Resistance of Cement-Asphalt Emulsion Mixtures to Freezing and Thawing

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ABSTRACT

This paper describes resistance of cement-asphalt emulsion mixtures (CEM) to freezing and thawing with the emphasis on the behaviour of water.
Portland cements and asphalt emulsions have long been used separately for base course construction. The advantages of using these two materials in dense-graded mixtures have been well established. However, it has been also pointed out that the former has a disadvantage of shrinkage cracking and that the latter lacks initial bearing capacity.
In Japan, CEM was first developed as the base of New-Tokaido Line about 15
So far the author has been investigated mechanical properties of CEM through Marshall Test, Uni-axial Test, Bending Test, Stress Relaxation Test before this paper.
The ASTM C-666 test method was utilized for resistance of CEM to rapid freezing and thawing. In this procedure, the following variables were included : (1) cement content (2) emulsion content (3) curing time (4) freezing and thawing time (5) method of evaluation.
This paper primarily describes the effect of all the above variables.

RESISTANCE OF CEMENT-ASPHALT EMULSION MIXTURES TO FREEZING AND THAWING

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1. Introduction

Portland cement and asphalt emulsion have been used in pavement construction for the treatment of base course granular materials, and the potential advantages of using these materials have been reasonably well established. However, the disadvantages of using them have been also recognized by pavement engineeres in the field. They are shrinkage cracking for cement treated mixtures and lack of initial strength for emulsion treated mixtures. Accordingly, investigations have been made into the effect of adding small amounts of asphalt emulsion to cement mixtures (CM) or portland cement to emulsion mixtures (EM). So far considerable number of papers has been published, but the nature of cement-asphalt emulsion mixtures (CEM) has not been well cleared.

The author has been studying the mechanical properties of CEM and this paper describes the resistance of CEM to freezing and thawing with the emphasis on the bihaviour of water.

2. Methods of Experiment

(1) Materials

Materials used for making specimens include portland cement, asphalt emulsion and aggregates. The properties of asphalt emulsion used and the quality standards by the Japan Asphalt Emulsion Association[1)] are shown in Table 1. The crushed aggregate used in this study was from Kuzuu, Tochigi Prefecture. It was separated by sieving and then recombined to give a appropriate grading as shown in figure 1.

(2) Preparation of Specimens

The specimens used in this study were 12.7cm high by 10cm diameter cylindres compacted at a constant level of effort according to the typical method defined in the Manual for Design and Construction of Asphalt Pavements[2] by the Japan Road Association.

The variables included in the specimens are as follows :

1) cement contents for CM : C=2%, 4% (2 kinds)
2) emulsion contents for EM : E=6% (one kind)
3) cement and emulsion contents for CEM : combinations of C=2%, 4%, E=2%, 4%, 6%, 8% (8 kinds)

C and E are determined by the following formulae :

$$C(\%) = W_C / (W_C + W_E + W_A) \times 100$$

$$E(\%) = W_E / (W_C + W_E + W_A) \times 100$$

where W_C : weight of cement
W_E : weight of emulsion
W_A : weight of aggregate

Appropriate amount of water was added to these materials before compaction in order to give the mixtures the optimum moisture content.

(3) Curing of Specimens

After compaction and stripping from molds, the specimens were cured at room temperature(20°C) and approximately 60~80 percent relative humidty for 7,14,28,56 days.

(4) Freezing and Thawing Test

Freezing and thawing tests were performed using the method similar to that of ASTM C-666[3] . Weight and dynamic modulus of elasticity of specimens were measured after each cycles of freezing and thawing, and finally uni-axial compression test was conducted after 30 cycles.

3. Determination of Optimum Moisture Content

The optimum moisture content for CM (cement + aggregate + water added), EM (asphalt emulsion + aggregate + water added) and CEM (cement + emulsion + aggregate + water added) was determinated first.

Figure 2 shows the results for CM obtained by specimens changing cement content and amount of additional water. It can be concluded from the figure that the optimum moisture content of CM is constant (8%) without being influenced by cement content. The amount of additional water which give CE the optimum dry density very according to emulsion content as shown Figure 3. However, if the amount of water added and included in emulsion is used as a parameter instead of amount of water added, the optimum moisture content becomes nearly constant (8%) as shown Figure 4. This leads to the conclusion that the water included in emulsion also works as a lubricant when EM is compacted.

Based on the results mentioned above, it is easy to presume that the optimum moisture content of CEM will be also dependent on the amount of water added and included in emulsion. Figure 5 shows that the presumption could be reasonable.

4. Experimental Results

(1) Weight Change of Specimens

The weight of specimens changes according to evaporation and absorption of water during curing, immersion in water and test. Figure 6 indicates the typical trend of weight change for CM, EM and CEM.

The weight of specimens just after compaction (Phase I) decreases owing to evaporation during curing in the air until it reaches Phase II. Then specimens are immersed in water and the weight increases by soaking water.

At Phase III, freezing and thawing test is begun. During the test, the weight of specimens increases at first, but it gradually decreases and specimens are broken finally.

This process of weight change will be discussed in the followings.

(2) Weight Chage by Evaporation

This is a weight change which occurs during the process from Phase I to Phase II. When C=2% (Figure 7), the weight of CM and EM decreases to 94.0% and 93.5% of initial weight respectively independent of curing time. However, in the case of CEM, the more emulsion content causes the less evaporation of water at 7 days, while the weight is constant 94.0% (the same value as that of CM) at 56 days independent of emulsion content. This means that cement content is the principal factor of controling evaporation and that emulsion has the effect of delaying evaporation.

Similar trend was obtained from specimens containing 4% of cement as shown in Figure 8.

(3) Weight Change by Absorption

This is the weight change from Phase II to III. The relative value of absorption W_0(%) was defined here as follows :

$$W_0(\%) = (W_2 - W_1) / W_1 \times 100$$

where W_1 : specimen weight before immersion
W_2 : specimen weight after immersion

Figure 9 and 10 show the change of relative value of absorption. The value is largely influenced by emulsion content for all curing days. It is apparent from the figures that emulsion in CEM limits water absorption.

(4) Weight Change during Tests

The change of relative weight of specimens containing 2% of cement after curing of 7 days is shown in Figure 11. As for CM, the relative weight decreases to 94% according to curing in the air for 7 days. Then it increases up to 99% by 4 hours' immersion. This specimen was broken by only one cycle of freezing and thawing test, decreasing the weight rapidly.

The relative weight of EM decreases to 93% according to curing, but very little increase is gained by immersion. Then the relative weight increases during test and is still increasing at 30 cycles.

The spesimen of CEM with C=2%, E=2% behaves likely as CM. But the effect of adding 2% of emulsion is found in reduction of evaporation and absorption, and increase of resistance to freezing and thawing. It is easily realized from the figure that the more emulsion content, the more resistant mixtures are gained.

Test results for C=4% are shown in Figure 12. General trend is similar to that of Figure 11, though resistance to freezing and thawing becomes higher.

(5) Change of Relative Dynamic Modulus of Elasticity

The relative dynamic modulus of elasticity E_R(%) is calculated as follows :

$$E_R(\%) = E_A / E_B \times 100$$

where E_A : dynamic modulus of a specimen after any cycles

E_B : dynamic modulus of a specimen before freezing and thawing

This is used as an indicator for resistance to freezing and thawing.

Figure 13 and 14 show the change of dynamic modulus during test for specimens cured for 7 days. The modulus generally decreases according to the increase of cycles, however, the rate of decrease is small if emulsion content is rich.

Figure 15 and 16 show the results tested after curing of 56 days. Resistance of spesimens to freezing and thawing in this case is higher than that of in Figure 13 and 14.

The relative dynamic modulus after 30 cycles is compared in Figure 17 and 18 showing the effects of cement content, emulsion content and curing time. Though the effect of cement content is not so clear, emulsion content and curing time influence considerably on the values of the modulus.

(6) Uni-axial Compressive Strength

The compressive strength after 30 cycles is shown in Figure 19 and 20. Comparing both figures, it is realized that the strength of CEM with C=4% is nearly two times larger than that of CEM with C=2%. This means that the level of strength is primarily determined by cement content even after freezing and thawing. These figures also indicate the existence of the optimum emulsion content around 5%.

5. Conclusuions

Results of experimental studies on the resistance of CEM to freezing and thawing are summarized as follows :

(1) The optimum moisture content of CEM could be determined based on the amount of water added and included in asphalt emulsion.

(2) Asphalt emulsion in CEM has the effect of limiting water absorption.

(3) Under the conditions of this experiments, the resisntance of CM to freezing and thawing is very low, but compressive strength of CEM after freezing and thawing is controled by cement content.

(4) The optimum emulsion content may exist as for the compressive strength after 30 cycles, but larger amounts of cement and aspahlt emulsion generally give the mixtures higher resistance to freezing and thawing.

Acknowledgement

The author wishes to express his thanks to Mr. Toshiaki Nomura for the assistance of experiments and preparation of the paper.

References

1) The Japan Asphalt Emulsion Association, "The comparison of Old and New Standards for Modified Asphalt Emulsion", Asphalt Emulsion, No.70, 1982

2) The Japan Road Association, "Manuals for Design and Constructicn of Asphalt Pavements", 1978

3) ASTM C 666-80, "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing"

Table. 1 Quality Standards and Test Results for Asphalt Emulsion.

			Quality Standards by the Japan Asphalt Emulsion Association		Test Results	
Engler Viscosity, at 25℃			2～30			4.4
Residue on 1190μm Sieve		%	max.	0.3		0.06
Stability to Mixing, with Cement		%	max.	1		0.3
Residue from Evaporation Test		%	min.	57		58.0
Residue	Penetration at 25℃		60～300			162
	Ductility at 15℃	cm	min.	80	min.	100
	Solubility in Trichloroethane	%	min.	97		99.2
Settlement, 5days		%	max.	5		1.3
Particle Charge			No Regulation		Neutral	

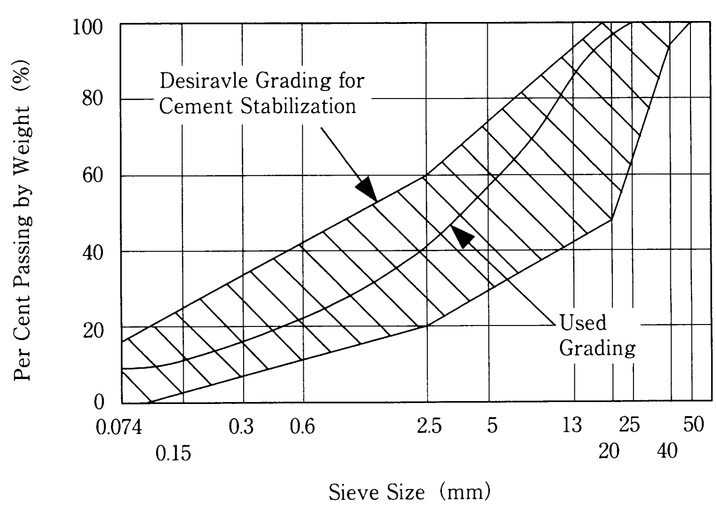

Fig. 1 Grading Curves for Aggregates

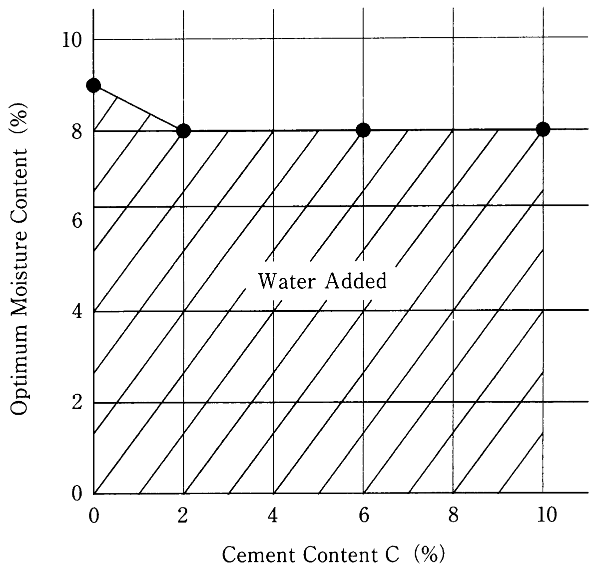

Fig. 2 Optimum Moisture Content
of Cement Mixtures

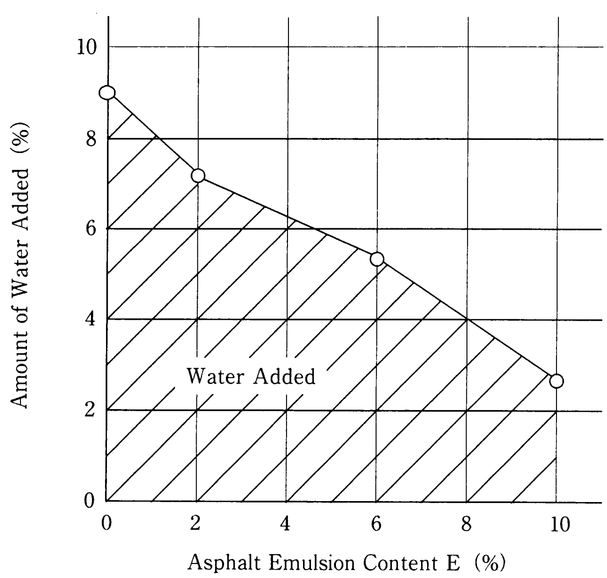

Fig. 3 Amount of Water Added for
Asphalt Emulsion Mixtures

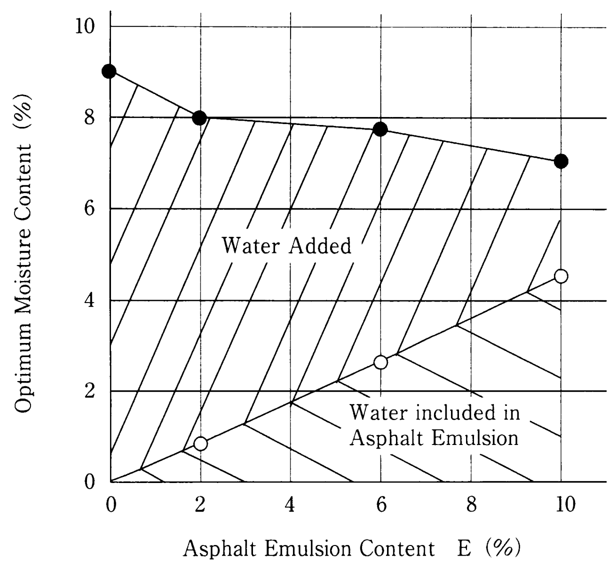

Fig. 4 Optimum Moisture Content of
Asphalt Emulsion Mixtures

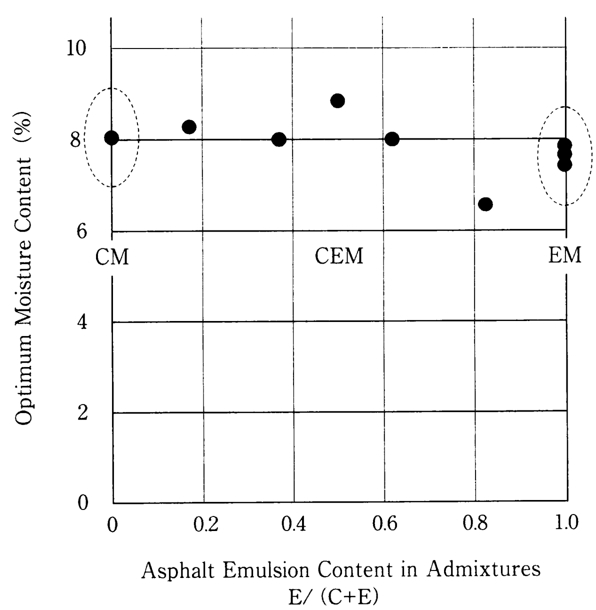

Fig. 5 Optimum Moisture Content of
Cement-Asphalt Emulsion Mixtures

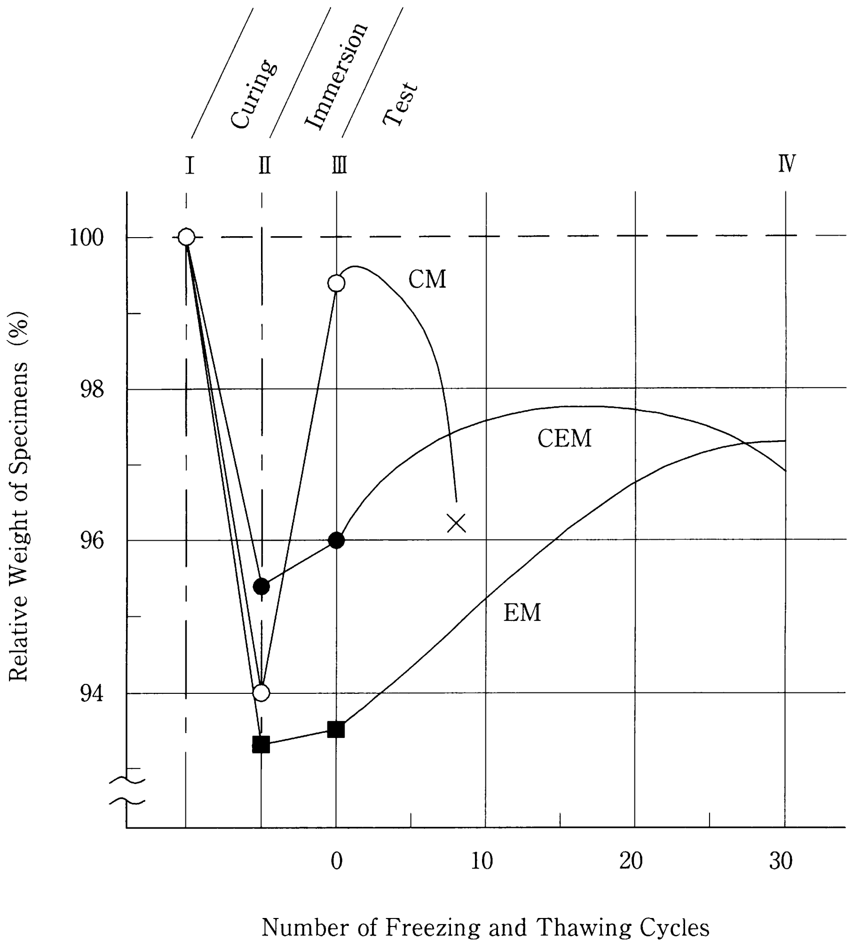

Fig. 6 Typical Trend of Weight Change of Specimens

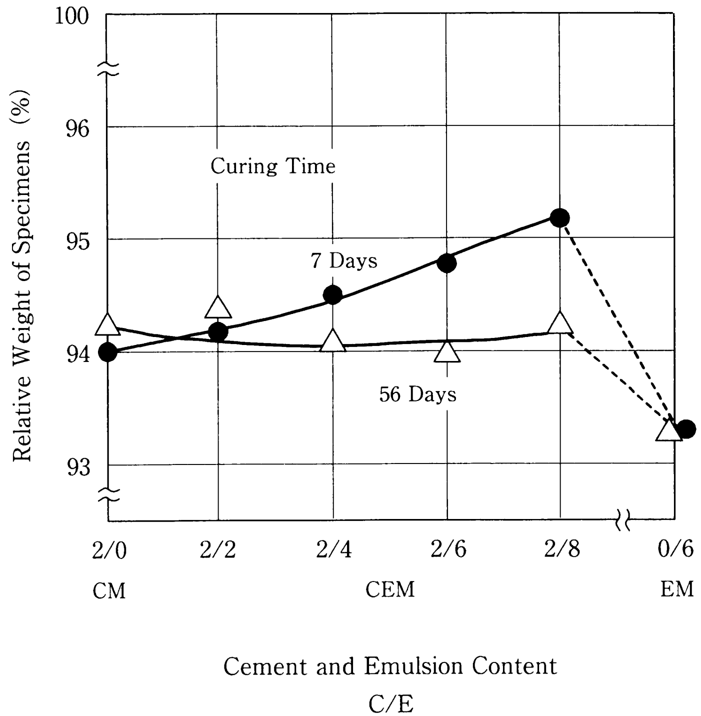

Fig. 7 Weight Change of Specimens by Evaporation (C=2%)

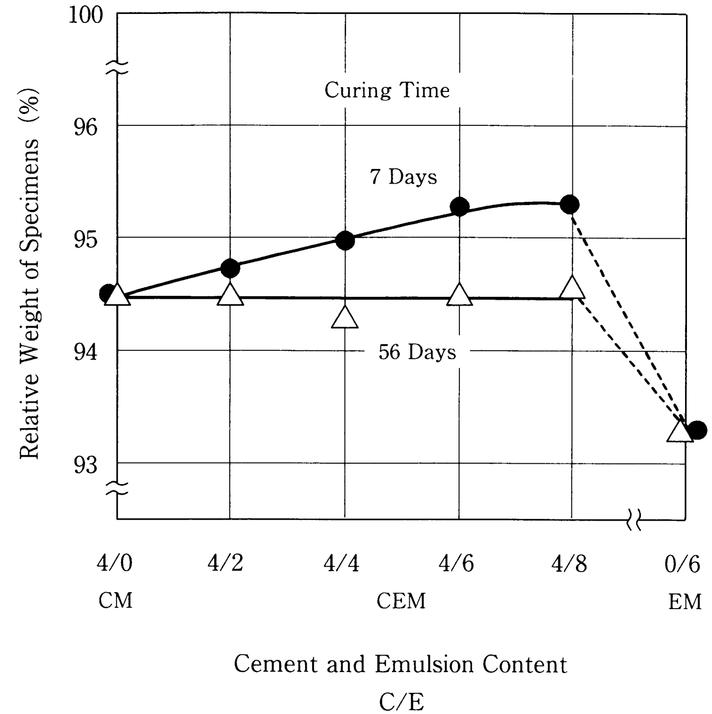

Fig. 8 Weight Change of Specimens by Evaporation (C=4%)

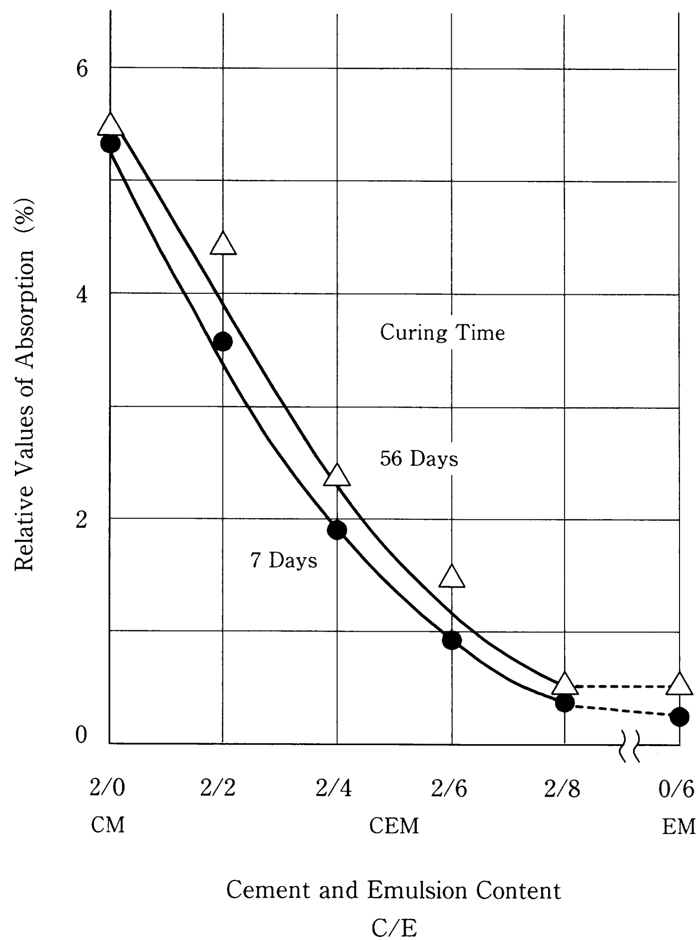

Fig. 9 Absorption Change of Specimens by Immersion (C=2%)

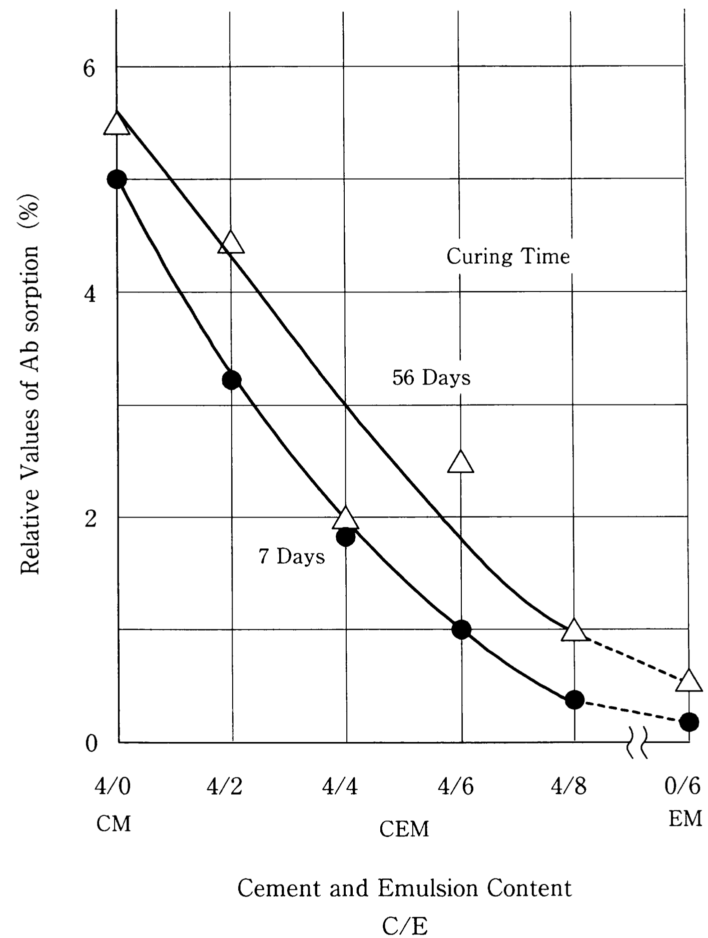

Fig. 10 Absorption Change of Specimens by Immersion (C=4%)

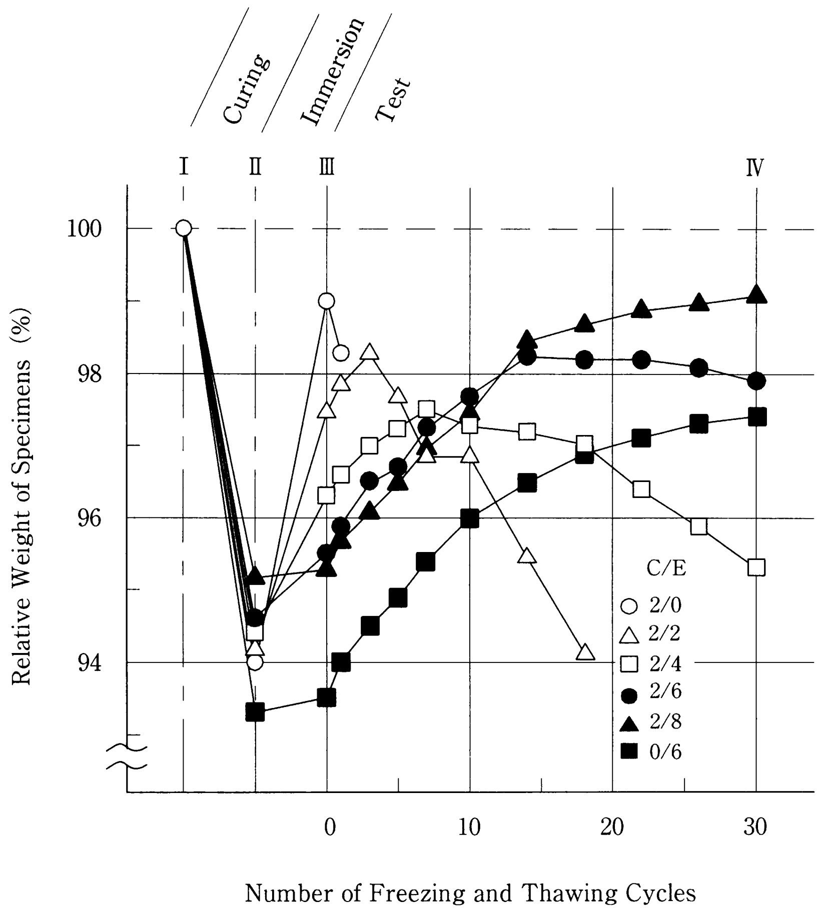

Fig. 11 Weight Change of Specimens (C=2%)

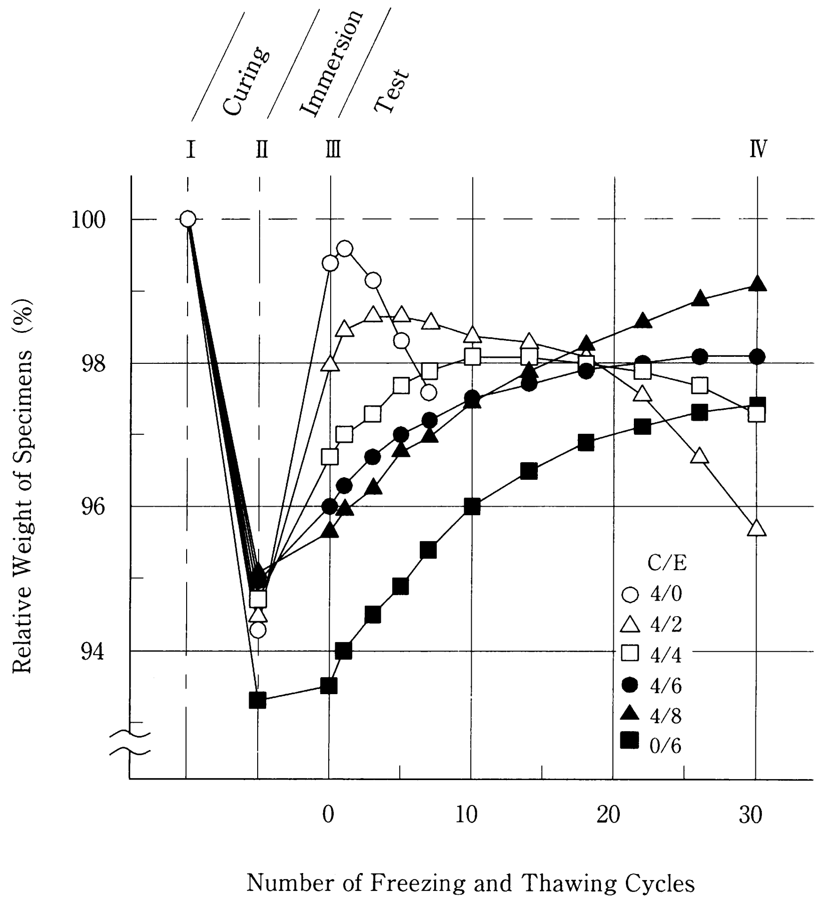

Fig. 12 Weight Change of Specimens (C=4%)

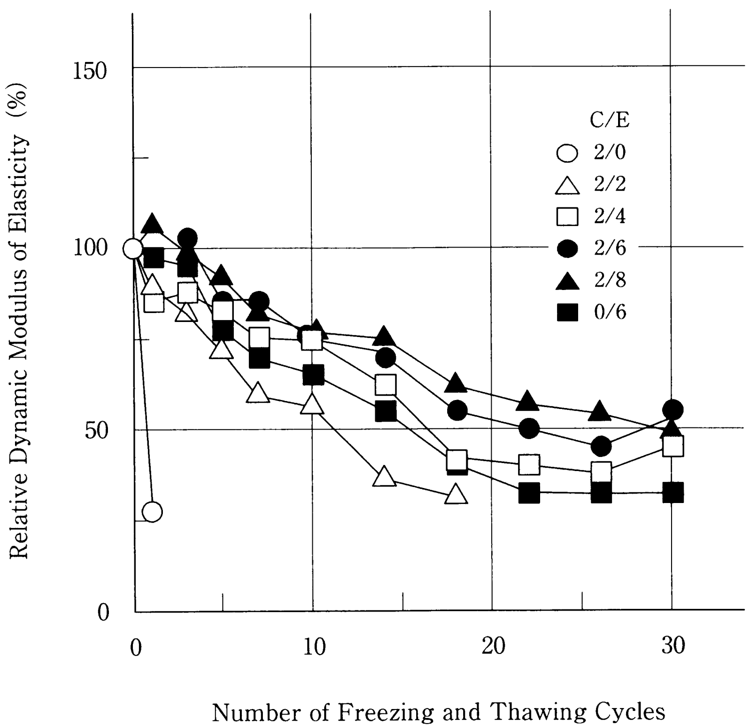

Fig. 13 Change of Relative Dynamic Modulus of Elasticity (Curing Time 7 Days, C=2%)

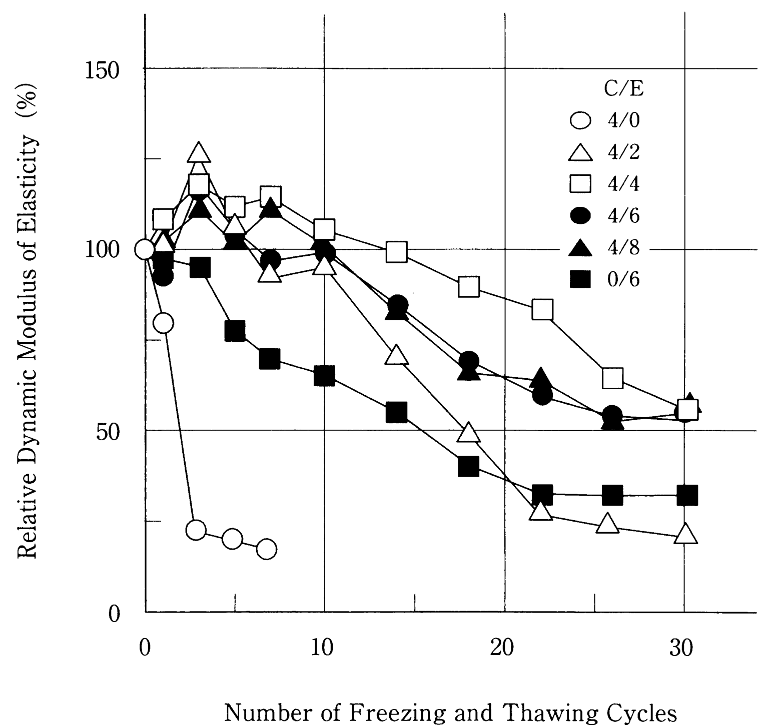

Fig. 14 Change of Relative Dynamic Modulus of Elasticity (Curing Time 7 Days, C=4%)

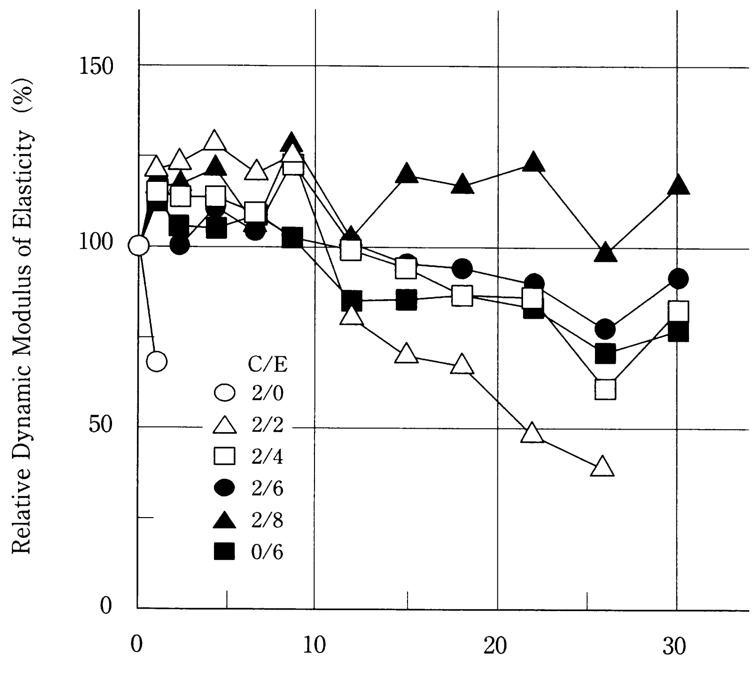

Fig. 15 Change of Relative Dynamic Modulus of Elasticity (Curing Time 56 Days, C=2%)

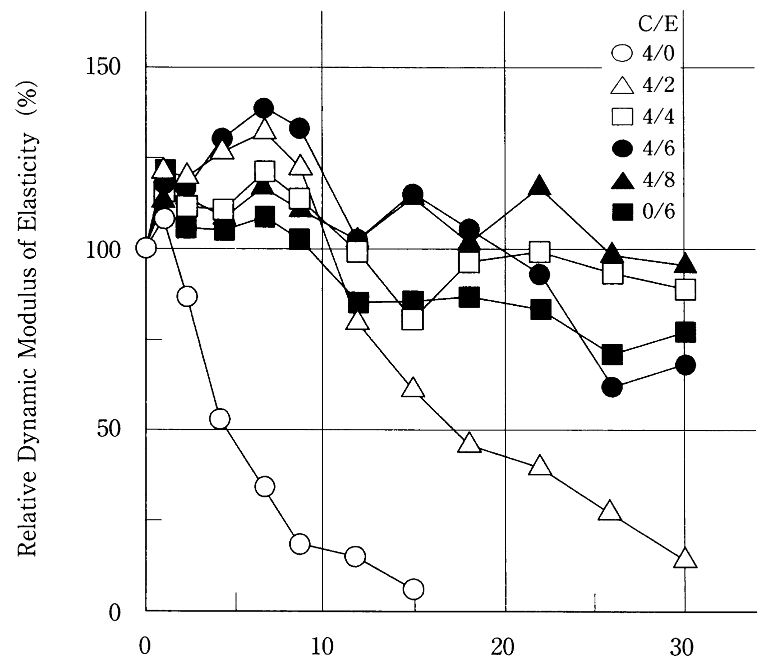

Fig. 16 Change of Relative Dynamic Modulus of Elasticity (Curing Time 56 Days, C=4%)

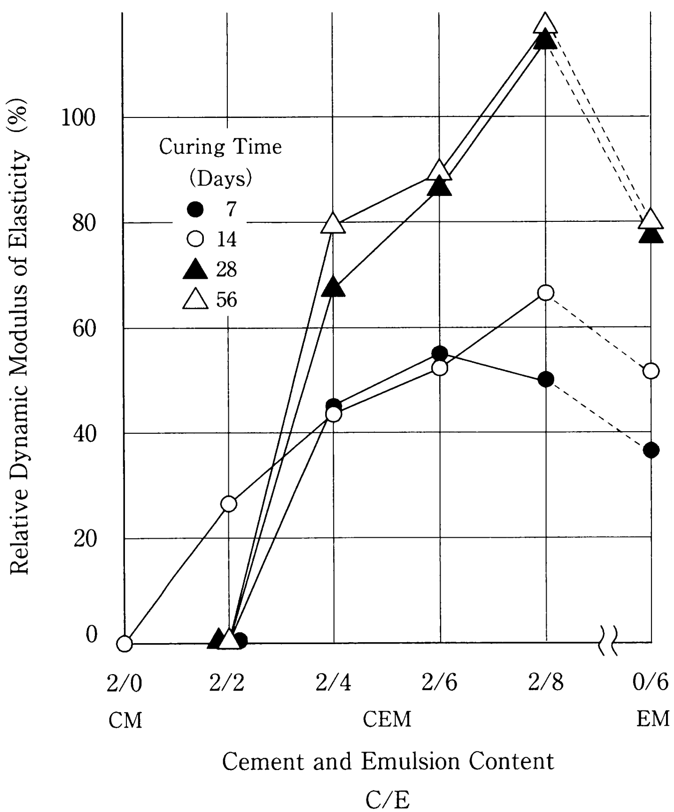

Fig. 17 Change of Relative Dynamic Modulus of Elasticity after 30 Cycles (C=2%)

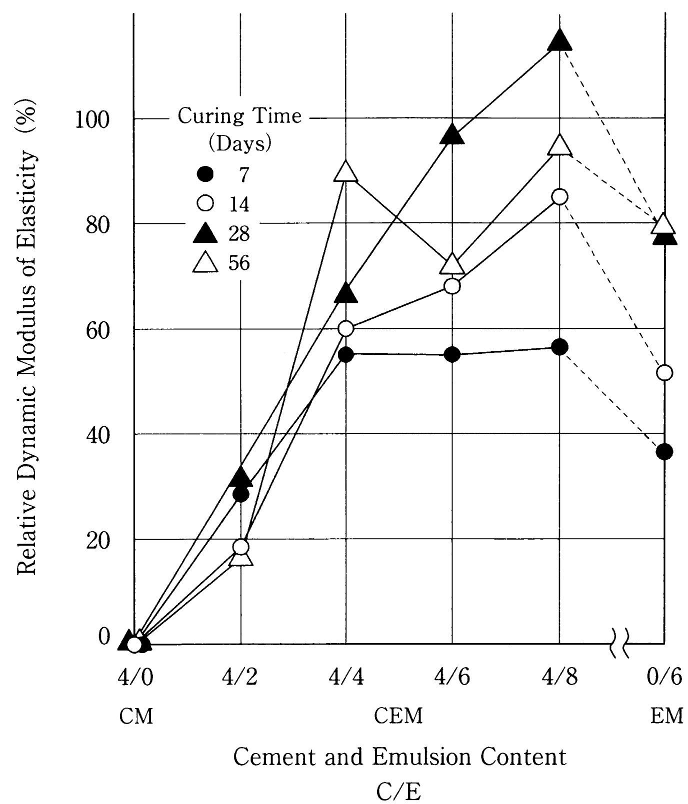

Fig. 18 Change of Relative Dynamic Modulus of Elasticity after 30 Cycles (C=4%)

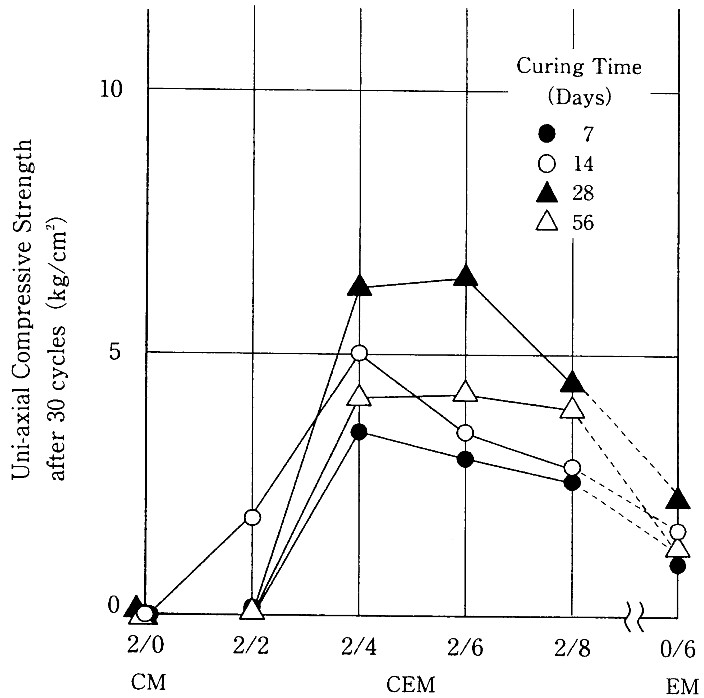

Fig. 19 Compressive Strength of Specimens after 30 Cycles (C=2%)

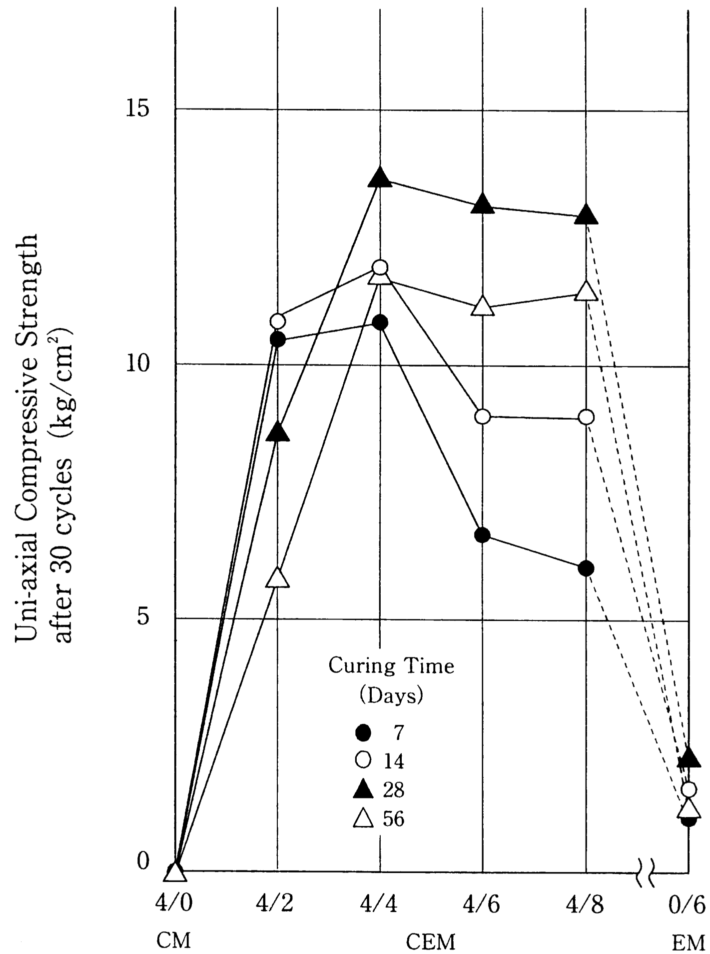

Fig. 20 Compressive Strength of Specimens after 30 Cycles (C=4%)