Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(6) (2019) 355-358
DOI: 10.22060/ceej.2018.12371.5188

Influence of Bacteria on Performance of Air Entrained Concrete

N. Parastegari, D. Mostofinejad*

Department of Civil Engineering, Isfahan University of Technology, Isfahan, Iran

ABSTRACT: Biological methods (adding bacteria to mixing water) is a one way to increase durability of concrete and repairing the cracks. Studies show that concrete contains bacteria has harsh environment, i.e. very high pH, small pore size and dry conditions, hence bacteria should be protected from this circumstances. In this study, for the first time, air entrained concrete is used for protecting the bacteria in the harsh condition of concrete. The effect of using sporosarcina pasteurii, which is a calcium carbonate-producing bacteria, on the performance of air entrained concrete has been studied in the carbonation depth; to do so, 24 concrete prisms were made using bacterial strains accompanied with mixing water. The results indicated that bacteria incorporation in air entrained concrete, near the source of calcium, reduces carbonation depth.

Review History:
Received: 6 January 2017
Revised: 26 March 2018
Accepted: 29 March 2018
Available Online: 9 April 2018

Keywords:
Air-entrained Concrete
Bacteria
Carbonation Depth
Air Bubble
Curing Environment

1- Introduction

Advantages such as high compressive strength, availability of raw materials, and low preparation cost make concrete one of the most important and widely used construction materials. Under harsh environmental conditions, aggressive agents such as sulfates and chlorides penetrate the concrete through these cracks to damage the concrete matrix and reinforcing bars, thereby lowering its load bearing capacity strength even further. While concrete cracks are not only expensive to repair, they are often hard to detect as well. Studies have shown that calcium carbonate precipitated by bacteria fills concrete pores to improve its durability [1-5].

In this paper, in order to protect the bacteria from the harsh environment of the concrete, air entrained concrete in three different percentages were produced. Then specimens were divided to two different curing environment. After 28 days, specimens were transmitted to the carbonation chamber in order to investigate concrete permeability by carbonation depth test.

2- Methodology

2- 1- Bacteria and their growth conditions

Sporosarcina pasteurii (PTCC 1645: DSM 33) from the genus Bacillus was the microorganism used in this study. Using a bacterial concentration of 10^7 cells/mL in the suspension, lyophilized bacteria were activated under sterile conditions. A liquid medium containing 20 g urea, 6.0 g peptone, and 3.0 g meat extract per liter of distilled water was first sterilized by autoclaving for 30 min at 121 °C. The bacteria were then cultured in the medium thus prepared before the cultures were incubated at 30 °C on a shaker incubator for 48 h at 115 rpm. Then, bacteria and its culture medium were directly added to the mixing water of concrete.

Corresponding author, E-mail: dmostofi@cc.iut.ac.ir

2- 2- Concrete mix design

The concrete mixes were designed as per ACI-211 [6] to attain a 28-day compressive strength of 25 MPa. The mixing proportions are reported in Table 1. Type I Portland cement in accordance with USA standard/ASTM-C150 [7] (CEM I-42.5 N) was used. Gravel 4.75-9.5 mm and sand 0-4.75 mm in size were used as the coarse and fine aggregates, respectively.

Table 1. Mix design for 1 m^3 of concrete

Portland cement	Water	Coarse aggregate	Fine aggregate
373.8 (kg)	206.5 (kg)	739.3 (kg)	993.5 (kg)

2- 3- Test procedure

The present study was conducted to explore the possibility for reducing concrete permeability as verified by carbonation depth tests.

The factors investigated in the experiments included two levels (presence and absence) of bacteria, three levels (0, 5 and 8 %) of concrete air content, and two curing environment (water and the solution of calcium lactate and urea). A

fractional factorial split plot design was adopted as the experimental design. Based on this design, six mix designs with different levels of bacteria and air content were prepared and the specimens cast were divided into two groups to be exposed to the different curing environments. After 28 days, specimens were transmitted to carbonation chamber for 4 weeks.

2- 4- Carbonation depth

If carbon dioxide penetrates into the concrete through its surface, it will react with the alkaline component of the cement paste to reduce its pH value to about 9. Reduction in alkalinity leads to the corrosion of reinforcing bars [8]. In order to determine carbonation depth, the phenolphthalein was used as the indicator. Briefly, the specimens, once cured, were kept for a period of 4 weeks in a sealed chamber containing 3-5% carbon dioxide at a relative humidity of 60-70% according to RILEM standard [9]. They were then removed from the chamber and split in the same way as they would for the tensile splitting test. The indicator was immediately sprayed on the split surface. The non-carbonated parts of the specimen would be distinguished by a change of color to purple after 24 h while the carbonated parts would exhibit no change in color. Six points on the two edges of the carbonated part were selected and the average depth of carbonation (mm) was determined.

2- 5- Scanning electron microscopy (SEM)

Microstructural analysis was carried out in order to investigate the performance of bacteria near the air voids in long term. Samples with 10 mm dimension were taken from treated and control specimens to compare their microstructures. First, the samples were dried in oven at 110 °C for 24 hours, then coated with a thin layer of gold.

3- Results and Discussion

After four weeks, the specimens were extracted from the carbonation chamber and their carbonation depth were measured.

According to previous studies, the existence of air voids in concrete makes changes in its durability characteristics. The optimum percentage of air voids in air-entrained concrete is between 3-6% of cement weight. In general, air voids in concrete have reduced its carbonation depth and specimens with 5% air voids have less carbonation depth than air entrained concrete with 8% air voids. In fact, air voids reduce the permeability of concrete and increase its resistance against of carbon dioxide gas penetration.

Based on statistical analysis, the addition of bacteria alone is not significant because the difference in the carbonation depth of specimens containing bacteria and non-bacterial samples is negligible (5%). Actually, the interaction of the bacterial with other factors clearly shows the effect of bacteria in carbonation depth.

SEM figures show that calcium carbonate precipitated in specimens with air voids, fills some voids. Because in control specimen air voids can be easily seen while in bacterial lower number of voids could be seen. In fact, bacteria house in air voids and precipitate calcium carbonate. After a while, some of air voids fill with the crystals of calcite.

The Interaction effect between bacteria and air content shows that in bacterial specimens by increasing air voids, carbonation depth decreased. Adding bacteria in specimens with 8% air voids, 45 % decrease carbonation depth. It may be suggested that bacteria settled in air voids and the air entrained protected them against the dry and alkaline concrete environment.

The interaction effect of bacteria and curing environment shows adding bacteria decreased carbonation depth in specimens cured in calcium lactate and urea. This may be explained by the fact that calcium carbonate precipitation by bacteria increased when source of calcium is near that so the performance of concrete increased.

4- Conclusions

In this paper in order to investigate the performance of bacteria on air-entrained concrete, a few specimens with specific percentage of sporosarcina pasteurii and different percentage of air voids, were cast. Moreover, the performance of bacteria was investigated in two different curing media. After curing period (28 days), the specimens transmitted to carbonation chamber for 4 weeks, after the measurement of the carbonation depth, the following results were obtained:

1. Carbonation depth of air-entrained concrete is less than normal concrete and the lowest carbonation depth is observed in air-entrained concrete with 5% air voids.
2. Adding bacteria to Air-entrained concrete with 8% air voids, 45% decreases resulted in its carbonation depth. Actually the optimum percent of using air voids in order to surviving bacteria from harsh environment in concrete is 8%.
3. In control specimens (without bacteria), the carbonation depth was increased by curing in calcium lactate and urea as a result of that this curing environment has acidic properties which increase carbonation depth.
4. In bacterial specimens, curing in calcium lactate and urea decreases carbonation depth because it provides a rich calcium source for bacteria to precipitate more calcium carbonate in order to fill the pores in concrete.

References

[1] Y.Ç. Erşan, F.B. Da Silva, N. Boon, W. Verstraete, N. De Belie, Screening of bacteria and concrete compatible protection materials, Construction and Building Materials, 88 (2015) 196-203.

[2] H.M. Jonkers, A. Thijssen, Bacteria mediated remediation of concrete structures, in: Proceedings of the second international symposium on service life design for infrastructures. Delft, The Netherlands, 2010, pp. 833-840.

[3] H.M. Jonkers, A. Thijssen, G. Muyzer, O. Copuroglu, E. Schlangen, Application of bacteria as self-healing agent for the development of sustainable concrete, Ecological Engineering, 36(2) (2010) 230-235.

[4] F. Nosouhian, Mostofinejad, D., and Hasheminejad, H., Influence of biodeposition treatment on concrete durability in a sulphate environment, biosystems engineering, 133 (2015) 141-152.

[5] J.Y. Wang, D. Snoeck, S. Van Vlierberghe, W. Verstraete, N. De Belie, Application of hydrogel encapsulated carbonate precipitating bacteria for approaching a realistic self-healing in concrete, Construction and Building Materials, 68 (2014) 110-119.

[6] ACI 211, Standard Practice for selecting Proportions for Normal, Heavyweight, and Mass concrete, , in, Farmington Hills, MI, USA, 2009.

[7] ASTM C 150, Standard Specification for Portland Cement, in, ASTM International, West Conshohocken, PA, 2009.

[8] V.G. Papadakis, Vayenas, C. G., & Fardis, M. N. , Fundamental modeling and experimental investigation of concrete carbonation, ACI materials journal, 88(4) (1991).

[9] RILEM Concrete Permanent Committee, Measurement of hardened concrete carbonation depth, Materials and Structures, Research and Testing, (1984) 435-440.

Please cite this article using:

N. Parastegari, D. Mostofinejad, Influence of bacteria on performance of air entrained concrete, *Amirkabir J. Civil Eng.*, 50(6) (2019) 1103-1112.

DOI: 10.22060/ceej.2018.12371.5188