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Development of spraying agent for reducing drying shrinkage of mortar

Hiromi Fujiwara[1], Masanori Maruoka[2] and Lingling Liu[3]

[1]Professor, Dept. of Civil Engineering, Utsunomiya University, Japan
[2]Associate Professor, Dept. of Civil Engineering, Utsunomiya University, Japan
[3]Graduate School of Engineering, Utsunomiya University, Japan

E-mail: fhiromi@cc.utsunomiya-u.ac.jp

Abstract. Mortar used to repair is sometimes exposed to drying state in early ages after construction and a few days later water is sprayed frequently on the surface of the mortar in order to prevent cracks. This research studied on shrinkage characteristic of mortar subjected to drying conditions like this. The result showed that the water spraying on the mortar after initial drying did not have any effect to prevent shrinkage, but increased. And it also showed when various chemical agents are mixed and used in watersprayingit had the prevention effect on shrinkage. This report was to understand this kind of phenomenon and clarify the mechanism. In addition, based on the results, the new spraying agent was developed to reduce drying shrinkage.

1. Introduction

Concrete structures are prone to crack. And cracks have bad influence on structure members, and even can have a bad effect on the whole structure. Up to now, researches about preventing or reducing cracks especiallydrying shrinkage crack have been carried out. And some effective methods have been developed. Using chemical agent to reduce crack is one of those methods.

But for large buildings, using chemical agent is not affordable. Moreover, admixture is another effective method to prevent crack. It wasreported that as admixture, ureacould reduce drying shrinkage. When the urea is used 50kg/m^{3}in concrete, drying shrinkage decreases about 60%[1)].

Under this condition, this study is intended to develop new spraying agent to reduce drying shrinkage. And the new agent is mainly urea and some special chemical agent. Urea is inexpensive and can be got easily. What's more, the spraying is easier to operate than mixing admixture inalready mixed concrete plant. In this research, the length of test pieces had been measured at different days to calculate the drying shrinkage. And compressive strength test was also completed to find out the strength property of the test pieces under different spraying conditions.

2. Outline of Experiments

This research studied the drying shrinkage property of mortar and the effect that new chemical agent had to mortar compared with an existing agent.And this study also aimed to search out the best concentration of urea that can reduce the drying shrinkage to the greatest extent. And the experiment also had different series of water cement ratio and soaking day to find out the effect these conditions could have to drying shrinkage. This experiment soaked the test pieces to simulate spray. The length of the test pieces were measured at different days(1,3,7,14,21,28,42,56,70,91).

2.1. Materials

The materials used in the experiment are given in table 1. Urea was used when dissolved in water. The main ingredient of coating-type shrinkage reducing admixture is glycol ether-based derivatives.

2.2. Mixing Method

After the cement and the fine aggregate were mixed for 1 minute, water was added and mixed together one more minute by using Omni-type mixer.The mixer was with a nominal capacity of 10 litres. And thesize of mortar test piece was 40×40×160 mm.

2.3. Demoulding

Demoulding was done at one day after mixing. After demoulding, test pieces were put in the constant temperature room at 20ºC with 60% relative humidity.

2.4. Test items

2.4.1. Mortar flow test. The test was conducted according to the JIS R5201-2015"Physical Testing Methods for Cement"[2]. And the results are given in table 2.

*2.4.2. Compressive Strength.*The test was conducted according to the JIS R1108-2006"Compressive Strength Testing Methods"[3].The conditions that compressive strength test was conducted are marked by ○ in table 2.

2.4.3. Drying shrinkage. The length of the test pieces were measured at different days(1,3,7,14,21,28,42,56,70,91).Gauge plug was used to measure the length of the test pieces.

2.5. Testing conditions

Experiment conditions are given in table 2.The soaking liquid were nothing, water, and urea solution. Urea30% means the mass of urea is 30% in the solution. Urea40% and urea50% are the same.And soaking time had three levels, 1 minute,10 minutes, and 30 minutes.Soaking was conducted at the 3rd day or 7th day after demoulding and strength tests were completed at different days (7 and 28).

Table 1. Materials

Materials	Symbol	Type	Density(g/cm³)
Cement	C	Ordinary Portland cement	3.15
Water	W	Tap water	1.00
Fine aggregate	S	River sand	2.63
Chemical agent	U	Urea	1.32
	W	Tap water	1.00
	P	Coating-type shrinkage reducing admixture	0.99~1.05

Table 2. Experiment Conditions

W/C	S/C	soaking liquid	soaking time (minute)	soaking day （after demoulding)	Symbol	Mortar flow （mm)	Compressive Strength test
40%	1.2	nothing			40%N	191	
		water	1	3rd	40%3W		
				7th	40%7W		
		urea50%		3rd	40%3U50%		
				7th	40%7U50%		
50%	1.7	nothing			50%N	199	○
		water	1	3rd	50%3W		○
				7th	50%7W		
			10	3rd	50%3W10min		
			30	3rd	50%3W30min		
		urea30%	1	3rd	50%3U30%		○
		urea40%	1	3rd	50%3U40%		
		urea50%	1	3rd	50%3U50%		
				7th	50%7U50%		
			10	3rd	50%3U50%10min		
			30	3rd	50%3U50%30min		
		Coating-type shrinkage reducing admixture	1	3rd	50%3P		
				7th	50%7P		
60%	2.4	nothing			60%N	197	
		water	1	3rd	60%3W		
				7th	60%7W		
		urea50%		3rd	60%3U50%		
				7th	60%7U50%		

3. Test results and Discussion

3.1. Effects of water cement ratio and soaking day

For different water cement ratios, length changes are shown in figure 1, figure 2 and figure 3.

When the soaking liquid were nothing and water, drying shrinkages of test pieces were almost same and larger than other conditions.However, when the soaking liquid was urea, drying shrinkage of test pieces reduced. Compared with N, when using urea solution, drying shrinkage at most decreased 19% at 40% water cement ratio, 34% at 50% water cement ratio, and 33% at 60% water cement ratio.As for soaking day, at the same water cement ratio, no matter the soaking liquid was water or urea50%, the drying shrinkage was less of 3rd day then that of 7th day. Especially, at 50% water cement ratio, it was

found that when using urea50% on 3rd day, the drying shrinkage decreased 19% compared with using urea50% on 7th day.

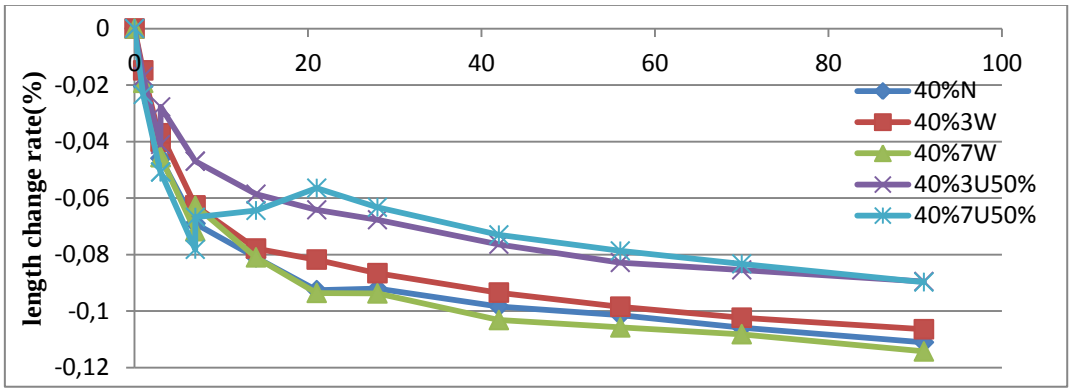

Figure 1. Length change rates(W/C=40%)

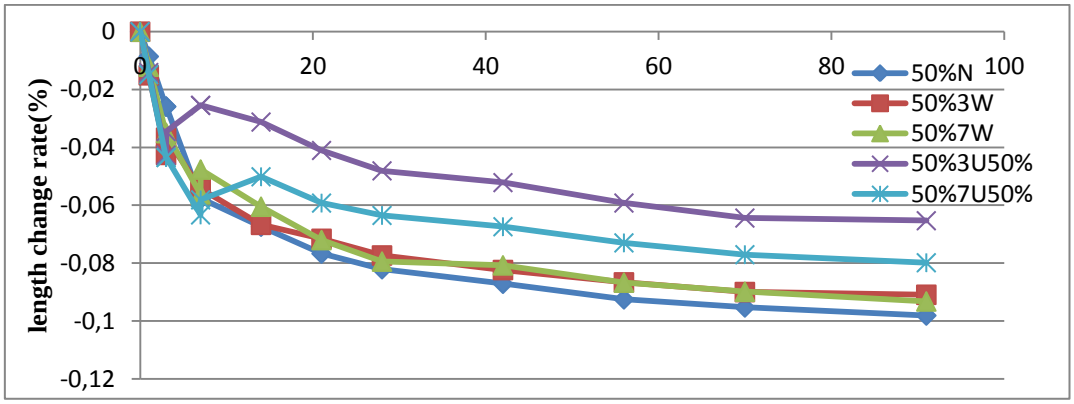

Figure 2. Lehgth change rates (W/C=50%)

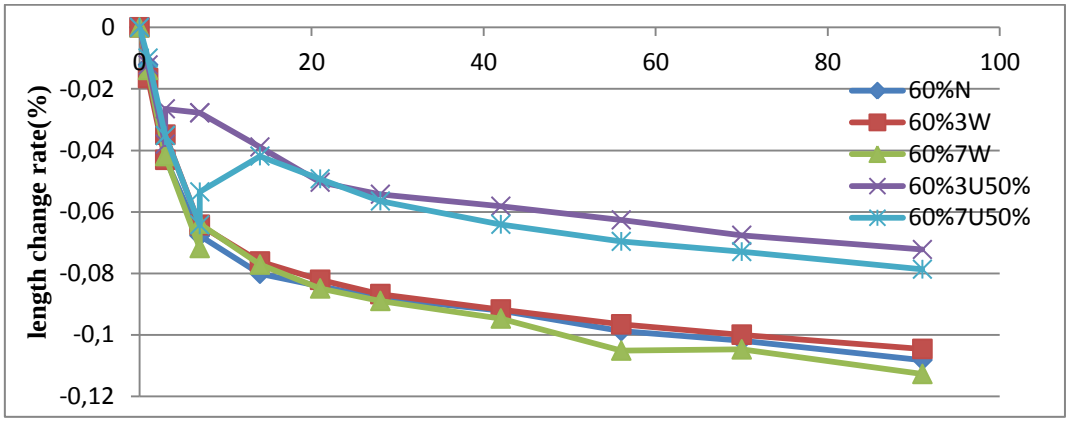

Figure 3. Length change rates (W/C=60%)

3.2. Effects of soaking time

Length changes of test pieces at 50% water cement ratio when the soaking time was different are shown in figure 4. From this figure, it was found that the longer the soaking time, the less the drying shrinkage. However, when using water, the longer the soaking time, the more the drying shrinkage. When soaking time was 30 minutes, the drying shrinkage was even only 23% as that of N. In addition, after soaking for 10 or 30 minutes, it was observed that urea crystallized on the surface of test piece out from the inside.

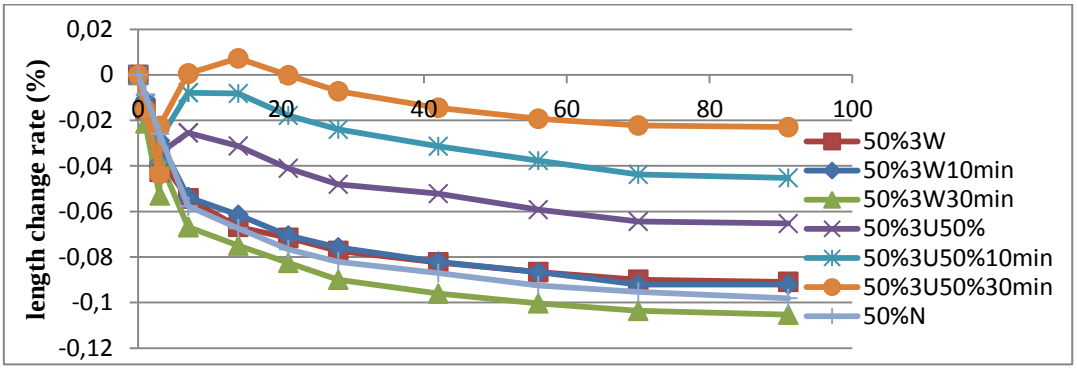

Figure 4. Length change rates (different soaking time)

3.3. Effects of concentration of Urea

Length changes of test pieces when the urea concentration was different are shown in figure 5at 50% water cement ratio.Using urea30%, urea40% and urea50%, the drying shrinkages were 76%, 75%, 64% in turn as that of N, and the drying shrinkage of test pieces soaked in water was less than that of N. In summary, the higher the urea concentration, the less the drying shrinkage. And all the results were better than the test pieces soaked in water or nothing.

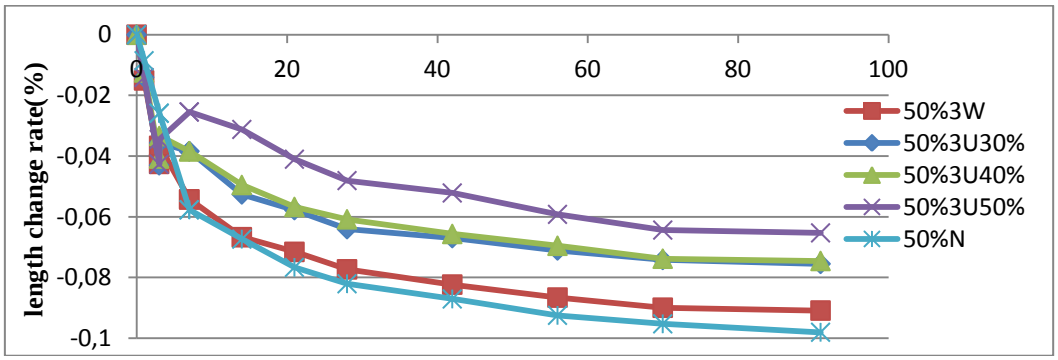

Figure 5. Length change rates (different urea concentration)

3.4. Compared to Coating type shrinkage reducing admixture

Length changes of test pieces when the soaking liquid were urea solution and coating type shrinkage reducing admixture are shown in figure6at 50% water cement ratio. When soaking day was 3rdday, the effect of coating-type shrinkage reducing admixture was not as good as urea solution.Nevertheless, when soaking day was 7th day, the effect of Coating-type shrinkage reducing admixture was better than urea solution.But all the results were better than using nothing to soak test pieces in.

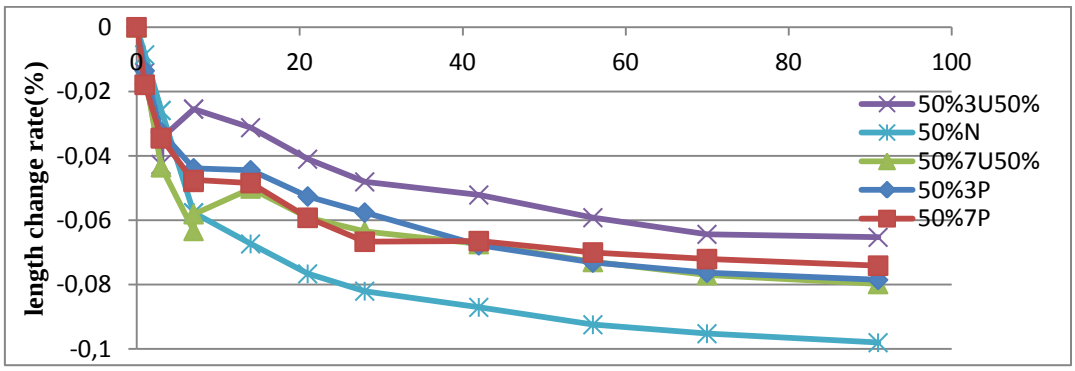

Figure 6. Length change rates (different soaking liquid)

3.5. Compressive Strength

The results are shown in figures 7.As the water cement ratio increased, the strength decreased. The compressive strengths of urea50%-type were higher than that of N-type at different water cement ratios.It was thought that after soaked in urea solution, the drying shrinkage of mortar became smaller, so the internal compressive stress inside mortar became smaller, so when being compressed, it can bear more external pressure. So the compressive strength increased.

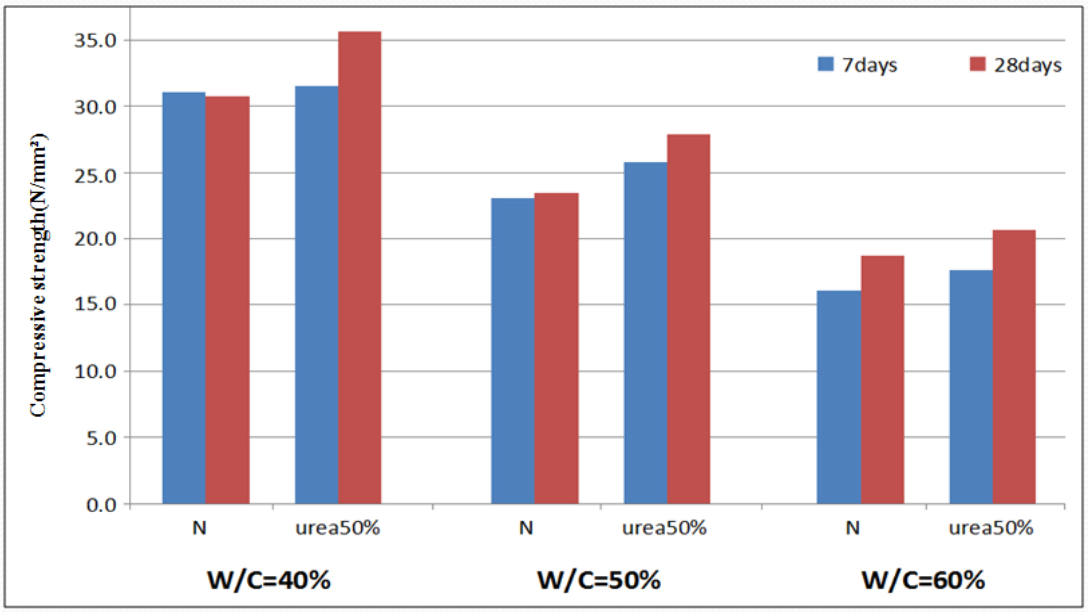

Figure 7. Compressive strength

4. Conclusions

Urea is easy to soluble in water, but also easy to precipitate from water. So it was probable that urea permeated mortar when soaking and crystallized in the gaps inside mortar when the water evaporates. So it was found that after soaked by urea solution, mortar's drying shrinkage decreased.

The results of this study can be summarized as following:

1) Using urea solution to soak mortar can reduce drying shrinkage.
2) When the urea solution concentration is higher, the effect is better.
3) When the soaking time is longer, the effect is better.
4) Compressive strength increases after using urea50%.
5) Some agents are better to be used at third day than seventh day.

References

[1] KawaiT andSakataK 2007 *Proceedings of the Japan Concrete Institute*.**29** 644
[2] Japan Standards Association 2015, *JIS R 5201 Physical test method of cement.*
[3] Japan Standards Association 2006, *JIS R 1108 Compressive strength test method.*