electrical resistivity on mortars. Specific gravity of crushed sand is 2.64 and the maximum grain size is 4 mm. In the experiments, CEM 1 42.5 R cement which is suitable to TS EN 197-1 [16] standards have been used.

2.1 Production of Specimen

The mortars whose water/cement ratio is 0.70 are produced with cement dosage of 350. The 5 lt capacity mixer is used to mix admixture. Then the mortars put in electrically isolated wooden moulds whose sizes are 5 × 5 × 10, 5 × 5 × 15, 5 × 5 × 20 and 5 × 5 × 25 (in cm). Unit volume component of 350 dosage mortar has shown in Table 1.

Table 1. Component of mortar per cubic meter

Sample Code	Cement (kg/m^3)	Water (lt/m^3)	Crushed sand (kg/m^3)
M350	350	175	2104

Initially for the mixture of mortars, aggregate and cement were used for 1 min in order to have dry mixture. Then almost 2/3 of mixture water were added to the admixture Finally chemical admixture in the remainder (1/3) of water were put into the admixture and the process of mixing were continued for 3 min. Prepared mortars were put into wooden moulds which has different sizes as 5 × 5 × 10, 5 × 5 × 15, 5 × 5 × 20 and 5 × 5 × 25 (cm × cm × cm). Then some of mortars were applied to 7.5, 15, 22.5 and 30 V stress by direct current (DC) power- supply source during 24 h and some of them were used to control specimen at laboratory conditions. For applying stress intensity to specimens, two copper electrodes were used and put in head end of moulds.

2.2 Preparation of Experimental Setup

For applying stress intensity to the specimens a DC power-supply source Hioki mark which has 30 canal and 60 V capacity has been used. Firstly power supply was connected to a port ("+" pole and "−" pole separately), then data logger was connected to the port. Then direct connection from the port to the specimens was made to apply DC current. In order to measure the temperature of specimens to which stress applied, K type thermocouple were connected. Finally the data from data logger were saved and their graphics were drawn. A view of mortar which electrical current applied to has shown in Fig. 1.

3 Results and Discussions

For measuring temperature of mortars, K type thermocouple was used and in every 2 min the temperature values were recorded by data logger. The comparison of specific hydration temperature of hardening specimens which 7.5, 15, 22.5 and 30 V stress are applied in terms of the setting time is shown in Fig. 1.

From the beginning of hydration time, temperature of cement based mortars have been measured and saved. The mortars whose sizes are 5 × 5 × 10 and 5 × 5 × 15 (in cm) are chosen because the temperature is higher when it is compared with other size of mortars. It is observed that as the stress intensity increases, temperature values get lower, except for 5 × 5 × 10 (Fig. 2).

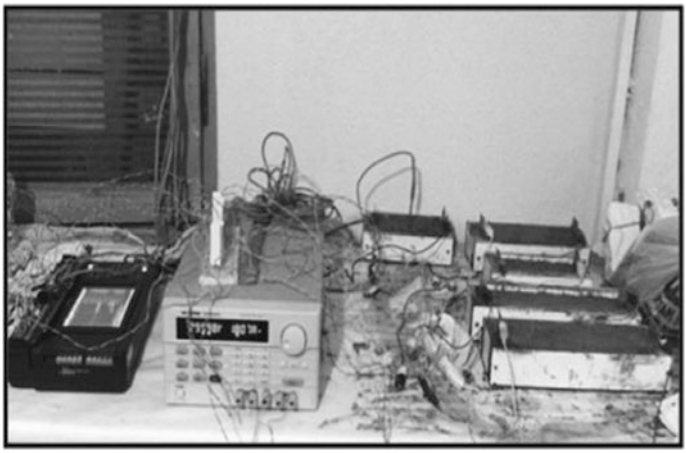


Fig. 1. A view of mortar which electrical current applied to

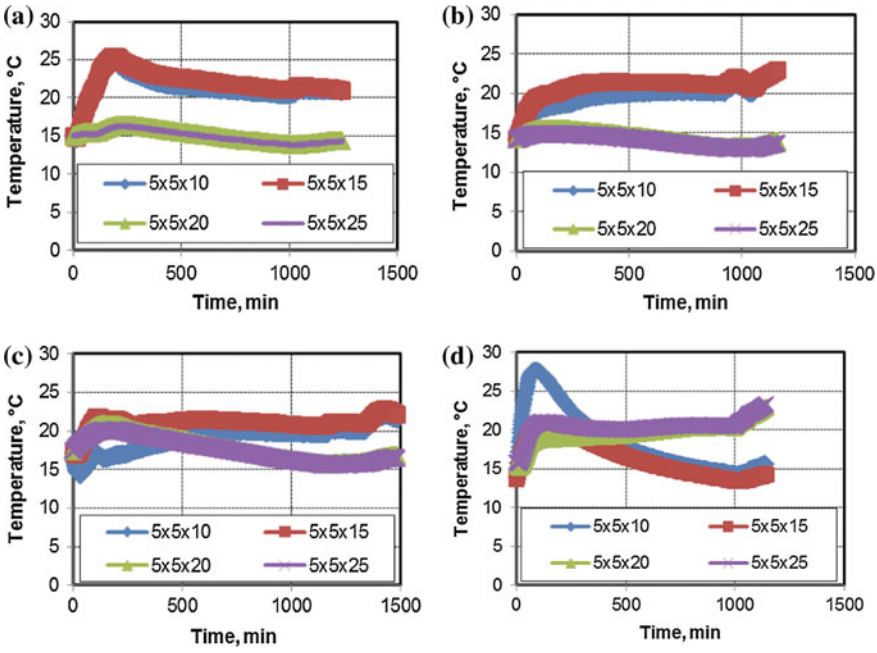


Fig. 2. Specific hydration temperature of mortars (**a** 7.5 V, **b** 15 V, **c** 22.5 V, **d** 30 V)

The conductor between two electrodes in mortar mixture was initially the water in the mixture which is in the liquid phase. At the beginning, all the pores in the mixture have connections among themselves. Therefore, the electrolysis between the electrodes has arisen from the free water of these pores. However, hydrated products occur in the course of time because of the reaction of the main components in the cement paste with

water, and the pores which were once connected to each other have been separated. Accordingly, electrical resistivity of cement paste increase in time and when the cement completes its hardening time, its electrical resistivity amount reaches the maximum value. Consequently, the electrical resistivity of cement is directly associated with the hydration of the cement. The mortar having different size have been investigated during the time until the setting time of the mortar has taken (one day at the laboratory having suitable conditions). The resistivity results are presented in Fig. 3 for different voltage.

The conduct of electrical current on the mortar is directly associated with distance of plates in mortar. Due to the electrical conductivity of mortar, it can be seen in Fig. 3 that the mortar which has low distance (5 × 5 × 10 cm) conducts much more electrical current when compared to high distance plates (5 × 5 × 25 cm) in mortar. Therefore, the temperature of low distance mortars was increased and mortar hydrated faster than mortars with high distance. Consequently, resistivity has higher values in small size moulds (5 × 5 × 10 cm) than high distance plates (5 × 5 × 25 cm). When the distance of plates is increased, the resistivity values of mortar were reduced under all the voltage values. On the other hand, the voltage has higher effect on low distance of plate than high distance. The relative compressive strength values were also determined after 28 days of electrical curing process. It can be seen in Fig. 4.

It was interestingly found that when the superposed graphics are examined, it is seen that when the stress intensity is increased (up to 15 V) and the sizes of specimens are made taller (5 × 5 × 20 and 5 × 5 × 25), compressive strength of the specimens are getting higher.

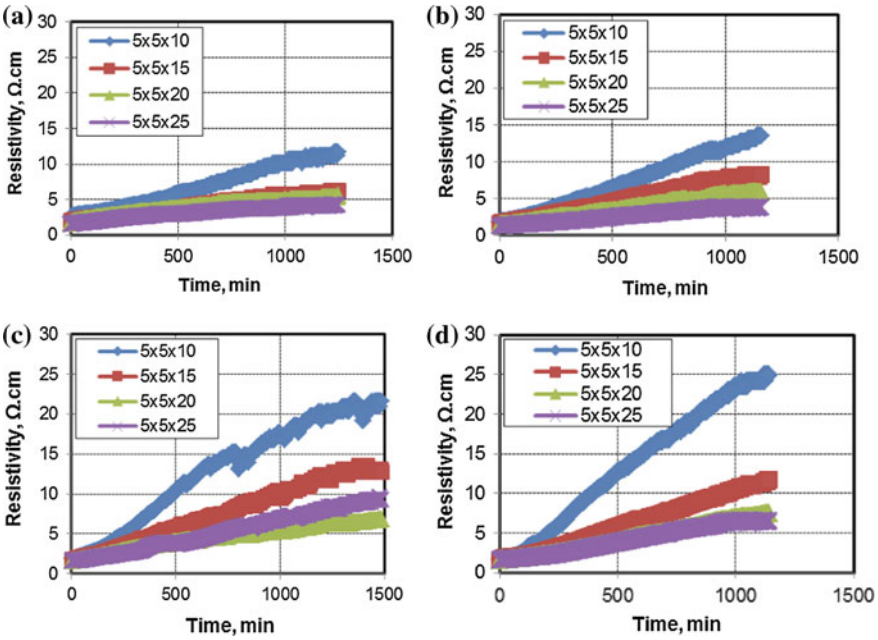


Fig. 3. Electrical resistivity of hardening mortars (**a** 7.5 V, **b** 15 V, **c** 22.5 V, **d** 30 V)

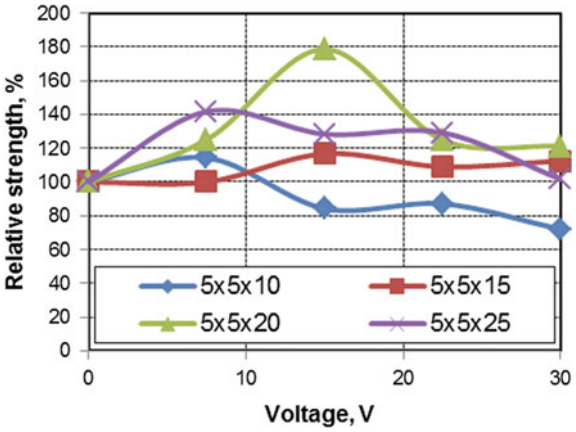


Fig. 4. Relative compressive strength of mortar after DC electrical curing

4 Conclusions

In this study, the effect of stress intensity as a result of applying 7.5, 15, 22.5 and 30 V stress at 5 × 5 × 10, 5 × 5 × 15, 5 × 5 × 20 and 5 × 5 × 25 (in cm) sizes have been investigated. Several conclusions can be drawn from this study:

- When the stress intensity applied to mortars increase (7.5–30 V), specific hydration temperature becomes higher.
- As electrodes approach each other, electrical resistivity becomes higher due to increasing of temperature. The resistivity has higher values in small size moulds (5 × 5 × 10 cm) than high distance plates (5 × 5 × 25 cm). When the distance of plates is increased, the resistivity values of mortar were reduced under all the voltage values.
- It can be interpreted that a relationship between measuring temperatures related with hydration time of mortars and resistivity. The electrical resistivity of cement paste increase in time and when the cement completes its hardening time, its electrical resistivity amount reaches the maximum value.
- It is concluded that, 15 V stress application and 20 cm plate distance is the optimum values for the highest strength. When the stress intensity is increased (up to 15 V) and the sizes of specimens are made taller (5 × 5 × 20 and 5 × 5 × 25), compressive strength of the specimens are getting higher.

Consequently, DC electrical curing of cement based mortar can be modified by the applying of voltage at 15 V with distance of 20 cm. Furthermore, the hydration duration of mortar can be accelerated as a result of applying electric current.

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