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Can seawater be used as mixing water for durable and sustainable RC structures?

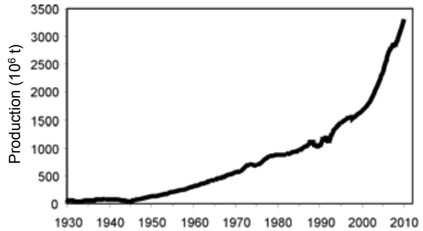
Federica Lollini[1], Maddalena Carsana[1], Matteo Gastaldi[1], Elena Redaelli[1], Luca Bertolini[1] and Antonio Nanni[2]

[1]Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Milan, Italy

[2]University of Miami, Civil Architectural and Environmental Engineering, Miami, United States

Sustainability of construction industry

Cement production:



emission of CO_2

consume of natural resources

material waste

use of chloride-contaminated raw materials for the production of concrete


seawater


Recycled aggregates

Effects of seawater

The use of chloride-contaminated raw materials for the production of concrete may affects:

The setting time

The workability

The kinetics of hydration of portland cement

The corrosion of black steel reinforcement

Aim of the research

This project is aimed at demonstrating the safe utilization of seawater and salt-contaminated aggregates (natural or recycled) for a sustainable concrete production when combined with non-corrosive reinforcement to construct durable and economical concrete infrastructures.

- Comparison between the performance of concrete made with seawater and salt-contaminated aggregate with that of concrete made with traditional constituents to assess the role of chloride-contaminated raw materials on the properties of fresh and hardened concrete.
- Evaluation of the suitability of using chloride-contaminated raw materials for sustainable and durable RC structural elements with: i) a grade of stainless steel bars suitable for the required combination of design service life and environmental exposure; and, ii) non-corrosive composite FRP bars.

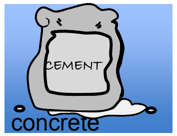
This work focuses on a preliminary evaluation of the possibility of replacing fresh water with seawater when combined with different types of stainless steel reinforcement.

Case studies

Environmental exposure:

- Temperate climate
- Subtropical climate

Materials:



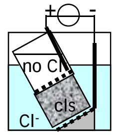
- portland cement (w/b = 0.45)
- fly ash cement (w/b = 0.45)

- black steel
- UNS S30453 (low-carbon austenitic stainless steel)
- UNS S32304 (duplex stainless steel)
- UNS S32205 (duplex stainless steel)
- UNS S24100 (austenitic stainless steel)

- fresh water
- seawater

Selection of input values

$$p_f = P\{g<0\} = P\left\{Cl_{th} - \left\{C_0 + (C_{s,\Delta x} - C_0)\left[1 - erf\frac{d_c - \Delta x}{2\cdot\sqrt{D_{app}\cdot t}}\right]\right\} < 0\right\}$$



Cl_{th} (critical chloride threshold)

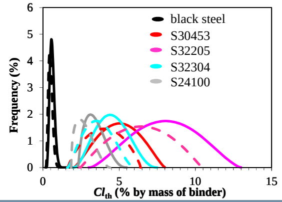
$C_{s,\Delta x}$ (chloride content at a depth Δx)

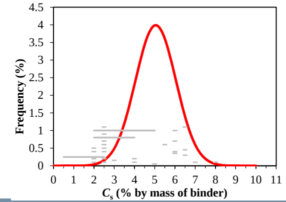
D_{app} (diffusion coefficient) — D_{RCM} (rapid chloride migration coefficient); T_{real} (temperature) 293 and 298 K

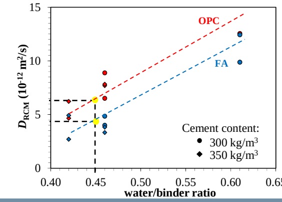
C_0 (initial chloride content) 1 and 0.98 % by mass of binder

t (service life) 100 years

d_c (concrete cover thickness)

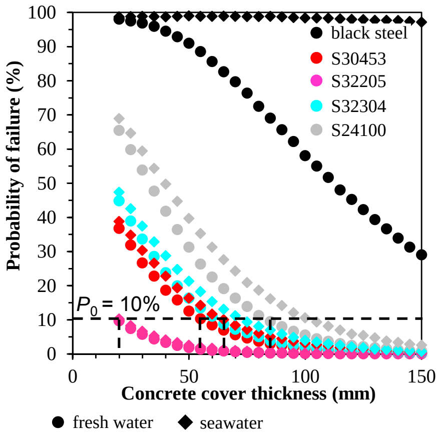




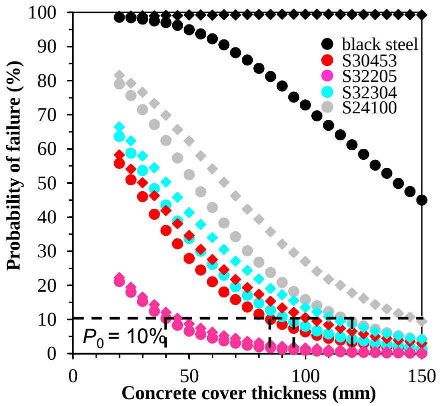


Evaluation of the concrete cover

Temperate climate – t_{sl} = 100 y

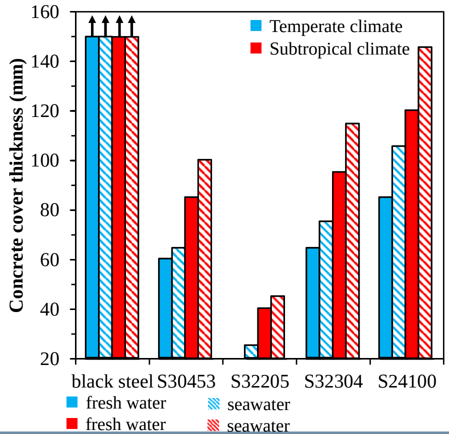


Subtropical climate – t_{sl} = 100 y

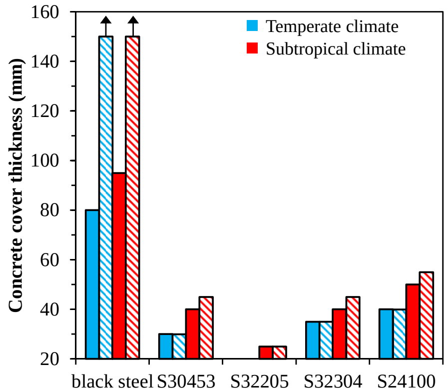


Evaluation of the concrete cover

Portland concrete – t_{sl} = 100 y

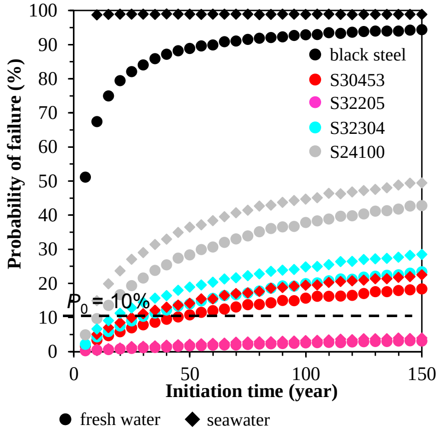


Fly ash concrete– t_{sl} = 100 y

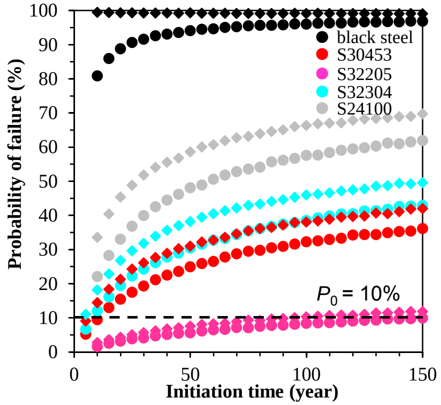


Evaluation of the service life

Temperate climate - c = 45 mm



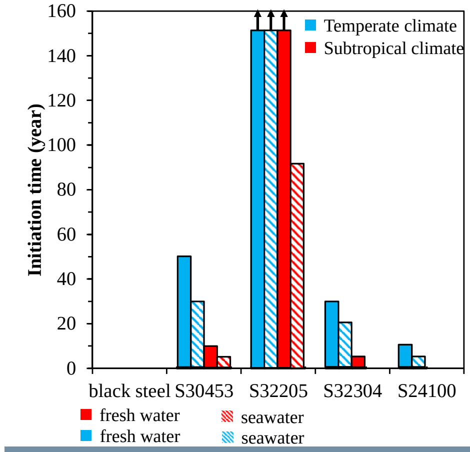
Subtropical climate - c = 45 mm



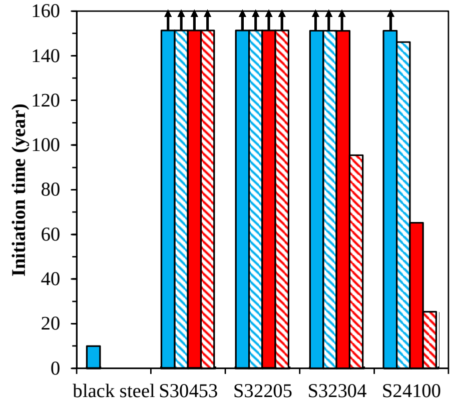
federica.lollini@polimi.it

Evaluation of the service life

Portland concrete – c = 45 mm



Fly ash concrete – c = 45 mm



federica.lollini@polimi.it

Conclusions

A preliminary assessment of the durability of RC elements in two different marine environments made with mixed-in seawater and different types of stainless steel reinforcement was carried out by means of a probabilistic performance-based approach.

The simulations showed that in both environments several design options (i.e., types of concrete and reinforcement, and concrete cover thickness) may be selected to reach a target service life of 100 years; however in the harsher subtropical environment the available design solutions were more limited.

The use of stainless steel reinforcement allowed a significant reduction of the concrete cover thickness in comparison to black steel to values easily obtainable in practice and, for the same grade of stainless steel, higher concrete cover thickness was required in the harsher environment.

The use of seawater as mixing water led to an increase of the required concrete cover thickness in comparison to the use of fresh water, which depended on the type of stainless steel, showing that only some combinations of concrete type and stainless steel grade were suitable.

federica.lollini@polimi.it