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Preliminary Assessment of Durability of Sustainable RC Structures with Mixed-in Seawater and Stainless Steel Reinforcement

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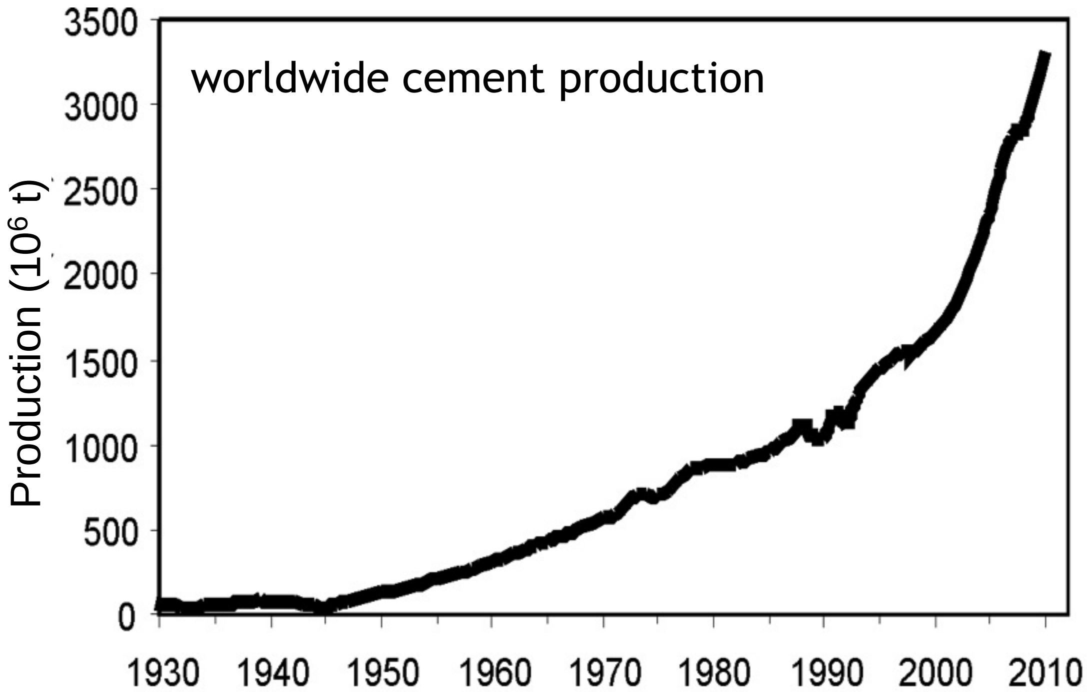
Introduction

Concrete plays a remarkable socio-economic role in the world. More than 18B tons of concrete are nowadays produced every year, requiring large amounts of natural resources.

Can we save natural resources?



➡ new cements and mineral additions

Introduction

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Can we save natural resources?

<u>Water</u>

Approximately 1.5 trillion liters of freshwater are used annually in concrete production for mixing, curing and equipment cleaning.

<u>Aggregates</u>

Recycled concrete aggregate (RCA) is abundant.

Worldwide, construction and demolition wastes make about 30% of the total.

Introduction

Chlorides in seawater cause de-passivation of the steel and consequent corrosion phenomena.

We need to prevent corrosion by limiting the initial chloride content in concrete and designing durability by preventing chloride penetration.

Technology development over the last two decades has made available FRPs and stainless steels to replace the conventional black steel reinforcement when the durability of a structure is of concern.

Concrete itself could become a more sustainable material, allowing:

- the use of seawater for mixing and curing
- the use of salt-contaminated recycled concrete aggregates (RCA)
- the use of cements without chloride restriction (e.g. use solid waste as kiln fuel as well as adding kiln dust back to the clinker)
- ...

Research program

infravation
An Infrastructure Innovation programme

Research project - Within the framework of *ERA-NET Plus Infravation*, an infrastructure innovation program on “Advanced systems, materials and techniques for next generation infrastructure”, the **SEACON project** - Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement was recently started.

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This project aims 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.

Long-term experimental tests

\+ 2 field demonstration projects (USA and Italy) + LCA LCC

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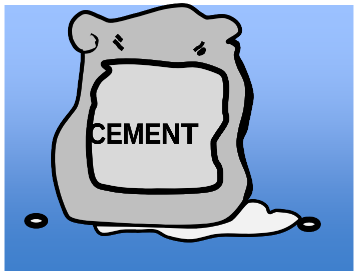
This presentation – Considering the lack of sufficient fresh water in many regions of the world, this paper focuses on a preliminary evaluation of the possibility of replacing fresh water used to mix concrete with seawater, combined with different types of stainless steel reinforcement.

Case study

<u>Environmental exposure</u>:

Splash zone
Mediterranean Sea

<u>Materials</u>:



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

- fresh water
- seawater

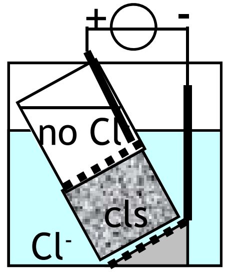
Type	UNS	EN	Approx. comp.	Microstructure
XM-28	S24100	-	18%Cr-12%Mn	Austenitic
304L	S30453	1.4311	18%Cr-10%Ni	Austenitic
23-04	S32304	1.4362	23%Cr-4%Ni	Duplex
22-05	S32205	1.4462	22%Cr-5%Ni	Duplex

+ Reference black steel bars

fib Model code design equation - Selection of input values

Limit state: *corrosion initiation*

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



Cl_{th} (critical chloride threshold)

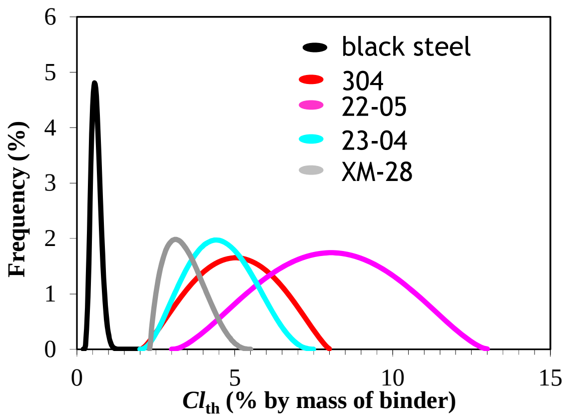
$C_{s,\Delta x}$ (chloride content at a depth Δx)

D_{app} (diffusion coefficient): D_{RCM} (rapid chloride migration coefficient)

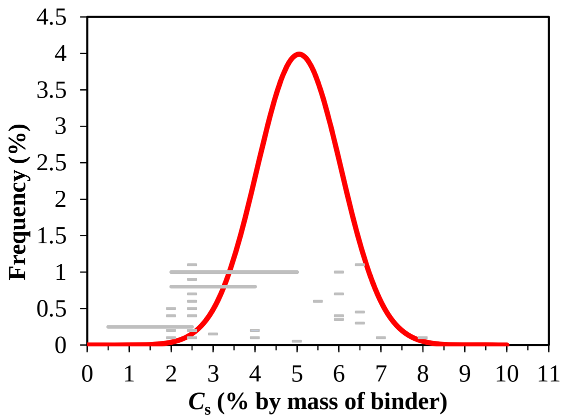
C_0 (initial chloride content) 1% by mass of binder (seawater)

d_c (concrete cover thickness)

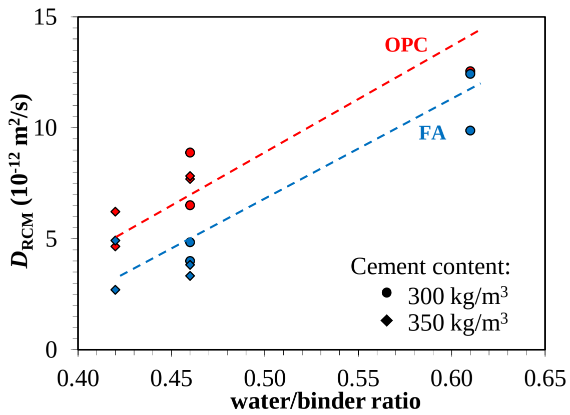
t (service life)



M. Gastaldi et. al., 3rd ACI Workshop on New Boundaries of Str. Concr., Bergamo 3-4 October 2013.

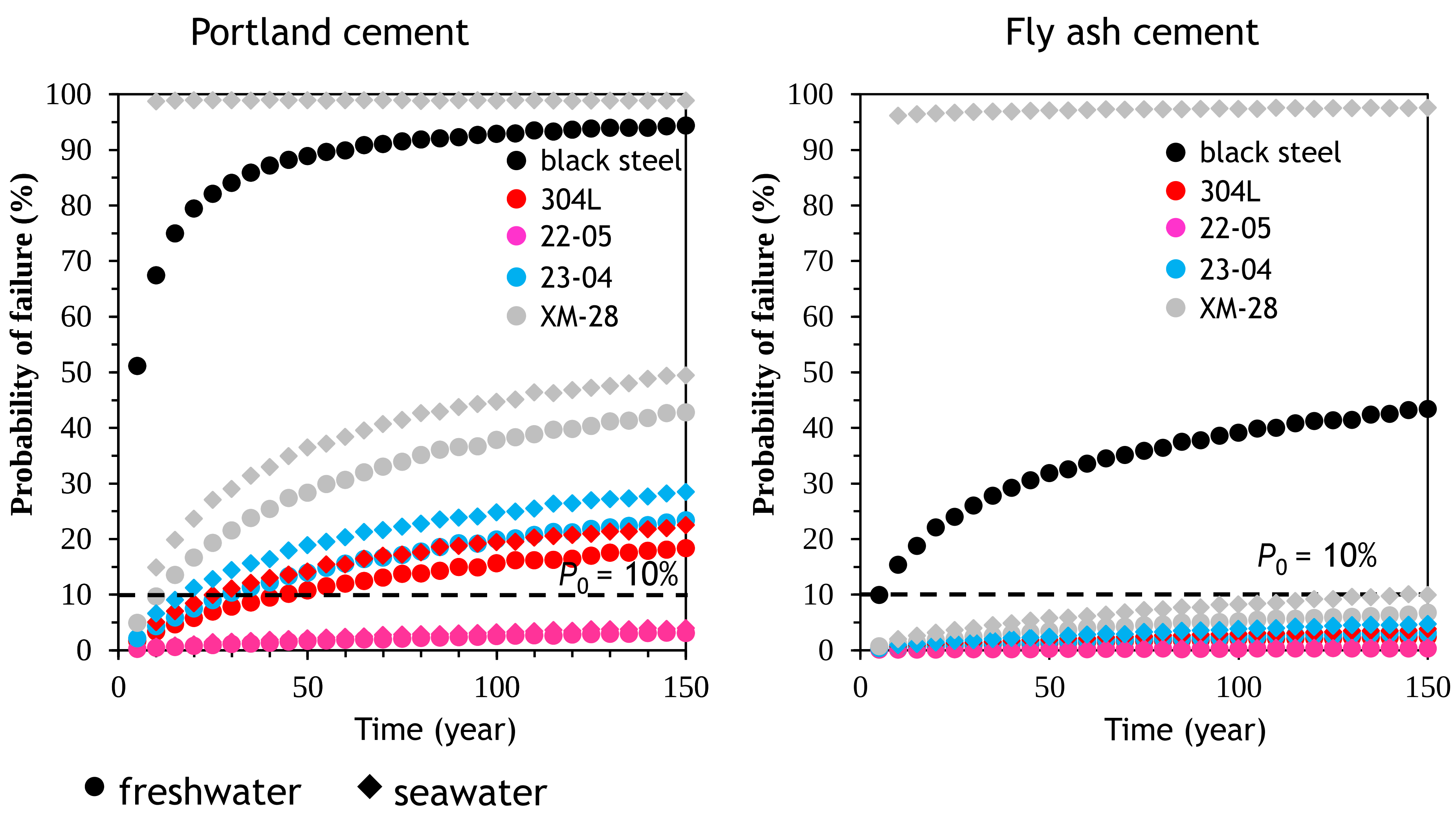


F. Lollini et al., *Constr. Build. Mater.*, **79**, 2015

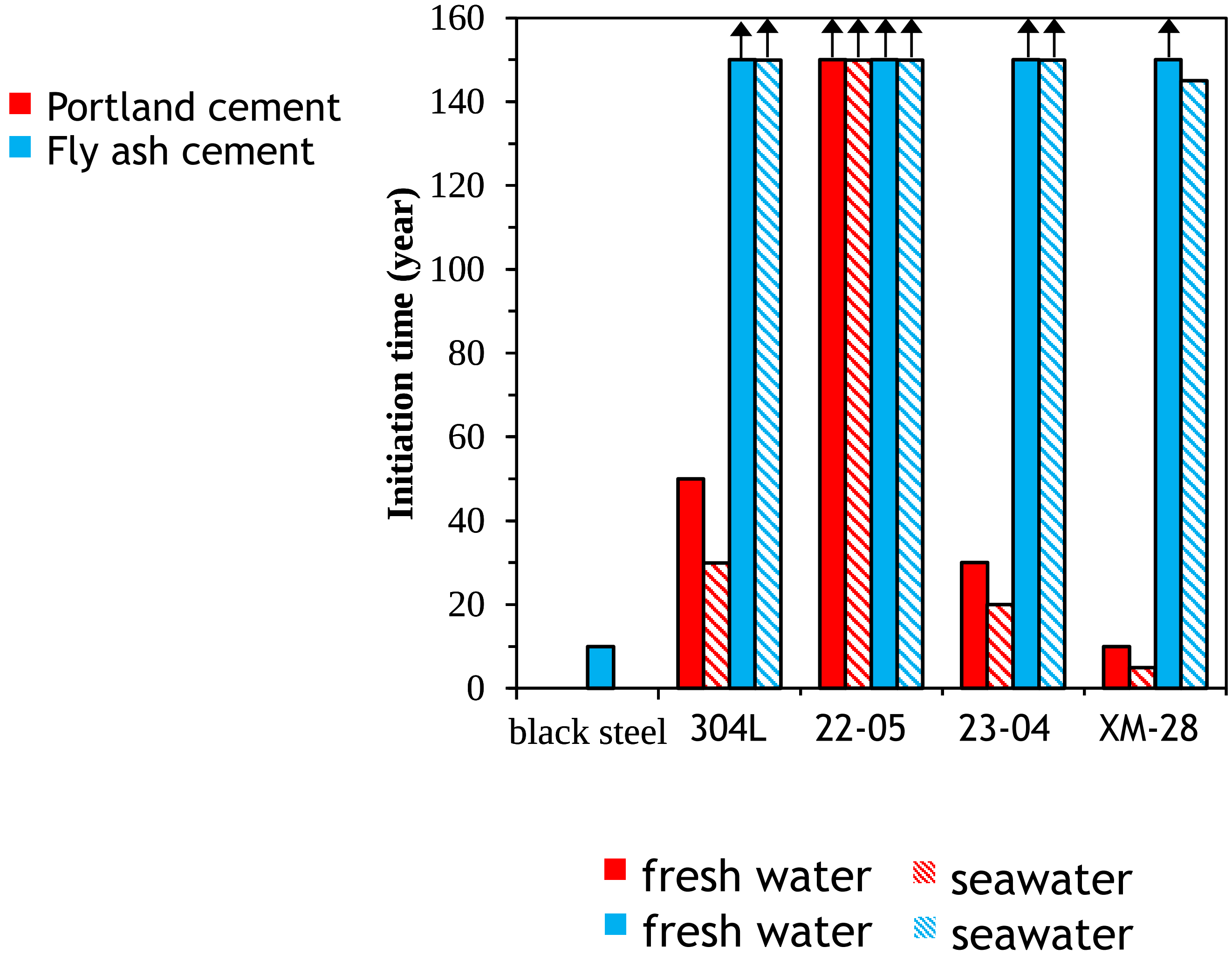


F. Lollini et al., *Constr. Build. Mater.*, **120**, 2016

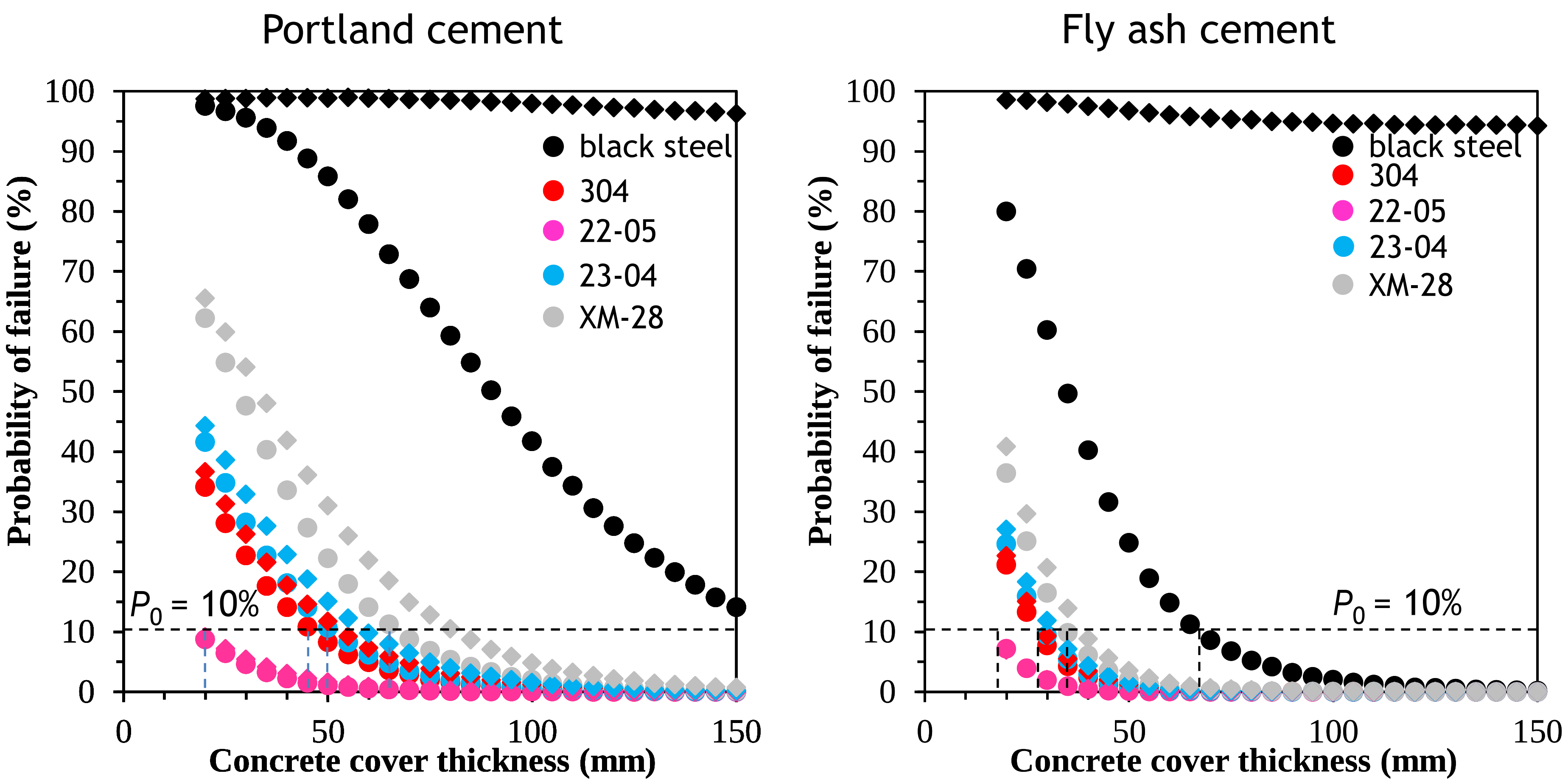
P_f vs time for mean concrete cover of 45 mm (w/c = 0.45)



Service life calculated for d_c = 45 mm and P_f = 10%

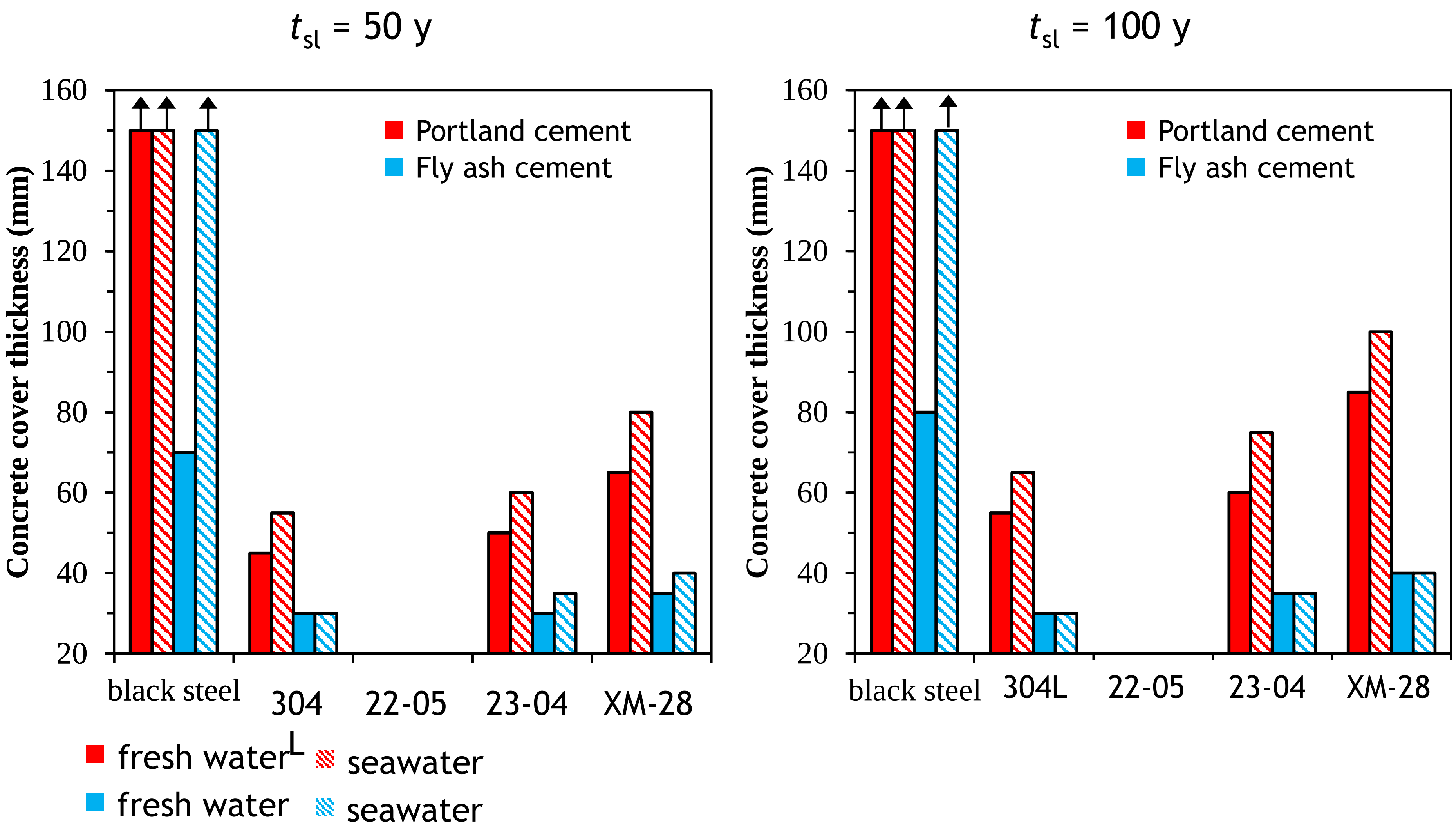


P_f vs mean concrete cover for t_{SL} = 50 years (w/c = 0.45)



● freshwater ◆ seawater

Mean concrete cover required for P_f = 10%



Conclusions

A preliminary assessment of the durability of RC elements made with mixed-in seawater and exposed to the splash zone in a temperate climate was carried out by means of a probabilistic performance-based approach, assuming literature values for the critical chloride threshold of stainless steels and no effect of seawater on the diffusion coefficient.

Using conventional concrete, several design options were found to be suitable to reach target service lives of 50 or 100 years, by using different grades of stainless steel reinforcement, which allowed the use of reasonable values of concrete cover thickness.

The use of seawater as mixing water led to a modest 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 various combinations of concrete composition and stainless steel grade may suitable.

The choice of the most appropriate design option could be made through LCA and LCC analyses. Such analyses as well as validation of the hypothesis made for the input parameters in this work will be carried out within the SEACON project.