Maciej Lech, Tomasz Juszczak, Jerzy Wawrzeńczyk
Structure and Environment 2022, vol. 14, (1), pp. 1-10, Article number: el 001
https://doi.org/10.30540/sae-2022-001

Structure and Environment
ISSN 2081-1500
e-ISSN 2657-6902
https://content.sciendo.com/sae
https://sae.tu.kielce.pl

sciendo

Kielce University of Technology

DOI: 10.30540/sae-2022-001

A STUDY ON CARBONATION DEPTH PREDICTION FOR CONCRETE MADE WITH GBFS CEMENT AND FA ADDITION

BADANIE DOTYCZĄCE PROGNOZOWANIA GŁĘBOKOŚCI KARBONATYZACJI BETONU WYKONANEGO Z CEMENTU GBFS Z DODATKIEM FA

Maciej Lech[1]*, Tomasz Juszczak[2], Jerzy Wawrzeńczyk[1]
[1]Kielce University of Technology, [2]Grolman Poland

Abstract

This paper presents the results of the examination of accelerated carbonation of concrete mixes made with CEM III / A blast furnace slag cement and the addition of fly ash. The test program was developed using an experiment design with two factors: a water-binder ratio and a fly-ash / cement ratio. Carbonation depth measurements were carried out according to FprCEN/TS 12390-12 (CO_2 concentration = 4%, T = 20°C, RH = 55%). Associated tests were also carried out, including compressive strength, porosity, depth of absorption, water penetration depth, and capillary suction.

Analysis of the test results allowed us to determine the influence of binder composition on concrete carbonization depth under standard test conditions. The results show that the carbonation depth increases along with the increase in the W/B ratio and as a result of the increase in the fly ash content in the binder.

A mathematical model was developed to describe the carbonation process over time, which can predict the depth and rate of concrete carbonation. Furthermore, it was found that there is no close relationship between other properties tested (e.g. strength) and the depth of the carbonated concrete.

Keywords: concrete carbonation, carbonation model, carbonation accelerated testing, GBFS cement, FA addition

Streszczenie

W pracy przedstawiono wyniki badań przyspieszonej karbonatyzacji mieszanek betonowych wytworzonych cementem żużlowym wielkopiecowym CEM III/A z dodatkiem popiołu lotnego. Program badań został opracowany na podstawie projektu eksperymentu z dwoma czynnikami: stosunkiem wody do spoiwa oraz stosunkiem popiołu lotnego do cementu. Pomiary głębokości karbonatyzacji przeprowadzono zgodnie z FprCEN/TS 12390-12 (stężenie CO_2 = 4%, T = 20°C, RH = 55%). Przeprowadzono również powiązane testy, w tym wytrzymałości na ściskanie, porowatości, głębokości absorpcji, głębokości penetracji wody i ssania kapilarnego. Analiza wyników badań pozwoliła na określenie wpływu składu spoiwa na głębokość karbonatyzacji betonu w standardowych warunkach testowych. Wyniki wskazują, że wraz ze wzrostem stosunku W/B oraz zawartością popiołu lotnego w spoiwie wzrasta głębokość karbonatyzacji.

Opracowano model matematyczny do opisu procesu karbonatyzacji w czasie, który umożliwia przewidywanie głębokości i szybkości karbonatyzacji betonu. Ponadto stwierdzono, że nie ma ścisłego związku między innymi badanymi właściwościami (np. wytrzymałością) a głębokością betonu karbonatyzowanego.

Słowa kluczowe: karbonatyzacja betonu, model karbonatyzacji, przyspieszone badania karbonatyzacji, cement GBFS, dodatek FA

*Kielce University of Technology, Poland, e-mail: maciejl@tu.kielce.pl

REFERENCES

[1] He T., Xu R., Chen Ch., Yang L., Yang R., Da Y.: *Carbonation modeling analysis on carbonation behavior of sand autoclaved aerated concrete*. Constr. Build. Mater. 2018, Vol. 189, pp. 102-108. DOI:10.1016/j. conbuildmat.2018.08.199.
[2] Aleksander M., Thomas M.: S*ervice life prediction and performance testing – Current developments and practical applications*. Cem. Concr. Res. 2015, Vol. 78, pp. 155-164. DOI:10.1016/j.cemconres.2015.05.013.
[3] Marques P.F., Chastre C., Nunes A.: *Carbonation service life modelling of RC structures for concrete with Portland and blended cements*, Cem. Concr. Compos. 2013, Vol. 37, pp. 171-184. DOI:10.1016/j.cemconcomp.2012.10.007.
[4] Oner A., Akyuz S., *An experimental study on optimum usage of GGBS for the compressive strength of concrete*. Cem. Concr. Compos. 2007, Vol. 29, pp. 505-514.
[5] Ekolu S.: *Model for practical prediction of natural carbonation in reinforced concrete: Part 1-formulation*. Cem. Concr. Compos. 2018, Vol. 86, pp. 40-56. DOI:10.1016/j. cemconcomp. 2017.10.006.
[6] Guiglia M., Taliano M.: *Comparison of carbonation depths measured on infield exposed existing r.c. structures with predictions made using fib-Model Code 2010*, Cem. Concr. Compos. 2013, Vol. 38, pp. 92-108. DOI:10.1016/j. cemconcomp. 2013.03.014.
[7] Czarnecki L., Woyciechowski P.: *Modelling of concrete carbonation; is it a process unlimited in time and restricted in space?* Bulletin of the Polish Academy of Sciences Technical Sciences 2015, Vol. 63, No. 1, DOI: 10.1515/ bpasts-2015-00062.
[8] Czarnecki L., Woyciechowski P.: *Prediction of the reinforced concrete structure durability under the risk of carbonation and chloride aggression.* Bulletin of the Polish Academy of Sciences Technical Sciences 2013, Vol. 61, No. 1, pp. 173-181, DOI: 10.2478/bpast.2013.0016.
[9] Woyciechowski P., Woliński P., Adamczewski G.: *Prediction of Carbonation Progress in Concrete Containing Calcareous Fly Ash Co-Binder*. Materials 2019, Vol. 12, 2665. DOI:10.3390/ma12172665.
[10] Fagerlund G.: *Durability of Concrete Structures*, Arkady, Warszawa 1997 (in Polish).
[11] Zhang X., Zhou X., Zhou H., Gao K., Wang Z.: *Studies on forecasting of carbonation depth of slag high performance concrete considering gas permeability*. Applied Clay Science 2013, Vol. 79, pp. 36-40. DOI:10.1016/j. clay.2013.02.020.
[12] DeSchutter G., Audenaert K.: *Evaluation of water absorption of concrete as a measure for resistance against carbonation and chloride migration*. Mater Struct. 2004, Vol. 37, 591-6.
[13] Roziere E., Loukili, A., Cussigh F.: *A performance based approach for durability of concrete exposed to carbonation*. Constr. Build. Mater. 2009, Vol. 23, No. 1, pp. 190-199. DOI:10.1016/j. conbuildmat.2008.01.006.
[14] CEN – European Committee for Standardization, EN 206. Concrete – Specification, Performance, Production and Conformity. Brussels, Belgium, 2013.
[15] Harrison T.A., *Equivalent durability concept*. Workshop proceeding no. 8: Nordic Exposure sites – input to revision of EN 206 – 1, Hirtshals, Denmark, November 12-14, 2008.
[16] Fib, Model Code for Concrete Structures 2010 – International Federation for Structural Concrete. DOI: 10.1002/9783433604090, 2013.
[17] Final Draft FprCEN/TS 12390-12: Testing hardened concrete – Part 12: Determination of the potential carbonation resistance of concrete: Accelerated carbonation method. CEN 2010.
[18] EN 12390-12: Testing hardened concrete – Part 12: Determination of the potential carbonation resistance of concrete: Accelerated carbonation method. CEN 2020.
[19] Gruyaert E., Philip V.H., Nele D.B.: *Carbonation of slag concrete: effect of the cement replacement level and curing on the carbonation coefficient – effect of carbonation on the pore structure*, Cem. Concr. Compos. 2013, Vol. 35 (1), pp. 39-48. DOI:10.1016/j.cemconcomp.2012.08.024.
[20] Sanjuán M.A., Piñeiro A., Rodríguez O.: *Ground granulated blast furnace slag efficiency coefficient (k value) in concrete*. Applications and limits, Mater. Constr. 2011, Vol. 61 (302), pp. 303-313. DOI:/ 10.3989/mc. 2011. 60410.1988-3226.
[21] Ekolu S.: *A review on efects of curing, sheltering, and CO_2 concentration upon natural carbonation of concrete*. Constr. Build. Mater. 2016, Vol. 127, pp. 306-320. DOI:10.1016/j.conbuildmat.2016.09.056.
[22] Zhang L.M., Jiang W.H.: *A study on carbonation of concrete in natural condition and its correlation with artificial accelerated carbonation*, J. Xi'an Inst. Metall. Constr. Eng. 1990, Vol. 22 (3), pp. 207-214.
[23] Raport CEN/TR 16639:2014: Use of k-value concept, equivalent concrete performance concept and equivalent performance of combinations concept.
[24] Younsi A., Turcry Ph., Aït-Mokhtar A., Staquet S.: *Accelerated carbonation of concrete with high content of mineral additions: Effect of interactions between hydration and drying.* Cem. Concr. Res., 2013, Vol. 43, pp. 25-33. DOI:10.1016/j.cemconres.2012.10.008.

[25] Sisomphon K., Franke L.: *Carbonation rates of concrete containing high volume of pozzolanic materials*. Cem. Concr. Res., 2007, Vol. 37, No. 2, pp. 1647-1653, DOI: 10.1016/j.cemconres. 2007.08.014.
[26] Deja J.: *Carbonation aspects of alkali activated slag mortars and concrete*s, Silicates Industriels 2002, Vol. 67 (3/4), pp. 37-42.
[27] Giergiczny Z., Glinicki M., Sokołowski M., Zielinski M.: *Air void system and frost-salt scaling of concrete containing slag-blended cement*. Constr. Build. Mater., 2009, Vol. 23, pp. 2451-2456. DOI:10.1016/j.conbuildmat.2008.10.001.
[28] Wawrzeńczyk J.: *The methods of testing and predicting of concrete freeze-thaw durability*. Monography M92, Kielce University of Technology, Kielce 2017 (in polish). PL ISSN 1897-2691.
[29] Song H.W., Saraswathy V.: *Studies on the corrosion resistance of reinforced steel in concrete with ground granulated blast-furnace slag – an overview*. Journal of Hazardous Materials 2006, Vol. 138, 226-233. DOI:10.1016/j.jhazmat.2006.07.022.
[30] Sisomphon K., Copuroglu O., Fraaij A.L.A.: *Development of blast-furnace slag mixtures against frost salt attack*. Cem. Concr. Compos. 2010, Vol. 32:630-8. DOI:10.1016/j.cemconcomp.2010.06.001.
[31] Lolini F., Redaelli E.: *Carbonation of blended cement concretes after 12 years of natural exposure*. Constr. Build. Mater. 2021, Vol. 276. DOI.org/10.1016/j.conbuildmat. 2020. 122122.

Authors Contributions: Conceptualization, JW (Jerzy Wawrzeńczyk), TJ (Tomasz Juszczak); Methodology, TJ and ML (Maciej Lech); Formal Analysis, JW and M.L.; Investigation, M.L and T.J; Writing-Original Draft Preparation, JW and T.J; Writing-Review and Editing, JW and T.J. and M.L.; Visualization, TJ. and M.L.

Funding: This research was funded by the Faculty of Civil Engineering at Kielce University of Technology.

Conflicts of interest: The authors declare no conflict of interest.