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INFLUENCE OF CALCIUM CARBONATE ON THE DURABILITY OF MORTAR EXPOSED TO SEA WATER SOLUTION

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ABSTRACT

Normal portland cement mortar discs containing precipitated or ground limestone at dosages of 0, 2.5, 5 and 15% were made at water/cement ratios of 0.42 or 0.6. They were hydrated in lime water or sea water solution for periods up to 1 year. The length and modulus of elasticity changes were monitored periodically.

Mortars containing $CaCO_3$ (both coarse and fine) exhibited more than 3 times the expansion of the reference in sea water. The expansions were greater in samples containing fine $CaCO_3$. The modulus of elasticity were low especially in samples containing precipitated $CaCO_3$ and exposed to sea water.

INTRODUCTION

Various types of byproducts and waste materials such as fly ash, slag, silica fume and rice husk are used in concrete as additives with success. Limestone dust poses disposal and environmental problems and has been suggested for use as an additive to portland cement. The Canadian Standard CSA CAN3-A5.M83 allows the addition of up to 5% carbonate for Type 10 normal portland cement and this has been extended to Type 30 high early portland cement.

Although considerable amount of work has been carried out on the physical and mechanical properties of concrete containing limestone dust there are some conflicting results and also not much data is available on the durability of concrete containing calcium carbonate. There is concern about the long term durability of concrete containing lime dust [1].

Feldman and Ramachandran have developed a non-destructive method of evaluating the properties of mortar discs exposed to various solutions [2]. This method was adopted to determine the modulus and expansion of mortar bars containing 0-15% $CaCO_3$ of two finenesses and exposed to sea water up to a year.

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EXPERIMENTAL

Materials

Cement: Type 10 normal portland cement was used having the following chemical composition: SiO_2 = 19.83%, Al_2O_3 = 4.18%, Fe_2O_3 = 3.20%, CaO = 60.06%,
MgO = 4.09%, Na_2O = 0.45%, K_2O = 0.89%, SO_3 = 3.93%, free lime = 1.15%, and loss on ignition = 1.53%. The mineralogical composition was as follows: C_3S = 49.93%, C_2S = 19.18%, C_3A = 5.66%, C_4AF = 9.74%.

Sand: A laboratory concrete sand was used. The fineness modulus was 2.38. Sieve analysis according to sieve size (mm) and weight percentage passing in brackets was as follows: 5 (100); 2.5 (93.9); 1.25 (79.4); 0.63 (67.5); 0.32 (17.15); 0.14 (3.37).

Calcium Carbonate: Two types of calcium carbonate were used. One type was a precipitated carbonate supplied by Anachemia. It had a surface area of 6.88 m^2/g determined by the nitrogen adsorption method. The second type was obtained by grinding limestone to particle sizes finer than 15 µm. Nitrogen surface area was 2.25 m^2/g. Particle size analysis was performed using a Sedigraph particle size analyzer. The particle size range (diameter) for the precipitated material was 1-5 µm. The ground material had particles in the range 1-40 µm.

Test Solutions: Two solutions were used for sample exposure. One was a saturated lime solution. The other was a laboratory-prepared sea water containing 2.7% NaCl, 0.32% $MgCl_2$, 0.22% $MgSO_4$ and 0.13% $CaSO_4$.

Specimen Preparation

Mortar mixes were prepared at water-cement ratios of 0.42 and 0.60. The cement:sand ratio for all mixes was 1:2.75. Calcium carbonate additions (ground and precipitated) were made in amounts of 0, 2.5, 5 and 15% by weight of cement. Superplasticizer (melamine type) was used for mixes at w/c = 0.42 containing 5, 15% calcium carbonate. The amounts were 0.4 and 1% by weight of cement respectively. Mortar cylinders (Ø 76.2 x 152.4 mm) were cast for each mix and cured for 7 days at 100% RH. Cylinders from each mix were then sliced to produce 6 mm thick discs. The discs were cured at 100% RH for an additional 7 days prior to immersion in the salt solution. Stainless steel Demec gauge reference points were positioned 50.8 mm apart on the specimen surface for length change measurements. The reference points were inserted in pre-drilled holes and secured with epoxy adhesive. In addition to the disc specimens, mortar cubes (50.8 mm) were cast for compressive strength determinations at 14 days.

Test Methods

Mortar discs were placed in separate baths containing either lime solution or sea water. Deflection and length change measurements were made at several time intervals up to 1 year. Deflection measurements were made on discs loaded at the midpoint and supported along the edge at points 120° apart. Loads applied using an Instron testing machine did not exceed 35% of the failure loads. The modulus of elasticity was calculated using the deflection data and elastic plate theory [3]. Length change measurements were obtained with a Demec mechanical strain gauge. The smallest division on the gauge corresponds to a strain of 2×10^{-3}%.

Compressive strength measurements of mortar cubes were performed according to ASTM C190.

RESULTS AND DISCUSSION

Modulus of Elasticity

Figures 1 and 2 present the results of the changes in moduli for mortars containing 0-15% $CaCO_3$ ground or precipitated respectively, and prepared at 0.42 and 0.60 w/c. Values are plotted for intervals up to one year.

All samples prepared at w/c = 0.42 and containing ground $CaCO_3$ show similar or slightly higher moduli with respect to the reference containing no $CaCO_3$ (Fig. 1). Addition of 15% precipitated $CaCO_3$ drastically reduces the modulus (Fig. 2).

All samples increase in modulus with time of exposure in lime water.

On exposure to sea water, generally, all the samples containing ground or precipitated $CaCO_3$ show lower moduli than the references (Fig. 1 and Fig. 2). All samples containing precipitated $CaCO_3$ showed a significant reduction in modulus with respect to the reference.

At w/c of 0.6 all samples, both reference and those exposed to sea water, generally showed lower moduli (Figs. 1 and 2) than those fabricated at w/c = 0.42. Exposure to sea water of mortars (w/c = 0.6) containing precipitated and ground $CaCO_3$ results in even more drastic reduction in moduli than was observed for samples prepared at w/c = 0.42.

Length Change

The results of the length change measurements for the same samples for which moduli measurements have been carried out are presented in Figure 3 and Figure 4. At w/c = 0.42 addition of ground $CaCO_3$ reduces the expansion values with respect to the reference whereas samples containing precipitated $CaCO_3$ showed enhanced expansion values.

On exposure to sea water, all samples show rapid expansion. The samples containing precipitated $CaCO_3$ and 15% ground $CaCO_3$ show much higher expansions than the corresponding reference specimens.

At w/c = 0.6 addition of both precipitated and ground $CaCO_3$ reduces the expansion relative to the reference sample.

On exposure to sea water the expansions for samples containing both ground and precipitated $CaCO_3$ are significantly higher than the references. Generally, samples prepared at w/c of 0.6 containing $CaCO_3$ expand more rapidly when exposed to sea water than those prepared at w/c = 0.42.

The reference mortar samples exhibited expansions of 0.05 to 0.06% in lime water. These values were higher than was expected. Experiments were done to determine expansion values when pastes and mortars containing 0 and 5% $CaCO_3$ were autoclaved to 216°C, after precuring for 14 days. The expansion values were found to be in the range of 0.06 and 0.08%. This confirms that the expansion observed during exposure to sea water is not the result of MgO or CaO hydration. The expansion of most of the specimens containing $CaCO_3$, when exposed to sea water, was greater than the reference samples. This may be related to the formation of carboaluminate and the enhanced formation of thaumasite.

Compressive Strength

The behaviour of mortars exposed to sea water could depend on their strength before exposure. Compressive strength results for all samples moist cured for 14 days are presented in Figure 5.

All samples prepared at w/c = 0.42 exhibited higher strength than those prepared at w/c = 0.60. In general, strengths are not affected by the addition of 2.5 to 15% ground $CaCO_3$ but the addition of 15% precipitated $CaCO_3$ results in a decrease of approximately 50%.

Although the compressive strengths (Fig. 5) are similar, in many cases, the samples containing both types of $CaCO_3$ exhibit much higher expansion than the reference samples when exposed to salt water (Figs. 3 and 4).

CONCLUSIONS

1. Use of small size mortar discs permits examination of the influence of a large number of test variables on their properties.
2. By using this method, the potential durability of a material such as cement with carbonate additions exposed to sea water, can be predicted.
3. Mortars containing $CaCO_3$ (both coarse and fine) have higher expansion values than the reference specimens when exposed to sea water. However, those containing coarse $CaCO_3$ show relatively lower expansions than those containing fine $CaCO_3$.
4. Higher compressive strength does not necessarily correlate with better durability to sea water.

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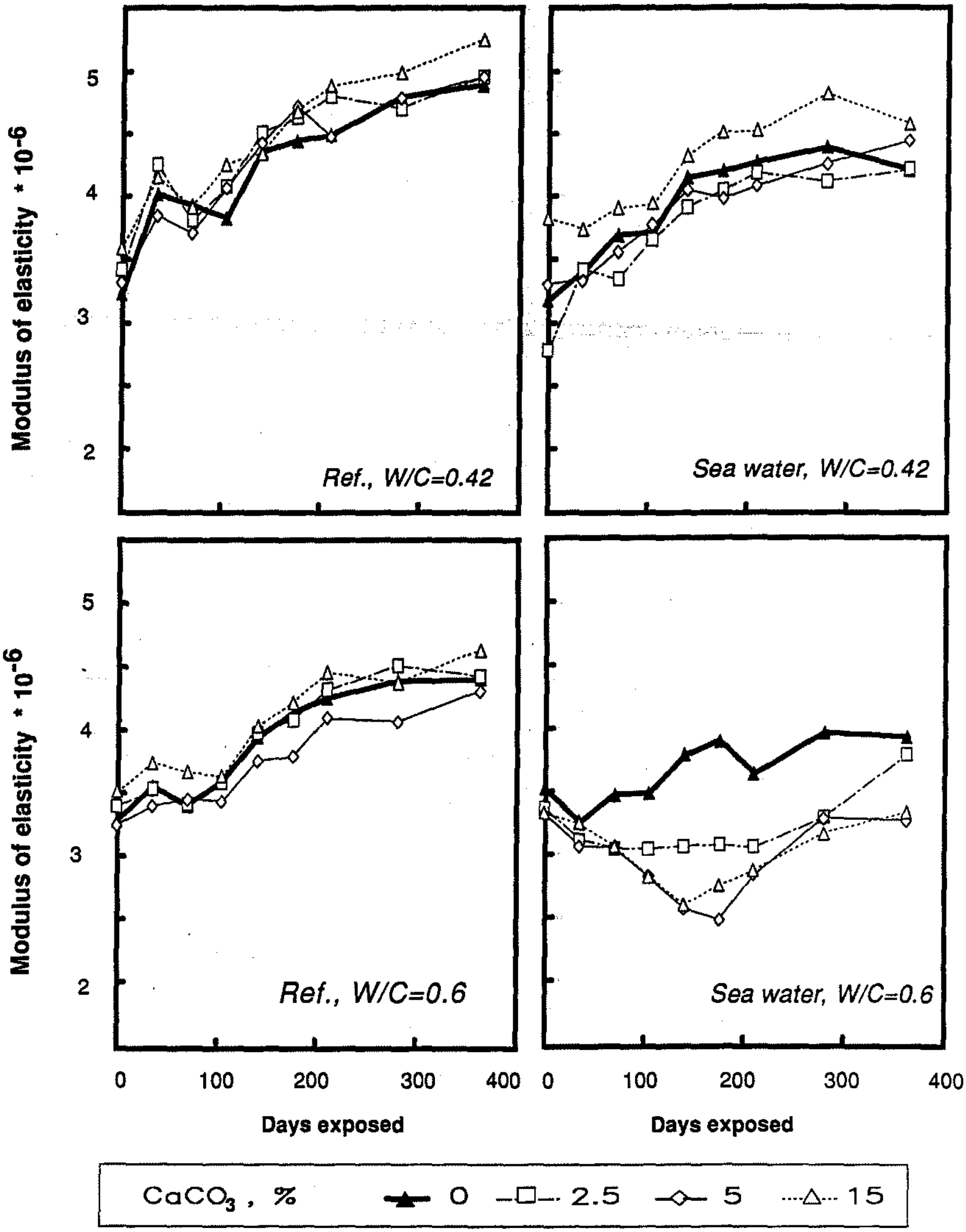

***Fig. 1.** Effect of ground calcium carbonate on modulus of elasticity of mortars exposed to sea water.*

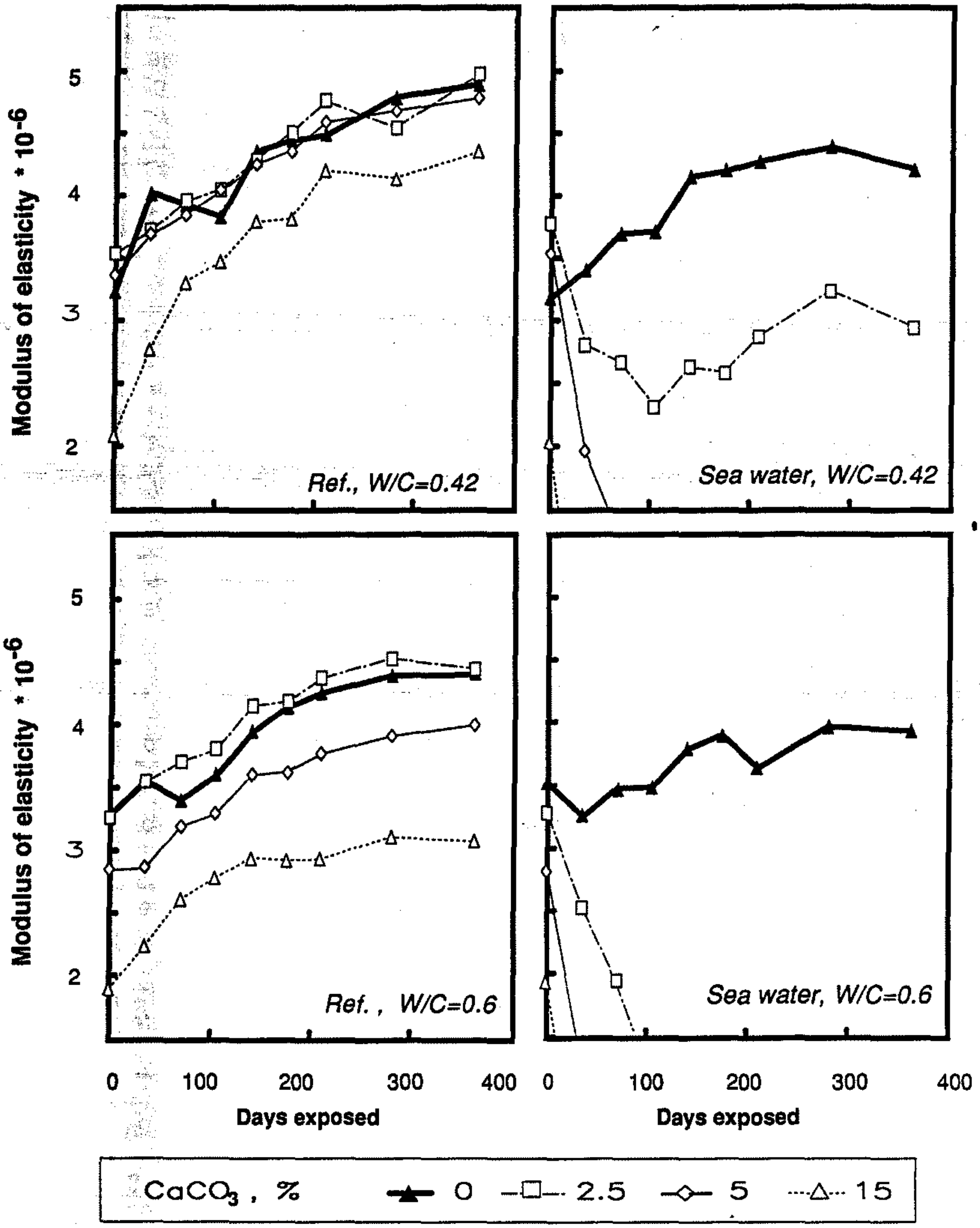

Fig.2. Effect of precipitated calcium carbonate on modulus of elasticity of mortars exposed to sea water.

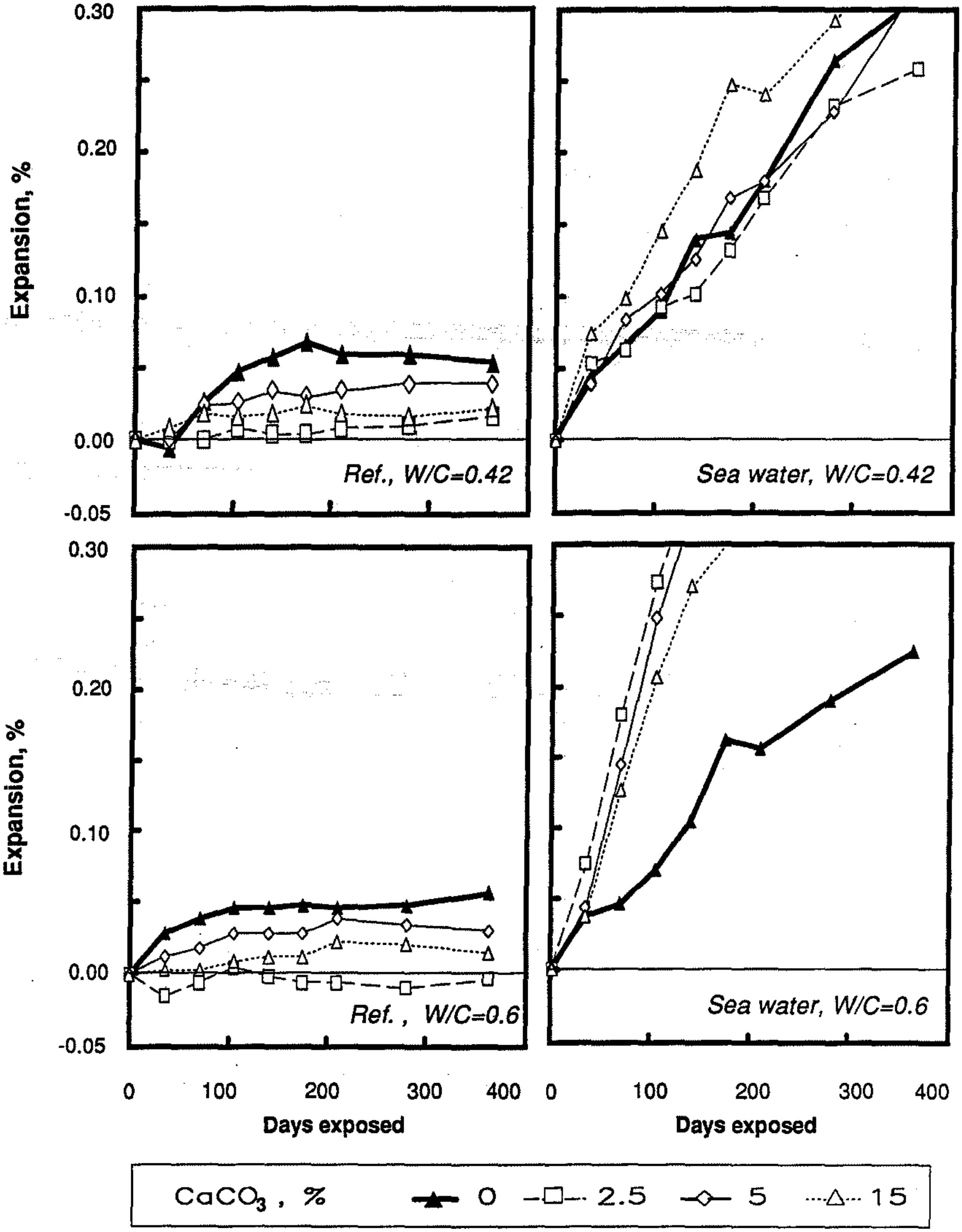

Fig.3. Effect of ground calcium carbonate on expansion of mortars exposed to sea water.

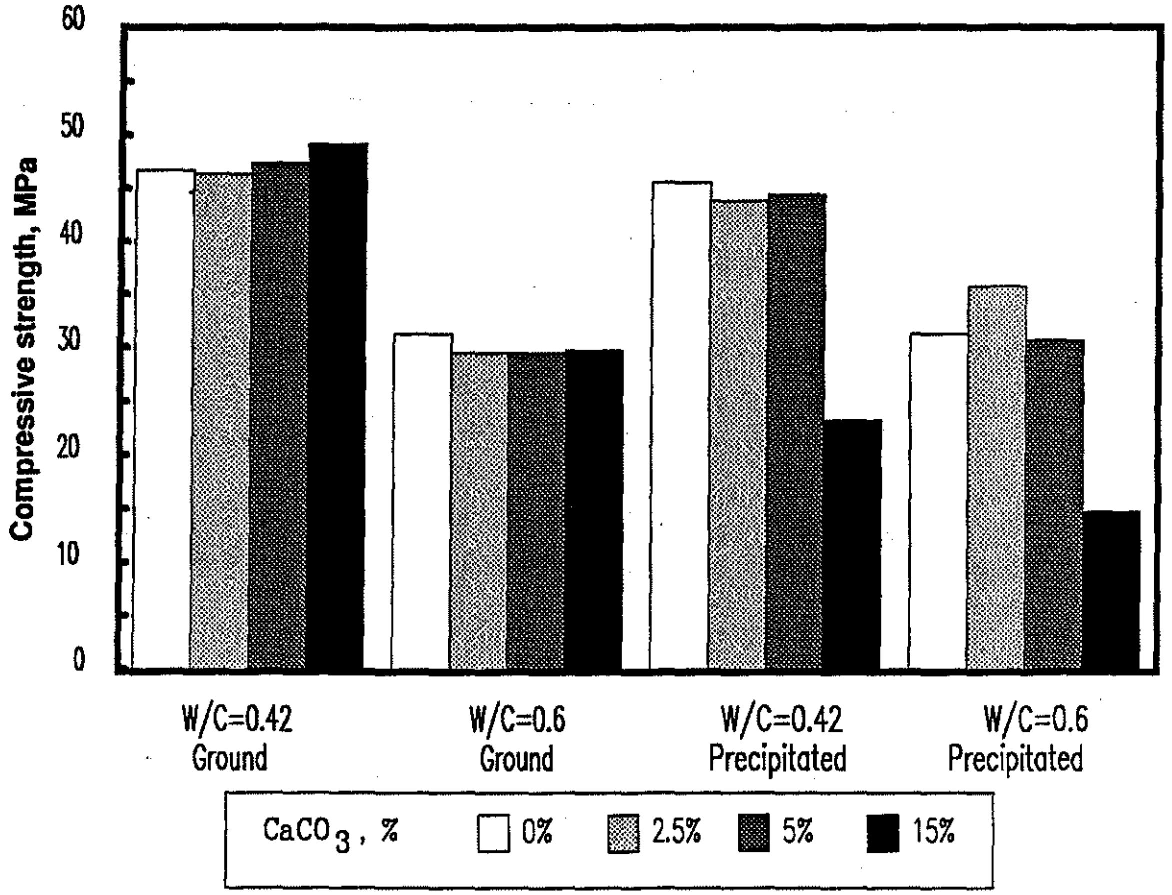

Fig.5. Compressive strength after curing for 14 days at 100% rh.