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Accelerating Test of Reinforced Concrete Member for Evaluating Durability*

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Abstract

The purpose of this study is to examine the following points for evaluating the durability and estimating the deterioration of reinforced structures in cold regions. (1) Developing modeling specimens of RC structure members, whose size is 10×10×40 cm in order to be able to conduct sthe rapid freezethaw tests by ASTM C 666 and loading. (2) The relation between the decrease of strength in the area of concrete subjected to freeze-thaw and the degree of reinforcing steel corrosion, and the decrease of bearing strength of RC concrete members. (3) The quantitative relation between the degree of cover deterioration and reinforcing steel corrosion. (4) A rapid freeze-thaw test was air is done and this method that was compared with freezethaw tests in water by ASTM.

The summary of results is as follows. The modeling specimens of RC members were able to be given the accelerating test. The change of weight and ultrasonic velocity of rapid freeze-thaw tests in air were smaller than that in water. The ultimate strength decreased with the cycle of freeze-thaw.

1. Introduction

The purpose of this study is to examine the following points for evaluating the durability and estimating the deterioration of reinforced structures in cold regions. (1) Developing modeling specimens of RC structure members, whose size is 10×10×40 cm in order to be able to conduct rapid freezethaw tests by ASTM C 666 and loading. (2) The relation between the decrease of strength in the area of concrete subjected to freeze-thaw and the degree of reinforcing steel corrosion, and the decrease of bearing strength of RC concrete members. (3) The quantitative relation between the degree of cover deterioration and reinforcing steel corrosion. (4) A rapid freeze-thaw test in air was done and this method that was compared with freeze-thaw tests in water by ASTM.

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2. Experimental Procedure

2.1 Deterioration Factors

A flow-chart for arranging factors of deterioration of RC structures in cold region is shown in Fig. 1. From this, a flow-chart of model experiments for evaluating RC members and predicting kaleidoscopic change was made and is shown in Fig. 2[1]. In this flow-chart, accelerating tests of freeze-thaw and electro-

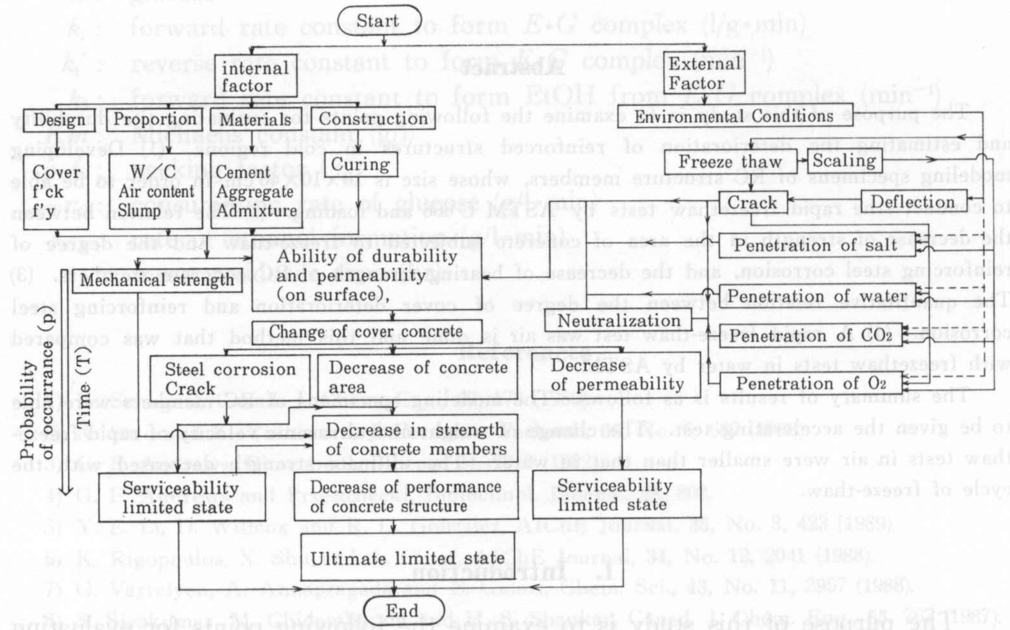

Fig. 1. Factors of progressive change of RC structure and flow of deterioration progress.

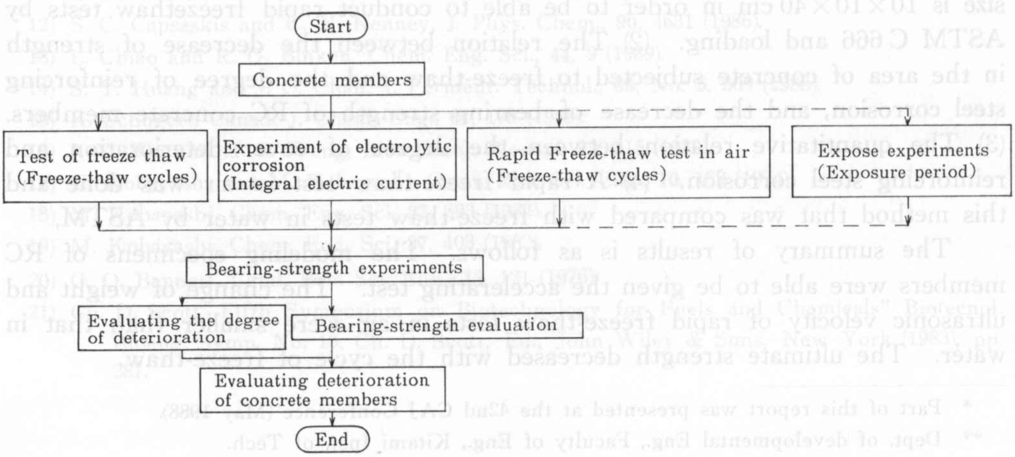

Fig. 2. Flow chart of model experiment for evaluating RC member and predicting progressing change.

lytic corrosion were carried out. The change in weight and ultrasonic velocity of concrete, rate of surface corrosion of reinforcing steel and integrating electric current were measured. The degree of deterioration were quantifyed with these data. The experimental cases were case 1 using fresh water and case 2 using sea water.

2.2 Specimens

(1) Materials and mix proportions

The properties of the concrete material are shown in Table 1. The fine and coarse aggregate were from Satunai river. The mix proportions of concrete are shown in Table 2. The properties of the reinforcing steel are shown in Table 3. In case 1, deformed bars were used in order to conduct bearing strength tests. In case 2, round bars were used in order to observed surface corrosion. The stirrups were stainless steel in order to evaluate only main steel corrosion influencing bearing strength. Furthermore the main steel and the stirrup were separated with vinyl tape in order to prevent partial spot corrosion.

(2) From and size

The form and size of specimens is shown in Fig. 3. In the specimens of

Table 1. Properties of materials of the concrete

Cement	Fine aggregate*	Coarse aggregate*	Admixture
Normal portland coment Ssecific gravity: 3.16	Speci fic gravity: 2.61 Absorption rate: 2.40%	Maximum size: 25 mm, Specific gravity: 2.66 Absorption rate; 1.63%,	AE agent Constitution: Anion active agent

* Place of production, was Satunai river.

Table 2. Mix proportions of the concrete

Kind of mix propor-tion	type of cement	W/C (%)	S/a (%)	Specified mix: Water (kg/m³)	Cement (kg/m³)	Fine aggre-gate (kg/m³)	Coarse aggre-gate (kg/m³)	Admix-ture (cc)	Property of fresh concrete: Slump (cm)	Air content (%)
N 451	Normal Portland cement	45	31	152	338	564	1277	48.5	6.3	3.5
N 452	Normal Portland cement	45	31	152	338	564	1277	39.7	8.0	4.8
N 55	Normal Portland cement	55	34	152	276	634	1258	46.9	8.0	4.5
N 65	Normal Portland cement	65	34	152	234	647	1279	52.9	9.2	5.1

Note; N 451 and N 452 are mix proportion for case 1 and case 2 respectively.

Table 3. Properties of reinforcing bars

Kind of reinforcing	Type	Diameter of reinforcing (mm)	Mark (JIS)	Properties of mechanics: Yielding point (kg/cm²)	Tensile strength (kg/cm²)	Proportion of extension
Main reinforcing	Hot rolling deformed bar	6	SD 30 A	3300	5200	27
Main reinforcing	Hot rolling bar type 1	6	SR 24	3360	4980	55
Stirrup	Austnite Stainless steel	4	SUS 304	—	5910	51

case 1, length of contact was maintained on the steel by bending the steel outside of the supporting point as shown in Fig. 3. A mortar spacer of w/c=40% was set before the placing of fresh concrete in order to correctly keep a cover of 10 mm and to provide a supporting point for the loading test. The concrete was placed in two layers and vibrated. The specimens of the compressive strength tests was $\phi 10 \times 20$ cm.

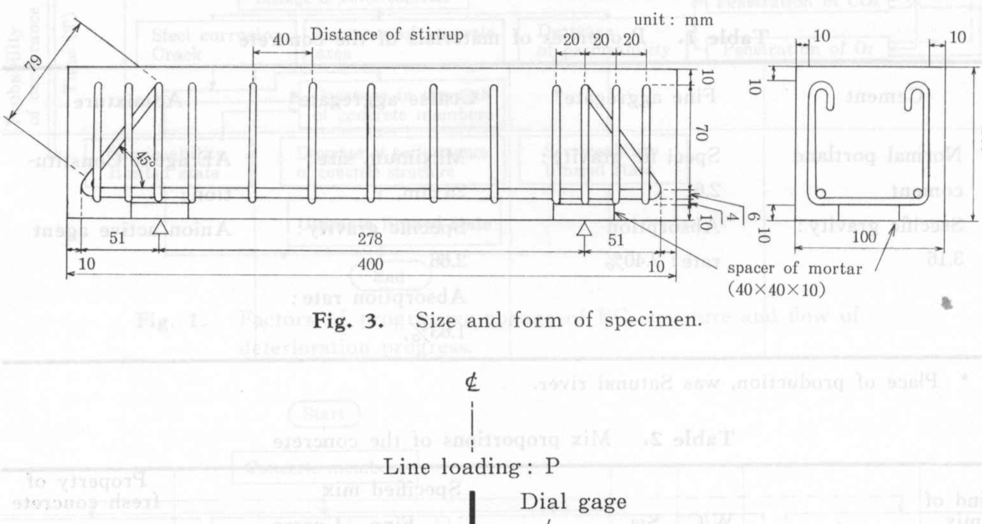

Fig. 3. Size and form of specimen.

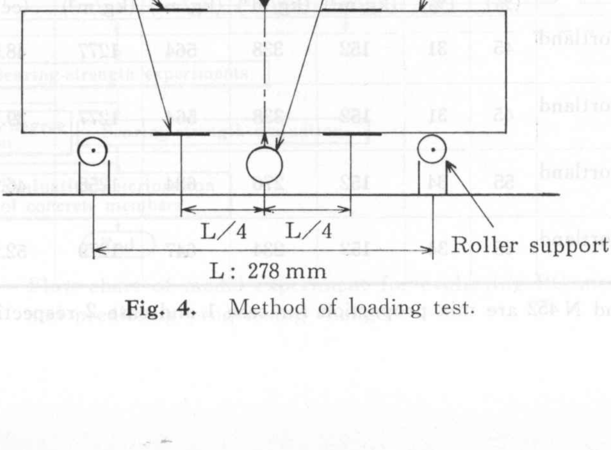

Fig. 4. Method of loading test.

2.3 Experiment Method

(1) Accelerating test

The method of the rapid freeze-thaw test was based on ASTM C666. But sea water was used in case 2. The beginning age of the freeze-thaw test was 28 days after placing. The beginning age of the electrolytic corrosion test was 91 days.

The rapid freeze-thaw test was done by the method shown in Table 4.

(2) The method of the exposure tests

The site of the exposure tests was Masuura beach, where the environment is influenced by freeze-thaw condition and sea water. The test is being continued.

(3) The method of the loading tests

The method of the loading tests is shown in Fig. 4.

Table 4. The method and condition of the rapid freeze-thaw test

Experiment environment : in Air
Maximum temperature in air : 22°C
Minimum temperature in air : −24°C
Maximum temperature in specimen : 6°C
Minimum temperature in specimen : −18°C
Humidity in air (Controlling above 5°C) : 84 (%)
Average number of freeze-thaw cycles in day : 6 cycles

3. Conclusion

3.1 Results of the Freeze-thaw Test

The tests result were arranged by linear regression analysis whose line passed 100% on initial value.

The relation between cycles of freeze-thaw and change in weight is shown in Fig. 5. In the case of 100 cycles, the changes in weight of w/c=45% and 65% were 98.4% and 95.6% respectively compared to the initial values. After 300 cycles, the changes in weight of w/c=45% and 65% were 98.4% and 95.6% respectively. The relation between freeze-thaw and the change in ultra sonic velocity is shown in Fig. 6. After 100 cycles, the changes in weight of w/c=45% and 65% were 97.0% and 95.6% respectively compared to the initial values. After on 300 cycles, the changes in weight of w/c=45% and 65% were 91.0% and 86.7% respectively.

The relationship between cycles of freeze-thaw in air and change in weight is shown in Fig. 7. In the case of 300 cycles, the change in weight of w/c=45% and w/c=65% were 99.5% and 99.7% respectively compared to the initial values. They are seldom not recognized to change.

The relationship between cycles of freeze thaw in air and the change in

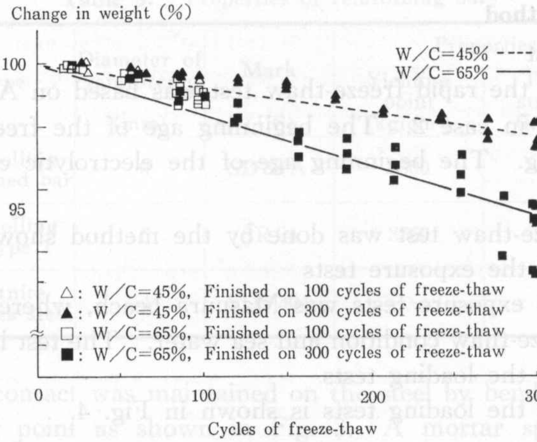

Fig. 5. Relation between cycles of freeze-thaw and change in weiget (%) (Freeze-thaw in water).

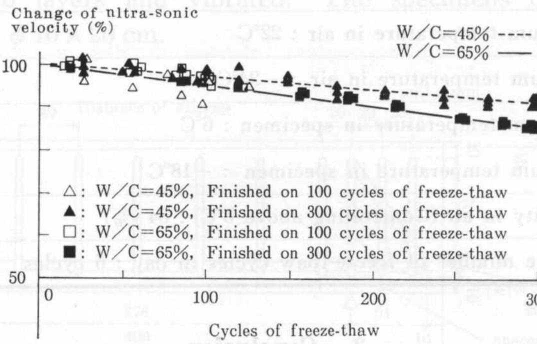

Fig. 6. Relation between cycles of freeze-thaw and ultrasonic velocity (Freeze-thawin water).

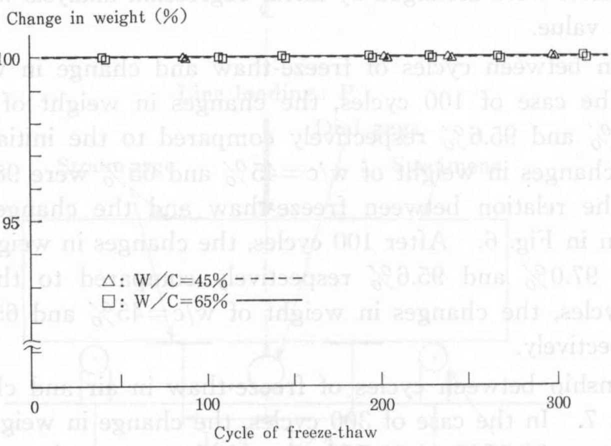

Fig. 7. Relation between cycles of freeze-thaw and change in weight (%) (Freeze-thaw in air).

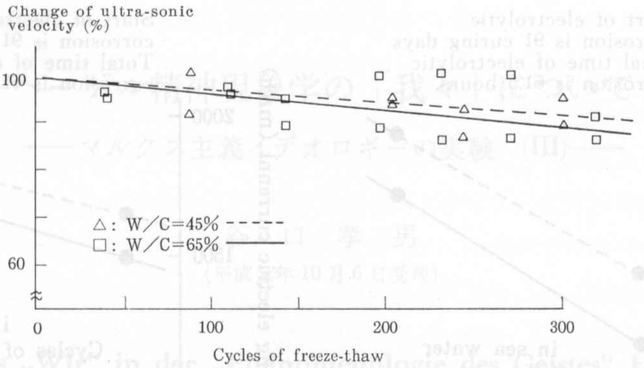

Fig. 8. Relation between cycles of freeze-thaw and ultrasonic velocity (Freeze-thaw in air).

ultra-sonic velocity is shown in Fig. 8. In the case of 300 cycles, the changes in weight of w/c=45% and w/c=65% were 92.3% and 90.0% respectively compared to the initial values. Their changes are smaller than those in water.

3.2 The Results of the Loading Tests

The relation between cycles of freeze-thaw and ultimate strength is shown in Fig. 9. In the case of w/c=45%, the bearing strength of 200 cycles and 300 cycles were 98.0% and 94.0% respectively compared to those of standard curing 91 days (0 cycles). In the case of w/c=65%, they were 94.0% and 82.0% respectively.

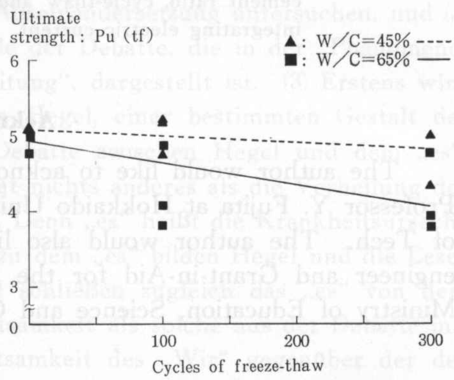

Fig. 9. Relation between cycles of freeze-thaw and ultimate strength. (Freeze-thaw in water).

3.3 The results of Electrolytic Corrosion

After rapid freeze-thaw tests, the result of electrolytic corrosion is shown in relation to water-cement ratio, or cycles of freeze-thaw and the ratio of the surface corrosion of steel in Fig. 10. In this relationship, increasing the water-cement ratio and cycles of freeze-thaw made the ratio of steel corrosion become greater. In the same way, the relationship between the water-cement ratio or integrating electric current for steel corrosion, and the ratio of surface corrosion of steel is shown in Fig. 11. In this relationship, when the water-cement ratio and the cycles of freeze-thaw increased, the integrating electric current tendency became greater at the same time. Accordingly, the tendency is that the surface cover concrete deteriorates and the reinforcing steel is corroded by the action of freeze-thaw.

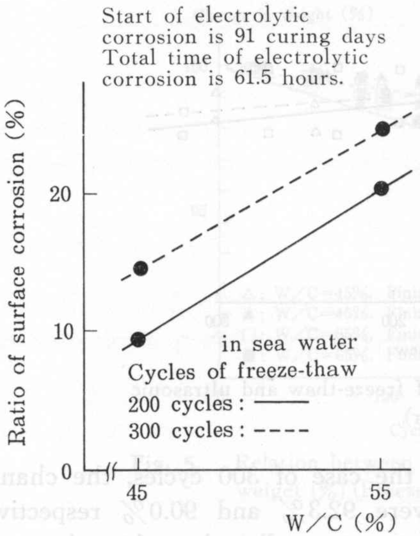

Fig. 10. Relation ship between water-cement ratio, cycle-thaw and integrating electric current.

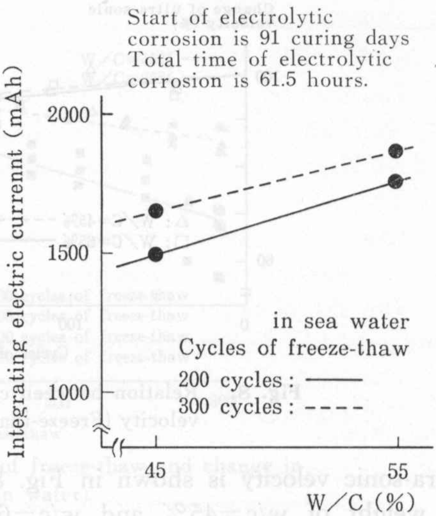

Fig. 11. Relation ship between water-cement ratio, cycles of freeze-thaw and ratio of surface corrosion.

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