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EFFECT FOR CONCRETE PROPERTIES ON BLENDING RATE OF GROUND GRANULATED BLAST FURNACE SLAG

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ABSTRACT

Considering the reduction of Carbon dioxide emissions, it is desired the use of ground granulated blast furnace slag as a replacement for cement. It is not enough organized the influence on the concrete given by the replacement ratio. In this research, the properties of fresh concrete and hardened concrete are arranged when the water binder ratio and the replacement ratio of ground granulated blast furnace slag are changed. It is hoped that this research will help to utilize ground granulated blast furnace slag.

Keywords: *Ground granulated blast furnace slag, Replacement ratio, Fresh concrete, Harden concrete, Carbonation, Penetrated chloride ion*

1. INTRODUCTION

In order to construct infrastructural structures, we need a lot of cement. However the use of a large amount of limestone results in a very large amount of carbon dioxide emissions in the production of cement. Considering global warming prevention and reduction of environmental impact, it is known that the production of large quantities of cement is greatly affected. Therefore, it is being considered in various countries around the world to use admixture as a replacement for cement. Here, we will summarize the characteristics of concrete when using ground granulated blast furnace slag byproduct from ironworks as a replacement for cement. In this study, it is arrangement of the characteristics of concrete when replacing cement with ground granulated blast furnace slag as fineness of about 4000 cm^2/g, which is usually used in Japan.

2. EXPERIMENT

Binders used for this experiment are Ordinary Portland cement (OPC) and ground granulated blast furnace slag 4000 (BFS). As shown in Table 1, the concrete has water binder ratio (W / B) of 35, 45, 55, 65%, and the amount of blast furnace slag was 0 to 70% as cement replacement. The replacement rate is selected according to the test. Sea sand (2.62 g / cm^3) was used for the fine aggregate, and crushed stone (2.64 g / cm^3) was used as the coarse aggregate. Using the AE water reducing agent, the slump was adjusted to 12 ± 2.5 cm and the air rate was adjusted to 4.5 ± 1% in the fresh concrete. Table 2 is shown the experimental test, bleeding test, setting test and adiabatic temperature rise test were conducted as fresh concrete. In addition, as a test of hardened concrete, compressive strength and elastic modulus, porosity, drying shrinkage test, permeability test, accelerated carbonation test and salt penetration test by electrophoresis were used.

Table 1. Mix proportion for this study

W/C	s/a	W	B
35	41.5	164	469
45	43.5		364
55	45.5		298
65	47.5		253

Table 2. Testing method

	Testing methods	W/B	Replacement
Fresh concrete	Fresh properties (slump, air)	35,45,55,65%	0,30,50,70%
	Bleeding		
	Setting		
	Ambient temperature rise		
Harden concrete	Compressive strength	35,45,55,65%	0,30,40,50,60,70%
	Elastic modulus		
	Porosity by MIP		
	Drying shrinkage	35,45,55,65%	0,30,50,70%
	Water permeability	35,45,55,65%	0,30,40,50,60,70%
	Accelerated carbonation	50%	0,50,60,70,80%
	Chloride ion permeability	50%	0,30,50,70%

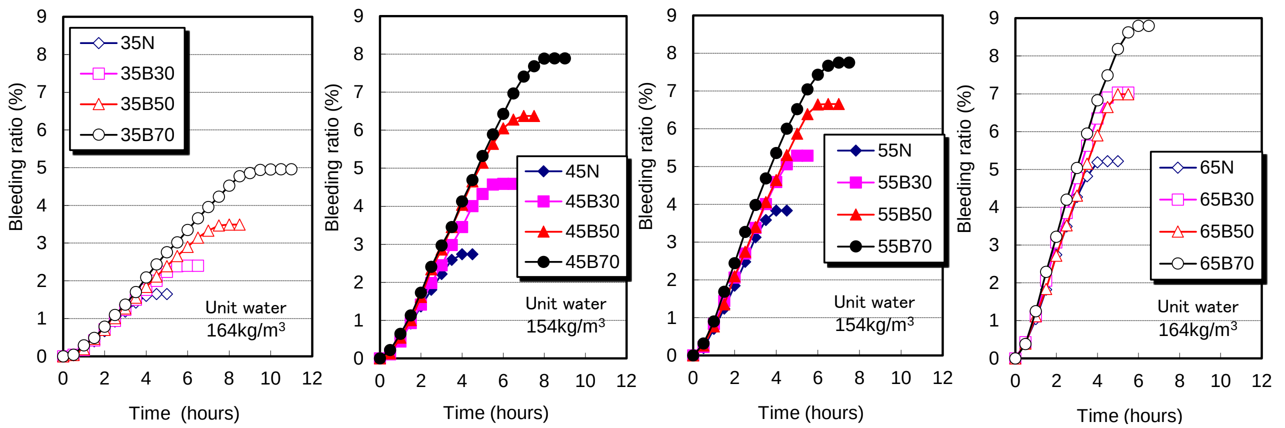


Fig. 1. Bleeding test results on different water binder ratio and replacement ratio

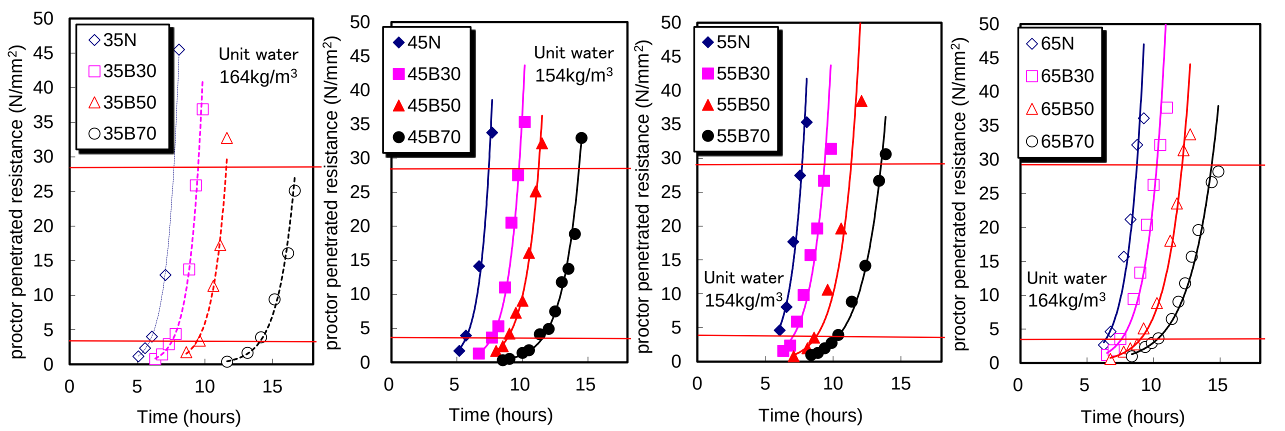


Fig. 2. Setting time results on different water binder ratio and replacement ratio

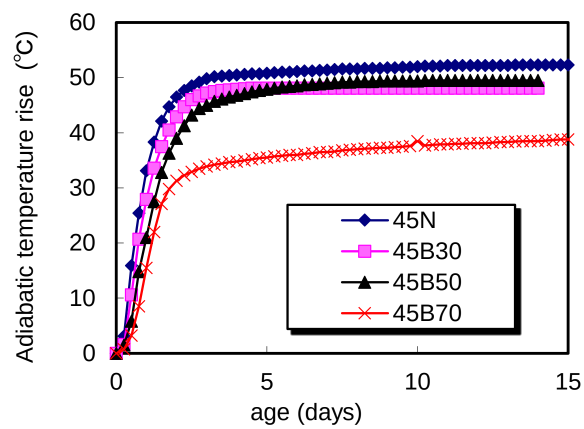
3. PROPETIES OF FRESH CONCRETE

3.1 Bleeding

Fig.1 shows the results of bleeding test at different water binder ratio of 35, 45, 55 and 65%. Due to the different amount of unit water, it was arranged the bleeding rate. Basically, it can be seen that adding a blast furnace slag powder increases the bleeding rate also increases, and the bleeding finishing time is long. Also, the larger the water binder ratio, the higher the bleeding rate. It can be seen that the influence of the replacement ratio is increased.

3.2 Setting test

Fig. 2 shows the setting test results at different water binder ratio of 35, 45, 55 and 65%. It can be seen that the setting time is longer by increasing the replacement ratio. On the other hand, it can be seen that the larger the water binder ratio, the smaller the difference of replacement ratio. It can be imagined that as the water binder ratio is smaller, as the replacement ratio increases, the proportion of ground granulated blast furnace slag in the whole increases, so that a delay in the hydration is observed.



	Q_∞	γ
0%	52.3	0.959
30%	48.1	0.922
50%	49.5	0.679
70%	39.8	0.569

Fig. 3. Results of Adiabatic temperature rise test

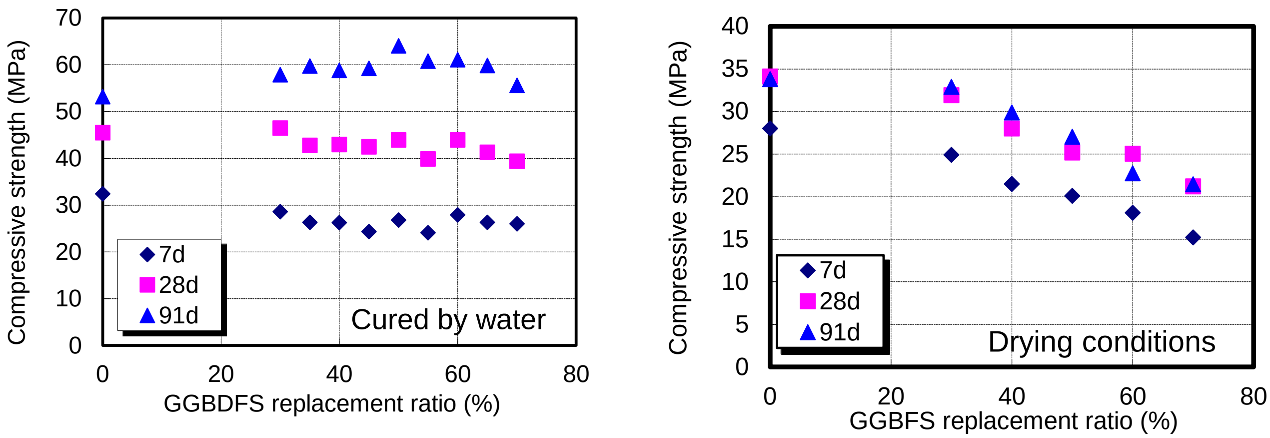


Fig. 4. Results of compressive strength (left: cured by water, right: cured by drying conditions)

3.3 Adiabatic temperature rise test

Fig.3 shows the results of the adiabatic temperature rise test at water binder ratio 45% for each replacement ratio. Compared to concrete using Ordinary Portland cement as 0%, the higher replacement ratio is the lower the temperature rise. Particularly, those having a replacement ratio of 70% are extremely lower adiabatic temperature rise. In addition, it can be said that the rate of rise can be suppressed because the temperature rise gradient becomes smaller as the replacement ratio becomes higher. On the other hand, at a replacement ratio of 50% compared with 30%, although the temperature rise speed is slow, the final temperature rise amount of 30%, which means that the effect of suppressing heat generation is small. This is thought to be due to the fact that the reaction of blast furnace slag proceeds as the temperature rises.

4. PROPETIESE OF HARDEN CONCRETE

4.1 Compressive strength

Fig. 4 shows the results of compressive strength at 7, 28 and 91 days on each replacement ratio in water binder ratio 45% as one example. The results are shown both the standard water curing and the exposed curing to the environment of 20 degree Celucius and Relative humidity 60% after one day remold. In the standard water curing, it can be seen that the strength decreases as the replacement ratio increases at the age of 7 days, however as the age increases, the strength is equal to or higher than the OPC. On the other hand, when the replacement ratio rises on the curing at drying condition, the strength remarkably decreases, and it is understood that the strength does not improve even after the age has passed. Fig 5 shows the compressive strength progress on different replacement ratio and curing conditions. Replacement ratio is higher, compressive strength at long period is higher in water curing conditions. However the compressive strength is not progress on drying condition. And strength on high replacement ratio has large difference of strength on water curing.

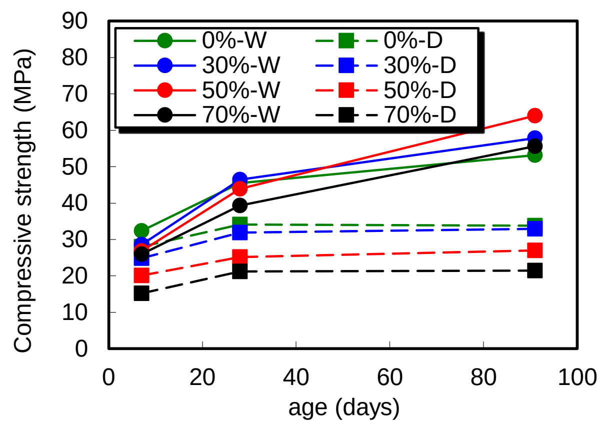


Fig. 5. Compressive strength progress

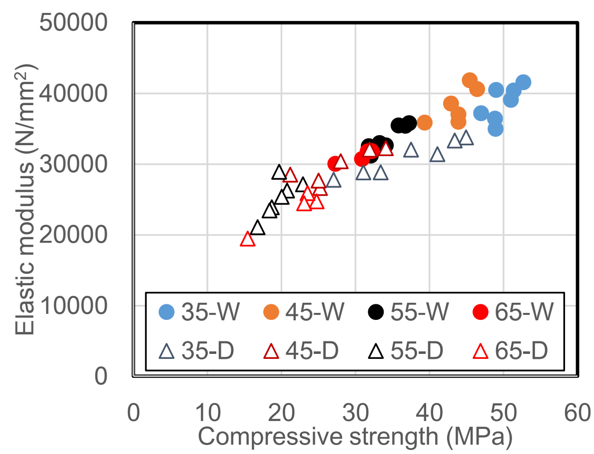


Fig. 6. Relationship between compressive strength and Elastic modulus

4.2 Elastic modulus

Fig.6 shows the good relationship between compressive strength and elastic modulus in standard water curing. It is found that the elastic modulus increases

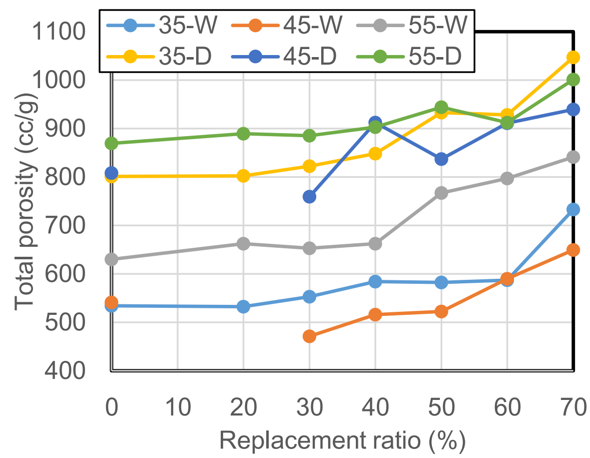


Fig. 7. Total porosity on different replacement ratio

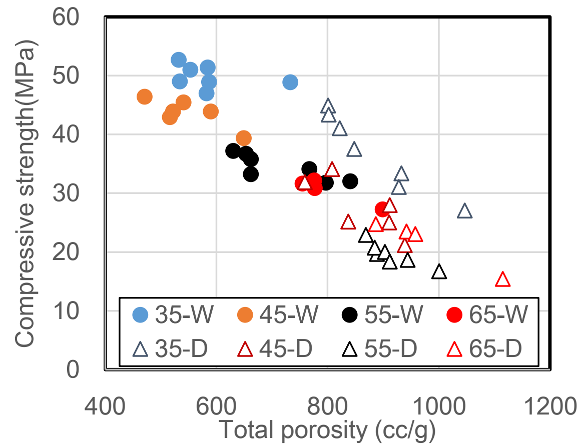


Fig. 8. Relationship between porosity and strength

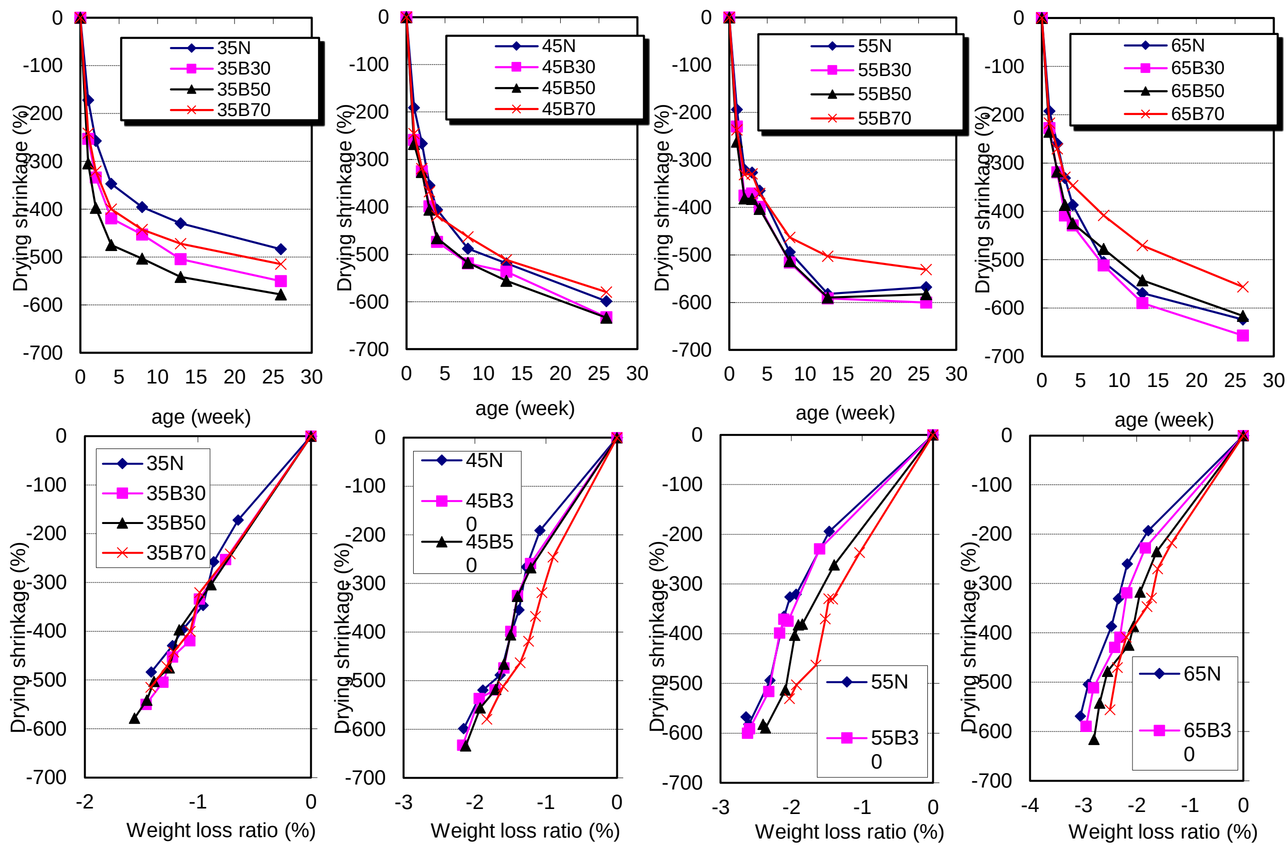


Fig. 9. Drying shrinkage results on different water binder ratio and replacement ratio

with increasing strength regardless of water binder ratio.

4.3 Porosity

Fig. 7 shows the results of total porosity measured by Mercury Intrusion Porosimetry on different replacement ratio. It is same tendency of total pore volume increases by high replacement ratio on the both curing conditions. However on drying condition, total porosity is same on different water binder ratio. Fig.8 shows the relationship between the total pore volumes and compressive strength. In water binder ratio 35%, the relationship between the total porosity and the strength is higher strength than the other water binder ratio, however in general, a correlation is found between the total pore volume and the compressive strength, and the pore determines are related the strength.

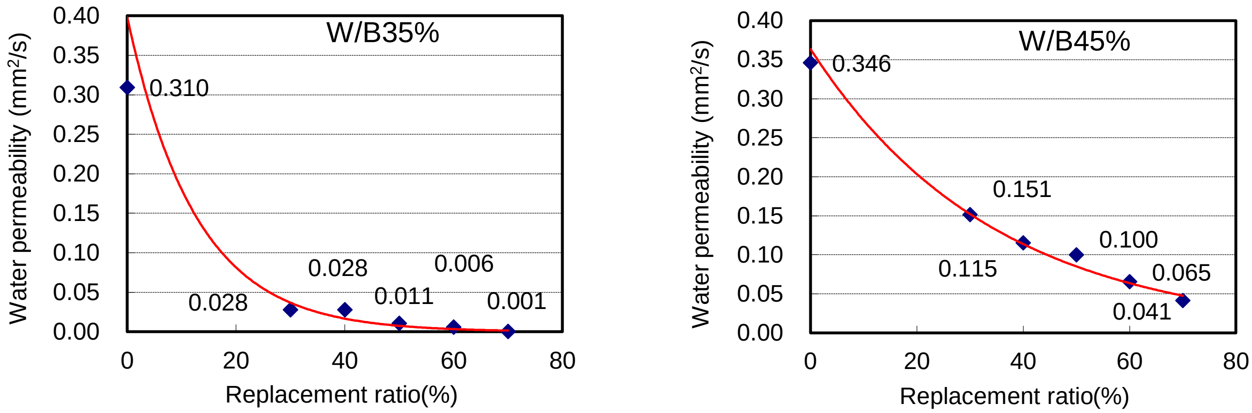


Fig. 10. water permeability coefficient (left: water binder ratio 35%, right: 45%)

4.4 Drying shrinkage

Fig. 9 shows the results of the dry shrinkage test until 26 weeks for each water binder ratio. Though the shrinkage is slightly suppressed in the case of 70% Fig. water permeability replacement, the difference is not so large. Therefore, figure shows the results of weight change rate and drying shrinkage.

4.5 Water permeability

Fig. 10 shows the permeability coefficients for each replacement ratio at different water binder ratio. Permeability test was conducted by input method. It is found that the water permeability coefficient is remarkably reduced by increasing the replacement ratio in any water binder ratio, and the water penetration resistance improves. The effect was observed to be larger as water binder ratio was smaller, and the effect of suppressing permeability coefficient by addition of blast furnace slag was recognized.

4.6 Carbonation

Fig. 11 shows the results of accelerated carbonation test when the replacement ratio is changed to 50-80%. Compared with concrete using only OPC, it can be seen that the carbonation depth increases as the replacement ratio increases. Fig. 12 shows the carbonation rate coefficient obtained from the accelerated carbonation results. It can be seen that the carbonation rate coefficient increases linearly as the replacement ratio increases.

4.7 Chloride ion penetration

In order to evaluate salt permeability, it was carried out a non-stationary electrophoresis test in this study due to prevent the long period testing time. As shown in Fig. 13, it is recognized that the chloride ion penetration effect as the replacement ratio increases. It is also obvious that the diffusion coefficient of chloride ion penetration decreases linearly as the replacement rate increases.

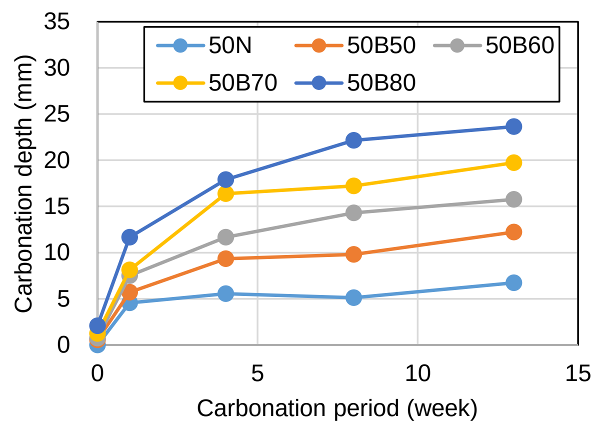


Fig. 11. Carbonation progress

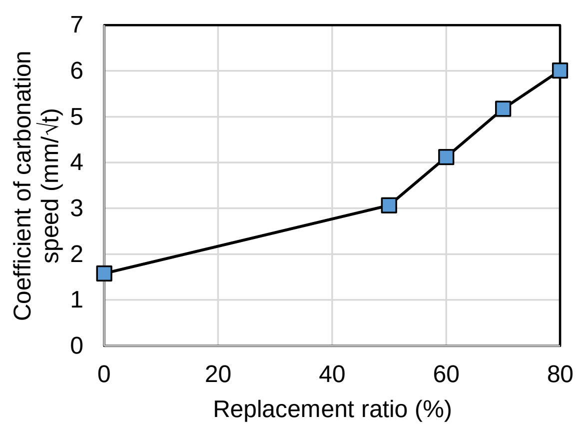


Fig. 12. Carbonation speed on different replacement

5. CONCLUSIONS

This study quantitatively evaluated the effect of preparing concrete with varying replacement ratio of ground granulated blast furnace slag. In the future, I hope that it will be helpful in the production of concrete using cement with high replacement ratio of grand granulated

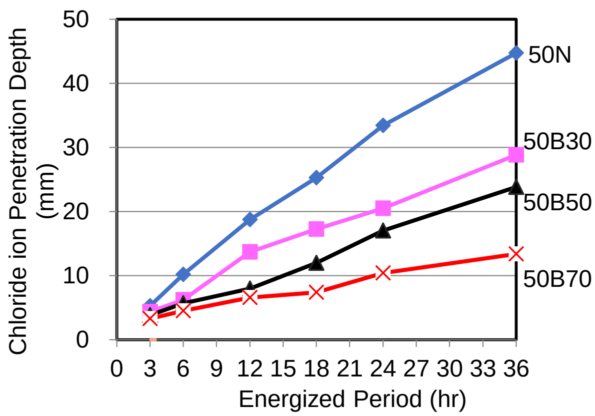


Fig. 13. Chloride ion penetration

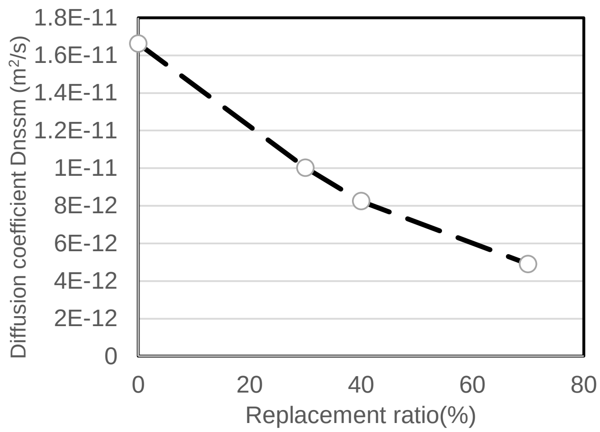


Fig. 14. Diffusion coefficient on different replacement

blast furnace slag in consideration of reduction of environmental impact.

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PHOTOS AND INFORMATION

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He is a Professor, Department of Civil Engineering, Shibaura Institute of Technology. His Current interests include cement chemistry, concrete engineering.