Mechanical and Physical Properties of Carbon Black Reinforced Concrete

Tayfun UYGUNOĞLU[1], Emriye ÇINAR[2], Barış ŞİMŞEK[3], İlker Bekir TOPÇU[4]
[1,2,]Afyon Kocatepe University, Engineering Faculty, Civil Engineering Department, 03200, Afyonkarahisar, Turkey
[3]Çankırı University, Engineering Faculty, Chemical Engineering Department, Çankırı, Turkey
[4]Eskişehir Osmangazi University, Engineering Faculty, Civil Engineering Department, 26480 Eskişehir, Turkey

Abstract

Most of the materials that are considered as waste in the world are made up of recyclable materials. The recycling of these materials, the protection of the balance of nature and the environment, the minimization of damage to nature, and the economy of the country are very important. Carbon black is a material obtained from waste car tires with recycling material. As a result of the recovery process, 25-30% of the tire amount is recovered as carbon black. Carbon black is now used as a basic raw material or additive in many industries. Carbon black, with 95% carbon element content, contains small amounts of oxygen, hydrogen and nitrogen. The high electrical conductivity of the material due to the high amount of carbon is a high material. In this study, the effect of carbon black concrete, which is a waste product, on the mechanical, physical and electrical conductivity properties of concrete was investigated by adding different ratios. With increasing carbon black ratio, water absorption, unit volume weight, strength, electrical resistivity decreased and porosity ratio increased.
Keywords: Concrete, Carbon Black, Waste Product, Electrical resistivity

1. Introduction

Concrete is basically made of aggregates glued by a cementitious materials paste, which is made of cementitious materials and water. Each one of these concrete primary constituents, to a different extent, has an environmental impact and gives rise to different sustainability issues [1,2]. The current concrete construction practice is thought unsustainable because, not only it is consuming enormous quantities of stone, sand, and drinking water, but also two billion tons a year of Portland cement, which is not an environment friendly material from the standpoint of energy consumption and release of green-house gases (GHG) leading to global warming[3]. Furthermore, the resource productivity of Portland-cement concrete products is much lower than expected because they crack readily and deteriorate fast. Since global warming has emerged as the most serious environmental issue of our time and since sustainability is becoming an important issue of economic and political debates, the next developments to watch in the concrete industry will not be the new types of concrete, manufactured with expensive materials and special methods, but low cost and highly durable concrete mixtures containing largest possible amounts of industrial and urban byproducts that are suitable for partial replacement of Portland cement, virgin aggregate, and drinking water [4,5]. According to this new vision, notwithstanding the energy consumption of cement production and the related carbon dioxide emissions, concrete can “adsorb” these negative effects and become an environmentally sustainable material. This outstanding effect is mainly attributable to the opportunity of easily incorporating mineral additions in concrete. Such mineral additions are quite different in nature, composition, and origin. Thanks to concrete technology developments, particularly connected to advances in concrete admixtures, mineral additions are used quite

frequently in concrete today. In fact, many by-products and solid recyclable materials can be used in concrete mixtures as aggregates or cement replacement, depending on their chemical and physical characterization [6]. Carbon black is a material obtained from waste car tires with recycling material. Carbon Black is used in a diverse group of materials in order to enhance their physical, electrical and optical properties. Its largest volume use is as a reinforcement and performance additive in rubber products. In rubber compounding, natural and synthetic elastomers are blended with Carbon Black, elemental sulfur, processing oils and various organic processing chemicals, and then heated to produce a wide range of vulcanized rubber products. In these applications, Carbon Black provides reinforcement and improves resilience, tear-strength, conductivity and other physical properties [7]. Carbon Black is the most widely used and cost-effective rubber reinforcing agent (typically called Rubber Carbon Black) in tire components (such as treads, sidewalls and inner liners), in mechanical rubber goods, including industrial rubber goods, membrane roofing, automotive rubber parts (such as sealing systems, hoses and anti-vibration parts) and in general rubber goods (such as hoses, belts, gaskets and seals) [8]. Besides rubber reinforcement, Carbon Black is used as black pigment and as an additive to enhance material performance, including conductivity, viscosity, static charge control and UV protection. This type of Carbon Black (typically called Specialty Carbon Black) is used in a variety of applications in the coatings, polymers and printing industries, as well as in various other special applications [9]. In this study, the effect of carbon black (CB) concrete, which is a waste product, on the mechanical, physical and electrical conductivity properties of concrete was investigated by adding different ratios (0%, 1%, 2% and 3%) . With increasing carbon black ratio, unit volume weight, strength, electrical resistivity decreased, porosity ratio and water absorption increased.

2. Experimental works

In the experimental study, crushed sand and aggregate have been used. Specific gravity of crushed sand and aggregate are 2.67 and 2.70, the maximum grain sizes are 4 mm and 11.2 mm. In the experiments, CEM I 42.5 R cement which is suitable to TS EN 197-1 [10] standards have been used.

2.1. Materials

Cement: CEM I 42.5 N cement which is suitable to TS EN 197-I standards have been used as binder. Chemical components of cement are given in Table 1.

Table 1.Component of cement

Oxide	CaO	SiO_2	CaO/ SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	SO_3	K.K.
Component,%	63,6	16,6	3,83	4,72	3,27	1,91	0,34	1,06	4,72	2,69

Aggregate: In the experimental study, crushed sand and aggregate have been used. Specific gravity of crushed sand and aggregate are 2.67 and 2.70, the maximum grain sizes are 4 mm and 11.2 mm.
Carbon Black: Carbon black is a material obtained from waste car tires with recycling material. Carbon black with a particle size of 30 μm was used in the concrete.
Mixing Water: Drinking water was used for mixing.

2.2. Production of specimen

Concretes with a water / cement ratio of 0.65 and carbon black (CB) content of 0%, 1%, 2% and 3% were produced. Initially for the mixture of concrete, crushed sand, aggregate and cement were mixed for 1 minute in order to have dry mixture. Then almost 2/3 of mixture water was added to the dry mixture. Finally the rest 1/3 of water were put into the mixture and the process of mixing was continued for 5 min. The 25 L capacity mixer is used. Then they are put in plastic moulds whose sizes are 10 cm x 10 cm x 10cm. Unit volume components of %0, %1, %2 and %3 rate carbon black substituted concrete have been shown in Table 2. After 24 hours, the samples were taken from the molds and cured in 20 ± 2 ^{0}C lime saturated water for 28 days.

Table 2. Component of concrete per cubic meter

Carbon black ration	Cement, kg/m^3	Water, lt/m^3	Carbon black kg/m^3	Crushed sand kg/m^3	Aggregate kg/m^3
%0	300	211	0	865	882
%1	297	211	3	865	882
%2	294	211	6	865	882
%3	291	211	9	865	882

3. Concrete Test

3.1. Porosity Ratio, Water Absorption and Unit Volume Weight

Porosity ratio, water absorption and unit volume weight, which are the basic physical properties of the samples, were determined by using standard TS EN 480-11 [11] test methods. The specific weight of the charges is determined by the Archimedes principle. The sample was allowed to stand at a temperature of 105±5 ° C until it reached a constant weight (approx. 24 h), after which the dry weights of the samples were determined. Subsequently, the specimens soaked in water for 24 h were saturated and their weights in water were determined and the apparent specific gravity, water absorption capacity and porosity values were calculated.

3.2. Compressive Strength

The compressive strength is most important characteristic of hardened concrete and normally for the purposes of the specification. Concrete cube test is the test the most knowledgeable, and is used as a method to measure the strength of the standard pressure for quality control purposes. The compressive strength of the concrete cubes was tested according to TS EN 13791 [12] for 1 and 28 days.

3.3. Electrical Resistivity

Electrical resistivity measurement of carbon black reinforced concrete in accordance with ASTM C 1760 [13] and resistance values (ohm-meter) were measured by two plate method. The resistivity values (R) were also determined by the following equation (1).

$$\delta = R\frac{A}{L} \tag{1}$$

Where, ρ is resistivity (Ω·m), R is resistance (Ω), A is sample area (cm^2) and l is sample length (m).

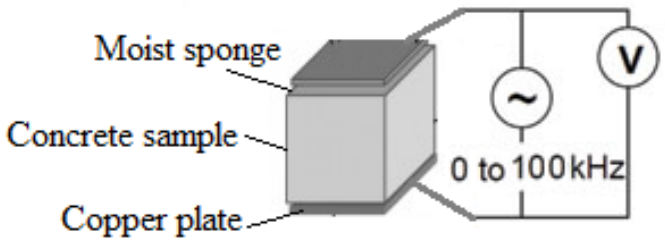


Figure 1. Electrical resistivity measurement on concrete

4. Results and Discussions

4.1. Porosity Ratio, Water Absorption and Unit Volume Weight

The porosity values of carbon black (CB) added concrete are given in Figure 2. It has been observed that the ratio of porosity slightly increases with increasing carbon black ratio. As the amount of carbon black increases, the amount of cement decreases. As the amount of cement decreases, the porosity rate increases. As the amount of cement decreases, the binding ratio decreases, so porosity increases. Porosity 13,77 was determined in unused concrete with carbon black. Porosity14,97 of concrete containing 3% ration carbon black.

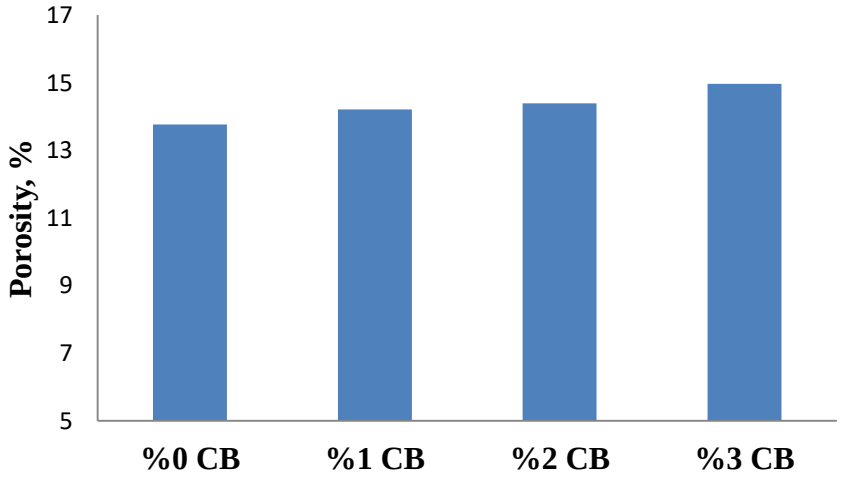


Figure 2. Porosity values of carbon black added concrete

The water absorption values of carbon black added concrete are given in Figure 3. It has been observed that the ratio of water absorption increases with increasing carbon black ratio. For instance, water absorption was increased from 6.16% to 6.83% when 3 wt.% CB was added into the concrete. It demonstrated that CB had adverse effect on the water absorption of concrete. This was mainly due to the very high surface area of CB particles.

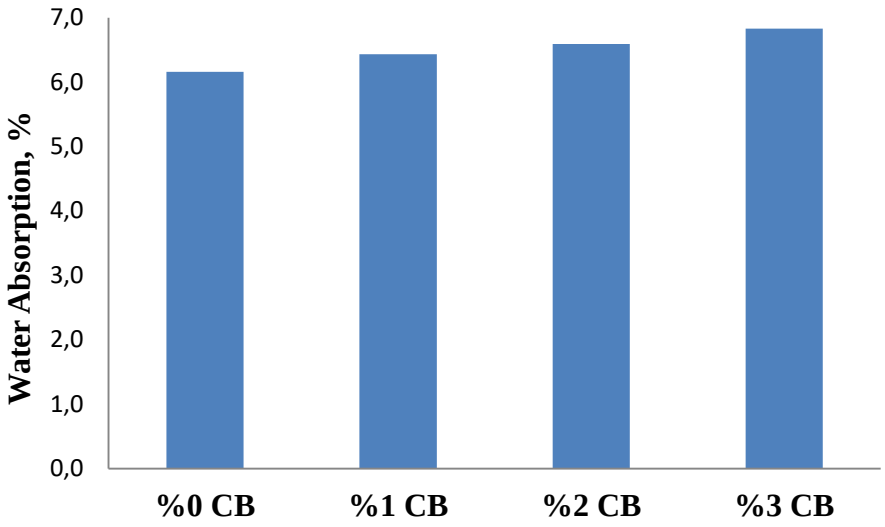


Figure 3. Water absorption values of carbon black added concrete

Unit volume weight values of carbon black added concrete are given in Figure 4. The unit weight slightly decreased with increasing carbon black ratio. When the unit weight of plain concrete is 2.24 kg/dm^3, it is 2.15 kg/dm^3 for 3% of CB blended concrete.

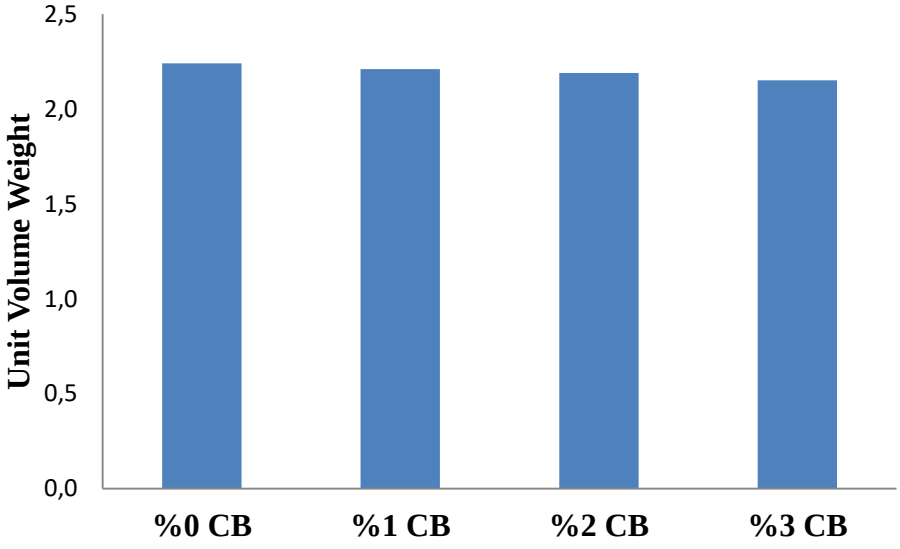


Figure 4. Unit volume weight values of carbon black added concrete

4.2. Compressive Strength

Compressive strength values of carbon black added concrete are given in Figure 5 for 1 and 28 days. With the increase of the ratio of carbon black, the compressive strength of 1 day decreased. With the increase of the ratio of carbon black, the compressive strength of 28 day decreased. As the amount of carbon black increases, the binder requirement also increases due to filling effect of very fine particles of carbon black. Therefore the compressive strength decreases.

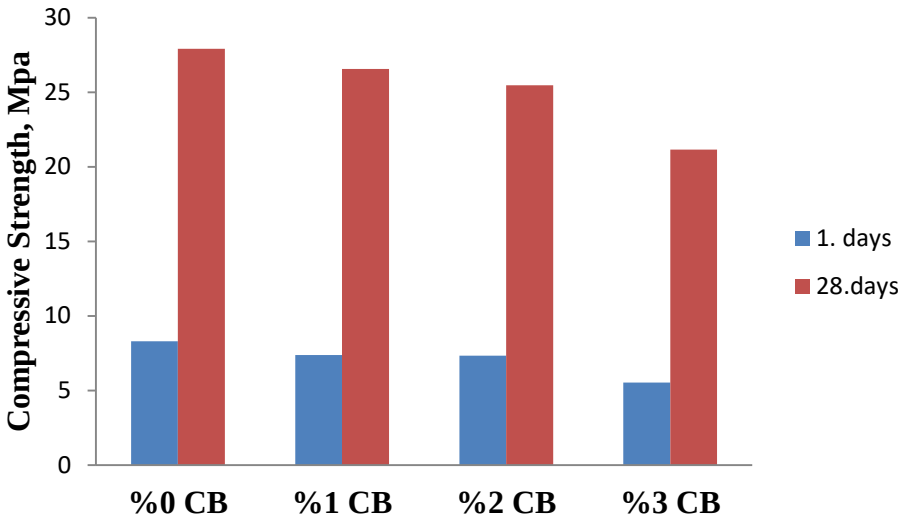


Figure 5. Compressive strength values of carbon black added concrete

4.3. Electrical Resistivity

The electrical resistance values of carbon black concrete with different ratios depending on the frequency are given in Figure 6. As is known, frequency is the number of cycles per second of an AC signal. In cement-based systems, electrical conductivity occurs due to ion transfer in cavity solutions and ion transfer is accelerated with increasing frequency. Therefore, resistance decreases. With the increase of carbon black ratio, electrical resistivity decreased. The electrical conductivity of carbon black has brought the concrete to the conductive structure, thus reducing the resistance.

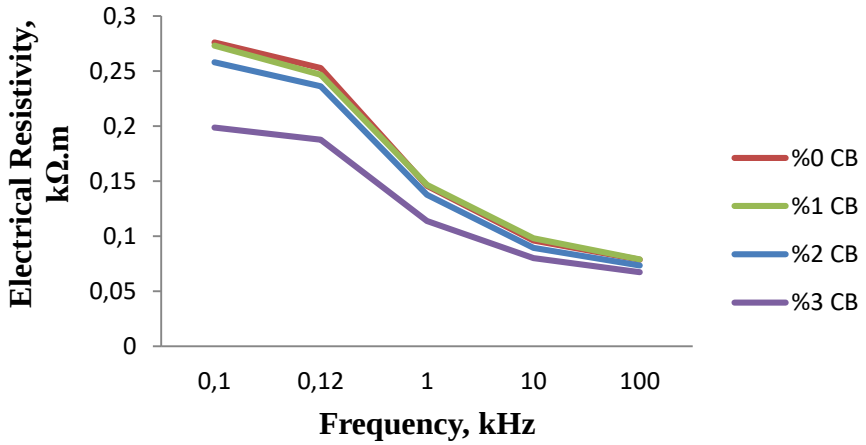


Figure 6. Electrical resistivity according to different frequency values

5. Conclusions

In this study, physical, mechanical and electrical properties of the concrete produced by adding carbon black in different ratios were investigated and the results obtained are given below.

- It has been observed that the ratio of porosity increases with increasing carbon black ratio.

- It has been observed that the ratio of water absorption increases with increasing carbon black ratio.
- The unit weight decreased with increasing carbon black ratio.
- With the increase of the ratio of carbon black, the compressive strength of 1 day decreased.
- With the increase of the ratio of carbon black, the compressive strength of 28 day decreased.
- With the increase of carbon black ratio, electrical resistivity decreased.

Acknowledgement

Authors thank to Afyon Kocatepe University for supporting the study with 17.FEN.BIL.40 Scientific Project.

REFERENCES

[1] Mehta, P.K. 1999. Concrete technology for sustainable development, Concrete International, 21(11): 47-53.

[2] Mehta, P.K. 2001. Reducing the environmental impact of concrete, Concrete International, 23(10): 61-66.

[3] Mehta, P.K. 2002. Greening of the concrete industry for sustainable development, Concrete International, 24(7): 23-28.

[4] Holland, T.C. 2002. Sustainability of the concrete industry – What should be ACI‟s role? Concrete International, 24(7): 35-40.

[5] Corinaldesi, V. & Moriconi, G. 2006. Behavior of beam-column joints made of sustainable concrete under cyclic loading, Journal of Materials in Civil Engineering, 18(5): 650-658.

[6] Malhotra, V.M. 2003. Concrete technology for sustainable development, In Sustainable Development in cement and concrete industries, Proc. two-day intern. Seminar, Milan, Italy, 17-18 October 2003, 11-18.

[7] Monteiro, A.O., Cachim, P.B., Costa, P.M.F.J., Electrical properties of cement-based composites containing carbon black particles, 5th International conference on Advanced Nano Materials, 2015, 193-199.

[8] Mahoutian, M., Lubell, A.S., Bindiganavile, V.S., Effect of powdered activated carbon on the air void characteristics of concrete containing fly ash, Construction and Building Materials, 2015, 80, 84-91.

[9] Gonga, H., Li, Z., Zhang, Y., Fan, R., Piezoelectric and dielectric behavior of 0-3 cement-based composites mixed with carbon black, Journal of the European Ceramic Society, 2009, 29, 2013-2019.

[10] TS EN 197-1, Cement- Stage 1: General cements – component, TSE, Ankara (2010) Turkey.

[11] TS EN 480-11, Admixtures for concrete, mortar and grout - Test methods - Part 11: Determination of air void characteristics in hardened concrete, Turkish Standard Institute, Ankara, Turkey, 2008.

[12] TS EN 13791, Assessment if in-situ compressive strength in structures and precast concrete components, TSE, Ankara (2010) Turkey.

[13] ASTM C 1760. Standard test method for bulk electrical conductivity of hardened concrete. West Conshohocken (PA): ASTM; 2012.

[14] B. Chen , B. Li, Y. Gao, T.C. Ling, Z. Lu, Z. Li, Investigation on electrically conductive aggregates produced by incorporating carbon fiber and carbon black, Construction and Building Materials 144 (2017) 106–114.