Journal of Civil, Construction and Environmental Engineering
2022; 7(6): 102-108
http://www.sciencepublishinggroup.com/j/jccee
doi: 10.11648/j.jccee.20220706.11
ISSN: 2637-3882 (Print); ISSN: 2637-3890 (Online)

Effects on the Surface Quality of Concrete According to the Changes in the Curing Methods and Compressive Strength

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To cite this article:
Nam Wook Kim. Effects on the Surface Quality of Concrete According to the Changes in the Curing Methods and Compressive Strength. *Journal of Civil, Construction and Environmental Engineering*. Vol. 7, No. 6, 2022, pp. 102-108. doi: 10.11648/j.jccee.20220706.11

Received: October 20, 2022; **Accepted**: November 10, 2022; **Published**: December 8, 2022

Abstract: The durability of concrete slabs is apt to be influenced by finishing methods and curing methods of concrete surface. Therefore, the finishing agent had better use in case of high strength concrete, the wet curing had better carry out on concrete surface. However, it is not obvious that when wet curing is started after finishing of concrete surface. In this study, the effects of the difference in finishing methods and curing methods on the surface properties of concrete were examined by surface tensile test, air permeability test, water absorption test and scaling test. As a result, use of the finishing agent was effective to improve the surface properties in high strength concrete. However, use of the finishing agent was ineffective in normal strength concrete. When wet curing was carried out, high strength concrete was more effective than normal strength concrete. The surface properties of concrete could be improved when the wet curing was begun after it passed for several hours from finale set of the setting time test for concrete. It is considered that, however, there is not much difference in surface quality within that range, and it is acceptable to start curing water the next day.

Keywords: Surface Quality, Curing Method, Strength, Finishing Method, Setting Time

1. Introduction

In site construction of concrete floor slabs, the method of construction and curing after concrete injection greatly affect the durability of the floor slabs, so that after finishing concrete, drying is prevented by sheets and water supply is cured by wet mats.

However, few cases have considered the timing of the start of water supply curing, and it is not clear at which time the water supply curing is most effective for surface quality.

In this study, lady-mixed concrete using Portland cement and fast-strength Portland cement was usually used in terms of surface quality of concrete floor slabs.

The effect of the difference in finishing methods based on the presence or absence of finishing aids and curing agents after concrete injection, the difference in curing methods using sheets and wet mats, and the timing of starting curing of water supply were studied [1~3].

Then, surface tensile test for evaluating surface strength, surface permeability test for evaluating material movement resistance, surface water absorption test, scaling test for evaluating frost damage resistance, and timing of start of water curing were evaluated [4].

2. Experiment

2.1. Manufacturing of Specimen

(1) Used materials and mix proportion of concrete

The results of concrete mixing, fresh test and compressive strength test are shown in Table 1 and Table 2. In the experiment, two types of ready-mixed concrete were used: 27MPa normal strength using ordinary Portland cement (density 3.16 g/cm^3) and 40MPa high strength using PC floor plate.

The maximum dimensions of all coarse aggregates are 25mm, the water cement ratio is 54% for N27 and 40% for H40. Fine aggregate of N27 was used river sand (2.61 g/cm^3), coarse aggregate was used crushed stone (2.64 g/cm^3), and AE water reducing agent was used for admixture.

As the fine aggregate of H40, a mixture of three types: crushed sand (2.66 g/cm^3), sandl (2.60 g/cm^3), and sandll (2.63 g/cm^3) was used in a 4:3 ratio. Crushed stones (2.69 g/cm^3) were used for coarse aggregates and AE water reducing agents were used for admixture.

The results of the fresh concrete test showed that in the case of N27, the slump was 100mm, the air volume was 5.0%, the temperature was 25°C, and the bleed rate was 1.25%. The results of the proctor penetration test (condensation time) were 6 hours from the start and 8 hours and 15 minutes from the end.

In the case of the H40, due to concerns about a decrease in the slump during the production of the specimen, the slump was 195mm, the air volume was 5.5% and the temperature was 31°C. The bleed rate was 0.08% and almost no water was floating. In addition, the results of the proctor penetration test were very short between the first and the last four hours and 40 minutes.

Table 1. *Mix proportion of concrete.*

Kinds	Cement	F_{CK}	G_{max} (mm)	W/C (%)	s/a	Unit weight (kg/m^3)				
						W	C	S	G	ad.
N27	N	27	25	54	45	170	315	810	990	3.78
H40	H	40	25	40	41	178	446	697	1003	4.46

Table 2. *Various test results of manufactured concrete.*

Kinds	Fresh concrete			Bleeding (%)	Setting time (h:m)		Standard curing (MPa)	Sealed curing (MPa)
	Slump (mm)	Air (%)	Temp. (°C)		Initial set	Final set	28 days	
N27	100	5.0	25	1.25	6:00	8:15	32.1	35.5
H40	195	5.5	31	0.08	4:00	4:40	50.5	47.3

(2) Specimen manufacturing

In this experiment, the thickness of the concrete floor slab was set to 300 mm, and the core was partially removed from the floor slab.

A cylindrical specimen of 150150×300 mm was used for testing. Concrete was driven in two layers and compacted with an internal oscillator.

(3) Curing method

A list of curing methods for specimens is shown in Table 3. The symbols shown in the table show NN with no sheet or wet mat, AN with sheet or wet mat, AA with sheet or wet mat, and the symbol '-' indicates items that have not been tested.

Water-based paraffin wax was used as the main ingredient for finishing aids and curing agents (hereinafter referred to as curing agents), and 150 ml/m^2 of standard amount was sprayed when roughing and bleeding were settled (N27 was 4 hours and 30 minutes after injection and H40 was 2 hours after injection). The sheet is made of polyethylene, the wet mat is made of urethane foam that can provide sufficient moisture, and the wet mat is installed immediately (0h), 3 hours (3h), 6 hours (6h), and 24 hours (24h).

The wet curing period shall be up to 7 days for N27 and 3 days for H40, referring to the standard specification of concrete. In addition, after finishing, sheet curing is performed until the wet mat is installed, and the form of the specimen is kept intact without demolding.

Figure 1 and Figure 2, respectively, show the curing of sheets and wet mats. After curing with a sheet and curing with a wet mat, air curing was carried out until the age of the test material in an air-conditioned laboratory.

2.2. Various Test Methods

(1) Surface tensile test

The surface tensile test was conducted using a simple tensile tester, which was marketed as certified by the KS F criteria by Korea Government Specification. The measurements were made at the center of the specimen, two N27 and three H40.

In addition, the test was conducted at 3 months of age at N27 and 1 month at H40. The surface tensile test is shown in Figure 3.

(2) Surface permeability test

The surface permeability test for the movement resistance of gases was carried out using the double chamber cell shown in SIA 262/1 by the Trent method. A chamber was placed in the center of the upper surface of the specimen. The test was conducted at two months of age at N27 and one month at H40.

The surface permeability test is shown in Figure 4. The surface permeability test was affected by the moisture content of the concrete surface and had to be carried out in a dry state to some extent, with a moisture content of less than 5.5 percent considered not to affect the surface permeability test under either curing.

(3) Surface water absorption test

The surface water absorption test, which showed the water's mobility, was carried out using the SWAT method. The measuring point was the center of the upper surface of the specimen and was absorbed for 10 minutes. The average value of two N27 and three H40 specimens was taken as the surface water absorption rate.

In addition, the test was conducted at two months of age at N27 and one month at H40. The surface water absorption test is shown in Figure 5.

(4) Scaling test

The scaling test, which shows the resistance to frost damage, is to freeze a specimen with a water film formed on the surface with a 3% sodium chloride aqueous solution at minus 18±3°C for approximately 16-18 hours in accordance with ASTMC 672 [5, 6].

It is melted at a temperature of 20°C for about 6 to 8 hours, which is set to one cycle (24 hours), and repeated for 50 cycles. Measurements were made every five cycles, and the accumulated aqueous solution was removed from the waterproofed test surface to measure the mass of the peeled debris.

In addition, the scaling test started at 4 months at N27 and 1 month at H40. The scaling test is shown in Figure 6.

Figure 1. *Sealed curing (AN).*

Figure 2. *Wet curing (AA).*

Figure 3. *View of surface tensile test.*

Figure 4. *View of air permeability test.*

Figure 5. *View of water absorption test.*

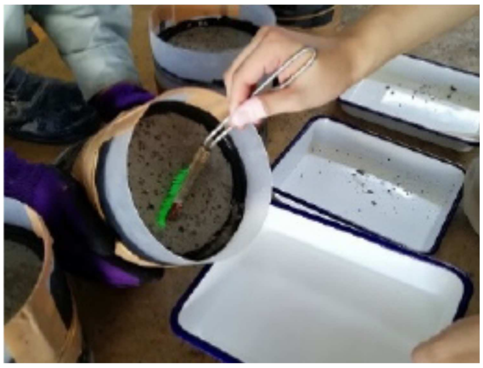


Figure 6. *View of scaling test.*

Table 3. *Detail of curing methods.*

(a) N27

Kinds	**Finishing agent**	**NN**	**AN**	**AA**			
				0h	**3h**	**6h**	**24h**
N27	None	●	●	●	●	●	●
	Add	●	●	●	●	●	●
H40	None	●	●	●	●	●	●
	Add	---	●	●	---	●	●

(b) H40

Test methods	**NN**	**AN**	**AA**			
			0h	**3h**	**6h**	**24h**
Surface tensile	×	○	○	○	○	○
Air permeability	×	△	○	○	○	○
Water absorption	×	○	○	○	○	○
Scaling	×	△	△	○	○	○

3. Experimental Results and Considerations

3.1. Results of Various Tests

(1) Surface tensile test

The results of the surface tensile test are shown in Figure 7 (a) and (b). In N27, tensile strength is greater without curing agents.

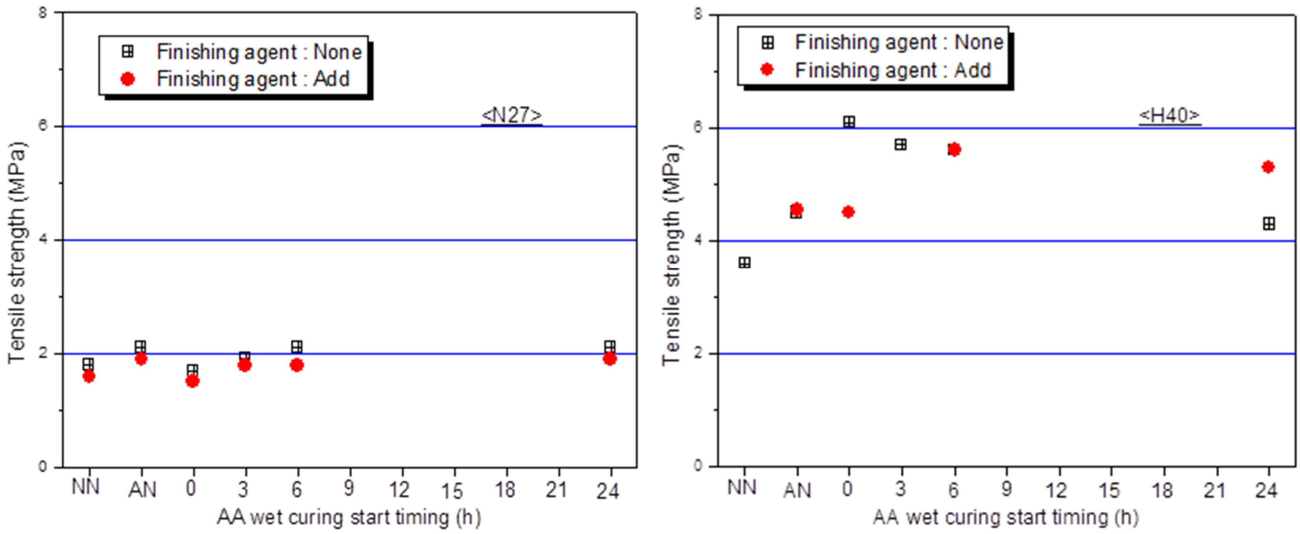
This may improve the workability of finishing with curing agents, but in less-strength concrete, the surface may have become slightly vulnerable.

In the case of water curing (AA), the slower the curing start time of wet mats, the greater the tensile strength.

Therefore, when curing water supply, it is considered that concrete should be cured to some extent. Also, when water supply curing is performed 24 hours after finishing (24h), the tensile strength of sheet curing only (AN) is almost the same. Only sheet curing is considered effective.

The tensile strength of H40 is small with no sheet and no wetting mat (NN) and increased by curing only sheet (AN), wetting mat and sheet (AA). In addition, there was not much difference between the wetting mat start time and the presence or absence of curing agents.

This is thought to be due to the fact that the surface layer begins to harden early because of its high nominal strength and fast-strength Portland cement [7~9].



(a) N27 (b) H40

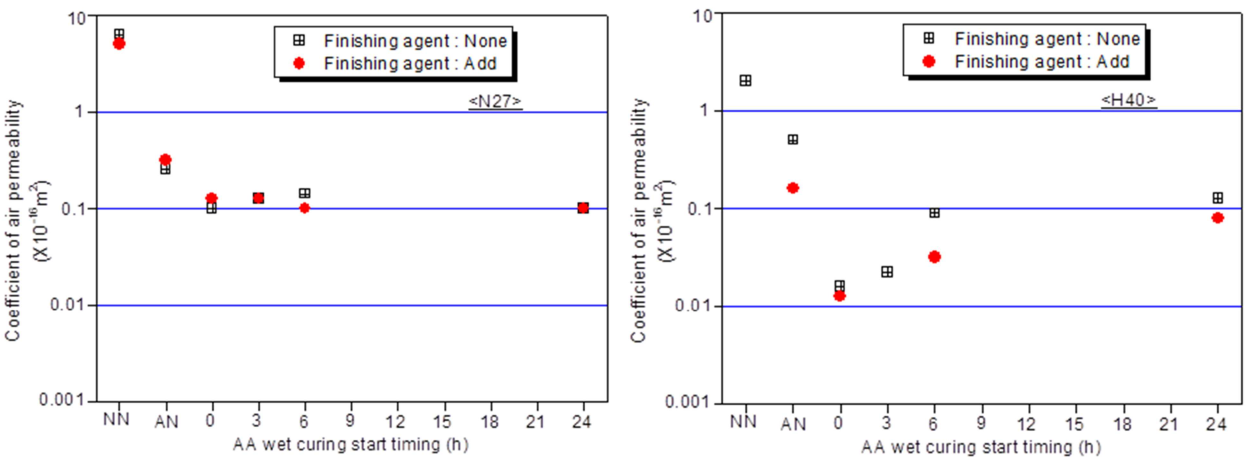
Figure 7. *Results of surface tensile strength test.*

(2) Surface permeability test

The surface permeability test results are shown in Figure 8 (a) and (b). In N27, the surface permeability coefficient of (AA) cured with wet mats and sheets is smaller than that of sheetless, wet matless (NN) and sheet curing only (AN). This is thought to be due to the prevention of drying with a wet mat and the acceleration of hydration reaction of the concrete surface by water supply. In addition, there was no difference between the presence or absence of curing agents and the start time of curing wet mats [10~12].

In the case of H40, a wet mat is also used (AA) to make the concrete surface layer dense and the surface permeability coefficient is reduced. And the surface permeability coefficient became slightly smaller with curing agents.

In addition, the wetting mat start time tended to decrease the surface permeability coefficient as soon as possible after finishing. In the case of H40, the surface permeability coefficient is slightly reduced, so it is thought that high-strength, fast-curing concrete has the effect of membrane curing in addition to improving workability.



(a) N27 (b) H40

Figure 8. *Results of air permeability test.*

(3) Surface water absorption test

The surface water absorption test results are shown in

Figure 9 (a) and (b). In N27, the surface water absorption rate was reduced without curing agents. Furthermore, the slower the curing start time of the wet mat, the smaller the surface water absorption rate and the denser it tends to become. This shows a similar trend with surface tensile test results. The surface water absorption rate of the H40 was reduced by curing (AA) with a wet mat and sheet. And the surface water absorption rate tended to be slightly lower with curing agents.

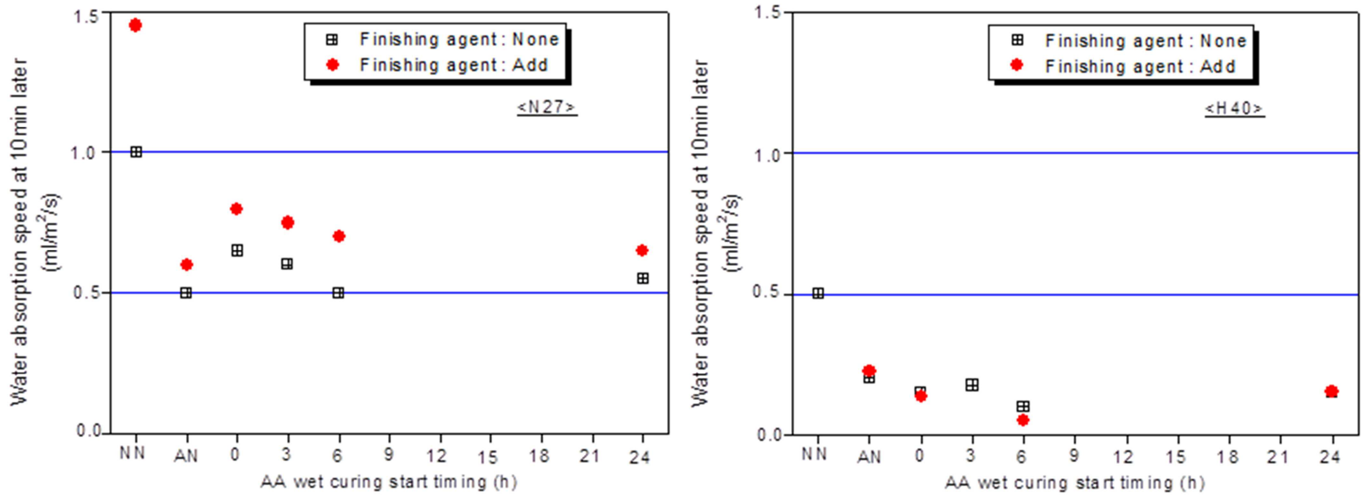
In addition, the surface water absorption rate was the lowest when curing was started with a wet mat six hours after finishing. Based on this, it is thought that there is an appropriate start time for water supply curing for the mobility resistance of water.

(4) Scaling test

The scaling test results are shown in Figure 10 (a) and (b). In N27, scaling tends to be smaller without curing agents.

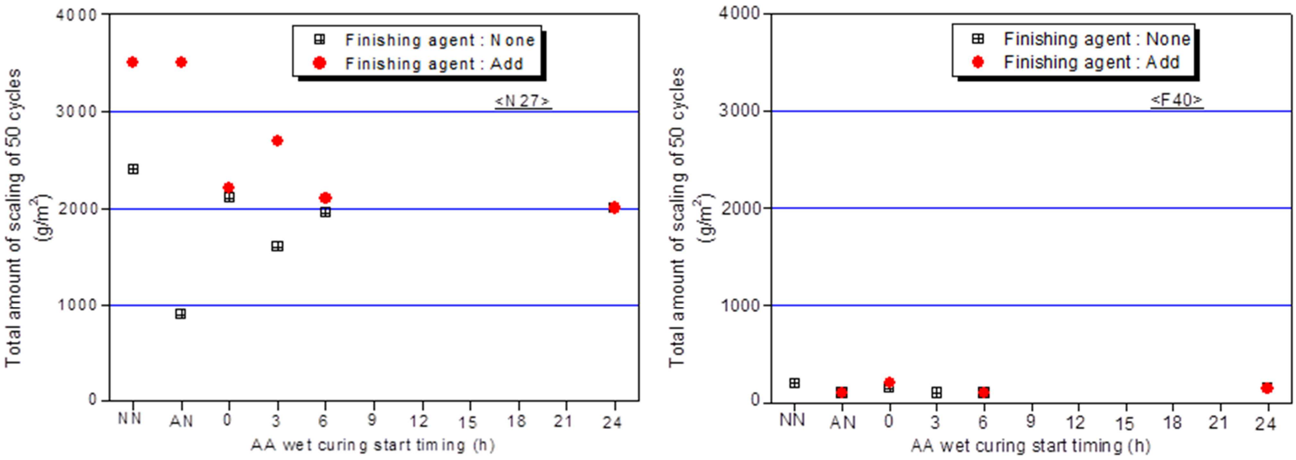
This can make the surface part vulnerable in less-strength concrete due to the spraying of curing agents, similar to surface tensile tests and surface water absorption tests.

In the H40, the difference between the use of curing agents was small, and the amount of scaling tended to decrease, not immediately after finishing, but after 3-6 hours after finishing with wet mats and sheets [13~15].



(a) N27 (b) H40

Figure 9. *Results of water absorption test.*



(a) N27 (b) H40

Figure 10. *Results of scaling test.*

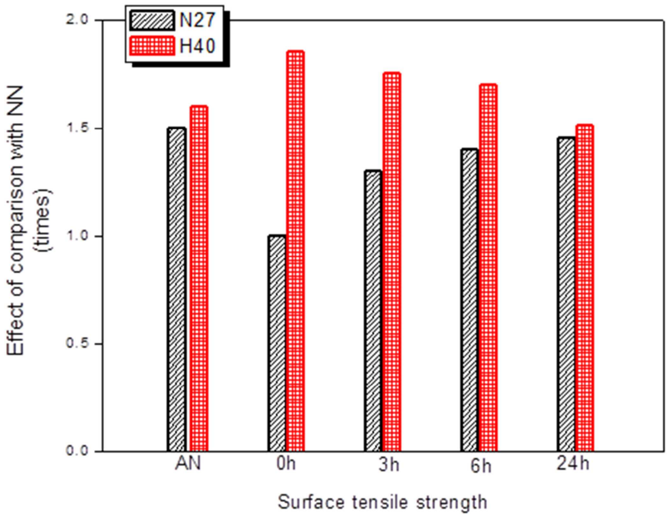
3.2. Effects of Each Curing on Airborne Curing

From various test results, the effect (multiple times) on the test values of sheetless and wet matless (NN) is shown in Figure 11 (a)~(d).

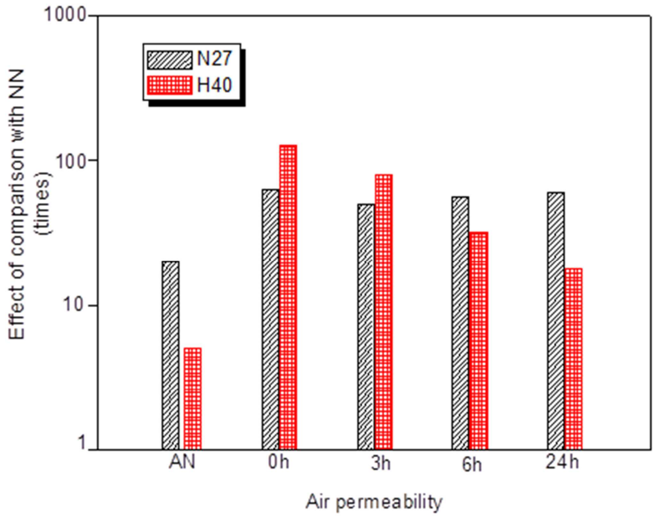
Here, we compare only without curing agents that can be compared with NN. There was no clear difference between N27 and H40 in the case of sheet curing only (AN) in the effect on NN in surface tensile test, surface water absorption test and scaling test. However, in the case of water curing (AA), H40 tended to be more effective than N27. This is said to have the most effect of water supply curing with a 45% water cement ratio [16].

Consistent with the report, water supply curing is considered the most suitable formulation for hydration that lacks moisture and is not too strong. In other words, the effect of feeding NN is thought to be greater at 42% (H40) than 55% (N27).

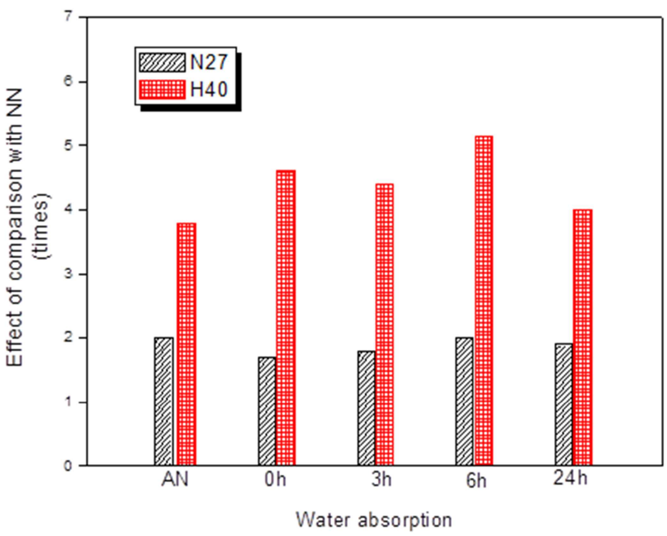
On the other hand, H40 does not tend to be more effective than N27 in surface permeability coefficient, and the combination is not affected much by water supply curing in terms of gas movement resistance. The mechanism will be an issue for the future.



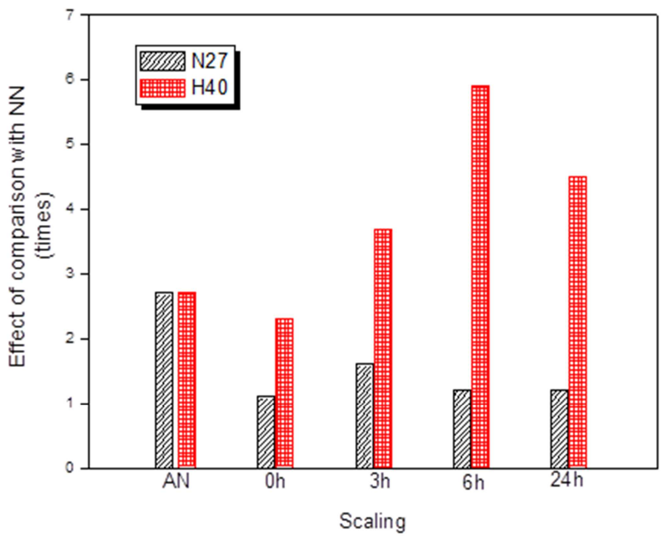
(a) Surface tensile strength



(b) Air permeability



(c) Water absorption



(d) Scaling

Figure 11. *Effect of NN by various test results.*

3.3. Evaluation of Curing Methods and Timing of Water Supply Curing

The evaluation of curing methods and timing of water supply curing is shown in Table 4.

In the table, the relative comparison in this experiment determined the presence or absence of curing agents comprehensively and evaluated them in three stages. Therefore, the difference between the presence and absence of curing agents is significant, and the AN evaluation of N27 in the scaling test is lowered.

In Table 4, as shown on the left, the N27 was highly evaluated in all tests when water supply was cured after 6 hours (6h) of completion. In addition, in the H40 on the right of Table 4, the test results improved when water supply curing started after 3 hours (3h).

Here, the time from the injection to the iron finish; N27 is 4 hours and 30 minutes from the injection, H40 is 2 hours from the injection, and the water supply curing start time; N27 is 6 hours from the finish, and H40 is 3 hours from the finish.

Subtracting the end of the proctor penetration test results of this experiment, N27 is 3 hours and H40 is 1 hour and 5 minutes. In other words, the timing of the start of water supply curing is considered to be effective in improving the surface quality of concrete if it is carried out the next day after several hours after the conclusion of the condensation time. However, there is no significant difference in surface quality within that range, and it is considered acceptable to start water curing the next day [17, 18].

Table 4. *Evaluation of curing methods and wet curing start timing.*

(a) N27

Test methods	NN	AN	AA			
			0h	3h	6h	24h
Surface tensile	∆	○	∆	∆	○	○
Air permeability	×	∆	○	○	○	○
Water absorption	×	○	∆	∆	○	○
Scaling	×	∆	○	○	○	○

(b) H40

Test methods	NN	AN	AA			
			0h	3h	6h	24h
Surface tensile	×	○	○	○	○	○
Air permeability	×	∆	○	○	○	○
Water absorption	×	○	○	○	○	○
Scaling	×	∆	∆	○	○	○

4. Conclusions

In concrete floor slabs, the effect of curing methods and timing of water supply curing on the surface quality of the floor slabs revealed as the follows.

1) The use of curing agents was effective in improving surface quality in H40, but when the strength is not so high as in N27, the surface area may become vulnerable.
2) In the case of water supply curing, it was effective for surface tensile strength, surface water absorption rate, and scaling when the strength was relatively high, such as H40 compared to N27. However, there was no difference in surface permeability coefficient due to compounding.
3) The timing of the start of water supply curing is effective in improving the surface quality of concrete when it is done the next day after several hours after the conclusion of the condensation time.

It is considered that, however, there is not much difference in surface quality within that range, and it is acceptable to start curing water the next day.

Acknowledgements

This work was grant funded by the Ministry of SMEs and Startups of the Korea government (No. S3290334).

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