**Zeitschrift:** IABSE reports = Rapports AIPC = IVBH Berichte

**Band:** 57/1/57/2 (1989)

**Artikel:** Frost resistance of fibre reinforced concrete containing microsilica

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**DOI:** https://doi.org/10.5169/seals-44225

# Frost Resistance of Fibre Reinforced Concrete Containing Microsilica

## Résistance au gel de béton renforcé de fibres de micro-silice

## Frostbeständigkeit von faserverstärktem Beton mit Flugasche-Zusatz

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Sergio Lai, born in 1954 has a degree in Civil Engineering and for 14 years has been engaged in materials testing at the University of Cagliari (Italy). He has carried out numerous investigations on the durability of concretes, participating in various International Congresses and has published more than 25 papers on the subject.

**SUMMARY**

This paper presents the results of extensive laboratory investigations aimed at determining the freeze-thaw resistance of conglomerates containing silica fume and polypropylene fibres. Particular attention has been focussed on the influence of mode of preparation on freeze-thaw resistance, as well as on the prediction of such resistance on the basis of tests of short duration.

**RÉSUMÉ**

Cet article présente les résultats d'une longue série d'essais de laboratoire cherchant a déterminer la résistance au gel-dégel des conglomérats contenants de la micro-silice et des fibres de polypropylène. Une attention particulère a été portée aussi bien à l'influence des méthodes de préparation sur la résistance au gel-dégel qu'aux prévisions de cette résistance avec des essais de courte durée.

**ZUSAMMENFASSUNG**

Anhand eines Langzeitversuches wurde die Frostbeständigkeit von faserverstärktem Beton mit Flugasche-Zusatz ermittelt. Besondere Aufmerksamkeit wurde dem Einfluss der Verarbeitungsmethode sowie der Korrelation zu Kurzzeitversuchen gewidmet.

## 1. INTRODUCTION

Condensed silica fume, a by-product of the ferro-silicon industry, is used as a partial replacement o in addition for cement in concrete and mortar. First investigation indicated improved frost resistance (1), (2), (3). When admixed with a conglomerate, silica fume (micronized silica) acts as a filler and its pozzolanic action is enhanced. The addition of polypropylene fibres to the cement mix, serves to check the formation of cracks caused by shrinking. Superplasticizing admixtures allow to balance the larger requirement of mixing water caused by the micronized silica and polypropylene fibres.
The purpose of this paper is to study the frost resistance of concretes containing condensed silica fume and polypropylene fibres when tested in accordance with UNI 7087-72, and with ASTM C666, procedure A, modificate.

## 2. EXPERIMENTAL PROCEDURES

### 2.1 Material and proportion

The cement used was Portland 525. The fine aggregate (specific gravity: 2,70, absorption: 2,65 %, fineness modulus: 2,90) was river sand and coarse aggregate (specific gravity: 2,54, absorption: 3,58 %, fineness modulus: 6,40, maximum size: 20 mm) was crushed gravel. Superplasticizer (naphthalene-sulphonate condensed with formaldehyde) was used as admixture. Mix proportion are shown in table 1. Water cement-silica ratios of the specimens were selected as 30, 35, 40, 45 and 50 percent for all freeze-thaw tests (slow and rapid freeze-thaw test up to 30 cycles, and standard test in accordance with UNI 7087-72).
The mix designation are shown in table 2.

### 2.2 Preparation of specimens

Eight 100x100x400 mm prism and eight 100 mm cubes were cast from each mix. After casting, the molded specimens were covered with a plastic sheet and left in the casting room at 20° C for 24 hours.
After demolding they were cured in 20° C water for 14 days (ASTM C666, procedure A, modificate); for UNI test they were cured in 20° C climatic room for 45 days and 20° C water for another 15 days.

## 3. TEST METHODS

### 3.1 UNI 7087-72

The freeze-thaw cycle consist of:
-lowering the temperature of the specimens in air from +5° to -25° C;
-keeping temperature at -25° C;
-elevating the temperature to +5° C with the specimens in water;
-keeping the temperature at +5° C.
The elastic modulus, length and mass of the specimens are measured periodically. The test continues for 300 cycles; it can be stopped when the conglomerate undergoes either a reduction in dynamic elastic modulus of 60 %, an expansion of 0,2-0,3 % or else a mass loss of more than 3 %.

### 3.2 ASTM C666, PROCEDURE A MODIFICATES (RAPID F-T TEST)

This test method covers the determination of the resistance of concrete specimens when subjected to rapidly repeated cycles of freezing and thawing in water. A freezing-and-thawing cycle consist of alternately lowering the temperature of the specimens from +5° C to -18° C (3 hours) and raising it from -18° C to 5° C (1 hour). The modification consist in considering temperatures varying between +5° and -20° C with different gradients in accordance with figure 1. The relative moduli of elasticity of the test specimens, in thawed condition, are determined.

### 3.3 Slow F-T tests

The slow freezing-thawing tests by two cycle a day were performed in air and with temperature simulated in agreement with figure 2.

## 4. TEST RESULT FOR RAPID AND SLOW FREEZE-THAW

Result of the rapid freeze-thaw test up to 30 cycle are shown in figures 3-4, which illustrates the relation between the number of cycles and relative dynamic modulus of elasticity for W/C+SF=0,50 and 0,45. After freeze-thaw test up 30 cycles, relative dynamic modulus dropped to about 70-85 and 75-83 percent respectively.
Results for slow freeze-thaw test up 30 cycles is shown in figure 5, which shows the relation between the number of cycles and relative dynamic modulus of elasticity after 7 days and 28 dayd curing at water/cement-silica ratio of 45 percent. The slow freeze-thaw test is not the most suitable for prediction long term behaviour as temperature gradients are too small and temperature ranges are not very wide.

## 5. TEST RESULT FOR UNI 7087-72 METHOD

The freeze-thaw tests were performed for 300 cycles and some of the results are shown in figure 6. The diminution in dynamic modulus fluctuates considerably, from between 40 % (C50,0) and 20 % (C45,20). It is shown that performance in freeze-thaw cycles improves both with increasing silica fume additions and decreasing W/C+SF ratio. Along with dynamic modulus measurements, the specimens were also tested, every certain number of cycles, to determine the decline in compression properties. Figure 7 shows dynamic modulus versus compressive strength for some W/C+SF ratios, keeping SF content constant at 20 % (80 kg/cu m).

## 6. CONCLUSIONS

Test results are summarized as follows:

1) Concretes containing silica fume were observed to perform better in freeze-thaw cycles; in certain cases the diminution is of the order of 20 %, against 38 % observed in the controls.
2) With fast freeze-thaw cycles the reduction in dynamic elastic modulus is 20, 24 and 28 % for the conglomerates with W/C+SF of 0,5 and silica fume addi-

ns of 20, 10 and 5 % by weight of cement.

3) The C50,20 series showed, with the UNI test, a reduction after 300 cycles of 25 % compared to 20 % with the rapid test.
4) The C50,0 series showed a diminution in dynamic elastic modulus of 39 % with the UNI test compared to 26 % with the rapid test.
5) Although not all the data necessary for a statistical analysis are available (the experiments are still in progress) the results so far suggest that for the conglomerates containing silica fume and for the controls, the freeze-thaw resistance can be predicted by means of the rapid test, since the UNI test yields a diminution in dynamic modulus greater by between 25 and 55 %.

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| W/C+SF | Slump | | | Unit Weight (kg/cu m) | | | |
|---|---|---|---|---|---|---|---|
| | (cm) | W | C | S | G | SF | Superplast. |
| .30-.35 | | | | | | 20 | |
| .40-.45 | 10 | variab. | 400 | 700 | 998 | 40 | variable |
| .50 | | | | | | 80 | |

Table 1 Mix proportion

| | W/C+SF | SF | Fibres |
|---|---|---|---|
| C30,0 | .30 | 0 | 0 |
| C30,5 | .30 | 20 | 1 |
| C30,10 | .30 | 40 | 1 |
| C30,20 | .30 | 80 | 1 |
| ...... | ... | .. | . |
| C50,0 | .50 | 0 | 0 |
| C50,5 | .50 | 20 | 1 |
| C50,10 | .50 | 40 | 1 |
| C50,20 | .50 | 80 | 1 |

Table 2 Mix designation

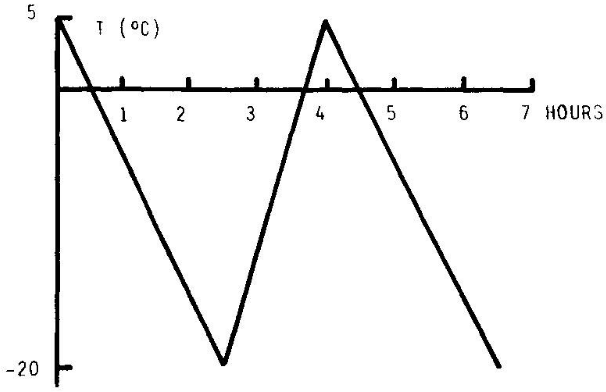


Fig.1 Rapid F-T test (gradients)

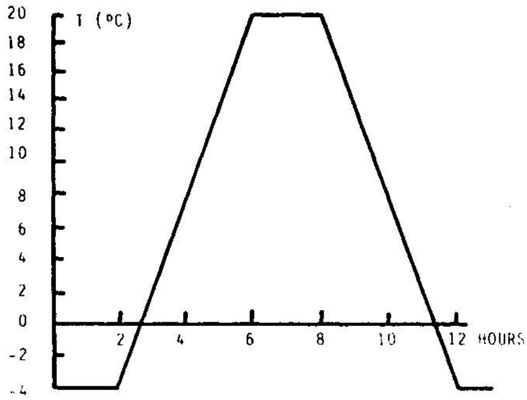


Fig.2 Slow F-T test (gradients)

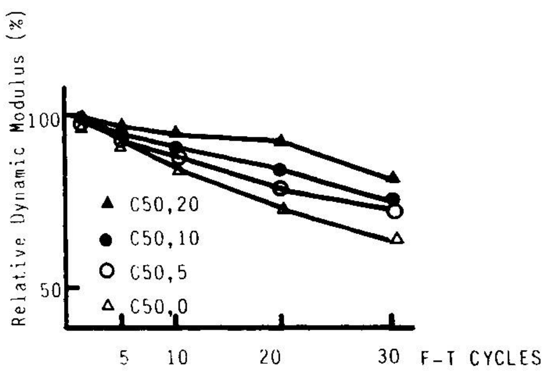


Fig.3 F-T cycle and relative dynamic modulus (W/C+SF=.50)

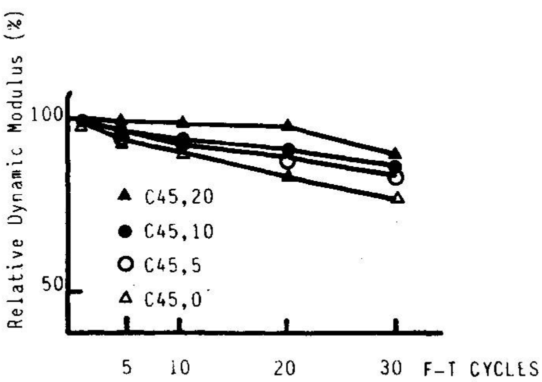


Fig.4 F-T cycle and relative modulus (W/C+SF=.45)

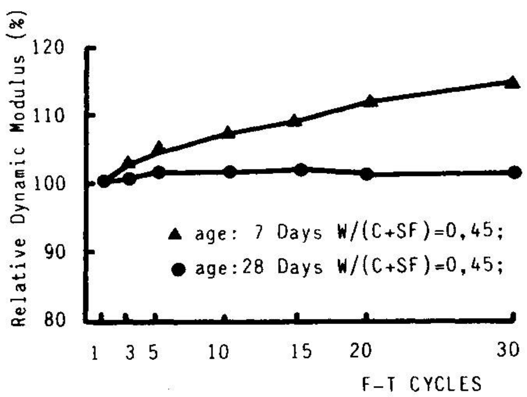


Fig.5 F-T cycle and relative dynamic modulus (slow test)

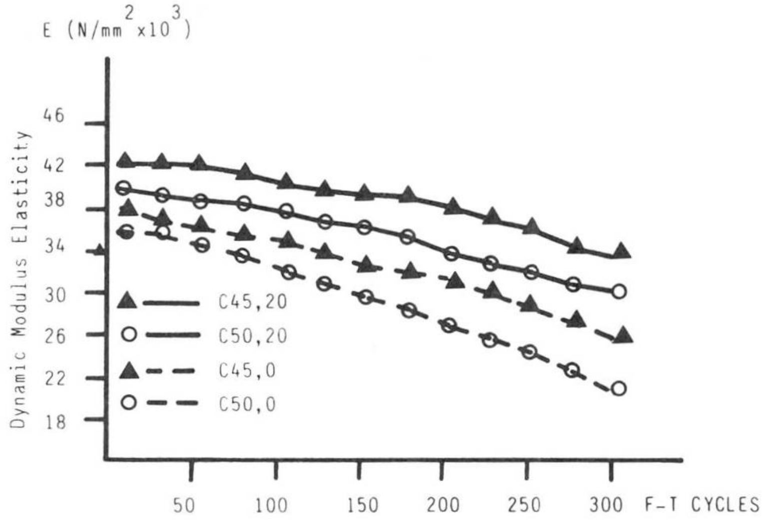


Fig.6 F-T cycle and relative dynamic modulus of elasticity

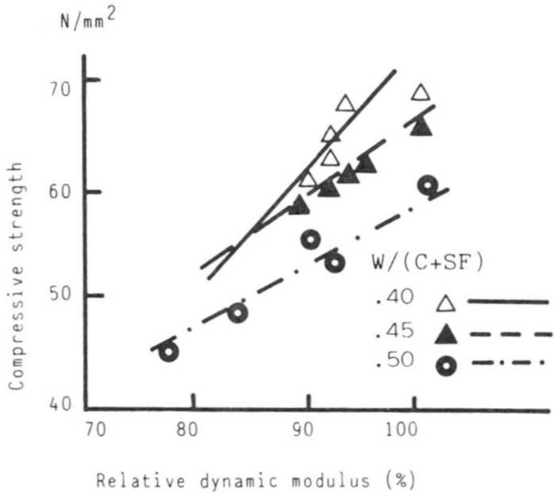


Fig.7 The relation between dynamic modulus and compressive strength

Fig.8 Distribution of fibers in hardened concrete