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EXPERIMENTAL STUDY ON DURABILITY OF ROOM TEMPERATURE CURING UFC MORTAR

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In recent years, as structures become higher, larger, and more durable concrete whose compressive strength of the concrete is 150 N/mm^2 or more have been put to practical use. It is for this reason that it is necessary to develop strengthening materials with equal or better performance. Furthermore, the development of high-performance concrete repair materials is carried out because demand to seismic strengthening and repair increases. In this study, considering these circumstances, it was conducted an experimental study with the aim of developing a repair material using room temperature curing UFC (R-UFC). A binder composition preparation of the R-UFC has excellent fluidity under pressure. It was achieved that high-grade thixotropy, high compressive strength, and high bending strength. It can also be sprayed continuously because of its high thixotropy. It was confirmed that the sprayed thickness was reached to 20mm by one work. Durability of this R-UFC was investigated and it was confirmed the high sulfate resistance, small drying shrinkage and low salt permeability.

Keywords: Room temperature curing, R-UFC, Spraying construction, Copper fiber, High strength.

1 INTRODUCTION

Super-high – strength fiber reinforced concrete (UFC) is a kind of material that has excellent compressive strength over 150 N/mm^2 and excellent durability. What is more, UFC can suppress the infiltration of adverse factor and has high toughness due to contained fiber. In the future, the demand of structure with a longer life and better maintenance will increase, so development of high performance repairing material is necessary. In this study, spraying repairing material using room temperature curing UFC (R-UFC) was developed and fundamental properties and durability of the R-UFC were evaluated.

2 THE FUNDAMENTAL PROPERTIES OF THE SPRAYING R-UFC

2.1 Material

Table 1 shows the materials used and Table 2 shows the characteristics of used fiber.

2.2 Mixture Condition

Water to binder ratio was set to 16% by weight, and sand to binder ratio was set to 30% by weight. A superplasticizer and an antifoaming agent were adjusted and added to achieve the target values that is 120±10 mm for mortal flow and under 2.0% for air volume. The delayed agent was added at the amount of 0.25% to powder in mass. The binding material composition is shown in Table 3.

Table 1. Material.

Material	Type	Symbol	Density(g/cm^3)
Binder	Ordinary Portland cement	OPC	3.16
	Blast furnace slag 20000	BS20	2.91
	Wollastonitea	WO	2.91
	Fly Ash	H-FA	2.67
	Anhydrous gypsum	H-AG	2.90
	Silica fume	SF	2.25
Fine aggregate	Silica sand	S	2.61
Water	Tap water	W	1.00
Chemistry admixture	Super plasticizer	SP	1.09
	Defoamer	DF	1.00
	Retardant	Re	1.17
Fiber	Copper fiber	F	8.90

Table 2. Characteristics of copper fiber.

Symbol	Fiber length (mm)	Fiber diameter (μm)	Density (g/cm^3)	Tensile strength (N/mm^2)	Aspect ratio
Cu 50*2.5	2.5	50	8.9	over 2000	50

Table 3. Ratio of powder composition.

OPC	SF	BS20	H-FA	H-AG	WO
54%	10%	20%	5%	5%	6%

2.3 Mixing Method

A 10 litter capacity omni type mixer was used for mixing. First, the powder and fine aggregate were added and mixed for 30 seconds, then water and superplasticizer were added and mixed for 9 minutes. And the antifoaming agent was added and mixed for 1 minute. Finally, the copper fiber was added and mixed for 1 more minute. This is the method for this experiment. In the real application, it was confirmed that it can be mixed within five minutes by using a hand mixer.

2.4 Test Items

2.4.1 *Fresh property tests*

(i) Mortar flow test
Mortar flow test was conducted according to ISO 9597I.

(ii) Air volume test
Air volume measurement of mortar was conducted according to ISO 4848.

(iii) Temperature test

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An alcohol stick thermometer was used and the temperature of the mortar was measured after mixing.

2.4.2 *Hardened property tests*

The test specimens of the following experiments were cured in water (20±2ºC) for 7 or 28 days.

(i) Compressive strength test
Compressive strength test was conducted according to ISO 1920-4. The test specimens were φ50 mm × h100 mm in size and the number of specimens was three for each condition.

(ii) Bending strength test
Bending strength test was conducted according to ISO 1920-5. The test specimens were 40mm×40mm×100 mm in size and the number of specimens was three for each condition.

2.5 Spraying Performance Test

The spraying performance of R-UFC was evaluated by pumpability, spraying capability and maximum sprayed thickness by one work (Ryohei 2019).

2.6 Test Results

Table 4 shows the results of fresh property tests. Table 5 shows the results of compressive strength test and flexural strength test. As shown in Table 5, when compared to that before spraying, the air volume after spraying decreased a little. The compressive strength showed over than 150N/mm^2 after spraying, and bending strength showed over than 25 N/mm^2. It is considered that this R-UFC showed sufficient hardened properties by cured at room temperature (20ºC).

Table 4. The test results of fresh property tests.

	Addition amount of SP (%)	Amount of air (%)	Temperature (℃)
Before spraying	1.25	2.0	36
After spraying		1.8	—

Table 5. The results of property compressive strength tests and flexural strength tests.

	Compressive strength (N/mm^2)		Bending strength (N/mm^2)	
	7 day	28 day	7 day	28 day
Before spraying	148.5	164.5	25.6	27.3
After spraying	151.4	152.1	25.2	26.2

2.7 Spray Property Test Result

The spraying performance evaluation test results were as following:

- Pumpability: excellent
- Sprayed capability: excellent
- Maximum sprayed thickness: 20 mm

Based on these test results, it is confirmed that the developed R-UFC has good workability in concrete spraying construction method and enough hardened properties as UFS by room temperature curing.

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3 DUABILITY OF THE SPRAYED R-UFC

3.1 Material

The same as 2.1.

3.2 Mixture Condition

The mixture condition shows in Table 6. In the mixture, water to binder ratio was set to 14%, and sand to binder ratio was set to 30%. In order to achieve same spraying thickness, the target value of flow was set to be 120±10 mm. The binder composition ratio is the same as 2.2.

Table 6. Mixture condition.

Water-to-Powder Ratio (%)	Sand Binder Ratio	Addition Amount of SP (P×%)	Air Amount (%)
14	0.3	1.2	Under 2.0

3.3 Mixing Condition

The same as 2.3.

3.4 Test Items

3.4.1 *Flesh property tests and hardened property tests*

The same as 2.4.1.and 2.4.2.

3.4.2 *Durability tests*

(i) Neutralization test

The steps of preparing specimens were shown in Figure 1. The test specimens were made by original method. First, concrete pieces were made by using dimensions of 100mm×100mm×400mm. Then, R-UFC was applied to cover to one aspect of the concrete pieces. Then when the test began, these test specimens were put in the neutralization tank (20ºC, 60±5 % Rh and 5±0.2 % CO_2). These test specimens were removed from the neutralization tank after 7, 28, 56, 91 and 182 days. Then, these test specimens were cut with a diamond cutter. After that, the phenolphthalein was sprayed on the cut surface, the uncolored part was measured.

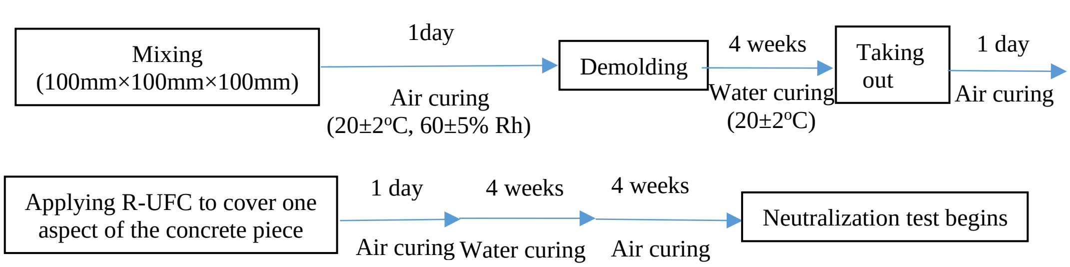

Figure 1. Neutralization test method.

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(ii) Drying shrinkage test
The length change of specimen was measured according to ISO 1920-8. The specimens were cured in water at 20±2ºC for 7 days before this test.

(iii) Salinity immersion test
The test specimen was 100mm×100mm×100mm in size. After demolding, the specimen was cured in water (20±2ºC) for 28 days. Then, the specimens were taken out from water and soaked in the 5 % NaCl solution at 20±2ºC for another 28 days. Then, after soaking for 28 days, the specimens were cut in halves by a diamond cutter. The 0.1mol/L silver nitrate solution was sprayed on the cut surface. Finally, the fluorescence part was taken as the chloride ion permeation area.

3.5 Test Result

3.5.1 *The results of fresh property tests and hardened property test*

Table 7 presents the results of fresh property tests and Table 8 presents the results of compressive strength test and flexural strength test. Compressive strength and bending strength were a little smaller than target values. It is considered that temperature of R-UFC after mixing was too high (40ºC). However, it is necessary to study more.

Table 7. The test results of fresh property tests.

Mortar flow (mm)	Addition amount of SP (%)	Amount of air (%)	Temperature (ºC)
126×126	0.33	2.0	40

Table 8. The results of property compressive strength test and bending strength test.

	Compressive strength (N/mm^2)	Bending strength (N/mm^2)
28 day	135.7	23.6

3.5.2 *The results of durability tests*

Table 9 shows the results of neutralization test and salinity immersion test. Figure 2 and Figure 3 present the results of drying shrinkage test. Both the neutralization and the salinity immersion test had good results. Compared to the result of the salinity immersion depth in past research (Takeshi and Hiromu 2014), good salinity immersion resistance was confirmed in this study. It was considered that high resistance to adverse factor due to the compactness of micro structures of it caused these results. What is more, the drying shrinkage rate was 1.80×10^{-4} calculated in the drying shrinkage test. Compared to 5.0×10^{-4} of the drying shrinkage rate of super-high-strength fiber reinforced concrete according to the standard of Japan Society of Civil Engineering (2004), good drying shrinkage resistance was also confirmed in this study.

Table 9. The result of a neutralization test and a salinity immersion test.

Material age (day)	7	28
Neutralization depth (mm)	0	0
Salinity depth (mm)	-	7.03(11.5mm in reference report (Takeshi and Hiromu 2014))

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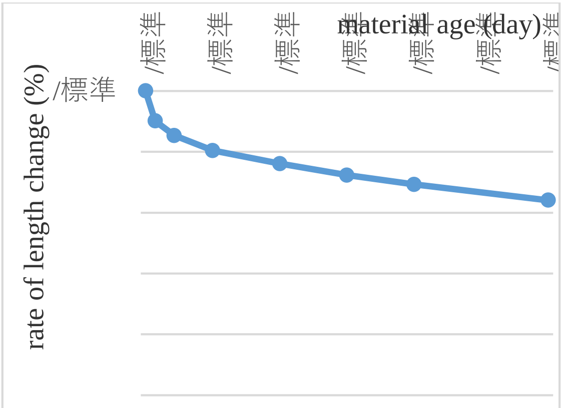

Figure 2. The result of property drying shrinkage test (rate of length change).

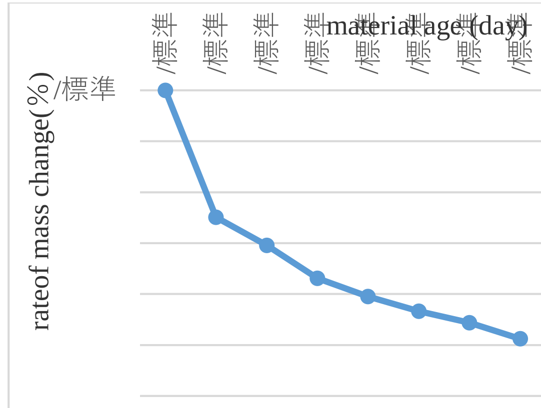

Figure 3. The result of property drying shrinkage tests (rate of mass change).

4 CONCLUSION

New spraying R-UFC was developed and its performance was evaluated. The knowledge obtained by this research is indicated below.

- The compressive strength exceeded 160 N/mm^2 and the bending strength exceeded 25 N/mm^2 by cured room temperature (20ºC). These were sufficient performance as UFC.
- In the spraying working, the new R-UFC showed high pumpability and excellent spraying capability. The maximum sprayed thickness by one work was 20 mm.
- Enough durability was confirmed because neutralization depth was 0mm and salinity immersion depth was 7.03mm. Also, it was confirmed that drying shrinkage of R-UFC showed very small according to standard of Japan Society of Civil Engineering (2004).

In addition to above results, for mixing, it was confirmed that it takes maximum 5 minutes by using a hand mixer. Therefore, enough applicability of R-UFC was confirmed.

References

Japan Society of Civil Engineers, *A Design and Guide for Construction of Super-High-Strength Fiber Reinforced Concrete (Plan)*, September, 2004.

Ryohei, O., *Development of the Normal Temperature Hardening Type Super High Strength Section Reinforcing Structure that Gave Thixotropy Property*, 2018 Master's Course Thesis, Utsunomiya University, 26-33 135-139, 2019.

Takeshi, I., and Hiromu, M., *Study for Improvement of Blast-Furnace Slag Cement Type A using Additional Binders to Improve Durability and Reduce Environmental Impact*, Proceedings of the Japan Concrete Institute, Japan Concrete Institute, 25 (0), 125-134, 2014.

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