Effect of Graphite Powder Additive on Electrical Conductivity in Cementitious Systems

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Abstract –As a result of snowfalls in the winter season, icing of airlines and highways in the world and our country causes very serious accidents. De-icers spilled on the roads or mechanical methods cause damage to the roads and stripping of aggregates. In order to eliminate such negative situations, the effect of graphite powder on electrical resistivity was investigated in cement mortar systems. Graphite powder, which is 0%, 0.5%, 1%, 2% and 4% by weight and passed through a 75 micro sieve, was added to the cement. Thus, machinability, flexure, pressure and electrical conductivity tests were carried out on the new sample. Graphite powder addition had a negative impact on machinability. It also had a positive effect on flexure and compression tests up to 1% addition rate. It was observed that the electrical conductivity of the graphite powder increased with the addition of the cement.

Keywords – Graphite Powder, Machinability, Electrical Conductivity, Electrical Resistivity, Flexure Test

I. INTRODUCTION

In order to prevent cracks in concrete, multifunctional cement-bonded composite systems are being developed for structural functions in terms of strength and durability [1]. Multifunctionality means use of the material to perform non-structural functions with natural resources such as solar energy without the need for an artificial energy source [2]. Multifunctional cementitious composites should be produced with composite materials created with the additives of carbon black, carbon fibers, carbon nanotubes and nanofibers by improving the conductivity of the material. These materials are developed and used in applications such as heating and electromagnetic protection [3].

In the study of Sedaghat et al., they had formed cementitious composites by adding graphene oxide from 1% to 10% in cement. They observed that the electrical conductivity of the material increased as the graphene addition rate increased [4].

In their study by Sharma and Kothiyal; 7, 14, 28 and 90 days compressive strength and direct current measurement tests were applied to the graphene oxide added cemented nanocomposites. As a result of these measurements, they observed a decrease in electrical resistance, but an improvement in compressive strength [5].

Mengqi produced a conductive concrete with graphite substitute and carbon fiber in his study. It has shown that the concretes it produces both provide high strength and are a good conductive material [6].

According to researchers; It was found that the electrical resistivity of the concrete was $6.54*10^5$ Ω.cm, and the electrical resistivity of the hardened concrete was $11.4*10^5$ Ω.cm [7], [8]. In addition, the electrical resistivity of saturated concrete was found to be 10^6 Ω.cm, and the electrical resistivity of dry concrete to be 10^9 Ω.cm according to the studies carried out by different researchers [9].

When pure concrete is only examined electrically, it is located between insulator and semiconductor materials. When a conductive additive material is added to the concrete matrix, its conductivity can be increased [10], [11]. Materials used as electrical conductors should be used in limited quantities to prevent deterioration of other physical and mechanical properties of concrete. The materials used as additives can have different conductivity, geometry and type. In many studies, additives in powder form such as graphite and carbon black have been used as electrical conductors.

II. MATERIALS AND METHOD

A. *Material*

In this study; CEM I 42.5 R Portland cement (PÇ) corresponding to ASTM Type I cement was used according to the EN 197-1 standard [12]. Graphite powder with 99% purity and <75 micron size was used as additive element. CEN reference sand produced at the Limak Trakya Cement Factory in accordance with TS EN 196-1 standards was used in the study [13]. The material mixing ratios of the test samples are given in Table 1.

Table 1. Mixing ratios of the samples prepared for the experiments

Sample No.	Graphite Powder (g)	Standard Sand (g)	Water (g)	Cement (g)
G	-	1350	225	450
G0,5	2,25	1350	225	450
G1	4,5	1350	225	450
G2	9	1350	225	450
G4	18	1350	225	450

Prismatic cement mortars prepared by pouring in the dimensions of 40×40×160 mm are shown in Figure 1.

Fig. 1 Samples

B. *Experiments*

At this stage, slump test of graphite powder additive cement mortars was carried out. The mortar mixtures prepared in accordance with TS EN 196-1 were filled into the truncated cone on the flow table. After the truncated conical mold was lifted slowly, the shaking device was rotated and the flowing diameter was measured in accordance with TS EN 1015-3. The average of these values was calculated. Flexure and compression tests were carried out to determine the mechanical properties. 40×40×160 mm3 cement mortars, which were kept in water for 7 and 28 days for flexure strength, were removed from the curing pool and subjected to flexure test with flexuring press. Compressive strength test was applied to six 40×40 specimens obtained by breaking as a result of flexure strength.

In the last stage of the experimental studies, electrical measurements were calculated. Electrical conductivity is used to show how the current flows freely on the material [12]. In the conductivity test, the current value is measured by giving a voltage to the produced sample. Therefore, a source and a measuring instrument were used for this experiment. A DC power supply was used for the source and a digital multimeter was used for the measuring instrument.

Two-point conductivity measurement method was used for electrical conductivity. Voltage was applied from the power source to two different points of the samples. The applied voltage value is set to 30 V. The current value was calculated according to this voltage value. Since the sample is not completely homogeneous, at least 5 different measurements were taken for each sample. According to the averaged current value, the resistance of the material was calculated by using Ohm's law. All samples were produced as 40*40*160 mm. Thus, each sample was measured under equal conditions. All measurements were made at room temperature. After the resistance value is found, the electrical conductivity value is calculated.

III. RESULTS

A. *Flow Diameter*

Spread diameter tests are shown in Figure 2. With the substitution of graphite powder, the spread of cement mortars decreased. In the calculations of the spreading diameter measured according to the reference sample; a decrease of 9.5% was observed in the addition of 0.5% graphite powder, 13% in the addition of 1% graphite powder, 22.6% in the addition of 2% graphite powder and 53.5% in the addition of 4% graphite powder. The decrease in the consistency value showed that the workability of the cement mortar decreased but increased the water requirement.

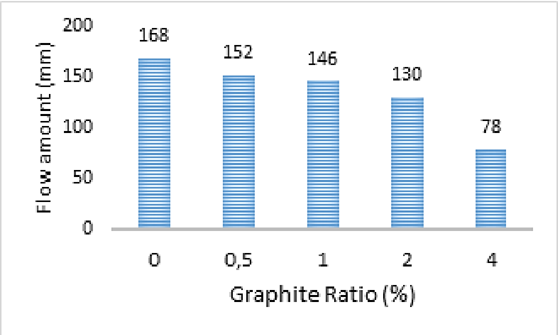

Fig. 2 Flow Experiment

Results should be clear and concise. The most important features and trends in the results should be described but should not interpreted in detail.

B. *Flexural and Compressive Strength*

7 and 28 days flexural strength of graphite powder additive cement mortars can be seen in Figure 3. When the 7 and 28-day flexural strengths are examined, flexural strength increases by 11% and 20% at the rate of 1% additive compared to the reference sample. However, decreases in flexural strength occurred after 1% additive ratio.

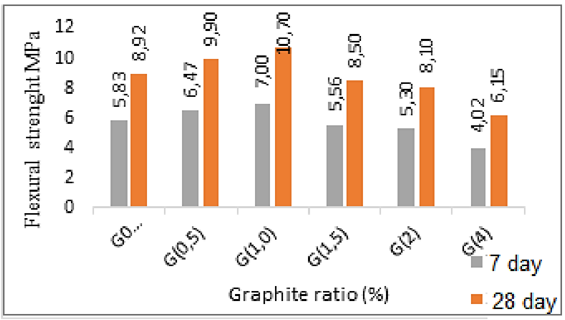

Fig. 3 Flexural Test of Cement Mortars with Graphite Powder Additive

7 and 28 days compressive strength of graphite powder additive cement mortars are shown in Figure 4. When the 7-day compressive strength is examined, it is seen that there is an increase of approximately 2.8% compared to the reference sample at a 0.5% graphite additive. this increase was found to be 3.73% in the 1% additive rate . When the 28-day compressive strength was examined, an increase of approximately 5% was observed at a 0.5% additive rate compared to the reference sample. This increase was measured as 5.95% in the 1% additive rate. However, there was a decrease in compressive strength after 1%.

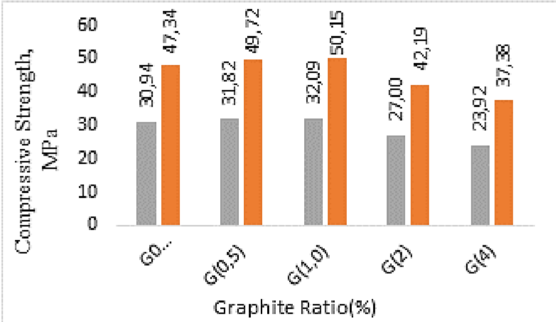

Fig. 4 Compression Test of Cement Mortars with Graphite Powder Additive

C. *Electrical Conductivity Test*

The electrical conductivity and resistivity values according to the graphite powder ratio in the hardened cement mortars are given in Figure 5 and Figure 6.

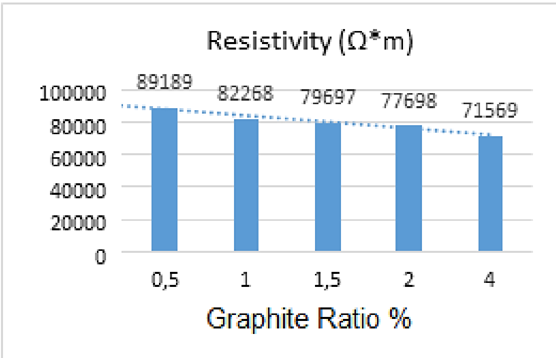

Fig. 5 Comparison of resistivity values of samples

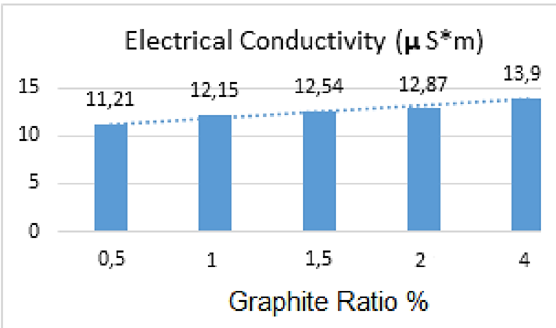

Fig. 6 Comparison of the conductivity values of the samples

It was clearly seen that the resistivity value decreased as the proportion of graphite powder added to the sample increased. The decrease in resistivity also increased the conductivity. The conductivity value is the lowest in 0.5% additive graphite powder and the highest in 4% additive graphite powder. It is seen that as the ratio of graphite powder added to the cement increases, the gaps formed between the material decrease and the electrical conductivity increases accordingly. When Figure 5 and Figure 6 are examined, it is seen that there is a linear increase in electrical conductivity when the graphite powder ratio increases in hardened cement mortars.

IV. CONCLUSION

It was observed that the flow of cement mortars decreased with graphite powder additive. It was observed that the water requirement in the material increased as the graphite additive ratio increased. It has been observed that graphite powder has a positive effect on flexural and compressive strengths up to 1% additive rate. However, after 1%, it had a negative effect on cement mortars. The electrical conductivity in the 4% graphite powder additive is 24.6% higher than the 0.5% graphite powder additive. In general, it was concluded that the electrical conductivity values increased with the increase in the use of graphite powder in hardened cement mortars.

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