Effect of Curing conditions on the Microstructure

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1. Introduction

Curing is a very important factor during the initial stage of construction for concrete structure to achieve the designed strength and durability. It is very important regarding to cement hydration process that the concrete structure is exposed to surrounding conditions such as drying condition and re-wetting condition at early age. Because of drying condition, water which is necessary for cement hydration evaporates from surface of concrete structures. However, there are many cases at the construction site which remolding is done at early age caused by short construction period and necessity to reuse formworks. On the other hand, there are some re-wetting conditions such as rain, changing in humidity and re-curing at the construction sites. In this research, we measured the hydration ratio, porosity and microstructure by using SEM for different curing condition.

2. The Outline of Experiment

In this research, we used two kinds of cement, one was OPC (Ordinary Portland Cement) [density: 3.16g/cm^3, Blaine: 3160cm^2/g], another was BB (Blast-Furnace Slag with OPC) [Slag: density: 2.91g/cm^3, Blaine: 6490cm^2/g]. We mixed cement paste (W/B = 0.35) for experiments. The size of specimens was so small in order to maintain uniform humidity in each specimen. During conducting those experiments, temperature was kept constant at 20ºC. The curing conditions conducted in this research were as follow:

W : Continuous water storage condition
50D : Continuous drying condition (RH50%)
50DW : Re-wetting condition (Water storage)
50Dwet : Re-wetting condition (RH98% storage)
50Dwrap: Re-wetting condition (Wrapped by wet cloth)
*re-wetting condition started after RH50% for 28 days

3. The results of this research

3.1 The results of cement hydration

Figure 1 shows the progress of hydration of two kinds of cement. Both of cements showed the same results in all conditions. Firstly, hydration of cement did not progress in 50D condition because water in hardened cement pastes evaporated from the surface. Therefore, cement was difficult to be continuously hydrated. In case of W condition, hydration of cement can progress because curing water supplied through the hardened cement paste. Therefore, there was enough water for good hydration. Re-wetting condition 50DW, hydration can progress after re-supplying water and hydration ratio was recovered to the same level as that of W condition. Therefore it is possible to re-hydrate the un-hydrated cement. Focusing on 50Dwrap and 50Dwet, OPC and BB showed good progress of hydration; however, their values were different from that of W condition at 120 days because there was not enough water for un-hydrated cement to be completely hydrated. In this condition, re-supplying water was not liquid. It is possible that the moisture vapor did not easily permeate through hardened cement paste. Moisture vapor was hardly adsorbed by large pores in hardened cement paste.

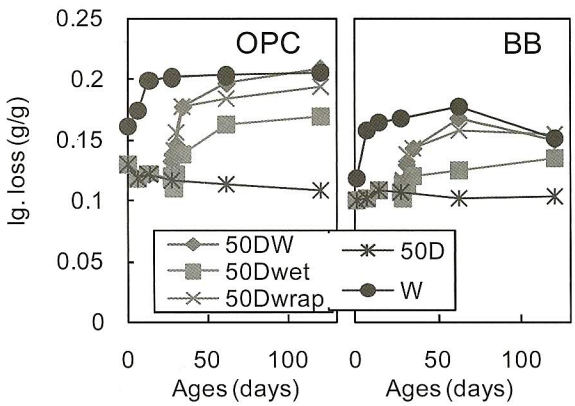

Figure 1 Progress of hydration

3.2 The results for microstructure

Figure 2 shows the pore distribution of different surrounding conditions and two kinds of cement. These results were measured at 56 days after casting cement pastes. As already stated, the hydration cannot progress in drying condition such as 50D and 50Dwet. As a result, there were many large pores in microstructure. On the other hand, the water saturated

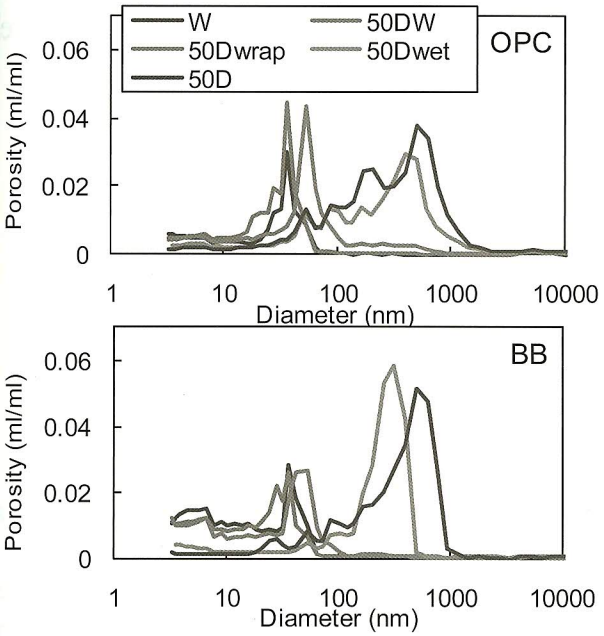

Figure 2 Result of porosity (Upper: OPC, Bottom: BB)

conditions, such as W, 50DW, and 50Dwrap, showed smaller pores than that of drying conditions. Especially, 50DW showed the same peak of pore diameter as W. It means that the cement hydration had already progressed from 50D. These phenomena depend on the cement hydration.

3.3 Observation the microstructures by using SEM

We tried to observe the microstructures of specimens by using SEM. Photo 1 shows the photos, produced by using BEI method, of the samples cured by three different conditions. This method can be used to investigate hydration progress and porous structures. The white area shows un-hydrated cements, the gray area shows hydrated products and the black area shows pores in the pictures obtained by BEI method. In case of 35D condition, there were many white and black area compared to that of W condition. It means that hydration of 35D did not progress and structure of 35D was more porous compared to that of W condition. On the other hand, there were some white area in picture of 35DW; however, it was not as much as that of 35D. It means that hydration progressed better than 35D.

Photo 2 shows the results of microstructures observed by using SEI method. This method can be used to investigate the cracks. Upper photos show the low magnifications and lower photos show high magnifications. We cannot see any crack on 35D; however, there were many connections of large pores. Picture of W shows a straight crack. There were completely penetrated epoxy resins in crack. It reveals that this crack occurred during drying and preparing the samples because drying the samples by vacuuming was very difficult at that time. It is called the

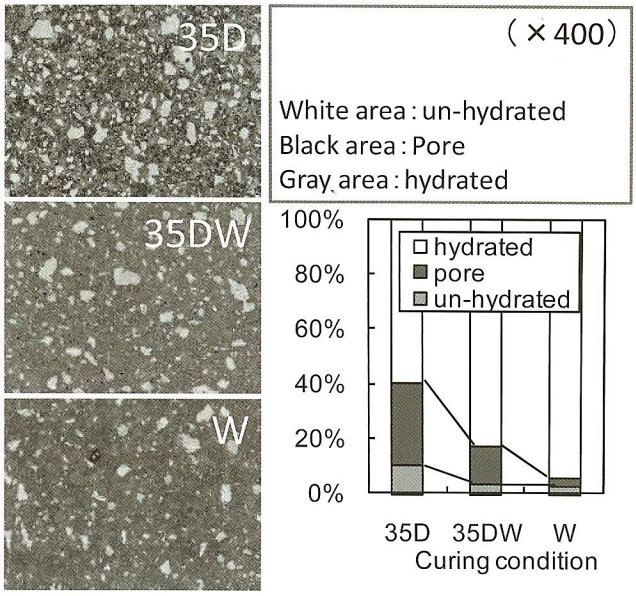

Photo 1

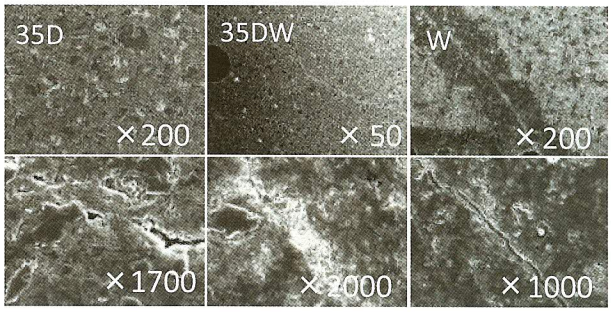

Photo 2

drying shrinkage. On the other hand, we can also see crack on 35DW condition; however, this crack was not straight. There were also penetrated white materials in this crack. These white materials were probable hydration products or calcium carbonate. This crack occurred before preparing the samples. It means that a crack did not occur during drying condition at early age; however, a crack occurred during re-wetting condition.

4. Summary

(1) The cement hydration stopped due to drying conditions at early age. However, the cement hydration can be recovered owing to re-wetting condition after drying condition. As a result, the microstructure will be fine.

(2) We can see the crack in the samples of re-wetting condition after we investigated microstructure by using SEM method.

This research was taken on LMC (Prof. Karen Scrivener Lab.) in EPFL when I had stayed EPFL in 2003.