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Evaluation of field concrete deterioration under real conditions of seawater attack

Ahmed Mahmoud Ragab [a], Mohamed Adel Elgammal [b], Osama AbdelGhafour Hodhod [a], Tamer ElSayed Ahmed [b,*]

[a] Structural Engineering Department, Cairo University, Egypt
[b] Engineering Division, National Research Center of Egypt, Egypt

HIGHLIGHTS

- Study the seawater attack on concrete specimens from the wave's repellent blocks.
- Trace the interaction of concrete with chlorides and sulfates in seawater.
- The specimens tested with XRF, SEM, EDX, and water soluble chloride test.
- SEM and EDX analyses prove that siliceous aggregate particles act as inert material.
- Mapping Technique determines the locations of cracks, voids, and capillary pipes.

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ABSTRACT

In order to study the long term behavior of concrete structures under the natural exposure to aggressive seawater attack, concrete samples are taken from the wave's repellent blocks at seashore in the north coast of the Mediterranean Sea. The samples cover a wide range of various exposure times differ from 4 years to more than 60 years. The samples composed from diverse concrete constituents and obtained from different locations along the seashore. The tests (XRF, SEM, EDX, water soluble chloride content using photometer techniques) where conducted on the extracted concretes.

1. Introduction

The chemical action of seawater on concrete is mainly due to the presence of $MgSO_4$, $MgCl_2$ with NaCl, as well as other dissolved salts [1].

The interaction of concrete with chlorides and sulfates in seawater leads to modification of the intrinsic concrete properties. Seawater contains high concentration of chlorides relative to less concentration of sulfates. Since, the concentration of ions in typical seawater is almost around 19,090 ppm of Chloride, and 2233 ppm sulfate. The chemical analysis show that the chloride concentration increases up to ten times sulfate concentration in typical seawater [2].

The ingress of sulfates constitutes a major risk of chemical aggression for concrete causing destructive expansion, and loss of bond between the cement paste and aggregate leads to strength loss [3]. These processes are commonly caused as a result of reactions between the tricalcium aluminate (C3A) in the Portland cement and sulfate ions to form expansive ettringite compound [4].

However, the high chloride concentration of the seawater solution could reduce the expansive nature of the ettringite formed by sulfate attack. So, chlorides have a tendency to bind C3A in the cement to produce chloroaluminate compounds, such as Friedel's salt, which do not cause any expansion. Also, ettringite formation

* Corresponding author.
E-mail address: sportnolt@yahoo.com (T.ElSayed Ahmed).

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Table 1
Sample location and its corresponding chloride and sulfate ions concentrations.

Name	Location	Start of exposure (Year)	Geographic location		Ions concentrations of seawater (ppm)	
			North	East	Chloride	Sulfate
T08	El-Tarh	2008	31° 16′ 17″	30° 07′ 45″	21,200	2101
M07	El-Mansheia	2007	31° 12′ 03″	29° 53′ 30″	19,400	2155
T03	El-Tarh	2003	31° 16′ 17″	30° 07′ 40″	21,200	2101
Q87	El-Qalaa	1987	31° 12′ 48″	29° 53′ 11″	19,400	2155
T85	El-Tarh	1985	31° 16′ 17″	30° 07′ 50″	21,200	2101
Q50	El-Qalaa	1950	31° 12′ 49″	29° 53′ 10″	19,400	2155

in chloride-rich environments is not associated with expansion and cracking [5].

The ingress of chloride into concrete causes fast and severe corrosion of the steel reinforcement. This reduces the cross-section of the reinforcement and consequently leads to the loss of its load carrying capacity [6].

The alkalinity medium of concrete prevents the reinforcement corrosion process until the chloride content at the steel surface has reached a certain threshold value. This value is often stated as critical chloride content or chloride threshold value [7]. So, the determination of chloride content within concrete indicates to how far the deterioration of the concrete is.

Table 2
Concrete ingredients and its corresponding compressive strength.

Name	W/C	Water (kg/m^3)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Admixture (Liter/m^3)	Compressive strength (kg/cm^2)
T08	0.34	135	400 (SRC)	684	1164 Dolomite	4 Sikament MG	371
M07	0.33	133	400 (SRC)	692	1180 Dolomite	4.5 Sikament MG	431
T03	0.34	135	400 (SRC)	684	1164 Dolomite	4 Sikament MG	350
Q87	0.47	165	350 (SRC)	630	1260 Dolomite	1 MC Admix.	312
T85	0.47	165	350 (SRC)	630	1260 Gravel	1 MC Admix.	300
Q50	0.65	196	300 (SRC)	598	1195 Lime stone	0	225

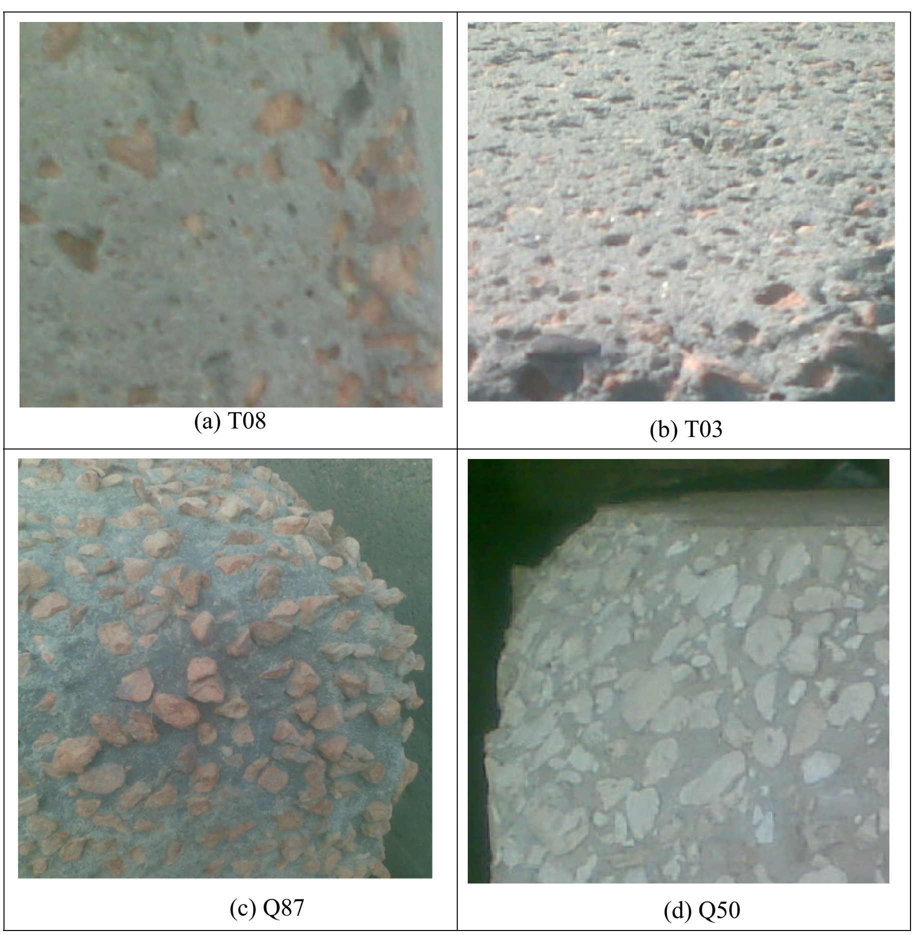

Fig. 1. Images of concrete blocks exposed to seawater attack.