Corrosion behaviour of reinforcement in seawater concrete

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Introduction

- Use of seawater for r.c. structures is prohibited
  (seawater $\sim 21000$ ppm Cl\(^-\) $\rightarrow \sim 4$ kg Cl\(^-\) per m\(^3\) concrete $\rightarrow \sim 1.3\%$ Cl\(^-\) by weight cement)

- Need to reduce environmental impact of concrete production

- Can seawater be used in combination with corrosion resistant reinforcement?

Effect of mixed-in chlorides on reinforced concrete

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XM-28
304L
22-05
23-04

GFRP

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SEACON aims at demonstrating the safe utilization of seawater and salt-contaminated aggregates for a sustainable concrete production when combined with non-corrosive reinforcement to construct durable and economical concrete infrastructures.

- Laboratory tests
- LCA/LCC
- Real-size demonstration projects (i.e., Italy and Florida, USA) to provide the opportunity for **long-term** performance monitoring
Objectives of WP4 - Italy

- Design, construct and monitor a demo-project utilizing seawater concrete with both stainless steel and GFRP reinforcement
- Monitor the long-term durability behaviour (beyond the end of the SeaCon project)

Participants:
- Politecnico di Milano
- Buzzi Unicem
- Pavimental
- Acciaierie Valbruna
- ATP

XIV Congresso AIMAT 2017
Ischia Porto (Na), 12-15 luglio 2017
- Asphalt production unit of Pavimental in Pontenure (PC)
- Next to A1 motorway (Piacenza Sud)
Description of r.c. culvert

- Runs parallel to road
- Collects waste water (de-icing salts)
- 30 m long, divided into six individual segments, 5 m each
### Scenarios and exposure conditions

- Each segment is representative of a combination of a type of concrete and a type of reinforcement
- Macro-climatic conditions: unsheltered, wetting/drying cycles
- Both carbonation and chloride penetration

<table>
<thead>
<tr>
<th>Segment</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
<td>Carbon steel</td>
<td>Carbon steel</td>
<td>SS 304 (1.4311)*</td>
<td>SS 23-04 (1.4362)*</td>
<td>GFRP**</td>
<td>Carbon steel</td>
</tr>
<tr>
<td>Concrete</td>
<td>Reference</td>
<td>SeaCon (seawater)</td>
<td>SeaCon (seawater)</td>
<td>SeaCon (seawater)</td>
<td>SeaCon (seawater)</td>
<td>RAP</td>
</tr>
</tbody>
</table>

* supplied by Acciaierie Valbruna  ** supplied by ATP
# Concrete compositions (from Buzzi)

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Ischia Porto (Na), 12-15 luglio 2017

<table>
<thead>
<tr>
<th>Dosage (kg/m³)</th>
<th>Reference concrete (A)</th>
<th>SeaCon concrete (BCD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM II/A-LL 42.5R</td>
<td>335</td>
<td>335</td>
</tr>
<tr>
<td>Fly ash</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Sand 0-5 mm</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Gravel 5-7 mm</td>
<td>365</td>
<td>365</td>
</tr>
<tr>
<td>Gravel 8-15 mm</td>
<td>630</td>
<td>630</td>
</tr>
<tr>
<td>Superplasticiser Addiment T75</td>
<td>2.19</td>
<td>2.19</td>
</tr>
<tr>
<td>Retarding agent VZ53</td>
<td>-</td>
<td>0.76</td>
</tr>
<tr>
<td>Water</td>
<td>175</td>
<td>-</td>
</tr>
<tr>
<td>Seawater</td>
<td>-</td>
<td>175</td>
</tr>
</tbody>
</table>

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Probes for corrosion monitoring

- SSC reference electrode for potential monitoring
- Multiple-reinforcement probes
- Electrical resistivity probes

Silver – silver chloride (SSC) reference electrode

Multiple-reinforcement probe

Resistivity probe
## Summary of electrical connections

<table>
<thead>
<tr>
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<td>Concrete</td>
<td>Reference</td>
<td>SeaCon (seawater)</td>
<td>SeaCon (seawater)</td>
<td>SeaCon (seawater)</td>
</tr>
<tr>
<td>Rebar</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>SSC-Ref</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Ti-Ref</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
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<tr>
<td>Res-probe</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Ti-mesh</td>
<td>-</td>
<td>V</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Multi-probe</td>
<td>V</td>
<td>V</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Activated titanium mesh*

*Box for electrical connections*
Execution of the culvert (1)

- Placing of reinforcement mesh
- Installation of probes

**Carbon steel and 304 stainless steel meshes (segments B and C)**

**Multiple-reinforcement probe (segment B)**

**Single probes (segment C)**
Execution of the culvert (2)

Concrete casting, compaction and curing

- Pouring of reference concrete (segment A)
- Compaction of SeaCon concrete (segment C)
- Curing of culvert (24 hours)
The culvert

- Completed by end of November 2016
- Measurement of potential of reinforcement and probes (manual and datalogger)
- Measurement of electrical resistivity of concrete
- Potential mappings vs. external reference electrode
Potential of reinforcement vs. embedded SSC reference electrode

Potential of carbon steel in reference and seawater concretes

Potential of stainless steels in seawater concrete

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Comparison with laboratory data in similar exposure conditions

Potential of carbon steel in reference and seawater concretes

Potential of stainless steels in seawater concrete

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• Potential of reinforcement vs. embedded SSC reference electrode
• Evolution of electrical resistivity of concrete on-site

*Concrete resistivity at the depth of the reinforcement (~30 mm)*
The results of monitoring of corrosion conditions of the reinforcement in the culvert during the first 7 months of exposure indicate that:
- Rebar potentials are in agreement with those obtained on reinforced specimens in the lab in similar conditions of exposure.
- Stainless steel rebars in seawater concrete show similar behavior as carbon steel in reference concrete.
- Datalogger will allow monitoring the potential of reinforcement virtually continuously, reducing the on-site inspections.
- Future analyses of chloride profiles and depth of carbonation will allow a better understanding the corrosion behaviour.
Grazie!

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