Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 7, S. 7-11, 9, 2023

Araştırma Makalesi

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 7, pp. 7-11, 9, 2023

Research Article

The Effect of Calcined Bentonite Clay on the Late-Age Electrical Conductivity of Cement Paste after Wetting and Drying Cycles

Emrah TURAN[1*] and Meral OLTULU [2]

[1]*Department of Civil Engineering, Atatürk University, Turkey*
[2]*Department of Civil Engineering, Atatürk University, Turkey*

[*]*(emrah.turan@atauni.edu.tr) Email of the corresponding author*

(Received: 26 September 2023, Accepted: 05 October 2023)

(3rd International Conference on Innovative Academic Studies ICIAS 2023, September 26-28, 2023)

ATIF/REFERENCE: Turan, E. & Oltulu, M. (2023). The Effect of Calcined Bentonite Clay on the Late-Age Electrical Conductivity of Cement Paste after Wetting and Drying Cycles. *International Journal of Advanced Natural Sciences and Engineering Researches*, 7(9), 7-11.

Abstract **–** In recent years, there has been a growing interest in the development of sustainable construction materials and technologies. One promising approach is the use of natural minerals and additives to enhance the properties of cementitious composites. Calcined bentonite clay is a natural pozzolanic material that has been shown to improve the compressive strength and durability of concrete. However, its effect on the electrical conductivity of cement paste is less well understood. This study investigates the effect of calcined bentonite clay on the electrical conductivity of cement paste after wetting and drying cycles. Cement paste samples were prepared with different proportions of calcined bentonite clay substitute (5%, 10%, 15%, 20%, 20%, 25% and 30%). The specimens were then subjected to wetting and drying cycles of 5, 10, 15, and 20 cycles. Electrical conductivity measurements were performed on the specimens after each wetting and drying cycle. The results of the study showed that calcined bentonite clay had a negative effect on the electrical conductivity of cement paste. The electrical conductivity of the specimens decreased with increasing calcined bentonite clay substitution level and with increasing number of wetting and drying cycles. Despite its negative effect on electrical conductivity, calcined bentonite clay was found to improve the compressive strength of cement paste in the long term. This suggests that calcined bentonite clay is a viable mineral additive for improving the durability of concrete, even if it is not suitable for applications where high electrical conductivity is required.

Keywords – Cement Paste, Calcined Bentonite Clay, Electrical Conductivity, Compressive Strength

I. INTRODUCTION

In the construction sector, environmentally friendly and sustainable building materials are given innovative properties and their performance is increased by improving their existing properties. Among these properties, electrical conductivity is emphasized for more comprehensive use of cement-based materials. Electrical conductivity can vary depending on changes in the internal structure of the material. Factors such as moisture content, porosity and structural changes can affect the electrical conductivity and various additives can be used to increase the conductivity [1-4]. The high cost of materials with good electrical conductivity (nanocarbon [5,6], carbon nanotubes [7,8], carbon fibers [9], carbon fiber (CNF) [10], graphene [11], steel fiber [12,13], aluminum shavings [14]) and the need to use them in high proportions is a limiting factor in increasing electrical conductivity. For this reason, it is important to discover a material with low cost and without supply problems.

The addition of calcined clay to cement, which is one of the clays increasingly used in cement-based composites, can cause changes in the physical and chemical properties of cement, which can provide advantages in various application areas. However, due to the characteristic structure of clays, attention should be paid to the volumetric changes that occur with water. These changes can provide important information on the durability of the material, the occurrence of cracks, the change of mechanical properties. In fact, it can accelerate the damage process in cement paste exposed to wetting-drying cycles over a long period of time [15,16].

This study aims to investigate the changes in electrical conductivity of cement paste with calcined bentonite clay admixture after wetting-drying cycles. For this purpose, calcined bentonite clay was substituted into the cement paste at a ratio of 5-10-15-20-25-30% of the cement amount. Then, 360-day compressive strengths and electrical conductivity values of these mixtures were determined and exposed to 5,10,15 and 20 wetting-drying cycles. Electrical conductivity was measured at the end of each wetting-drying cycle and compared with the electrical conductivities before the cycles.

II. Materials and Method

A. *Materials*

The bentonite clay used in the experiments was obtained from Çankırı province and commercially sold bentonite clay was used. The chemical content of bentonite was obtained from the company and given in Table 1. The specific gravity of bentonite was determined as 2.73 g/cm^3

Table 1. Physical and chemical properties of bentonite clay

Component	**Ratio, %**
SiO_2	69,1
Al_2O_3	15,2
Fe_2O_3	0,2
CaO	0,1
Na_2O	0,03
K_2O	11,07

CEM I 42.5R Portland cement produced in accordance with TS EN 197-1 was used to produce cement paste samples in the study. The physical and chemical properties of the cement are given in Table 2.

Table 2. Cement properties

Chemical and Physical Properties	**%**
Total SiO_2	19,84
Al_2O_3	4,91
Fe_2O_3	3,52
CaO	61,65
MgO	1,33
SO_3	2,70
CI	0,007
Loss on ignition	2,73
Insoluble matter	0,95

B. *Method*

The supplied bentonite clay was fired for 90 minutes after the temperature reached 900˚C in the automatic furnace, considering the study by Karakurt et al. (2020). The effects of the calcined bentonite on the cement paste were investigated by adding 5-10-15-20-25-30% by weight to the cement. In the preliminary experiments, the water/cement ratio was determined as 0.30. Firstly, dry calcined bentonite was added to the cement and mixed for 60 seconds. The mixing water was divided into two parts and added in two stages, each stage was mixed for 60 seconds.

Electrode immersed samples were measured on day 360 and at the end of 5-10-15-20 wetting-drying cycles at 200 kHz using the digital LCR meter shown in Fig 1. The samples were kept in the laboratory for 360 days. In order to maintain the same humidity level in electrical conductivity measurements, the samples were kept in the oven at 70 °C for 24 hours. The electrical resistivity of the samples was determined by means of the equation considering the second ohm's law.

$$\rho=(R.S)/L$$

In the equation: R is the electrical resistance measured with an LCR meter, S is the electrode area and L is the distance between the electrodes [17].

Table 3. Results for cement pastes with calcined bentonite additives

Group*	Compressive Strength, MPa	Electrical Resistance at the End of Wetting-Drying Cycles, Ω					Compressive strength at end of cycles, MPa	Alteration, %
		0	5	10	15	20		
Control	74,1	38547,6	430,1	609,5	744,8	976,8	73,9	0
CB0.05	77,4	39455,2	275,5	495,0	526,8	729,2	76,7	-1
CB0.10	81,6	39132,1	308,0	593,0	704,5	970,3	77,5	-5
CB0.15	76,3	38992,2	558,3	841,5	1171,6	1235,9	71,1	-7
CB0.20	75,4	37283,6	1119,9	1418,9	961,7	1597,3	68,2	-10
CB0.25	71,1	37456,3	1621,3	1958,3	2213,7	1892,6	62,3	-12
CB0.30	65,2	36232,8	1702,9	2388,4	2318,8	2489,7	56,7	-13

** In the sample coding, calcined bentonite is represented by "CB" and the additive ratio is indicated next to it. For example; CB0.10: CB calcined bentonite, 0.10 indicates the replacement ratio by weight to cement.*

Fig. 1. Electrical resistance meter

Compressive tests were performed on 50x50x50 mm cube specimens. The tests were performed at constant loading rate and 0.5 MPa/s was taken according to TS EN 12390-3AC.

III. Results and Discussion

The results for the control and calcined bentonite clay substituted cement pastes are given in Table 3.

It was observed that the substitution of calcined bentonite clay before the wetting-drying cycles did not significantly change the electrical resistance. Wetting-drying cycles caused a decrease in electrical resistance in the control group. This is thought to occur as a result of filling the pores with conductive water.

Electrical conductivity values decrease as a result of 5-10-15-20 wetting-drying cycles. It is seen that CB0.05 sample has the best performance as a result of wetting-drying cycles. This is thought to be due to the formation of a more compact structure as a result of the reaction of the voids formed at the end of wetting-drying in the calcined bentonite clay substituted specimens with portlandite. The compressive strength of the cement paste before and after cycling is given in Fig 2.

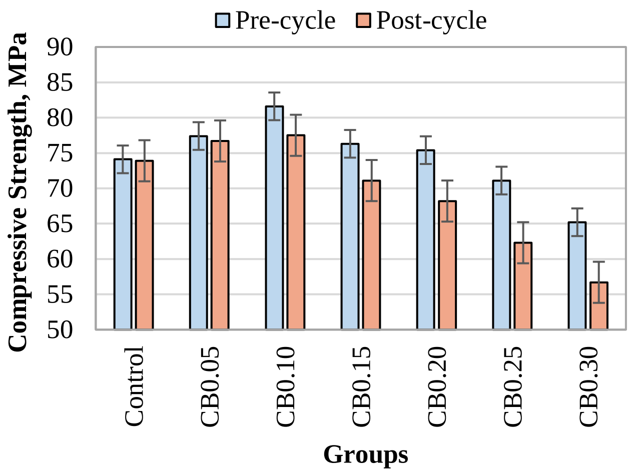

Fig. 2 Compressive strengths before and after wetting-drying cycles

The compressive strength of the cement paste decreased after the wetting-drying cycles. It is seen that the amount of decrease increases with the substitution of calcined bentonite clay after a certain ratio. This is thought to be due to the fact that at the end of the wetting-drying cycles, calcined bentonite clay forms weak zones due to the lack of portlandite to react more in the sample and the amount of damage in the cement paste increases. Among the additive groups, the compressive strength decreased between 1% and 13% at the end of the wetting-drying cycles. The lowest decrease in compressive strength was observed in the CB0.05 group and the highest decrease was observed in the CB0.30 group.

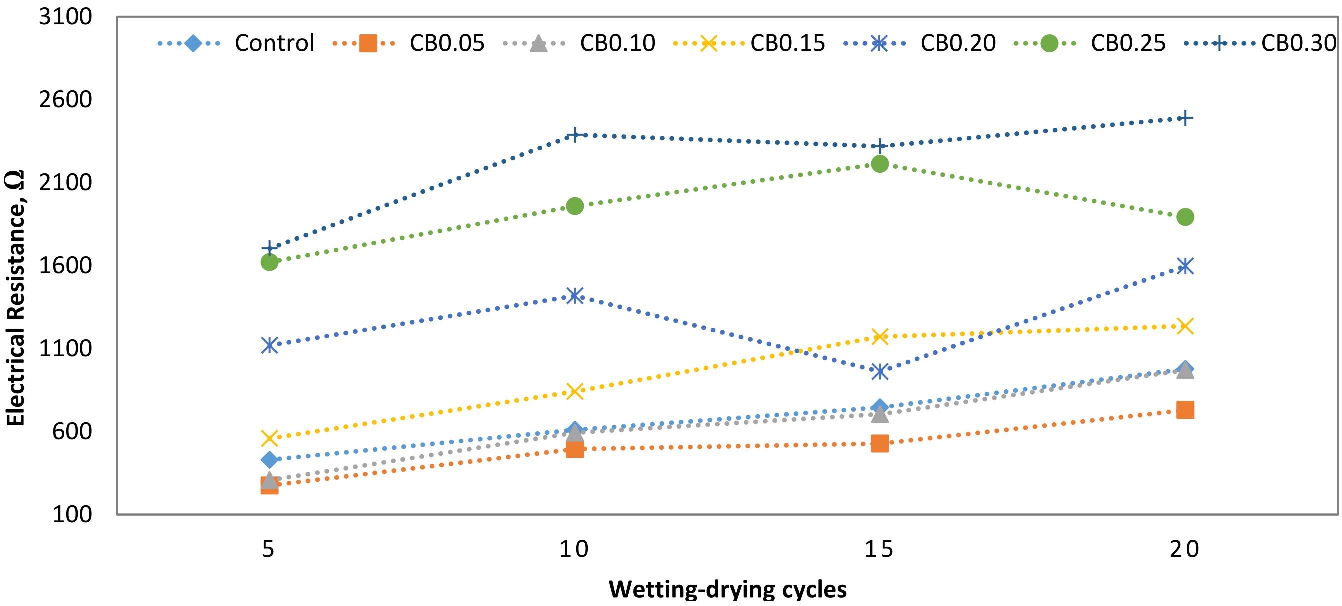

Fig. 3 Electrical resistance after and after wetting-drying cycles

CONCLUSION

In this study, electrical conductivity and compressive tests were carried out at the end of wetting-drying cycles on specimens with 5-10-15-20-25-30 wt% calcined bentonite clay substituted into the cement paste at the end of wetting-drying cycles. The conclusions drawn from the study can be listed as shown below:

- -Calcined bentonite clay substitution did not significantly change the electrical conductivity. Soaking-drying cycles caused a decrease in electrical resistivity in the control group. However, resistance increased in the calcined bentonite clay substituted groups.
- As a result of the wetting-drying cycles, a decrease in the electrical conductivity values of the calcined bentonite clay substituted samples was observed. These results indicate that the voids formed as a result of wetting-drying are effective in damaging the cement paste or increasing cracking.
- It has been observed that wetting-drying cycles have a negative effect on the mechanical properties of cement paste and the addition of calcined bentonite clay has a mitigating effect. At this point, it is considered that the use of calcined bentonite clay should be evaluated in terms of sustainability and therefore, it may have potential advantages when used in cementitious composites.

Investigation of mechanical properties of cement composites with calcined bentonite clay substitutes at higher wetting-drying cycles will contribute to the literature.

REFERENCES

[1] G.M. Kim, F. Naeem, H.K. Kim, H.K. Lee, Heating and heat-dependent mechanical characteristics of CNT-embedded cementitious composites, Compos Struct. 136 (2016) 162–170. https://doi.org/10.1016/j.compstruct.2015.10.010.

[2] R.S. Ruoff, D.C. Lorents, Mechanical and thermal properties of carbon nanotubes, Carbon N Y. 33 (1995) 925–930. https://doi.org/10.1016/0008-6223(95)00021-5.

[3] J.-P. Salvetat, J.-M. Bonard, N.H. Thomson, A.J. Kulik, L. Forró, W. Benoit, L. Zuppiroli, Mechanical properties of carbon nanotubes, Appl Phys A Mater Sci Process. 69 (1999) 255–260. https://doi.org/10.1007/s003390050999.

[4] K. Tanaka, T. Sato, T. Yamabe, K. Okahara, K. Uchida, M. Yumura, H. Niino, S. Ohshima, Y. Kuriki, K. Yase, F. Ikazaki, Electronic properties of carbon nanotube, Chem Phys Lett. 223 (1994) 65–68. https://doi.org/10.1016/0009-2614(94)00421-8.

[5] W. Dong, W. Li, L. Shen, D. Sheng, Piezoresistive behaviours of carbon black cement-based sensors with layer-distributed conductive rubber fibres, Mater Des. 182 (2019) 108012. https://doi.org/10.1016/j.matdes.2019.108012.

[6] G.H. Nalon, R.F. Santos, G.E.S. de Lima, I.K.R. Andrade, L.G. Pedroti, J.C.L. Ribeiro, J.M. Franco de Carvalho, Recycling waste materials to produce self-sensing concretes for smart and sustainable structures: A review, Constr Build Mater. 325 (2022) 126658.

https://doi.org/10.1016/J.CONBUILDMAT.2022.126658.
[7] W. Dong, W. Li, K. Wang, B. Han, D. Sheng, S.P. Shah, Investigation on physicochemical and piezoresistive properties of smart MWCNT/cementitious composite exposed to elevated temperatures, Cem Concr Compos. 112 (2020) 103675. https://doi.org/10.1016/j.cemconcomp.2020.103675.
[8] D. Hou, D. Wu, X. Wang, S. Gao, R. Yu, M. Li, P. Wang, Y. Wang, Sustainable use of red mud in ultra-high performance concrete (UHPC): Design and performance evaluation, Cem Concr Compos. 115 (2021) 103862. https://doi.org/10.1016/j.cemconcomp.2020.103862.
[9] L. Deng, Y. Ma, J. Hu, S. Yin, X. Ouyang, J. Fu, A. Liu, Z. Zhang, Preparation and piezoresistive properties of carbon fiber-reinforced alkali-activated fly ash/slag mortar, Constr Build Mater. 222 (2019) 738–749. https://doi.org/10.1016/j.conbuildmat.2019.06.134.
[10] D.K. Hardy, M.F. Fadden, M.J. Khattak, A. Khattab, Development and characterization of self-sensing CNF HPFRCC, Mater Struct. 49 (2016) 5327–5342. https://doi.org/10.1617/s11527-016-0863-z.
[11] J. Tao, X. Wang, Z. Wang, Q. Zeng, Graphene nanoplatelets as an effective additive to tune the microstructures and piezoresistive properties of cement-based composites, Constr Build Mater. 209 (2019) 665–678. https://doi.org/10.1016/j.conbuildmat.2019.03.173.
[12] A. Belli, A. Mobili, T. Bellezze, F. Tittarelli, Commercial and recycled carbon/steel fibers for fiber-reinforced cement mortars with high electrical conductivity, Cem Concr Compos. 109 (2020) 103569. https://doi.org/10.1016/j.cemconcomp.2020.103569.
[13] E. Demircilioglu, E. Teomete, O.E. Ozbulut, Strain sensitivity of steel-fiber-reinforced industrial smart concrete, J Intell Mater Syst Struct. 31 (2020) 127–136. https://doi.org/10.1177/1045389X19888722.
[14] E. Turan, M. Oltulu, Alüminyum Talaşı Katkılı Çimento Hamurunun Mekanik ve Elektriksel Özellikleri, in: International IDU Engineering Symposium – IES'21, İzmir, Turkey, 2021, 2021.
[15] J. Diaz-Basteris, J.C. Sacramento Rivero, B. Menéndez, Life cycle assessment of restoration mortars and binders, Constr Build Mater. 326 (2022). https://doi.org/10.1016/j.conbuildmat.2022.126863.
[16] F. Wang, J. Huang, H. Zhao, Mechanical sandstone deterioration due to cement binder material materials under dry-wet cycling, Case Studies in Construction Materials. 18 (2023) e02169. https://doi.org/10.1016/J.CSCM.2023.E02169.
[17] R.A. Serway, J.W. Jewett, Physics for scientists and engineers, Cengage learning, 2018.