SEACON

Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement

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[1] This report is the same as the one submitted to the primary project sponsor: Infravation

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1 Publishable summary

The research project "SEACON: Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement" addresses the issue of sustainability from the perspective of the construction material most used worldwide. This 2.5-year project started on October 1, 2015. It was proposed and carried out by a transnational consortium of six partners and three collaborators including two academic institutions, six companies, and a department of transportation. During the course of the project, a fourth collaborator joined the consortium.

The goal of SEACON is to promote the use of best practices in both the production of concrete and reinforced concrete (RC) structures by implementing alternative materials. The aim is to reduce the use of critical resources by replacing them with alternatives that can be chloride-contaminated coupled with non-corrosive reinforcement. This approach would extend the affordability and sustainability of constructed elements under aggressive environmental conditions without affecting their longevity and durability. The three overarching objectives of the research program are:

- to confirm scientific evidence, through experimental work, that the presence of chlorides is not harmful to the properties of plain concrete;
- to prove, through laboratory studies, the successful use of composite (glass fiber reinforced polymer – GFRP) and stainless steel reinforcement in concrete made with seawater, salt-contaminated aggregates, and high-chloride content cement; and,
- to demonstrate this technology by means of two field prototypes, incorporating commercial design, while developing model specifications and guidelines to be proposed for adoption to national and international standard-writing agencies.

The work plan was subdivided into seven Work Packages (WPs), of which five dealt with technical issues and two with dissemination and management, respectively. Laboratory and analytical work, including LCC/LCA studies, were conducted, and the technical results have been made available to the public via the internet (see http://seacon.um-sml.com/) as well as a number of presentations at national/international conferences and peer-reviewed publications in conference proceedings and journals. As important, the laboratory results made possible the planning and execution of the two field demonstrations that will be monitored beyond the duration of the SEACON project. The first demonstration is an open culvert project undertaken in Italy that was constructed during the last week of November 2016 along Motorway A1, near the city of Piacenza. Three concrete mix designs were considered (traditional concrete, concrete mixed with seawater and concrete produced with recycled asphalt pavement) in combination with different types of reinforcement (black-steel, GFRP, and stainless steel rebar's).

The second demonstration is the vehicular five-span bridge currently under construction in Homosassa, Florida (start date January 2017, expected end date December 2018). The bridge was designed by the Florida Department of Transportation for Citrus County, the owner, and includes a number of innovations that make it unique. SEACON technology was used in the bulkhead caps (made of concrete with seawater) and the gravity walls (made of concrete with recycled aggregates). All these elements were reinforced with GFRP.

Both demonstrators served as the testbed for comprehensive and detailed LCC/LCA studies that have proved the viability of the technologies investigated in the project. Additionally, they provided the opportunity for developing the drafts for a new generation of construction and design specifications.

2 Project results

2.1 Seaconcrete

Buzzi Unicem has demonstrated the feasibility of producing high-chloride content concretes (containing high-chloride content binders, low-energy/CO_2 binders, seawater as mixing water, recycled concrete aggregates, recycled asphalt pavement aggregates and chloride-contaminated aggregates) through both laboratory and on-site tests without affecting their final performance

Characterization tests, led by Buzzi, have been carried out in part at Buzzi labs and in part at POLIMI labs. The study was developed at different levels with the final objective of comparing the performance of concrete made with seawater and salt-contaminated aggregate with that of concrete made with traditional constituents. In particular, the selected concretes have been studied in terms of strength development, mineralogical and microstructural analysis, resistance to degradation, carbonation, and chloride penetration.

Mineralogy and microstructure. Chlorides have an accelerating effect if Portland cement is used, proved by the formation of AFm phases, mainly Friedel's Salt (FS), and ettringite at the beginning of the hydration process. They also influence the microstructure, leading to the formation of a denser cement matrix and smaller capillary and gel pores.

The formation of FS ($3CaO{\cdot}Al_2O_3{\cdot}CaCl_2{\cdot}10H_2O$) is the main mineralogical evidence observed during the hydration of cement; FS is formed in a relatively lower amount, compared to the total chloride amount added. In fact, Nuclear Magnetic Resonance (NMR) studies have shown that about 20% of the Al_2O_3 present in cement is converted to FS. Al_2O_3 is a minor constituent of Portland cement, so the majority of the chlorides added are not bound. No evidence of modification of the silicate phase was observed. The pore solution of the cement paste is therefore oversaturated in salts.

Dimensional stability and compressive strength development. The shrinkage and expansive behaviors of Portland based formulations are worsened by chloride additions (in particular when seawater is used), probably due to the higher surface tension of the pore solution when oversaturated in salts, which causes a more rapid water loss from the pores induced by an higher internal tension of the CSH gel. No effect on the compressive strength was observed, remaining unchanged after seawater was added as mixing water.

Strength of studied concrete was also tested after a moist curing in seawater of 28 days, followed by conditioning in seawater for one year. No relevant differences can be observed in terms of mechanical properties after the first 4 months in seawater immersion. Conversely, curing in seawater might affect the strength of concrete with the increase of exposure time. These tests should be repeated with two or more years of seawater immersion conditioning.

Durability. The use of seawater as mixing water affects the durability of concrete mainly with regards to the sulfate attack. It was verified that mortars and concretes that contain chlorides behave worse when submitted to sulphate attack (in Na_2SO_4 and $MgSO_4$ solutions), but also when cured in seawater. The higher expansion, that is always double with respect to the reference, doesn't seem critical for the cement studied, and no damage was observed in the samples. The reason for this expansion is probably related to an ionic exchange between sulphate and chloride ions, resulting in a higher mobility of sulphate ions towards the concrete, and of chloride ions in the opposite direction. The same effect is probably observed in the case of seawater curing, where sulphates are well bound in cement, allowing chlorides to migrate out of the concrete and forcing sulphates to move inside the concrete in order to counterbalance the ionic charge.

Alkali-silica reaction was also tested in concrete with reactive aggregates, and no evidence of a higher risk of alkali-silica reaction was observed. It is not clear why, even with such a high Na_2O content, no higher expansion was observed, but a possible explanation for this phenomenon could be the inhibition of the $Si(OH)_4^-$ dissolution from the aggregate due to the higher Cl^- content of the pore solution. With regard to the experimental results previously summarized, it is wise to suggest the use of low C3A cements (or sulphate resistant cements) for seaconcrete applications.

The permeability of concrete is an important factor in the durability of reinforced concrete. It is well-known that phenomena leading to degradation of reinforced concrete depend on the processes that allow transport of water, carbon dioxide, chloride ions, oxygen, and electrical currents into concrete. Tests aimed at studying the role of chloride-contaminated raw materials on the concrete transport properties showed that, in the case of the mixes studied in this work, chloride contamination does not significantly affect the resistance to carbonation penetration and the capillary absorption. Whilst an influence was observed in the resistance to chloride penetration, it seems that the presence of chloride in the raw materials led to a higher resistance to chloride penetration.

2.2 Reinforcement

2.2.1 Glass fiber reinforced polymer (GFRP)

The Florida Department of Transportation (FDOT) has implemented material and construction specifications for the use of GFRP reinforcing. Standard Specification ***Section 932-3*** addresses the material and testing requirements: while similar to the recently released ASTM D7957 reinforcing bar specifications, there are minor differences and additional test requirements. Several construction related specifications (Sections ***400***, ***407***, ***410***, ***415***, and ***450***) address concrete structures, three-sided box culverts, four-sided box culverts, reinforcing bar placement, and prestressed concrete, respectively. Additionally, FDOT has developed standard FRP bar bending standard drawings under ***Index D21310,*** and instructions for designers under document ***IDDS-D21310***.

The University of Miami (UM), along with the FDOT, led the development of a draft for the second edition of the AASHTO Bridge Design Specifications for GFRP-RC Bridges (AASHTO BDS-GFRP). The document formalizes in regulatory text the lessons learned through the design and construction of the project demonstrations. Objectives included making the provisions for GFRP-RC design more rational and offsetting the excessive conservatism of some requirements. The development of a comprehensive bridge design standard is paramount to allow for a wide and safe deployment of GFRP-RC in transportation infrastructure.

Durability GFRP reinforcement in seawater concrete has been studied by embedding bars in concrete beams and immersing the beams in seawater at 60 °C (140 °F) as accelerated conditioning. GFRP reinforced beams made with fresh water were also cast to serve as the benchmark. Each beam, with the dimensions of 152.5 x 190.5 x 1422.5 mm (6 x 7.5 x 56 in.), was reinforced with four #5 GFRP bars, each 1360 mm (53.5 in.) long, which leads to a minimum of 30 mm (1.2 in.) of concrete cover. The reason for conditioning the specimens in seawater at 60°C is to increase the diffusion rate of the concrete pore solution into the GFRP bars and accelerate the chemical degradation processes for the same time of immersion. It should be noted that, aside from gravity, no load was applied to RC beams during conditioning. Every six months, one beam is removed from the conditioning chamber, and the bars are extracted by splitting concrete with hammer drills. Extreme caution was exercised in the extraction so as not to damage the bars. Extracted bars were tested in terms of residual tensile properties and transverse and horizontal shear strengths, and were compared to the pristine bar properties as an indicator of degradation due to exposure. These properties are critical for application of GFRP bars as reinforcement in concrete structures. All tests were performed at room temperature 48 hours after the extraction. This time period is needed to install the steel-pipe anchors for tensile tests; however, in order to be consistent, all the specimens dried at room temperature for 48 hours before mechanical tests.

After 1.5 years of accelerated aging, it can be concluded that introduction of seawater into the concrete mixture does not negatively affect durability of GFRP reinforcement. The GFRP bars extracted from the seawater and fresh water concrete have shown comparable performance. Tensile properties have not been significantly impacted after 1.5 years of exposure to the accelerated aging compared to the pristine values. However, horizontal and transverse shear strength decreased by less than 20%, which could be mainly due to temperature effects. Microstructure of the extracted GFRP bars was also studied using Scanning Electron Microscopy (SEM) and no significant degradation was observed.

Bond strength between GFRP rebar and seawater concrete was also examined as the other important durability property of GFRP reinforcement. 200-mm (8-in.) seawater and conventional concrete cubes with embedded #3 GFRP rebar were cast and exposed to seawater at 60 °C (140 °F). The total bond length was 5*d*, in which *d* is the bar diameter, 10 mm (3/8 in.). Every six months, three cubes from each mixture are removed from the conditioning chamber and the bond strength between the GFRP rebar and concrete is determined by pull out testing. The steel-pipe anchor was used at the loading end and an LVDT was used at the free end of GFRP bars to measure the slip during testing. The bond strength of the GFRP bars in seawater and conventional concrete after 1.5 years exposure to the accelerated conditioning is compared to the specimens cast from the same concrete mixtures but conditioned in the controlled lab environment as a bench mark. The results show about 30% reduction in the bond strength between GFRP bars in both conventional and seawater concrete. This also confirms the comparable behavior of GFRP bars extracted from conventional and seawater concrete. Post-mortem specimens were split in half to observe the status of the portion of bar bonded to concrete; from this, one can conclude that the failure occurred at the interface between bar skin (made of sand coating and helically wrapped strand) and bar core. The same mode of failure was observed in both control and conditioned specimens. Microstructural inspections using SEM also confirms this “peeling” phenomenon. GFRP bars from other manufacturers having different surface treatments; when tested as part of a parallel investigation, they did not show this bond degradation phenomenon.

2.2.2 Stainless steel

FDOT has also implemented material and construction specifications for the use of stainless steel reinforcing. ***Standard Specification* *Section 931-1*** addresses the material and testing requirements, while the conventional steel reinforcing construction specifications are considered adequate under ***Sections 400*, *407*, *410*, *415***, and ***450*** (concrete structures, three-sided box culverts, four sided-box culverts, and reinforcing placement, respectively).

In order to investigate the corrosion behavior of stainless steel and, for comparison, traditional carbon steel, reinforced concrete slabs were cast. Beyond the conventional carbon steel, tests were carried out on 16 mm ribbed bars of stainless steel of grades 304L, 22-05, 23-04, and 20 mm ribbed bars XM-28. 8 different types of concrete were considered: a reference mix with virgin ingredients (without chloride); two mixes contaminated by chlorides from the cement (one with a higher amount of fly ash); one mix with seawater used as mixing water; and one mix with recycled concrete aggregate (RCA) used to partially replace the natural coarse aggregate. Furthermore, concretes with mixed-in chlorides were made: in particular, chlorides were added as NaCl to the mixing water in order to reach chloride contents of 1, 3 and 5% by mass of binder.

Two different types of reinforced concrete slabs were cast. A 250×120×50 mm^3 prism slab reinforced with one bar of each type of steel with a concrete cover thickness of 15 mm was made for exposure tests, and a 350×120×80 mm^3 prism slab with a hollow on the upper surface with dimension of 310×80×30 mm^3 and reinforced with one bar of each type of steel with a concrete cover thickness of 10 mm was made for ponding test, in order to study the effect of further penetration of chlorides.

After the 7-day curing, the slabs for exposure tests were exposed outdoor to Milano atmosphere in an unsheltered condition, on the roof of the Department of Chemistry, Materials and Chemical Engineering of the Politecnico di Milano, where no further penetration of chlorides was expected, in order to simulate a structure made with chloride contaminated raw materials exposed far from the sea and the marine aerosol. After approximately one year of outdoor exposure, exposure cycles were carried out. In particular, the slabs were exposed to the following exposure conditions of temperature (T) and relative humidity (R.H.) for 2-4 weeks until stable conditions were reached: T= 20°C/R.H. = 60% (indoor exposure); T= 20°C/R.H. = 100% (immersion); T= 38°C/R.H. = 100%; T= 50°C/R.H. = 90%; and T = 50°C/R.H. = 100% (immersion), in order to study the effects of temperature and relative humidity on the corrosion behavior of carbon and stainless steel bars.

The slabs for ponding tests were subjected to ponding with a 3.5% NaCl solution, in order to simulate the further penetration of chlorides.

Corrosion tests on reinforced concrete slabs exposed outdoors in an unsheltered environment and to cycles of temperature and relative humidity showed that, in absence of any further penetration of chlorides, as can occur for structures far from the sea, no corrosion was induced on any of the stainless steel bars employed in this study, even when 5% of chlorides were mixed in and when the slabs were exposed to the harshest environmental conditions (e.g. temperature higher than 38°C and relative humidity higher than 90%). Hence, the use of chloride contaminated raw materials for the production of concrete, which could lead to a chloride content (for instance, when seawater is used as mixing water) of around 1% by mass of cement, seems to be allowed in combination with any of the SSR bars tested in this project, even those with the lower corrosion resistance and costs, such as the XM-28.

Conversely, carbon steel bars showed to be unsuitable in the harshest environmental conditions when embedded in the seawater concrete and in the concrete with 1% of mixed-in chlorides. As expected, corrosion occurred on carbon steel bars in 3%-Cl and 5%-Cl concrete, even when exposed to the least aggressive environment.

The further penetration of chloride ions led to the initiation of corrosion on the carbon steel bars embedded in the different mixes, suggesting that the initial chloride content, due to the use of chloride contaminated raw materials, was only slightly lower than the chloride content which promotes the initiation of corrosion in the studied exposure conditions. The further penetration of chloride did not lead to the occurrence of corrosion on any of the stainless steel bars embedded in concrete made with chloride contaminated materials. However, the tests are still ongoing to promote, at the bar depths, the chloride content expected during the design service life of a real structure.

Further tests are underway to study the combined effect of chloride and carbonation on the corrosion behavior of reinforcement. Reinforced concrete specimens that were subjected to accelerated carbonation will be exposed to different temperatures and humidity, and the corrosion related parameters will be monitored. Results are expected to be available in the next 2-3 months.

2.3 LCC/LCA

Full LCA analyses of the two demo projects were carried out in compliance with the ISO 14040 and 14044 standards. The two structures were analyzed under two main scenarios: cradle-to-gate, and cradle-to-grave. However, the cradle-to-gate analysis is inherently limited in this special case because it does not take into account the benefits coming from non-corrosive reinforcements during the structure service life.

Thanks to the collaboration of the ATP Company, the LCA of GFRP bars based on primary data was done. Considering the lack of public data on these reinforcements, this was a great achievement. For the other reinforcement bars (i.e. carbon steel and stainless steel), literature data of good quality is available, so they were used in the analyses. The comparative analysis of the three types of reinforcement has revealed that on a mass basis, carbon steel is the least impacting, while GFRP and stainless steel have larger environmental impacts. Stainless steel is competitive with respect to GFRP only if a high amount of recycled material is considered in its production. In any case, the two non-corrosive reinforcements have alternating behaviors depending on the impact category analyzed. However, thanks to its lower density, GFRP is competitive and superior to any other reinforcement on a volume basis. This fact helps reduce the total impact of the reinforced concrete, as the reinforcing ratio on a mass basis is typically lower when using GFRP.

Buzzi Unicem also supplied primary data on cement production LCAs. This is a particularly relevant point which underlines the reliability and soundness of the analyses.

Selected for its simplicity and linearity, the Italian demo culvert was used for comparative testing to understand if alternative and non-conventional concrete mix designs combined with high-durability reinforcements could decrease environmental impacts associated to the entire life of the structure.

The case study is composed of six sections where non-corrosive bars and concrete mixes are combined:

- Section A: Carbon Steel (CS) + reference concrete;
- Section B: CS + SEACON concrete;
- Section C: Stainless Steel (SS) 304 + SEACON concrete;
- Section D: SS 23-04 + SEACON concrete;
- Section E: GFRP + SEACON concrete;
- Section F: CS + Recycled Asphalt Pavement (RAP).

For each section of the culvert, the service life was evaluated in order to define the maintenance schedule. Different scenarios were considered to understand the relevance of input parameters and maintenance schedule on LCA results.

Section B, taking into account service life, proved to be the worst solution. The use of seawater as mixing water requires the use of high-durability reinforcements, otherwise the corrosion problems start too rapidly, and first repair operations occur shortly after the installation.

Section A, compared to section F, showed approximately the same results, since the only difference was the use of RAP. However, the use of recycled aggregates results in a small reduction of the environmental impacts.

Sections C and D, which contained stainless steel bars, did not require any major repair operation. Considering the environmental performance, stainless steel guaranteed a reduction of the environmental impacts with respect to carbon steel thanks to the higher content of recycled materials and the absence of major repairs. The high-durability rebar allows the use of seawater for mixing, therefore reducing the consumption of fresh water. To conclude, stainless steel bars proved to have a higher environmental performance with respect to carbon steel rebar under the assumptions considered. The use of stainless steel rebar seems to be better with respect to carbon steel in more aggressive environments - rich of chlorides - where the service life of carbon steel decreases. Furthermore, in coastal areas, stainless steel rebar could be combined with seawater for mixing, reducing the transportation and lowering the water footprint thanks to the avoided use of tap water.

Finally, section E proved to have the highest environmental performances. The use of GFRP results in the lowest environmental impacts practically in every category except for Ozone Depletion Potential with respect to stainless steel, and in the Abiotic Depletion with respect to carbon steel. Nevertheless, the differences for these impact categories were quite small. The only drawback of this material seems to be the current impossibility of recycling it at the end-of-life. From a circular economy point of view, this means that all the reinforcing material would go to a landfill at the end-of-life, in opposition to steel, which can be completely recycled.

Several sensitivity analyses were performed to show the relevance of key parameters: number of repair operations, and reinforcing ratio of GFRP. Repair operations highly affected LCA results, determining that high-durability rebar is preferred in aggressive environments for long time horizons (i.e. 100 years in the present study). Doubling the amount of GFRP rebars and maintaining fixed the amount of steel reinforcements, section E resulted as more impactful than sections with stainless steel reinforcements. However, at the same reinforcing volume, GFRP proved to be the reinforcing material with highest environmental performance.

After all these LCA analyses, we can safely conclude that GFRP-RC, combined with the use of seawater and non-conventional cements, is an effective environmentally friendly technology to construct infrastructures in high chlorinated environments and in areas characterized by water scarcity.

The second demo project, the Halls River Bridge, is a much more complex infrastructure compared to the Italian culvert. In the case of the bridge, two comparisons at the level of design were made: one alternative is a full FRP-reinforced bridge structure, and the other is a more traditional one with only carbon steel as reinforcement.

Although there are many geographical differences between the two structures, which might have affected the results (i.e. different energy mixes between Italy and USA, or longer transport distances), the outcomes of the second study are perfectly in line with those of the Italian culvert. Indeed, considering the cradle-to-grave perspective, the use of only FRP-reinforcements has revealed benefits in almost every considered impact category, except Abiotic depletion and Ozone layer depletion.

Analogously, LCC analyses were performed on both demo projects. The structures were supposed to be demolished at the end of the study period, materials without value landfilled and metal scrap sold. GFRP scraps were supposed to be without residual value due to the complex, heterogeneous, and anisotropic characteristics that make it difficult to be reused or recycled, even if this assumption may not be true in 100 years.

In the case of Italian culvert, real discount rate was fixed at 0.01%, as indicated by the Society of Environmental Toxicology and Chemistry (SETAC) for long-term investments. A sensitivity analysis was also performed to show the relevance of the real discount rate on the discounting of future activities.

With a real discount rate of 0.01%, section A and F were the worst, with stainless steel proving to be a prefarable choice to carbon steel. The use of GFRP bars, thanks to the low weight, reduced the manpower cost at the construction site. Moreover, the relatively low cost of the material and the absence of major repairs made section E the most cost effective option.

A sensitivity analysis was performed to understand the relevance of the real discount rate on the analysis results. As the real discount rate increases, total repair costs tend to decrease. The high initial costs of high-durability rebar may not be recovered during the life of the structure.

The real discount rate at which the use of stainless steel reinforcements becomes unfavorable with respect to carbon steel was approximately 1%. On the other hand, GFRP bars remained the best reinforcing option up to a real discount rate of approximately 5%.

In the case of the HRB, a design-based LCC analysis was presented. As in the case of LCA, the FRP-RC and FRP-Prestressed Concrete (PC) bridge design option is compared with one based on carbon steel reinforcement. Although at the design stage, the LCC has benefitted from a large amount of primary data collected directly on site. In the case of the bridge, both direct and indirect costs were accounted for.

Despite its higher construction cost, FRP-RC/PC is a life-cycle-cost-effective alternative to conventional steel-RC/PC solutions. FRP is durable and light-weight, which allows for an aggressive construction schedule, reducing not only construction costs, but also indirect driver costs caused by bridge works.

In addition, among the indirect cost, the user cost is estimated to show the impact that a replacement construction has on users. It is important to note that the user cost of an FRP-RC/PC solution is less impacting than a steel-RC/PC alternative. This is an additional positive implication of a more aggressive schedule that leads to a faster construction time-frame.

Experience suggests that a steel-RC/PC structure hardly endures its projected service life without undergoing maintenance and reparation to account for loss of strength following corrosion of the reinforcement. However, in this study, repair costs on the steel-RC/PC side were not included in the analysis. An in-depth investigation on the maintenance side is expected to further emphasize the economic appeal of FRP-RC/PC solutions.

2.4 Demonstration projects

The two demonstration projects are presented in some detail in sections **8 Appendix A - Italian Demo Project: Culvert** and **9 Appendix B - US Demo Project: Halls River Bridge**.

3 Encountered challenges and solutions

3.1 Seaconcrete

Preliminary studies on cement pastes and mortars proved the accelerating effect of chlorides on Portland cement; in order to counteract this effect, a retarding agent needs to be added to Portland concrete mixtures.

A worsening effect of the concrete shrinkage behavior was observed when Portland cement is used in combination with chlorides. This effect can be mitigated through the use of shrinkage-reducing admixtures or small amounts of expansive agent.

Recycled concrete aggregates proved to limit the concrete workability: in this case, special admixtures to extend the maintenance of the concrete consistency have to be used.

The use of low C_3A cements (or sulfate resistant cements) is suggested to counteract the sulphate attack related to the use of seawater (both as mixing water and a curing solution).

3.2 Reinforcement

3.2.1 GFRP

Despite the comparable performance between the durability of GFRP reinforcement in conventional and seawater concrete, some properties of the GFRP bars have degraded after exposure to accelerated aging. The durability of the GFRP reinforcement is highly dependent on manufacturing, chemical composition of the resin matrix, characteristics of the fiber-resin interface, and interfacial imperfections that may develop during the manufacturing process. The susceptible interface between bar core and bar skin, which causes the “peeling” phenomenon, can be easily improved by employing different manufacturing techniques for creating a deformed surface needed to bond concrete.

3.2.2 Stainless Steel

On the market, several types of stainless steel are available, characterized by different costs and corrosion resistances. Hence, the choice of the most suitable grade of stainless steel for a specific environment is not an easy task. Experimental tests were carried out on 4 grades of stainless steel exposed to different exposure conditions, showing that all of them were suitable when exposed in conventional and seawater concrete. However the final choice can be made only through a proper design of the service life. At this regard, probabilistic-performance based approaches were used. Their application requires the knowledge of materials, as well as environmental parameters. The determination of some material parameters is still unavailable due to the long time required to test. Literature data, which needs to be assessed, was used.

Another challenging task that was encountered in the experimental activity was the design of solutions that would allow long-term monitoring of corrosion conditions of reinforcement in the field demonstration activity, where a much longer service life and lesser accessibility are expected in comparison with laboratory conditions. This task was faced by setting up specific corrosion probes made with the two types of stainless steels used in the demo project (see §8) that were designed to be embedded in the culvert and to provide complementary data to better understand the corrosion behavior of reinforcement. In addition, a tailor made acquisition system, that allows continuous monitoring of the corrosion potential, was designed and calibrated in the laboratory in order to be used onsite for long-term monitoring in real exposure conditions.

3.3 LCC/LCA

Lack of primary data, or reliable secondary data, is always the main challenge when performing a full LCA of complex systems, and certainly the HRB is. In the present studies, most secondary data is of high quality, and the amount of primary data very large. The challenge was the FRP bars, because the literature is very poor, and reliable production data cannot be found. However, GFRP primary data was supplied by the ATP Company, solving the problem for GFRP. On the contrary, for CFRP (used in the HRB, but not in the culvert), it was not possible to find primary data, and the data available in the inventory databases are not fully updated. Nonetheless, the amount of CFRP in the HRB is not relevant. For this reason, sensitivity analyses were run to prove that LCA results are completely reliable.

As for LCC, thanks to the collaboration of partners and of the Astaldi Company, there were no problems in data collection.

4 Contribution to the challenge

4.1 Seaconcrete

Buzzi Unicem has demonstrated that the only obstruction to producing concretes rich in chlorides (coming from different sources; the binder, the mixing water, or the aggregates) is represented by the presence of the Standards and Codes limit. In any case, the concrete properties can be maintained or improved by adopting ad-hoc strategies to counteract the possible negative effects.

4.2 Reinforcement

4.2.1 GFRP

Recommendations, which result from the analysis of lab findings in combination with performance monitoring of the demo projects, should be considered in order to improve the manufacturing process of GFRP bars and, consequently, its durability in terms of bond behavior.

4.2.2 Stainless steel

The results of the service life design with stainless steel reinforcement confirmed that the durability of a reinforced concrete structure strongly depends on the grade of stainless steel, and only an accurate design of the concrete mix, type of steel, and construction details can guarantee the target service life in a specific environment, taking into consideration all of the environmental loads which can act on the element (e.g. chlorides and carbonation).

4.3 LCC/LCA

A full cradle-to-gate LCA of GFRP produced by the ATP Company was performed. Some data was already presented at an international conference, and a full LCA report will be submitted for publication in international journals to make it available for other researchers and practitioners.

5 Published deliverables and achieved milestones

The list of deliverables that were part of the project is reported in Table 1. Similarly, the list of milestones is reported in Table 2. All deliverables were provided to the sponsor and, when applicable, made available to the public via the SEACON website. All milestones were achieved.

Table 1 – Deliverables list

Del. no.	Deliverable name	WP no.	Nature[1]	Dissem. level[2]	Responsible partner	Delivery month
D5.1	Transfer the work of ECOLABEL FP7 and PEF to SEACON	5	O	PP	POLIMI	1
D7.1	Kick off meeting	7	O	PP	UM	1
D1.1	Report on properties and sources of alternative materials	1	R	PU	BUZZI	3
D1.2	Report on required field test properties of concrete	1	R	PU	BUZZI	6
D2.1	Report on field of implementation of GFRP-RC	2	R	PU	UM	9
D3.1	Report on field of implementation of SSR	3	R	PU	POLIMI	9
D1.3	Mix design for tests with non-corrosive reinforcement	1	O	PP	BUZZI	12
D2.2	Report on required field test properties of GFRP-concrete	2	R	PP	UM	12
D3.2	Report on required field test properties of the SSR-concrete	3	R	PP	POLIMI	12
D1.4	Mitigation strategy for overcoming negative effects	1	O	PP	BUZZI	14
D2.3	Recommendations for demo in WP4	2	O	PP	UM	15
D3.3	Recommendations for demo in WP4	3	O	PP	POLIMI	15
D4.1	Selection of infrastructure for on-site application	4	D	PP	UM	15
D5.2	Optimization of mix design from first LCA data	5	O	PP	POLIMI	15
D6.2a	Workshop organization (Milano, Italy)	6	O	PU	POLIMI	15
D7.2	Midterm report	7	R	PP	UM	15
D2.4	Report on long-term tests	2	R	PU	UM	20
D3.4	Report on long-term tests	3	R	PU	POLIMI	20
D4.2	Field demo of culvert in Italy	4	D	PU	BUZZI	22
D4.3	Field demo of bridge in Florida	4	D	PU	OC	22 - Delayed to 28
D4.4	Long-term on-site monitoring of field demos	4	D	PU	UM & POLIMI	23
D5.3	Report on LCA	5	R	PU	POLIMI	25 - Delayed to 28
D5.4	Report LCC analyses described as TCO	5	R	PU	POLIMI	25 - Delayed to 28
D6.4	Exploitation book	6	R	PP	AV	25
D4.5	Collection of LCA and LCC data from field demos	4	O	PP	UM & POLIMI	28
D5.5	Economic assessment	5	R	PU	POLIMI	30
D6.1	Conferences, seminars and technical events in EU	6	O	PU	AV	Continuing
D6.2b	Workshop organization (Miami, FL)	6	O	PU	UM	Moved to 19
D6.3	Conferences, seminars and technical events in USA	6	O	PU	AV	Continuing
D6.5	Guideline for standardization	6	R	PU	UM & POLIMI	30
D7.3	Final report	7	R	PU	UM	30

[1]**R** = Report, **P** = Prototype, **D** = Demonstration, **O** = Other
[2]**PU** = Public; **PP** = Restricted to other program participants (including the Commission Services (CS)); **RE** = Restricted to a group specified by the consortium (including CS); **CO** = Confidential, only for members of the consortium (including CS).

Table 2 – List of milestones

Milestone number	Milestone name	Work package(s) involved	Expected month	Means of verification
MS1	Establish consortium	7	2	Approval of charter
MS2	Seaconcrete mix designs	1	12	Laboratory work completed
MS3	Seaconcrete and GFRP rebar	2	15	Laboratory work completed
MS4	Seaconcrete and SSR rebar	3	15	Laboratory work completed
MS4-A	Midterm report	7	15	Report submitted to Sponsor
MS5	Culvert (IT)	4	22	Field demo completed
MS6	Bridge (FL)	4	22 - Delayed to 28	Field demo completed
MS7	LCC/LCA measures	5	25	Survey and data assembled
MS8	Outreach	6	15-30	Attended national/international events
MS9	Standardization guidelines	6	30	Guidelines to code-writing authorities
MS10	Final report	7	30	Report submitted to Sponsor

As per project requirements, the deliverables and reports were uploaded on the monitoring section of the Infravation management website.

For a detailed list of tech transfer activities conducted during the project, reference is made to section **10 Appendix C – Tech transfer activities**. The last table in this section reports “Lunch & Learn” seminars conducted by UM PhD students at the offices of contractors, engineering firms, and public organizations. The objective of these events, sponsored by SEACON partner Owens Corning, was to create awareness in new technology. The outcomes of these seminars have been extremely positive.

A list of publications is presented in section **11 Appendix D – Publications**.

A website was developed as per project requirement (see http://seacon.um-sml.com/). The website provides relevant information/links to the overall public including: team members, news feeds, tech transfer, and announcements. A private login is available to team members. Noteworthy are two video clips available under the “home” tab describing demo projects undertaken by the team members.

The number of visitors to the website was monitored on a weekly and monthly basis. Statistics for the week of 3/11/18 to 3/18/18 and the month of 2/16/18 to 3/18/18 are presented in Figure 1 to Figure 3.

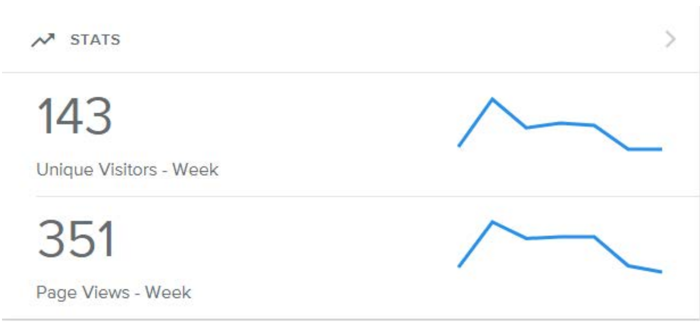

Figure 1 – Number of unique visitors and page views of SEACON website between 3/11/18 to 3/18/18

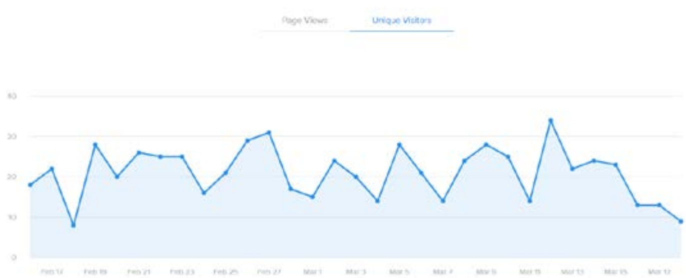

Figure 2 – Number of unique visitors of SEACON website between 2/16/18 to 3/18/18

Figure 3 – Number of page views of SEACON website between 2/16/18 to 3/18/18

6 Remaining research questions and recommendations for further research

6.1 Seaconcrete

A deeper laboratory investigation needs to be done:

- to find strategies to limit the leaching of chlorides into surrounding soils (risking contamination of the adjacent structures with traditional reinforcement);
- to elaborate theories and modeling of the chemical reactions involved in sulphate attack;
- to test the effect that seawater has on low and high C3A cements and on sulphate resistant cements;
- to collect more data about the binding mechanisms of chloride.

In addition, the production of seaconcretes based on innovative binders (in particular, with high amount of Al_2O_3) has to be investigated, for both the concerns with the mechanisms involved when seawater is used, and the mechanical behavior shown when combined with GFRP reinforcement.

It could be interesting to deepen the study, exploring alternative uses of seawater in other phases of concrete production; for example, the role of seawater as a curing agent.

6.2 Reinforcement

6.2.1 GFRP

Microstructural studies using energy dispersive X-ray spectroscopy (EDX) can be used to better understand the chemical aspect associated with the degradation of some properties of the GFRP bars after exposure to accelerated aging.

6.2.2 Stainless steel

The correct selection of the suitable stainless steel reinforcement (SSR) grade based on the exposure condition, type of concrete, and design service life is still an open issue. As a matter of fact, to carry out this selection, data on corrosion resistance (i.e. chloride threshold for pitting corrosion initiation) of the different SSR grades are needed. Little data on the resistance to chloride-induced corrosion of different SSR grades is available, and they refer only to traditional SSR and laboratory tests, not on real RC infrastructures. Furthermore, the effect of concrete carbonation on the critical chloride threshold is still unclear.

Since the tested grades of stainless steel proved to provide excellent resistance to corrosion in seawater concrete (even after further chloride penetration), other less alloyed and less costly grades may be addressed in future research to assess their corrosion behavior in seawater concrete.

6.3 LCC/LCA

As for LCA, the critical point for future assessments of environmental sustainability of FRP-PC/RC is the lack of reliable and updated inventory data for CFRP. Moreover, the LCA performed during this project on GFRP is based only on data from one producer. It should be advisable to find the collaboration of other producers to increase generalizability.

Moreover, maintenance activities of complex infrastructures based on FRP-PC/RC needs further investigation.

7 Lessons learned

7.1 Seaconcrete

Greater awareness of the alternative reinforcements, in particular GFRP, already present on the market has been developed to create successful collaborations.

A better understanding of the Mechanisms occurring in concrete when chlorides are intentionally added.

The feasibility of producing safe cements with a higher addition of chloride, coming from the raw materials used, has been proved.

7.2 Reinforcement

7.2.1 GFRP

Based on the results obtained in this project, the use of seawater as mixing water for a concrete mixture has no significant effect on the durability of GFRP bars.

7.2.2 Stainless Steel

Irrespective of the presence of chlorides in the raw materials used to produce concrete, the use of stainless steel allows guaranteed long service life, on the order of 100 years, even in the case of the further penetration of chlorides.

7.3 LCC/LCA

LCA and LCC analyses have revealed an extremely high potential in reducing environmental impacts. Indeed, an extensive use of seawater and non-corrosive reinforcements in civil infrastructures can positively affect some of the major environmental concerns society is facing, such as water scarcity and global warming.

8 Appendix A - Italian Demo Project: Culvert

A culvert for the collection of drainage waters was designed and built inside the asphalt production plant of Pavimental in Pontenure (close to Piacenza). The culvert is parallel to the A1 motorway, and intersects two lateral gutters for the removal of the waters coming from the adjacent roadway. The motorway is subject to de-icing salts during winter time. In addition, the culvert, being unsheltered, is exposed to wetting and drying cycles (Figure 4).

Figure 4 – Culvert (left) and a lateral ditch for water collection from roadway (right)

The culvert is 30 m long and is divided into 6 individual segments; each segment is representative of a given scenario in terms of type of concrete and type of reinforcement, as shown in Table 3. Compositions of concrete mixes are shown in Table 4. The culvert was completed in November 2016. The evolution of the corrosion conditions of the reinforcement was monitored both manually and with the aid of a data logger, which was specifically designed and built within the project. Besides initial characterization of materials in the laboratory, some cores were taken from the culvert after about 1 year (October 2017) to check the evolution of compressive strength, chloride content, and other physio-chemical parameters. Figure 5 shows the results of compressive tests on concretes produced through the preliminary laboratory investigations in comparison to the on-site concretes.

Table 3 – Types of reinforcement and concrete in culvert segments

Segment	**A**	**B**	**C**	**D**	**E**	**F**
Reinforcement	Carbon steel	Carbon steel	Stainless steel 304 (1.4311)	Stainless steel 23-04 (1.4362)	GFRP	Carbon steel
Concrete	Reference	Seawater	Seawater	Seawater	Seawater	RAP

Table 4 – Composition of concrete mixes (dosage in kg/m^3)

Concrete	Reference	Seawater	RAP
CEM II/A-LL 42.5R	335	335	335
Fly ash	30	30	30
Sand 0-5 mm	800	800	766
Gravel 5-7 mm	365	365	246
Gravel 8-15 mm	630	630	526
RAP	-	-	226
Superplasticiser Addiment T75	2.19	2.19	2.19
Retarding agent VZ53	-	0.76	-
Water	175	-	175
Seawater	-	175	-

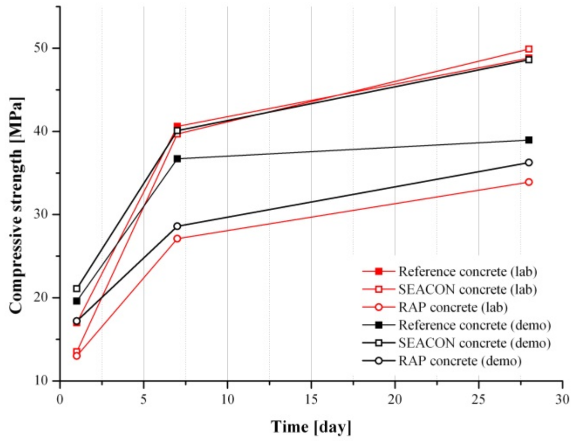

Figure 5 – Strength developments of laboratory concretes vs. on-site concretes

Figure 6 shows the potential of the reinforcement as a function of time, for (A) carbon steel, (B) seawater, and (F) RAP concrete, and for stainless steels (C) 304 and (D) 23-04 in seawater concrete. Initially, the potential was very negative in all conditions, in particular for carbon steel. Afterwards, the potential of carbon steel increased with different rates and reached values of -50/-100 mV vs SSC in reference and RAP concrete, and -200 mV vs SSC in seawater concrete. Also stainless steel showed a slightly increasing trend and reached values of -90 mV vs SSC for 304, and -24 mV vs SSC for 23-04. Although the rebar potential by itself is not enough to draw conclusions on the corrosion conditions of the steel, in real exposure conditions, where many factors affect its value, the preliminary results highlight two different behaviors: carbon steel in reference and RAP concrete and stainless steel in seawater concrete, on one side, and carbon steel in seawater concrete, on the other side. The latter condition is characterized by lower potential values compared to the former. Table 5 summarizes the results of electrochemical measurements and concrete characterization after 1 year: it can be seen that the corrosion rate of steel reinforcement in segment B (that could be measured thanks to the presence of a counter electrode embedded in the concrete) was slightly lower than 1 mA/m^2, and that the chloride contents at the depth of the reinforcements were the same as the initial values for all the segments.

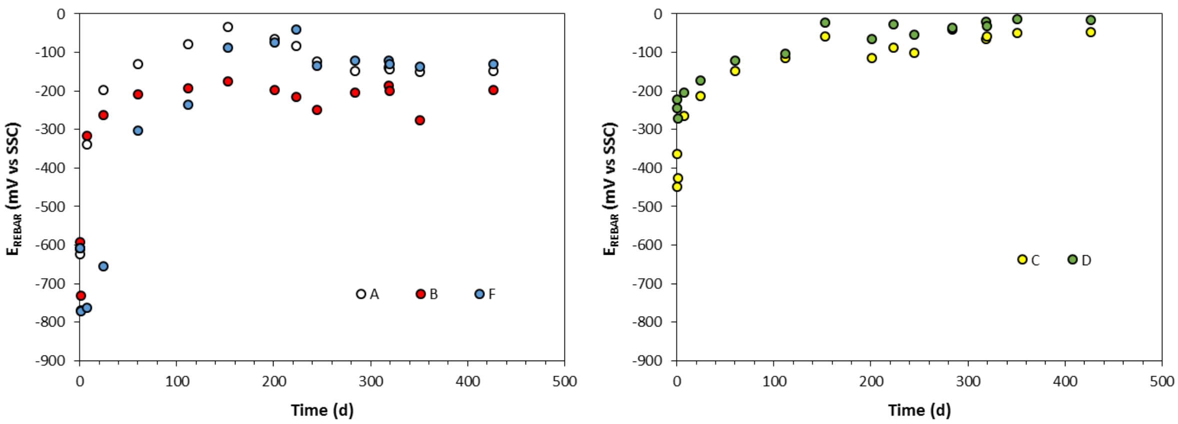

Figure 6 – Potential of reinforcement vs. SSC reference electrode as a function of time: carbon steel in segments A, B and F (left) and stainless steels in segments C and D (right)

Table 5 – Corrosion potential (E), corrosion rate (V_{corr}), concrete resistivity (ρ) and chloride content (Cl) at reinforcement depth of after about one year of exposure

Segment	E (mV vs SSC)	V_{corr} (mA/m2)	ρ (Ω·m)	Cl (% cem)
A	-151	-	43	0.1
B	-275	0.94	75	0.75
C	-49	-	104	0.75
D	-14	-	85	0.75
E	-	-	97	0.75
F	-136	-	39	0.2

Figure 7 shows the concrete resistivity that was measured with the embedded probe at the depth of the reinforcement, as a function of time. Immediately after casting, the resistivity was very low (< 5 ohm·m), then it increased with an alternated trend, remaining lower than 40 ohm·m in all concretes. After 1 year, reference concrete (*A*) and RAP concrete (*F*) showed values of around 40 ohm·m, while seawater concrete (*B*, *C*, *D*, and *E*) showed values around 100 ohm·m.

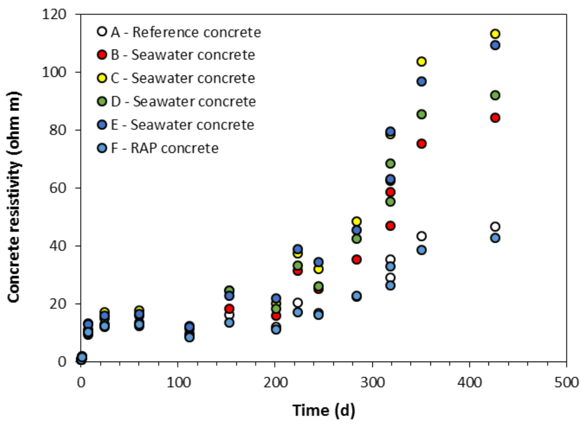

Figure 7 – Concrete resistivity at reinforcement depth as a function of time

The results of the initial characterization, monitoring of corrosion parameters, and physio-chemical analyses carried out after 1 year will serve as a starting point for a better understanding of the future measurements, which will be continued after the completion of the project, in order to collect data on the long-term corrosion behaviour in real exposure conditions.

9 Appendix B - US Demo Project: Halls River Bridge

The US demo project consists of a vehicular bridge built with non-corrosive reinforcement that replaces the functionally obsolete Halls River Bridge in Homosassa, FL. The choice of deploying composite materials as internal reinforcement is mostly due to the fact that the bridge substructure condition is classified as extremely aggressive due to chloride concentrations in the surrounding water and close proximity of the superstructure to water. Then, the use of non-corrosive bars and stirrups addresses long-term durability of cast-in-place concrete bulkhead caps, pile caps, wing-walls, back-walls, deck, traffic barriers, and approach slabs.

The new bridge has five short spans for a total length of 57.69 m, 609.6 mmwide traffic lanes, 2.41 m of outside shoulders, and 1.49 m wide sidewalks with a standard traffic barrier and bridge pedestrian/bicycle railing on each side.

Figure 8 shows the plan and elevation view of the entire bridge (source design project by FDOT).

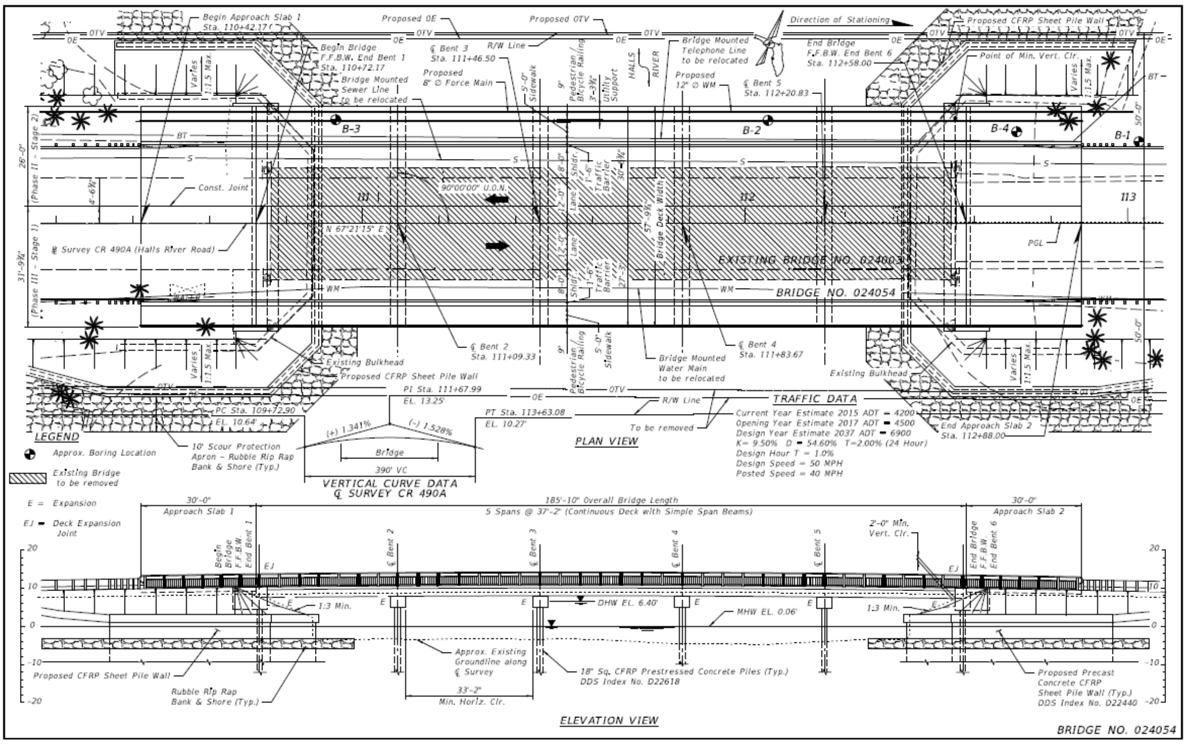

Figure 8 – Plan and elevation view of the FRP-RC Bridge

9.1 Materials and SEACON components

The bridge main structure consists of 36 CFRP square PC bearing piles, 235 CFRP-PC/GFRP-RC sheet piles, 45 HCB hybrid beams, 6 GFRP-RC bent caps, GFRP-RC bulkhead caps, traffic railings and approach slabs, and a 19.20 m long GFRP-RC gravity wall, resulting in the absence of any steel reinforcement in the entire bridge structure.

In addition to innovative reinforcement solutions, the Halls River Bridge features deployment of sustainable concrete mixes in the elements of the substructure. Concrete mixed with seawater is used for the bulkhead cap (Figure 9), while concrete with recycled concrete aggregates (RCA) and concrete with recycled asphalt pavement (RAP) is used for the GFRP-RC gravity walls. White cement concrete and concrete made of a combination of slag and fly ash are used for the GFRP-RC traffic railings for enhanced visibility. The bulkhead cap includes independent wall portions to be periodically extracted and used as test blocks to assess FRP durability in chloride-exposed seaconcrete. The test blocks include GFRP, CFRP, and BFRP bars. All the test blocks, along with the bulkhead sections, were cast with green (seawater) concrete, highlighted in green in Figure 9. The total length of the bulkhead cap sections is about 175.26 m, while the length of the test blocks is approximately 120.40 m.

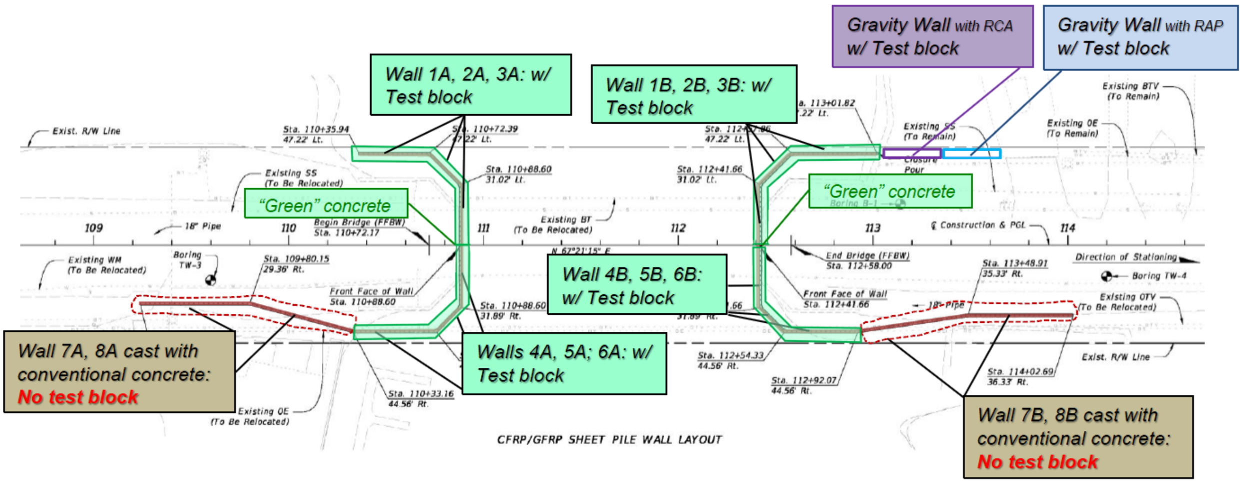

Figure 9 – Bulkhead cap for sheet pile walls design

9.2 CFRP-PC Bearing Piles

The Halls River Bridge comprises a total of 36 CFRP-PC bearing piles, divided over 6 bent caps. The piles are designed according to FDOT Index series 22600 (FDOT, 2016a), for a compressive strength of 732 kip. The cross section is squared with a side of 457.2 m. Prestress is applied through 12 CFRP strands of 15.2 mm diameter tensioned at 34 Kip each. Confinement is provided by a spiral of 5.1 mm. A concrete clear cover of 76.2 mm is guaranteed, which is a value closer to standard practice for steel reinforcement in aggressive subtropical environment. The piles were designed to be driven by impact hammer. Figure 10 show pile driving activities for a series of piles in "Bent 3".

Figure 10 – CFRP-PC bearing piles

During pile installation, the contractor experienced unexpected events and unpredictable soil conditions. To accommodate the unforeseen soil conditions, pile splicing was required. In particular, three 20.12 m piles in "Bent 2," were driven to their cut-off elevation without reaching the required bearing capacity and, therefore, needed to be spliced. In total, six CFCC-prestressed splice piles, 12.80 m long, were fabricated and then connected on-site by epoxy bonded stainless steel dowels and driven to bearing.

9.3 GFRP-RC Bent Caps

The substructure is also detailed to be resistant to corrosion by utilizing GFRP reinforcement. Six GFRP-RC bent caps with a rectangular cross section, having a width of 1.22 mm and a depth of 36 in. (914.4 mm), were cast with approximately 10.06 m^3 of concrete each (Figure 11). The GFRP bar cages are tied using plastic ties and easily moved and placed with the help of a 6-ton tilt deck double axel trailer and a 230-ton crawler crane. Figure 11 shows the GFRP reinforcement cage (left), a detail of the rubber-tipped vibrator (center), and the completed bent cap structure (right).

Figure 11 – GFRP-RC bent caps

9.4 CFRP-PC/GFRP-RC Sheet Piles

The sheet piles were designed for installation by water-jetting to a depth of 7.62 m for a total length of 8.23 m in a cantilever configuration. The unexpected presence of a layer of hard limestone reduced the installation depth to 4.57 m for relevant portions of the wall. To guarantee the required strength and stiffness to the retaining wall, an anchored variant was adopted. The sheet piles were cut to length, and the remaining portions were installed as deadmen. The sheet pile bulk head cap was connected to the deadmen through HSSS rebar tensioned using screw couplers. Figure 12 shows sheet piles installation operations.

Figure 12 – GFRP-RC sheet pile retaining wall

9.5 GFRP Bulkhead Cap and Test Blocks

The sea wall is composed by a total of 235 CFRP sheet piles. The following procedures and pictures only refer to the North-West side, where 35 sheet piles were installed, but the same method will be applied for all the four sections of bulkhead cap pours. Figure 13 shows the North-West section of bulkhead cap, during GFRP rebar tying activities.

Figure 13 – GFRP bulkhead cap cage

Given the sheet piles cut-off to new elevation (due to the already mentioned sea wall re-design), the notch was not guaranteed in some of the interlocks between the piles. Thus, the designed configuration female-female guaranteed at the top of the sheet pile for a length of 304.8 mm, was modified to a male-female connection.

Figure 14 illustrates actual location of FRP rebar inside the test blocks.

Figure 14 – Sample bars in test blocks before concrete casting

Test blocks are rectangular in cross-section, composed of 6 #5 bars made from CFRP/GFRP/BFRP that interchange location along the different wall sections, following the layout summarized in Table 6.

Table 6 – Rebar layout and test block extraction schedule

Wall	Rebar position in test block						Block extraction from casting		Concrete
	i	*ii*	*iii*	*iv*	*v*	*vi*			
1A	CFRP 0.6"		GFRP #5		BFRP #5		12	months	Green
2A	GFRP #5		BFRP #5		CFRP 0.6"		12	months	Green
3A	BFRP #5		CFRP 0.6"		GFRP #5		28	days	Green
1B	BFRP #5		CFRP 0.6"		GFRP #5		24	months	Green
2B	CFRP 06"		GFRP #5		BFRP #5		24	months	Green
3B	GFRP #5		BFRP #5		CFRP 0.6"		6	months	Green
4A	CFRP 0.6"		GFRP #5		BFRP #5		TBD		Green
5A	GFRP #5		BFRP #5		CFRP 0.6"		TBD		Green
6A	BFRP #5		CFRP 0.6"		GFRP #5		TBD		Green
4B	BFRP #5		CFRP 0.6"		GFRP #5		TBD		Green
5B	CFRP 0.6"		GFRP #5		BFRP #5		TBD		Green
6B	GFRP #5		BFRP #5		CFRP 0.6"		TBD		Green
GW	CFRP 0.6"		GFRP #5		BFRP #5		12 months	24 months	RCA
GW	CFRP 0.6"		GFRP #5		BFRP #5		12 months	24 months	RAP

The green concrete used for the seawall portion was a Class IV 5500 psi. After field-acceptance of the mix design, a total of 12.61 m^3 green concrete was poured through a 101.6 mm. pump. Placement of concrete was aided by the rubber-tipped vibrator on site, already used for the previous concrete pours. Three truck-loads of green concrete were poured for the three sections of wall. After each wall section form was filled, the top was then smoothly finished. Figure 15 shows activities of concrete placement and topping, along with the final product of bulkhead cap and test blocks, with HSSS rods anchoring to the deadmen structures.

Figure 15 – Bulkhead cap concrete placement and final product

10 Appendix C – Tech transfer activities

SEACON tech transfer activities - Year 2015

Code	Event name	Event date	Event location	Leader	Website
1	CAMX - ACE Innovation Award Competition	Oct. 26-29	Dallas, TX	Vorobiev	Yes
2	Infravation kick off meeting	Nov. 12-13	Brussels, Belgium	Bertola	Yes

Details of Year 2015 Activities

Code	Reference
1	Video at http://www.thecamx.org/
2	Bertola, F. "SEACON" http://www.infravation.net/projects/SEACON

SEACON tech transfer activities - Year 2016

Code	Event name	Event date	Event location	Leader	Website
1	Citizens Boards Lunch & Learn	Jan. 12	Miami, FL	Nanni	Yes
2	EPTA - 13th World Pultrusion Conf.	March 3-4	Prague, Czechia	Vorobiev	Yes
3	JEC World on the Agora of the SUSTAINABLE Planet	March 8-9	Paris, France	Vorobiev	No
4	Emerge Americas	April 18-19	Miami Beach, FL	Nanni	No
5	2016 Int. Concrete Sustainability Conf.	May 15-18	Washington, DC	Nanni	Yes
6	NACE Concrete Service Life Extension Conf.	May 23-25	Orlando, FL	Lollini	Yes
7	Int. Bridge Conf.	June 6-10	National Harbor, MD	Claure	No
8	5th Int. Conf. on Durability of Concrete Structures	Jun. 30-Jul. 1	Shenzhen, China	Redaelli	Yes
9	Convegno Nazionale AIMAT 2016	July 13-15	Ischia Porto (Na)	Lollini	Yes
10	4th Int. Conf. in Sustainable Constr. Mat.s & Technologies	August 7-11	Las Vegas, NV	Khatib	Yes
11	8th Int. Conf. on Concrete Under Severe Conditions-Environment & Loading	Sept. 12-14	Lecco, Italy	Bertolini	Yes
12	CAMX	Sept. 26-29	Anaheim, CA	Vorobiev &Nolan	Yes
13	Infravation Forum Session FS2	Oct. 18	Delft, Netherlands	Lollini	Yes
14	Int. Market Event Infravation innovation projects	Oct. 19	Delft, Netherlands	Lollini	Yes
15	Scientific Panel and Project Coordinators meeting	Oct. 19	Delft, Netherlands	Lollini	Yes
16	ACI convention	Oct. 23-27	Philadelphia, PA	Nanni	No
17	ASTM Int.-C13 Symp .of Concrete Pipe & Box Culverts	Dec 7	Orlando, FL	Gooranorimi	No
18	Int. Workshop on Seawater Sea-sand Concrete (SSC) Structures Reinforced with FRP Composites	Dec. 13	Hong Kong, China	Nanni, Bertolini, Canonico	Yes

Details of Year 2016 Activities

Code	Reference
1	Nanni, A. “Bridges of the Future – UM Quest for Sustainability” at http://advancement.miami.edu/NetCommunity/Page.aspx?pid=340
2	Vorobiev , M. at http://www.netcomposites.com/events/13th-world-pultrusion-conference/
3	Vorobiev, M. at http://www.jeccomposites.com/events/jec-world-2016/jec-world-2016/innovation-planets

4	E-merge Americas at SEACON in Emerge Americas
5	Nanni, A. "SEACON – a new research project towards the sustainability of concrete" athttp://www.scc2016.com/
6	Lollini, F., M. Carsana, M. Gastaldi, E. Redaelli, L. Bertolini and A. Nanni, "Can seawater Be Used as Mixing Water for Durable and Sustainable RC Structures?" at http://concrete.nace.org/
7	Claure, G., O. Gooranorimi, A. Nanni, F. De Caso y Basalo " Hecht Bridge - IBC 2016 Award Nomination For Project Medal" at https://eswp.com/bridge/bridge-home/
8	Bertolini, L., M. Carsana, M. Gastaldi, F. Lollini, E. Redaelli "Corrosion of Steel in Concrete and Its Prevention in Aggressive Chloride-Bearing Environments" at http://docs.lib.purdue.edu/icdcs/2016/
9	Lollini, F., M. Carsana, F. Torabian Isfahani, L. Bertolini at http://www.aim.it/it/d/13/31/1286/xiii-convegno-nazionale-associazione-italiana-ingegneria-dei-materiali-aimat
10	Khatibmasjedi, S., F. De Caso, A. Nanni3, "SEACON: Redefining Sustainable Concrete" at https://www.unlv.edu/scmt4
11	Lollini, F., M. Carsana, M. Gastaldi, E. Redaelli, L. Bertolini and A. Nanni, "Preliminary Assessment Of Durability of Sustainable RC Structures with Mixed-In Seawater and Stainless Steel Reinforcement" at http://www.consec16.com/
12	CAMX at http://www.thecamx.org/
13-15	Fifth Int. Symposium on Life -Cycle Civil Engineering, IALCCE2016 at http://www.ialcce2016.org/forums/
16	ACI Fall Convention at https://www.concrete.org/events/conventions.aspx
17	Gooranorimi, O., E. Dauer, W. Suaris, J. Myers, A. Nanni, "GFRP reinforcement in box culvert bridge: a case study after two decades of service" athttp://www.astm.org/SYMPOSIA/filtrexx40.cgi?+-P+EVENT_ID+2873+callforpapers.frm
18	CICE 2016 at https://www.polyu.edu.hk/risud/CICE2016/

SEACON tech transfer activities - Year 2017

Code	Event name	Event date	Event location	Leader	Website
1	SEACON Workshop	Jan. 13	Milan, Italy	Bertolini	YES
2	ACI Spring Convention	March 26-30	Detroit, MI	Khatib	YES
3	SEACON FORUM	May 3-4	Tampa, FL	Nanni	YES
4	XIV DBMC - 14th Int. Conf. on Durability of Building Materials and Components	May 29-31	Ghent, Belgium	Bertola and Dotelli	YES
5	Giornate Nazionali sulla Corrosione e Protezione	June 28-30	Milan, Italy	Lollini	NO
6	XIV AIMAT National Congress, XI National Conference on Materials Science and Technology	July 12-15	Ischia Porto, Italy	Redaelli	NO
7	Int. Workshop on Glass Fiber Reinforced Polymer Bar	July 18	Sherbrooke, Canada	Nanni	YES
8	5th Int. Conf. on Durability of FRP Composites for Construction and Rehabilitation of Structures	July 19-21	Sherbrooke, Canada	Khatib	YES
9	Khatib, S., “Durability of GFRP reinforcement in Seawater Concrete – Part 1”, at CAMX 2017	Dec. 14	Orlando, FL	Khatib	YES
10	Padilla, F., Gartman, M., Cadenazzi, T., “Halls-River Bridge: Corrosion-Free Design with FRP Composites”, at CAMX 2017	Dec. 13	Orlando, FL	Cadennazi	NO
11	Claure, G., Rocchetti, P., Siddiqui, M., Nolan, S., Nanni, A., “GFRP Innovative Shapes – Halls River Bridge Replacement Project”, at CAMX 2017 (paper and presentation)	Dec. 13	Orlando, FL	Claure	NO
12	CAMX Combined Strength Award Finalist, “Halls River Bridge – FRP Composites for Next Generation Infrastructure”	Dec. 11-14	Orlando, FL	Nolan	NO

Details of Year 2017 Activities

Code	Reference
1	http://seacon.um-sml.com/
2	https://www.concrete.org/events/conventions.aspx
3	http://seacon.um-sml.com/

4	Bertola, F., F. Canonico, A. Nanni, "SEACON Project: sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement," at http://www.ugent.be/ea/structural-engineering/en/dbmc2017/
5	E.M. Iannicelli-Zubiani, M.I. Giani, P.G. Stampino, G. Dotelli, A. Nanni, "Life cycle assessment of reinforced concrete units", at http://www.ugent.be/ea/structural-engineering/en/dbmc2017/
6	E. Redaelli, M. Carsana, M. Gastaldi, F. Lollini, F. Torabian Isfahani, L. Bertolini, "Corrosion behavior of reinforcement in seawater concrete" at https://www.aimat.net/portfolio-view/xiv-convegno-nazionale-aimat/
7	Lollini at http://www.aimnet.it/gncorr2017.htm
8 & 9	Nanni and Khatib at http://www.civil.usherbrooke.ca/CDCC2017/
10 to 12	CAMX at https://www.thecamx.org/camx-2017-hurricane-irma-update/

SEACON tech transfer activities - Year 2018

Code	Event name	Event date	Event location	Leader	Website
1	Nolan, S., Rossini, M., Nanni, A., “Seawalls, SEACON, and Sustainability in the Sunshine State” at 2018 TRB Annual Meeting (paper and presentation)	Jan 7-11	Washington, D.C.	Rossini and Nolan	NO
2	Nolan, S., Nanni, A., “Halls River Bridge – Composites Replace Steel Reinforcement” at 2018 TRB Annual Meeting (FRP Workshop 679 presentation)	Jan 7-11	Washington, D.C.	Nanni and Nolan	NO
3	LORCENIS – 24th Meeting	March 21-23	Stockholm, Sweden	Bertola	
4	ACI convention	March 25-29	Salt Lake City, UT	Rossini	NO
5	2nd International Workshop on Durability and Sustainability of Concrete Structures	Jun 6-7	Moscow (Russia)	Gastaldi	
6	Bertola, F., Canonico, F., Redaelli, E., Carsana, M., Gastaldi, M., Lollini, F., Torabian Isfahani, F., Nanni, A., “On-site demonstration project of reinforced concrete with seawater” at CTE conference 2018	June 13-15	Lecco, Italy	Bertola and Redaelli	
7	Italian Concrete Days 2018	Jun 13-15	Lecco, (Italy)	Lollini	
8	Italian Concrete Days (IDC 2018)	June 13-15	Lecco, (Italy)	Nanni	
9	9th International Conference on Fiber-Reinforced Polymer Composites in Civil Engineering (CICE 2018)	July 17-19	Paris, France	Rossini	
10	Sixth International Conference on Durability of Concrete Structures (ICDCS 2018)	July 18-20	Leeds, UK	Redaelli	NO
11	4th International Conference on Service Life Design for Infrastructures (SLD4), RILEM week 2018, invited presentation at the special session “Advanced Technology for Marine Concrete Structures”	Aug 26-29	Delft, NL	Redaelli	NO
12	The Sixth International Symposium on Life-Cycle Civil Engineering (IALCCE), Ghent, Belgium	Oct. 28-31	Ghent, Belgium	Dotelli	

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Details of Year 2018 Activities

Code	Reference
1 & 2	TRB 97th meeting at http://www.trb.org/AnnualMeeting/AnnualMeeting.aspx
3	LORCENIS Project at https://www.sintef.no/projectweb/lorcenis/
4	ACI Spring Convention at https://www.concrete.org/events/conventions.aspx
6	DSCS, Moscow, Russia at http://info-iae.ru/en/2nd-international-workshop-on-durability-and-sustainability-of-concrete-structures-dscs-2018/
6 to 8	IDC at http://www.icd-italianconcretedays.it/
9	CICE at http://www.cice2018.com/en
10	ICDCS at https://engineering.leeds.ac.uk/info/201479/conferences/270/sixth_international_conference_on_durability_of_concrete_structures_icdcs2018
11	RILEMWEEK 2018 at https://www.eventilo.com/93870/wiki/247757/sld4-conference
12	IALCCE. Ghent, Belgium at http://www.ialcce2018.org/#/home

SEACON Lunch & Learn Seminars - Years 2017 and 2018

Code	Event date	Event location	Company/Organization	Presenter
1	Oct. 24, 2017	Miami, FL	EAC Consulting, Inc.	Morteza Khatibmasjedi & Alvaro Ruiz Emparanza
2	Oct. 25, 2017	Coral Gables, FL	City of Coral Gables	Janna Brown & Guillermo Claure
3	Oct. 25, 2017	Miami, FL	DESIMONE Consulting Engineers	Houman Akbary Hadad & Vanessa Benzecry
4	Oct. 31, 2017	Fort Lauderdale, FL	Thornton Tomasetti	Morteza Khatibmasjedi & Carlos Morales
5	Oct. 31, 2017	New York, NY	Thornton Tomasetti (via webinar)	Morteza Khatibmasjedi & Carlos Morales
6	Dec. 12, 2017	Orlando, FL	Lein Construction	Morteza Khatibmasjedi, Francisco de Caso & Alvaro Ruiz Emparanza
7	Dec. 13, 2017	Orlando, FL	Parsons	Morteza Khatibmasjedi & Alvaro Ruiz Emparanza
8	Jan. 17, 2018	Tampa, FL	WSP - Parsons Brinckerhoff	Alvaro Ruiz Emparanza
9	Jan. 17, 2018	Tampa, FL	WGI Inc.	Alvaro Ruiz Emparanza
10	Jan. 17, 2018	Tampa, FL	FDOT D7 Structural Group	Alvaro Ruiz Emparanza
11	Jan. 18, 2018	Tampa, FL	Atkins	Alvaro Ruiz Emparanza
12	Jan. 18, 2018	Tampa, FL	City of St. Petersburg	Alvaro Ruiz Emparanza
13	April 2018 (TBD)	Tampa, FL	Atkins Miami	TBD
14	April 2018 (TBD)	Tampa, FL	AECOM	TBD

11 Appendix D – Publications (alphabetical order)

11.1 Articles Published in Refereed Journals

1. Gooranorimi, O., and A. Nanni, "GFRP Reinforcement in Concrete after 15 Years of Service," ASCE JCC, Vol. 21, No. 5, Sept.-Oct. 2017, DOI: 10.1061/ (ASCE)CC.1943-5614.0000806, 04017024-1 to 9.
2. Gooranorimi, O., W. Suaris and A. Nanni, "A Model for the Bond of a GFRP Bar in Concrete," Engineering Structures, 146 (2017) 34–42, June 2017.
3. Gooranorimi, O., W. Suaris, E. Dauer and A. Nanni, "Microstructural Investigation of Glass Fiber Reinforced Polymer Bars," Composites Part B: Engineering, Vol. 110, Feb. 2017, pp. 388–395.
4. Lollini, F., Carsana, M., Gastaldi, M., Redaelli, E., Torabian Isfahani, F., Bertolini, L., Corrosion behavior of reinforcement in concrete with chloride-contaminated raw materials-Part I: Laboratory tests, Metallurgia Italiana, Vol. 109(7-8), pp. 39-42, 2017.
5. Nolan, S. and A. Nanni, "Deployment of Composite Reinforcing Part 1: Impetus for more widespread application in transportation infrastructure," Concrete International, Vol. 39, No. 5, May 2017, p. 40-46.
6. E. Redaelli, M. Carsana, M. Gastaldi, F. Lollini, F. Torabian Isfahani, L. Bertolini, Corrosion behavior of reinforcement in concrete with chloride-contaminated raw materials-Part II: On site preliminary results, Metallurgia Italiana, Vol. 109, No. 7-8, July-August 2017, p. 43-46, 2017.
7. Spadea, S., Rossini, M., & Nanni, A. (2018). Design Analysis and Experimental Behavior of Precast Double-Tee Girders with CFRP Strands. *PCI Journal, 63(1)*, 72-84.
8. Xiao, J., C. Qiang, A. Nanni and K. Zhang, "Use of sea-sand and seawater in concrete construction: current status and future opportunities," Construction and Building Materials Vol. 155 (Aug. 2017), pp. 1101–1111.

11.2 Articles Published in Refereed Proceedings

1. Bertola, F. Canonico, F. and A. Nanni, "SEACON Project: sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement," RILEM Proceedings PRO 107; Proceedings of XIV DBMC - 14th International Conference on Durability of Building Materials and Components, 29-31 May 2017, Ghent University, Belgium; eds. G. De Schutter, N. De Belle, A. Janssens, N. Van Den Bossche ; RILEM publications S.A.R.L., Paris, France, 2017, 353-354; e-ISBN : 978-2-35158-159-9.
2. Cadenazzi, T., Rossini, M., Nolan, S., Dotelli, G., Arrigoni, A., & Nanni, A. (2018). Resilience and Economical Sustainability of a FRP Reinforced Concrete Bridge in Florida: LCC Analysis at the Design Stage. The Sixth International Symposium on Life-Cycle Civil Engineering (IALCCE). Ghent, Belgium.
3. Claure, G., F. De Caso and A. Nanni, "Construction and Monitoring of the Innovation Bridge," 34th Annual International Bridge Conference (IBC) Proceedings, national Harbor, MD June 5-8, 2017, pp. 22-34.
4. Gooranorimi, O., T. Bradberry, and A. Nanni, "Durability of GFRP Reinforcement in Built Structures: A 15-Year Old Concrete Bridge Deck," Fifth International Conference on Durability of Fiber Reinforced Polymer (FRP) Composites for Construction and Rehabilitation of Structures, July 19-21, 2017, Sherbrooke, Quebec, Canada, pp. 87-94.
5. Iannicelli Zubiani, E.M., M.I. Giani, P. Gallo Stampino, G. Dotelli and A. Nanni, "Life cycle assessment of reinforced concrete units," RILEM Proceedings PRO 107; Proceedings of XIV DBMC - 14th International Conference on Durability of Building Materials and Components, 29-31 May 2017, Ghent University, Belgium; eds. G. De Schutter, N. De Belle, A. Janssens, N. Van Den Bossche; RILEM publications S.A.R.L., Paris, France, 2017, 347-348; e-ISBN : 978-2-35158-159-9.

6. Khatibmasjedi, M. and A. Nanni, “DURABILITY OF GFRP REINFORCEMENT IN SEAWATER CONCRETE,” American Concrete Institute Special Publication.
7. Khatibmasjedi, M., G. Claure and A. Nanni, “DURABILITY OF GFRP REINFORCEMENT IN SEAWATER CONCRETE – PART I “ CAMX 2017 - The Composites and Advanced Materials Expo, December 12-14, 2017, Orlando, Florida.
8. Khatibmasjedi, M. and A. Nanni, “Durability of GFRP Reinforcement in the SEACON Project,” Fifth International Conference on Durability of Fiber Reinforced Polymer (FRP) Composites for Construction and Rehabilitation of Structures, July 19-21, 2017, Sherbrooke, Quebec, Canada, pp.273-282.
9. Khatibmasjedi, S., F. De Caso and A. Nanni, “SEACON: Redefining Sustainable Concrete,” Fourth International Conference on Sustainable Construction Materials and Technologies (SCMT4), August 7-11, 2016.
10. Lollini, F., M. Carsana, M. Gastaldi, E. Redaelli, L. Bertolini and A. Nanni, “Preliminary Assessment Of Durability of Sustainable RC Structures with Mixed-In Seawater and Stainless Steel Reinforcement,” 8th International Conference on Concrete Under Severe Conditions-Environment & Loading, Lecco, Italy, Sept. 12-14, 2016.
11. Lollini, F., M. Carsana, M. Gastaldi, E. Redaelli, L. Bertolini and A. Nanni, “Can Seawater Be Used as Mixing Water for Durable and Sustainable RC Structures?” NACE Concrete Service Life Extension Conference, Orlando, FL, May 23-25, 2016.
12. Rinaldi, V., M. Savoia and A. Nanni, “Safety-Shaped Concrete Bridge Railings and Traffic Barriers Using GFRP Reinforcement,” International Workshop on: “Durability & Sustainability of Concrete Structures” (DSCS 2015) Bologna (Italy), October 1-3, 2015, ACI SP-305, Eds.: A. Chiorino, L. Coppola, C. Mazzotti, R. Realfonzo, and P. Riva, SP-305-21, 9 pp.
13. Rocchetti, P., Claure, G., Nanni, A., “Implementation of Closed GFRP Stirrups in FDOT FRP-RC Design of Traffic Barriers”, at FRPRCS-13 / ACI 2017 (Los Angeles, CA)
14. Rossini, M., Bruschi, E., Matta, F., Poggi, C., & Nanni, A. (2017). Case-Specific Parametric Analysis as Research-Directing Tool for Analysis and Design of GFRP-RC Structures. *The 13th International Symposium on Fiber-Reinforced Polymer Reinforcement for Concrete Structures.* Anaheim, CA: American Concrete Institute.
15. Rossini, M., Cadenazzi, T., Nolan, S., & Nanni, A. (2018). SEACON and resilient FRP-RC/PC Solutions: The Halls River Bridge. *Italian Concrete Days.* Lecco, IT: Associazione Italiana Calcestruzzo Armato e Precompresso (AICAP) & Collegio dei Tecnici della Industrializzazione Edilizia (CTE).
16. Rossini, M., Spadea, S., & Nanni, A. (2018). Pedestrian Bridge as Claryifying Example of FRP-RC/PC Design. *Technical Session on Advances in Concrete Bridges: Design Construction and Rehabilitation in Memory of Dr. Dennis Mertz.* Salt Lake City, UT: American Concrete Institute.
17. Selicato, F., M. Moro, L. Bertolini and A. Nanni, “Sustainable Concrete Without Chloride Limits,” 2015 International Concrete Sustainability Conference, May 11-13, Miami, FL.; Proc. on line at: http://www.nrmcaevents.org/?nav=display&file=768
18. Selicato, F., M. Moro, L. Bertolini and A. Nanni, “Towards Sustainability of Concrete without Chloride Limits,” International Workshop on: “Durability & Sustainability of Concrete Structures” (DSCS 2015) Bologna (Italy), October 1-3, 2015, ACI SP-305, Eds.: A. Chiorino, L. Coppola, C. Mazzotti, R. Realfonzo, and P. Riva, SP-305-46, 9 pp.
19. Spadea, S., Rossini, M., & Nanni, A. (2017). Design of CFRP Pre-Stressed Double-Tee Girders and Experimental Behavior Under Service Load. *Fourth Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures (SMAR 2017).* Zurich, CH.

11.3 Articles Published in Non-Refereed Journals

1. Bertola, F., F. Canonico, M. Bianchi and A. Nanni, “The SEACON Project,” International Cement Review, June 2016, pp. 63-66.
2. Cadenazzi, T. (2017). Halls River Bridge: Corrosion-Free Design with FRP Composites. Part 3: Contractor Perspective. The Composites and Advanced Material Expo (CAMX 2017). Orlando, FL.
3. Cadenazzi, T., R. Hunter, M. Siddiqui, A. Nanni, “Halls River Bridge project”, Composite Manufacturing Magazine, 2018 in print.

12 Appendix E – Agendas of events and workshops

12.1 International Workshop on Seawater and Sea sand Concrete, Hong Kong, China

Final Announcement and Workshop Programme

International Workshop on Seawater Sea-sand Concrete (SSC) Structures Reinforced with FRP Composites

13 December 2016, Hong Kong, China

Organised by
Department of Civil and Environmental Engineering & Research Institute for Sustainable Urban Development (RISUD)
The Hong Kong Polytechnic University

Sponsored by
RISUD

Co-sponsored by
SEACON and Fibrpro International Limited

Aim

This workshop aims to provide the first international forum for in-depth exchanges on seawater sea-sand concrete (SSC) structures reinforced with fibre-reinforced polymer (FRP) composites (referred to as FRP-SSC structures) and closely related topics (e.g., behaviour of SSC; field exposure tests of FRP bars and tubes in marine environments) to achieve the following specific objectives:

(1) Examine in detail the advantages and challenges brought about by FRP-SSC structures;
(2) Provide a survey of research projects being undertaken or planned around the world on FRP-SSC structures and closely related topics;
(3) Identify key issues to be tackled before FRP-SSC structures can be widely accepted in practice; and
(4) Explore opportunities for international collaboration to accelerate research progress in the area.

Organizing Committee

Chair: Professor Jin-Guang TENG (cejgteng@polyu.edu.hk)
Co-chair: Dr. Jian-Guo DAI (cejgdai@polyu.edu.hk)
Secretariat: Dr. Guang-Ming CHEN (hustcgm@gmail.com)
Ms. Jan LIEN (jan.lien@polyu.edu.hk)

Workshop Programme

The workshop will last for one whole day and will be held on 13 December as a pre-CICE 2016 (14-16 December) workshop. The workshop will consist of invited presentations and extensive discussions. Each invited speaker will be given a 25-minute time slot: 15 minutes for the presentation and 10 minutes for the follow-on discussions.

Workshop Programme
Room V312, Floor 3, Jockey Club Innovation Tower (JCIT), PolyU

Time	Invited Speaker	Title of presentation
8:00-8:30	***Registration***	
8:30-8:40	***Opening remarks by Prof. J.G. Teng***	
8:40-9:05	Prof. Feng XING Shenzhen University, China	Study on the performance of concrete made with dredged marine sand from the Pear River mouth
9:05-9:30	Prof. Brahim BENMOKRANE University of Sherbrooke, Canada	Microstructural characterization and durability of GFRP reinforcing bars exposed to concrete environment & saline solution
9:30-9:55	Dr Itaru NISHIZAKI Innovative Materials and Resources Research Centre, Public Works Research Institute, Tsukuba, Japan	Degradation of FRP composites exposed to seawater
9:55-10:20	Prof. Gui-Jun XIAN Harbin Institute of Technology, China	Long-term exposure performance of FRP composites in marine environments
10:20-10:40	**Coffee Break**	
10:40-11:05	Prof. Jian-Fei CHEN Queen's University Belfast, UK	Behaviour of FRP-confined seawater sea-sand concrete
10:05-11:30	Prof. Xiao-Ling ZHAO Monash University, Australia	Current research at Monash University on hybrid construction using seawater sea-sand concrete and FRP
11:30-11:55	Prof. Jian-Zhuang XIAO Tongji University, China	Bond behaviour between seawater sea-sand concrete and FRP
11:55-12:20	Prof. Peng FENG Tsinghua University, China	Experimental study on seawater coral aggregate concrete filled FRP tubes under axial compression
12:20-14:00	**Lunch (Free for all participants)**	
14:00-14:25	Prof. Jin-Guang TENG The Hong Kong Polytechnic University, China	Hybrid structures made of seawater sea-sand (SSC) concrete and FRP: current status and research needs
14:25-14:50	Prof. Larry C. BANK City College of New York, USA	How do we determine the sustainability of seawater sea-sand concrete and fibre-reinforced polymer composite (FRP-SSC) structures?
14:50-15:15	A/Prof. Florence SANCHEZ Vanderbilt University,USA	Chemomechanical behaviour of cement-based materials and molecular dynamics modelling at interfaces
15:15-15:40	Prof. Yi-Qing NI The Hong Kong Polytechnic University, Hong Kong, China	Layer-by-layer assembly of multi-walled carbon nanotubes on long-period grating sensors for marine environmental monitoring
15:40-16:00	**Coffee Break**	
16:00-16:25	Prof. Antonio NANNI University of Miami, USA	SEACON and the Halls River Bridge project*
16:25-16:50	Prof. L. BERTOLINI Politechnic of Milan, Italy	Concrete durability and the A1 Motorway culvert project*
16:50-17:15	Dr. F. CANONICO Buzzi Unicem SpA, Italy	Perspective of a cement manufacturer on seawater sea-sand concrete*
17:15-18:00	**Discussions**	

* ***Presentation via WebEX***

12.2 SEACON First Workshop, Milan, Italy

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SEACON - Sustainable concrete using seawater, salt-contaminated aggregates, and noncorrosive reinforcement

Mid-term Workshop

13th January 2017, 15:00-17:45 CET (9:00-11:45 EST)

Lecture room MA.1, Politecnico di Milano, Mancinelli campus, via Mancinelli 7, 20131 Milan - Italy

Broadcast on-line via Skype Professional

Advancement of the SEACON project at month 15

Nowadays design standards worldwide aim at limiting the use of chloride-contaminated materials for reinforced concrete (RC) structures. Beside possible effects on the early stages of cement hydration and the long-term development of strength, the primary reason is corrosion of black steel reinforcement. However, the use of chloride-contaminated raw materials for the production of concrete would allow saving natural resources, such as fresh water, leading to enhanced environmental sustainability.

Within the framework of ERA-NET Plus Infravation 2014, an infrastructure innovation program on "Advanced systems, materials and techniques for next generation infrastructure" (http://www.infravation.net/), the SEACON project - Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement (http://seacon.um-sml.com) was started on October 2015. 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. Integral to the study are two experimental tracks.

During this workshop, the mid-term advancement in the research conducted by the various partners will be presented and discussed, in order to better finalize the prosecution of the project. The workshop is open to the project partners, collaborators, program managers, and funding organizations.

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Agenda

15:00 - **Opening of the workshop** - Bertolini (Politecnico di Milano)

15:05 - **Presentation of the SeaCon Project** - Nanni (University of Miami)

15:10 - **Effects of seawater and salt-contaminated aggregates on concrete** - Bertola (Buzzi)

15:30 - **Sea-concrete and GFRP rebars** - Nanni, Khatibmasjedi (University of Miami)

15:50 - **Use of sea-concrete and stainless steel rebars** - Carsana, Lollini (Politecnico di Milano)

16:10 - **LCA-LCC analyses of infrastructures made with SeaCon and GFRP or SSR bars** - Dotelli, Gallo Stampino (Politecnico di Milano)

16:30 - **Advancement of Halls River Bridge field demonstration project in Florida** - Nolan (FDOT)

16:50 - **Advancement of culvert along *A1* motorway field demonstration project in Italy** - Canonico (Buzzi), Pela (Pavimental), Redaelli (Politecnico di Milano)

17:10 - **Open discussion** on present results and project prosecution, with possible contributions from program managers and funding organizations (Infravation, ANAS and FHWA)

17:45 - **Closure of the workshop**

Registration

Registration to the workshop can be simply made by sending an email message to Dr. Matteo Gastaldi (matteo.gastaldi@polimi.it). The deadline for registration is 20 December 2016. People interested in participating on-line should specify the email address to which they wish to receive the invitation for the remote connection via Skype Professional.

12.3 SEACON Second Forum/FDOT Workshop, Tampa, FL

SEACON Forum and FDOT – Halls River Bridge Workshop
May 3 – 4, 2017
Tampa, Florida
Preliminary Agenda

SEACON Forum

Wednesday, May 3, 2017 8:00 AM to noon

Holiday Inn & Suites Tampa North
11310 North 30th Street, Tampa, Florida 33612

(Live streaming is being planned for the SEACON forum)

1. Introduction (Prof. A. Nanni)
2. Seawater/RCA Concrete
   a. TBA
   b. Halls River RCA/RAP Concrete Gravity Walls (WP4)
3. FRP Reinforcing
   a. TBA
4. SS Reinforcing
   a. TBA
5. Closing Remarks
6. Box lunch will be provided for forum attendees at FDOT - District 7 Headquarter (noon to 1:00 PM).
7. Shuttle transportation from Holiday Inn & Suites Tampa North to FDOT - District 7 Headquarter and back will be provided.
8. Dinner will be provided for Forum attendees at Holiday Inn & Suites Tampa North (6:00 PM to 8:00 PM)

FDOT – Halls River Bridge Workshop held by Florida Department of Transportation

Wednesday, May 3, 2017 1:00 PM to 5:00 PM

FDOT - District 7 Headquarter
Executive Conference Room
11201 North Malcom McKinley Drive, Tampa, Florida 33612

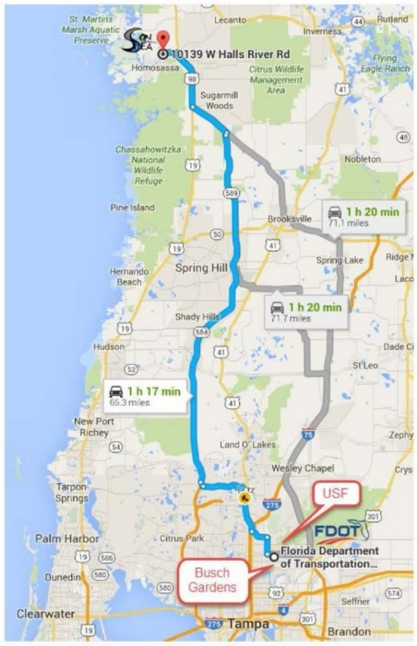
(Webinar live streaming will be available)

1. Welcome (5 min.)
2. Presentations (3 hrs)
   a. Project overview (Suarez/Pelham)
   b. Hybrid Composite Beams (Masseus/Siddiqui/Hillman)
   c. GFRP-RC Deck Design (Siddiqui/Nanni)
   d. GFRP-Traffic Railing Design (Nolan/Hudson)
   e. GFRP-RC Bent Cap Design (Elisha/ Siddiqui/Pelham)
   (Break 15 min)
   f. Back wall/ Wing Wall/ Diaphragm design(Siddiqui/Hunter)
   g. GFRP/CFRP Prestressed Concrete Sheet Pile Walls (Nolan/Koshy)
   h. CFRP Prestressed Bearing Piles (Nolan/Koshy)
   i. Research Project & Instrumentation Discussion (Knight/Kampmann)
   j. CEI's Insight & Future Recommendations (CEI/D7 Construction)
3. Closing Remarks (5 min.)

Halls River Site Visit
Thursday, May 4, 2017 7:30 AM to 1:00 PM

7:30 AM – 9:00 AM Travel 1.5 hrs – Shuttle bus will be provided
9:00 AM – 11:30 AM Site Tour (2.5 hrs by Contractor, CEI and Designer)
1. Contractor Insight & Recommendations (30 mins)
2. Walk the site (2 or 3 groups - 2 hrs)
11:30 AM adjourn (Return to Tampa)

Map to Halls River Bridge Site (FDOT/SEACON-WP4 Project):



12.4 Workshop on GFRP Bar, Sherbrooke, Canada

First Announcement and Call for Participation
International Workshop on
Glass Fiber Reinforced Polymer Bar
18 July 2017, Delta Hotel, Sherbrooke, QC, CANADA

Organisers:

Chair: Brahim Benmokrane, Professor of Civil Engineering and Tier-1 Canada Research Chair, and NSERC/Industry Research Chair, University of Sherbrooke, QC, CANADA

Co-Chair: Antonio Nanni, Inaugural Senior Scholar Professor and Chair Dept. of Civil, Arch. & Environ. Engineering, University of Miami, FL, USA

Introduction:

The deterioration of concrete infrastructure owing to corrosion of reinforcement steel is one of the major challenges facing the construction industry today. Worldwide, governments and industrial firms are looking for infrastructure systems that are stronger, last longer, are more resistant to corrosion and cost less to build and maintain. Engineers all over the world are searching for new and affordable construction materials as well as innovative approaches and systems to solve problems. As a result, in the last decade, there has been a rapid increase in using **innovative noncorrosive glass fiber-reinforced polymers (GFRP)** reinforcing bars for concrete structures due to enhanced properties and cost-effectiveness. The GFRP bars have been used extensively in different applications such as bridges, parking garages, water tanks, tunnels and marine structures in which the corrosion of steel reinforcement has typically led to significant deterioration and rehabilitation needs. Many significant developments from the manufacturer, various researchers and Design Codes along with numerous successful installations have led to a much higher comfort level and exponential use with designers and owners. After years of investigation and implementations, public agencies and regulatory authorities in North America have now included GFRP as **a premium corrosion resistant reinforcing material** in their corrosion protection specifications. Currently, Canadian Highway Bridge Design Code and the *AASHTO* LRFD Bridge Design Specifications contain design provisions for the design of concrete bridge members reinforced with FRP bars. As a result, over 400 bridges across Canada and USA have been designed and constructed using GFRP bars.

The workshop will be **one day ONLY** on 18 July 2017 as a PRE-**CDCC 2017** (19-21 July) international conference (**www.civil.USherbrooke.ca/CDCC2017**) which you are invited to attend too.

Objectives of the Workshop:

This workshop will provide a unique opportunity for end-users, contractors, consultants, engineers firms, GFRP bar manufacturers, and researchers to **exchange up-to-date knowledge** on the use of GFRP bars in concrete structures including **challenges and opportunities.** The workshop will consist of presentations by government authorities such as the Ministry of Transportation of Ontario, the Ministry of Transportation of Quebec, Florida Department of Transportation, and Texas Department of Transportation, consultants, GFRP manufacturers, researchers and open discussions.

Topics to be presented and discussed are:

1. End-User Perspective & Experience
2. Contractor Perspective & Experience
3. GFRP Bar Industry Overview & Future
4. Usage Expansion of GFRP bars
5. CSA, ACI, and AASHTO Codes, Standards, and Specifications Perspective
6. Ongoing technical issues/initiatives/gaps.

Call for Participation:

Structure owners, contractors, GFRP manufacturers, researchers/practitioners who would like to attend the Workshop should send a simple email to CDCC-2017@USherbrooke.ca or Brahim.Benmokrane@USherbrooke.ca to register their interest in attending the Workshop by **January 15, 2017.** The Workshop does not charge a registration fee, but this registration is necessary to guarantee a seat and for the proper planning of the Workshop.

Sponsors:

Natural Science and Engineering Research Council (NSERC) of Canada
Canada Research Chairs Program
University of Sherbrooke
University of Miami
SEACON (An Infravation Project)

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SEACON

12.5 Tech Session at TRB 2018, Washington, DC

TRB's 97th Annual Meeting, January 7-11, 2018, in Washington, D.C

Lectern Session: 679

Event Location: 204C, Convention Center

Sponsored By: Standing Committee on Structural Fiber Reinforced Polymers (AFF80)

Event Title: Innovative Applications of FRP Composites, Part 2 (Part 1, Session 277)

Event Date: Tue 1/9/2018, 3:45 PM-5:30 PM

Presentations

- Seawalls, SEACON, and Sustainability in the Sunshine State
- Halls River Bridge: Composites Replace Steel Reinforcement
- Experimental Testing of PC Girders with Damaged End Regions Repaired using FRP Laminates
- Smart Composite Materials for Terrestrial Infrastructures, Offshore Constructions and Transport