The Effect of Curing Period on the Durability of Concrete Using Blast-furnace Slag Blended Cement

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バージョン：

THE EFFECT OF CURING PERIOD ON THE DURABILITY OF CONCRETE USING BLAST-FURNACE SLAG BLENDED CEMENT

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ABSTRACT: *It is necessary for enwing the required performance of concrete structure, such as the strength and durability, by sufficient curing of concrete. Researchers focused mainly on only compressive strength, not durability. Besides, in most of their research, they used Ordinary Portland Cement (OPC), not blended cement. It is necessary to define the relationship between curing condition and concrete durability using OPC and blended cement. In this research, the effect on concrete durability of different curing conditions and periods of concrete using OPC and Blast-furnace slag cement type B(BB) were investigated. As a result, BB concrete durability is more sensitive to curing condition than OPC. However BB concrete has necessary for extended curing period of 2 days by OPC concrete for keeping enough durability. Moreover, curing is very important on the covering concrete using Blended cement.*

KEYWORDS: *Blast-furnace slag cement, Curing, Permeability, Durability*

1. INTRODUCTION

In recent years, it came to be able to perform prediction of the lifetime for concrete structures in case of the good material choice and construction condition. On the other hand, the performance for durability may be unable to be demonstrated in the combination of material choice and construction conditions. Today, the quality index of concrete is the compressive strength. The compressive strength is an important index for structural performance. However it is not a proper index for durability of concrete. Especially, curing condition greatly influences the durability performance of concrete. In case of curing for wetting condition, compressive strength and durability improve with cement hydration. However in case of inadequate curing, especially influence of drying at early age, it is thought that it has influence on the durability of structures.

On the other hand, considering earth environment, it is necessary to use the industrial by-product such as blast-furnace slag and fly ash. The curing at early age is very important for use of blended cement from considering the character and improving compressive strength. However there is little research which investigates between the relationship between curing and durability of concrete on using blended cement.

In this research, the relationship between curing and durability were investigated for the concrete using blast-furnace slag blended cement as compared with concrete using Ordinary Portland Cement. The influence of curing on concrete using blended cement was evaluated.

2. MATERIALS AND EXPERIMENTS

2.1. Mix proportion and parameter for experiment

Two types of cement were used for making concrete: One is N (OPC) and the other is BB made of 50% OPC and 50% BFS. Materials used are as follow:

N: Ordinary Portland cement [density: 3.14g/cm^3, Blaine: 3150cm^2/g]
BFS: Ground Granulated Blast-furnace slag [density: 2.91g/cm^3, Blaine: 4000cm^2/g]
S: sand from sea [density: 2.58g/cm^3, absorbent ratio: 1.52%]
G: Aggregate [density: 2.72g/cm^3, absorbent ratio: 0.36%]

The concrete specimen was ϕ100*200mm cylinder in order to give flexibility and simple test. Table-1 shows the mix proportion of concrete and Table-2 and Fig.1 show the parameters for experiment. Curing was carried out in 3 patterns. After curing, the specimens were exposed to Drying condition at 20 degree Cercius and Relative humidity of 60%.

Table-1 Mix proportion of concrete using N and BB cements

No	cement	W/C (%)	s/a (%)	Unit (kg/m^3)					Fresh propety		
				W	C	BFS	S	G	Slump (cm)	Air content (%)	Concrete temperature (°C)
N45	N	45	45.5	175	389	-	770	976	10.5	4.2	23.3
BB45	BB				194	194	764	969	11.5	4.2	22.4
N55	N	55	47.5		318	-	832	973	10.5	4.2	20.9
BB55	BB				159	159	827	967	13.5	4.8	23.1
N65	N	65	49.5		269	-	887	857	10.0	4.5	22.4
BB65	BB				135	135	882	952	11.5	5.5	22.2

Table.2 Parametersof experiment

Curing age	Curing methods		
	(1) packs C	(2) in water W	(3) Sealed S
1	D1	-	-
3	CD3	WD3	S3
5	CD5	WD5	-
7	CD7	WD7	S7
28	C28	W28	S28

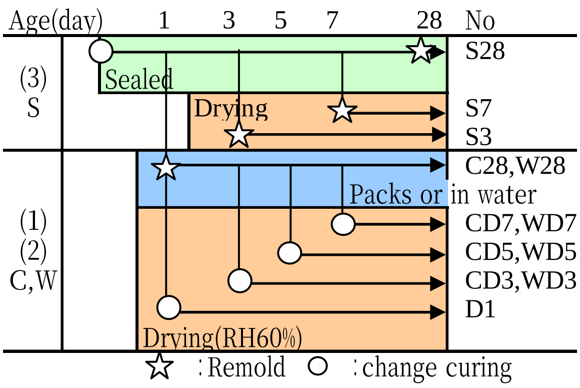


Fig.1 Curing conditions in experiments

2.2. Experimental items and methods

2.2.1 Compressive strength, Elastic modulus

These tests were carried out in accordance with based on JIS (Japanese industrial standerd). The mesurement age is 7, 28, 91 days.

2.2.2 Permeability test for gas

After cutting specimen, these sides were coating by epoxy coating for preventing gas permeability. The gas used was Nitrogen gas which does not affect hydration processes and by hydration products in concrete. The pressure of 0.4 MPa was applied to upper surface of the specimen, and the gas volume which permeated the inside of concrete was measured.

2.2.3 Test for water absorption in vacuum condition

The container was filled with water so that a specimen might be submerged by half was decompressed to the vacuum using the same samples as used 2.2.2 test. After one hour in vacuum and keep same condition at 3 hours, the sample was divided into two half and the domain that moisture was sucked up was measured.

2.2.4 Permeability test for water

The test was the input method and the water pressure of 1.0 MPa was applied from the sample upper surface. After the test, the sample was divided into two half and the depth of water was measured.

2.2.5 Accelerated carbonation test

These tests were carried out in accordance with based on JIS (Japanese industrial standerd). The accelarater carbonation ages are 2,4,13,26 weeks by mesurement. The coefficient of carbonation was calculated as correlation coefficient of root of time and carbonation depth.

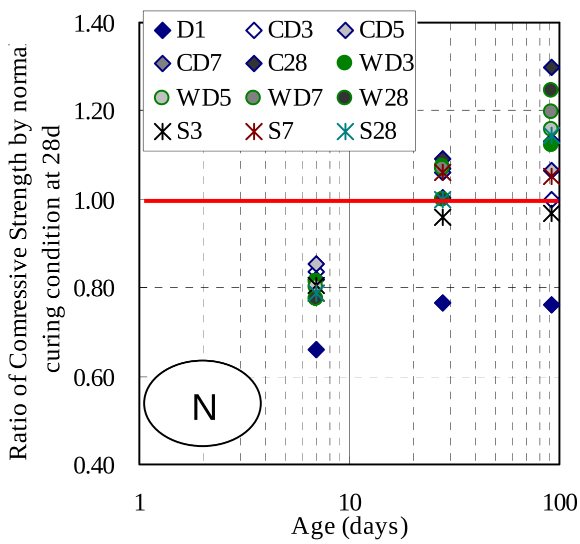
2.2.6 Porosity

The total porosity and the average pore diameter were measured using MIP system. The range of diameter by MIP was from 6 nm to 320 μm.

3. RESULT FOR TESTS

3.1 Property of Strength

Fig.2 shows that the ratio of compressive strength by standard curing at 28 days on N and BB concrete. Curing condition “D1”, means exposing drying condition just after remold at 1 day, is stopped the increasing strength. N has the 80% strength as standard curing, BB has only 60%. Curing condition “CD3” and “S3” means are not enough curing, are also not enough strength revel as standard curing on BB cement. On the other hand, condition “WD” means water supply condition, hold strength as normal condition.



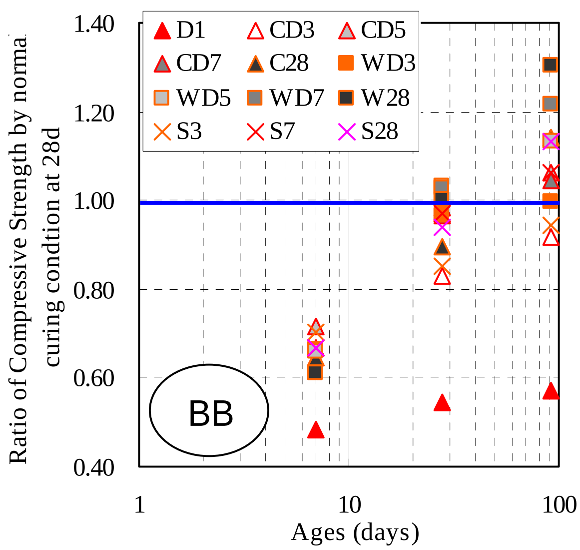


Fig.2 Effect of Curing on compressive strength

3.2 Property of Durability test

3.2.1 Gas permeability

Fig.3 shows the relationship between curing periods and gas permeability coefficient for the different kinds of cement and curing conditions. Curing condition C series means drying condition after packs for wet clothes, gas permeability of BB has not improve that of N at more long curing.

3.2.2 Water permeability and resistance for absorbing water in vacuum condition

Fig.4 shows the results for water permeability test. In case of curing for short period such as 1 and 3 days, water permeability coefficient of BB is large. However curing for long period such as 7 day or 28 days in water, water permeability of BB is recovered, and marks the same value of N.

Fig.5 shows the results as new test for absorbing water in vacuum condition. The coefficient of absorbing water in vacuum condition named AWV. AWV value calculated the ratio of water permeability area in vacuum by total specimen's cross section area. Comparing between BB and N, BB-C has a large value at 1 day curing. However after 3 days curing, the difference of the kind of cement is not so much. Also in water condition curing, BB has high resistance for water permeability compare with N sample.

3.2.3 Ratio for carbonation resistance

Fig.6 shows the result of carbonation ratio of concrete made of different cements and cured under different conditions. Concrete using BB is easily carbonated because the less of alkali content in concrete and also the less of $Ca(OH)_2$ compared with concrete using N. N and BB controlled the carbonation ratio as long curing periods. However concrete using N has small difference for different curing methods, while BB has large difference between curing condition “C”,”S” and “W”. It means that BB needs to be supplied moisture for hydration and improving durability. And longer N curing than 5 days for BB, ratio of carbonation resistance becomes constant for different curing periods.

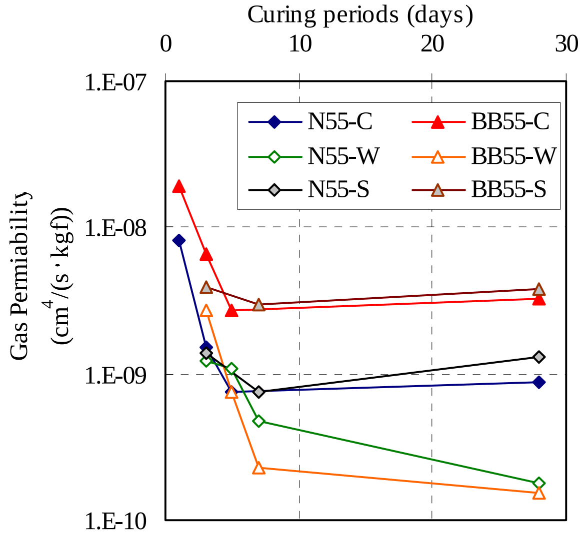


Fig.3 Result for gas permeability

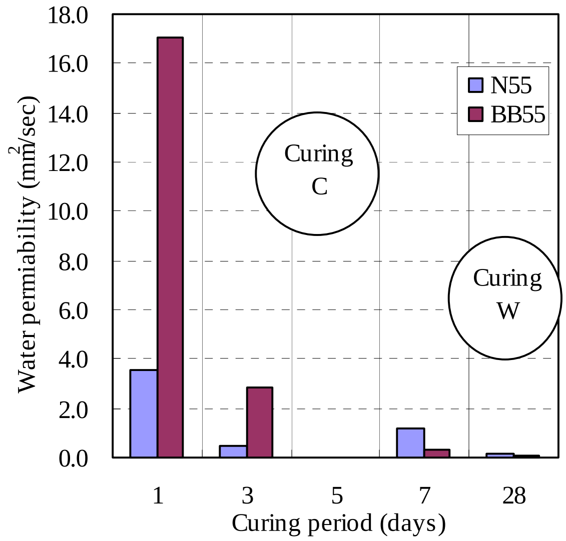


Fig. 4 Result for water permeability

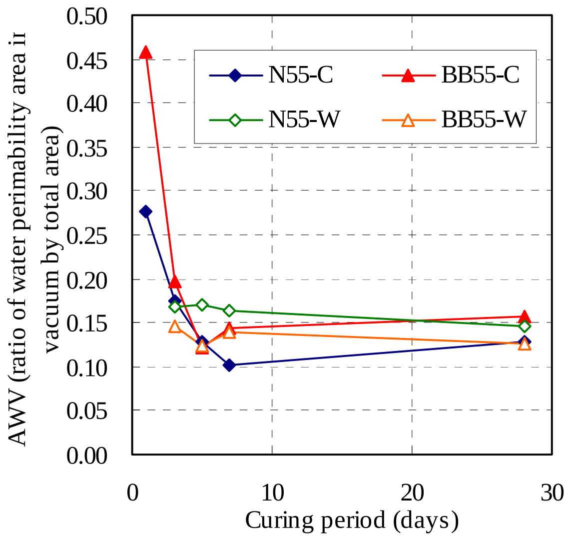


Fig.5 Result for AWV value (new test)

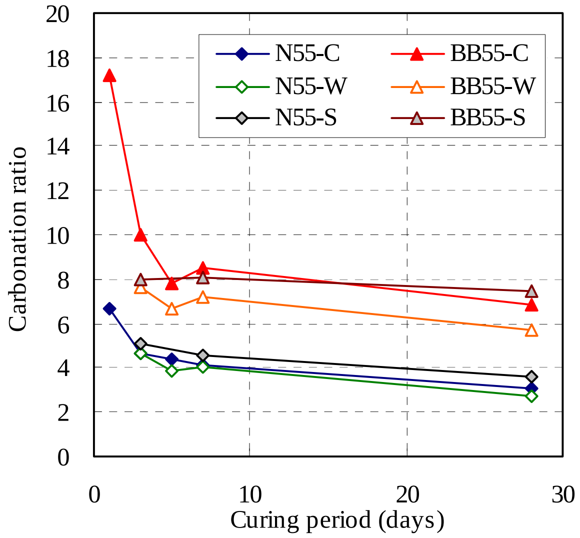


Fig. 6 Result for carbonation ratio

3.2.4 Porosity

Fig.7 shows the result of porosities measured by MIP of specimens cured in different curing periods. The large pore remained on curing condition “D1” each cements. However porosity improved at curing period of 3 days on N concrete. On the other hand, large pore remained at curing period of 5 days on concrete using BB. It means that BB concrete needed longer curing periods than N concrete.

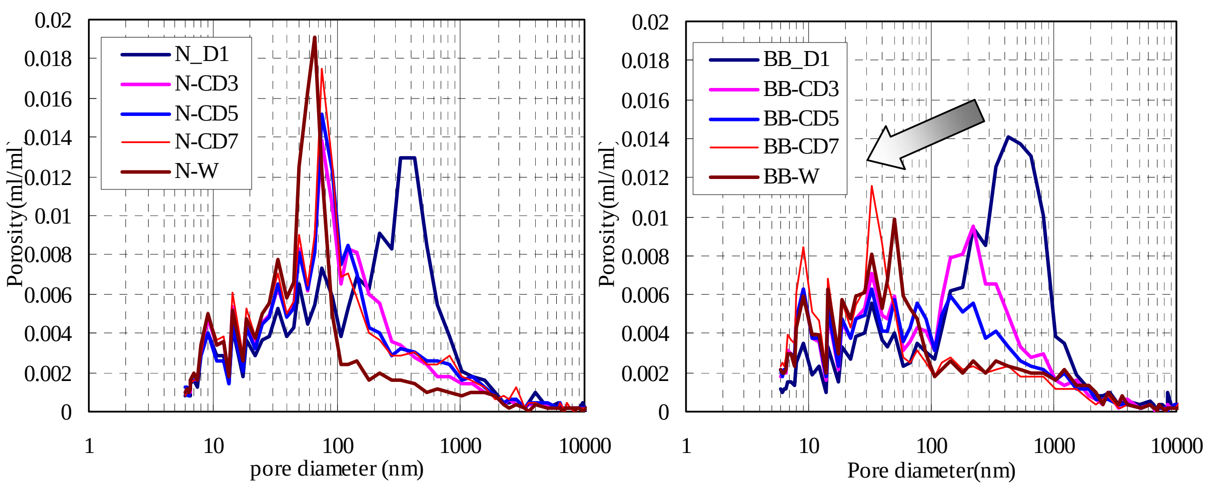


Fig.7 Result for porosity

3.3 Effect for water cement ratio

Fig.8 shows the durability value by different water cement ratio. Durability value deteriorated by linear with water cement ratio is higher. On each water cement ratio, durability value improved with curing for long period. Moreover, in case of curing “C”, durability of BB declined that of N, however it recovered in case of curing “W”.

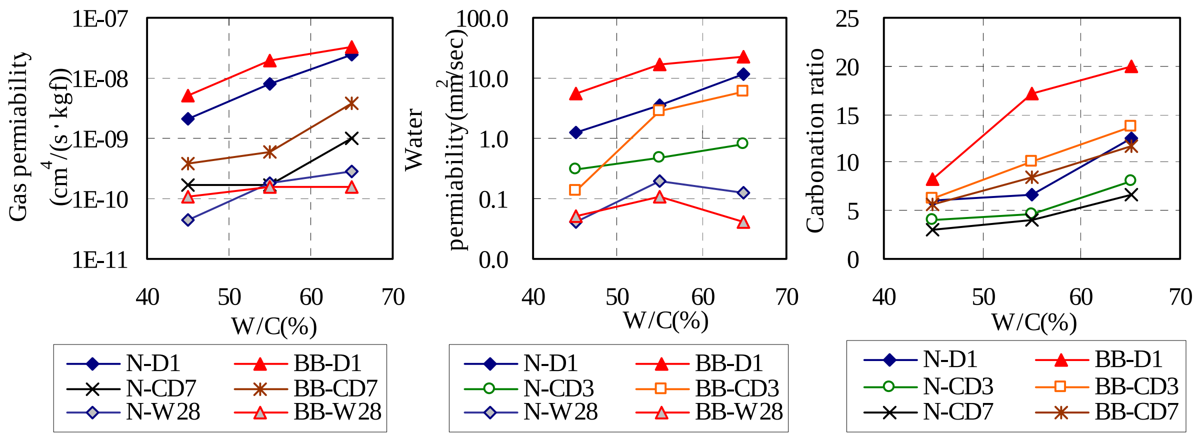


Fig. 8 Effect of curing periods on durability value of different W/C concrete

4. RELATIONSHIP BETEEN EACH PROPERTY

4.1 Porosity, Strength and Durability

Fig.9 shows the relationship between porosity and compressive strength as well as durability value. Usually, compressive strength and durability decreased with remaining large pore. No good relationship was observed. It means that it is difficult to explain compressive strength and durability using porosity in case of different curing conditions and periods. We have to consider the pore structures and the pore connectivity.

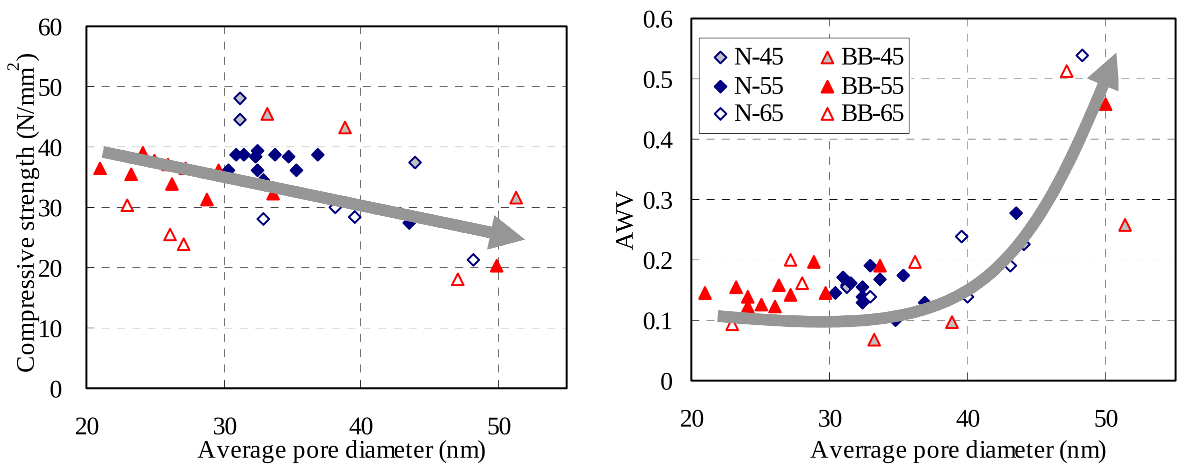


Fig. 9 Relationship between porosity and compressive strength or durability (AWV)

4. 2 Relationship between compressive strength and durability

Fig.10 shows that the relationship between compressive strength or AWV and each durability. We considered that AWV value means the evaluation for pore connectivity and permeability of concrete. It is possible to recognize the relationship between compressive strength and gas permeability. However gas permeability was improved more than compressive strength in water curing though long periods more 7 days. Moreover, it is able to restrain the carbonation ratio with compressive strength, regardless the kind of cement. It means that the carbonation ratio will be same value when the compressive strength is same. The relationship between AWV value and can be observed. It can be understood that the AWV value is an index of durability for difference curing conditions in this research.

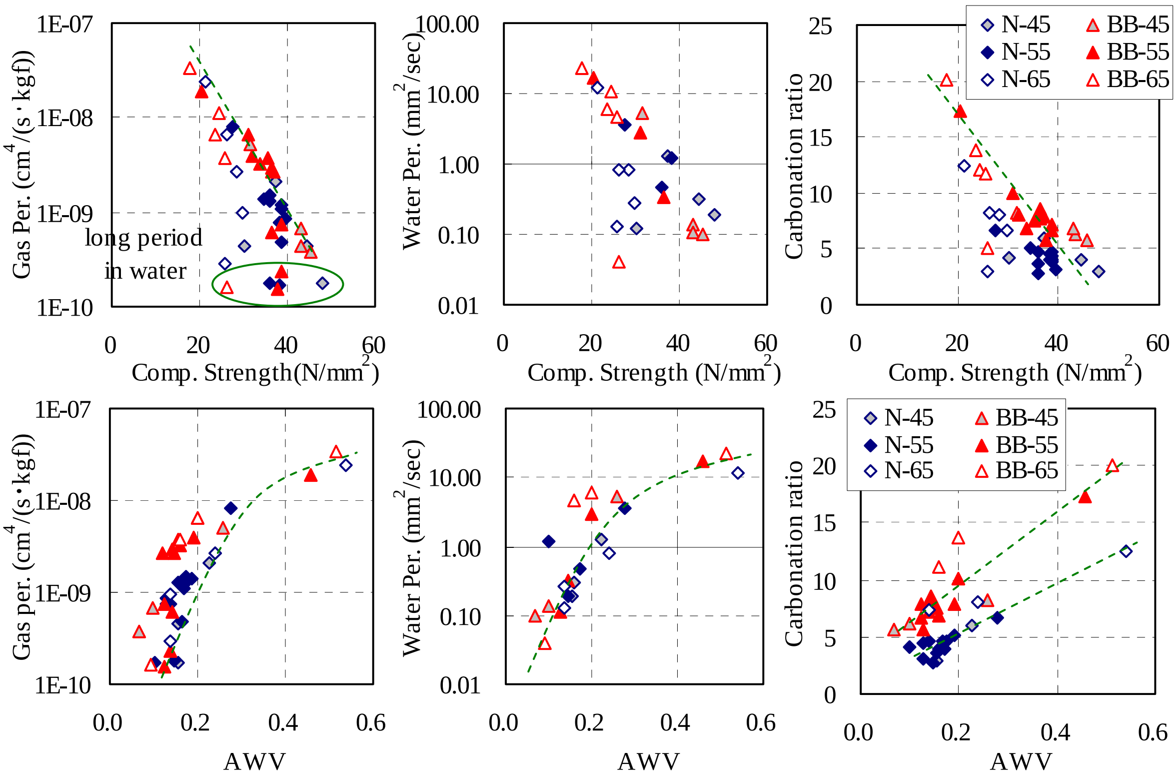


Fig. 10 Relationship between compressive strength or AWV and durability

5. CONCLUSIONS

The salient conclusions of this study when can be listed as following

1. Compressive strength increases with supplying more moisture on different curing condition.
2. Blended Blast-furnace slag cement type B concrete durability is more sensitive to curing than N of concrete. Therefore BB concrete has necessary for curing period extended 2 days by N concrete for keeping enough durability.
3. AWV (ratio of water permeability area in vacuum by total area) value is able to use for index of durability in range for this study.

In future works, we will investigate the humidity in concrete using structural specimens and try to make the value of coefficient for blended material by N.

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