Session 2: GFRP Bar Manufacturer's Installer's, & Supplier's Perspective

(3:20 - 5:20pm)

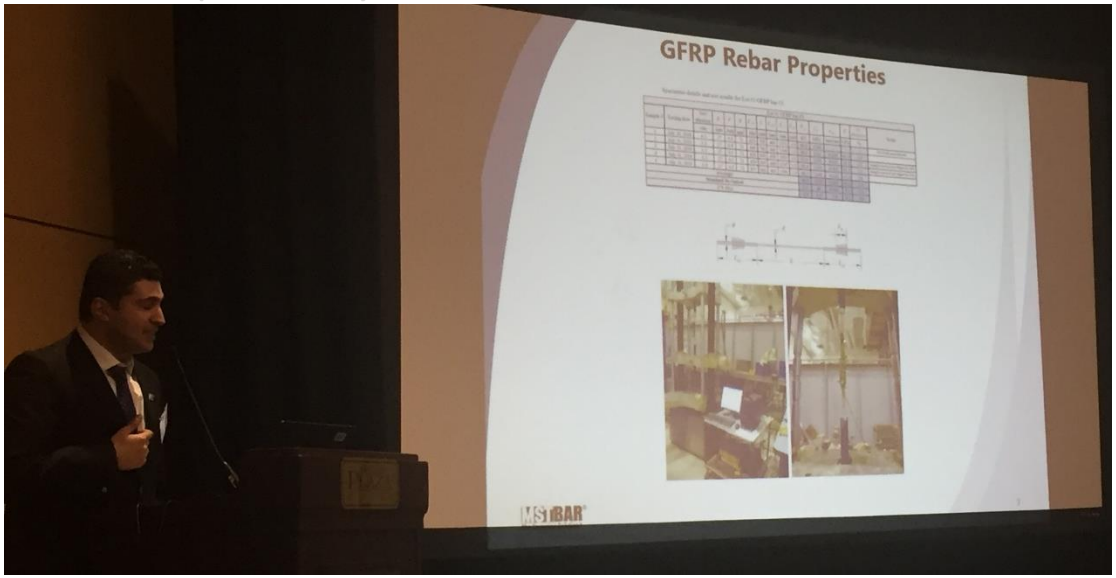
Presentations (3 @ 10 mins)

2.1 – B&B FRP Manufacturing Unique Projects *(Borna Hajimiragha)*

2.2 - Owens Corning Lessons Learned *(Doug Gremel)*

2.3 – GFRP Quality Control *(Xavier Seynave)*

Discussion 2.4 (90 mins)



Prepared by
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January 2019

Repair of Damaged Bent Caps & Columns Using SCC & GFRP Rebar

B&B FRP Manufacturing Inc.

SEG Ingeniería

ICONSA INGENIERÍA CONTINENTAL, S.A.

PCS

MSTBAR® The Corrosion Solution

“South Corridor” in Panama, Panama

- Inaugurated in 2000
- 1.5 miles
- 6 lanes
- NU1350 girders, five foot deep pile cap, 4 x 48” Diameter columns
- Road Concession - Toll road. Bought back by government in 2015

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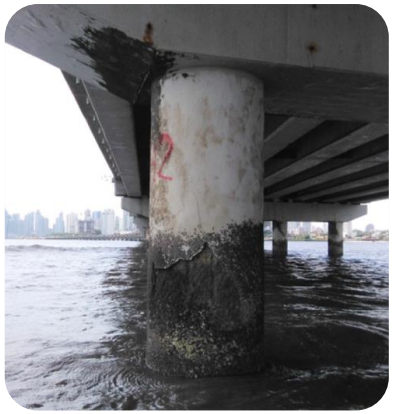
“South Corridor” in Panama, Panama

Initial Condition

- Highly Aggressive Environment
- Spalling in NU girders and in pile caps
- Columns have longitudinal cracks consistent with corrosion damage
- Concrete design strength
  - Columns 2500 psi
  - Pile Caps 4500 psi



Initial Condition

Left: damage at underside of bent caps, Right: close-up of broken corner of stirrup

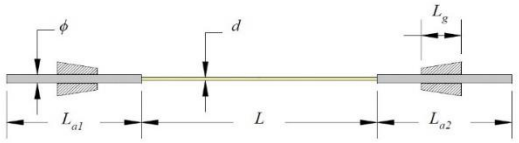
About the Rehabilitation Project

- 14M USD project
- Design & Build awarded to ICONSA
- 21 months
  - 3 months of evaluation and design of retrofits: concrete cores for strength, chloride contents, corrosion rate, corrosion potential, carbonation
  - 18 months of rehab works
- Seabed is dry during low tides for about 6 hours
- No daytime traffic closures allowed
- Three main activities:
  - Column Rehab
  - Bent cap
  - Superstructure

GFRP Rebar Properties

Specimens details and test results for Lot #1 GFRP bar #3.

Lot #1 GFRP bar #3																
Sample #	Testing date	Test duration	ϕ	d	A	L_{a1}	L	L_{a2}	L_t	L_g	P_u	f_u	ε_u	E	Ult Elongation	Notes
		min	mm	mm	mm^2	mm	mm	mm	mm	mm	kN	MPa	mm/mm	GPa	%	
1	July 20, 2018	4.1	27	9.5	71	420	705	400	1525	115	88.3	1244	-	-	-	No strain measurments
2	July 31, 2018	3.5	27	9.5	71	400	700	400	1500	115	88.1	1241	0.020	61.7	2.0	
3	July 31, 2018	3.2	27	9.5	71	450	695	450	1595	115	92.0	1295	0.021	61.5	2.1	Sample received not aligned in tube
4	July 31, 2018	3.3	27	9.5	71	450	697	400	1547	115	95.4	1343	0.022	61.5	2.2	Sample received not aligned in tube
5	July 31, 2018	2.9	27	9.5	71	497	603	400	1500	115	88.7	1249	0.020	61.8	2.0	
Average											90.5	1274	0.021	61.6	2.1	
Standard Deviation											3.2	44	0.001	0.1	0.1	
CV (%)											3.5	3.5	3.9	0.2	3.9	



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Column Rehabilitation

- Removal of contaminated concrete through hydro demolition
- Replace of highly damaged rebar
- Apply epoxy-cement passivator coat
- Apply Migrating corrosion inhibitor (longitudinal reinforcement is not exposed)
- Install GFRP cage for shrinkage control
- Install Permanent FRP jacket
- Cast new self-consolidating concrete (Type I cement, Corrosion inhibitor, ~12000 psi @ 28 days)

Two Options

- Use pre-packed repair mortar
  - PRO: Very little shrinkage, very high early strength, low permeability
  - CON: $$$$$$$$$
- Use self-compacting concrete with 3/8" aggregate
  - PRO: high early strength, low permeability, Surface resistivity is ~40 KOhm-cm, $$$
  - CON: possible shrinkage problem
- **Shrinkage in SCC was addressed by the use of GFRP reinforcement. Approximately 1.2M USD in savings.**

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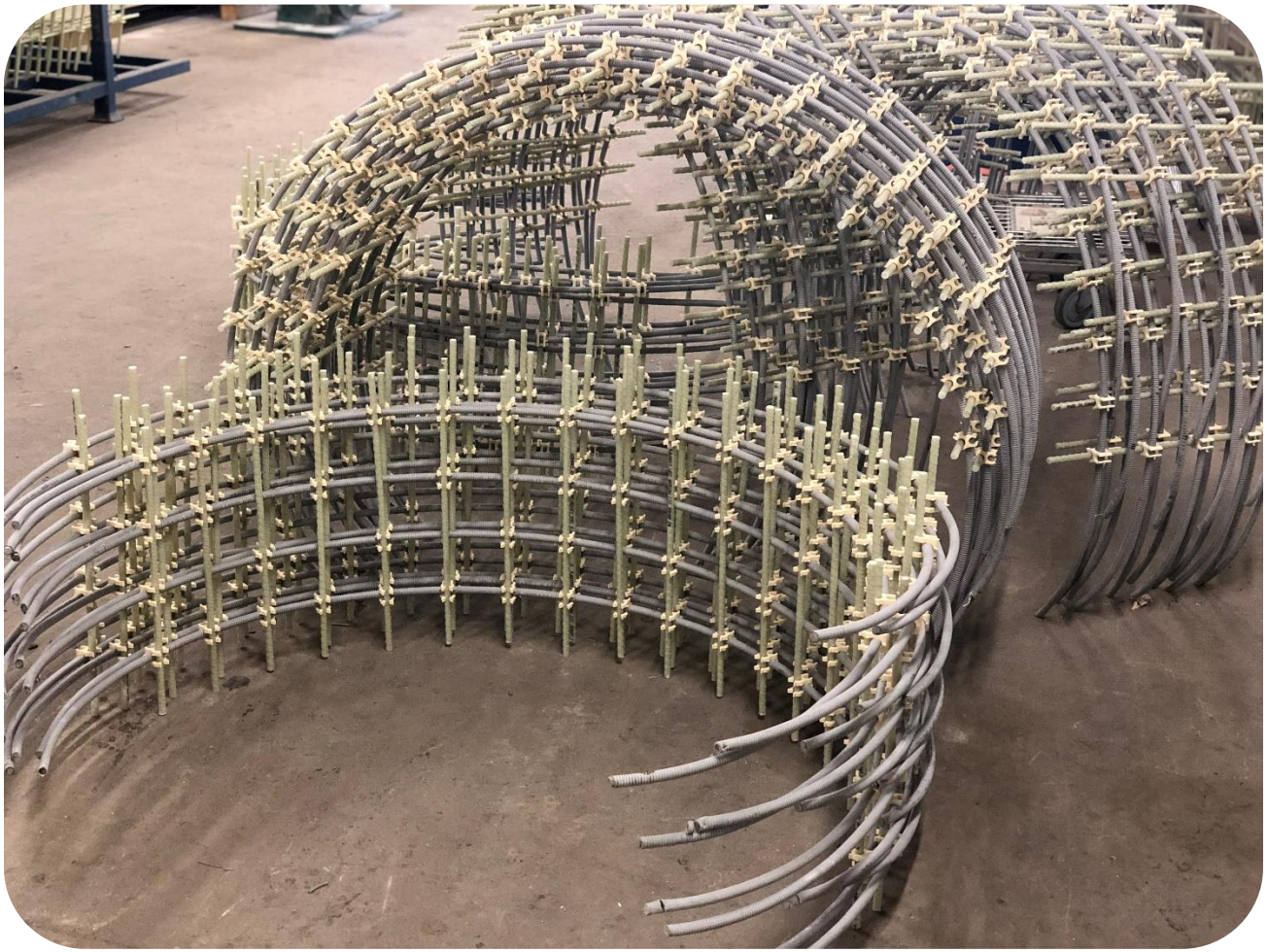

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Bent Cap Rehabilitation

- Hydro demolition of cover
- Some rebar replacement, epoxy-cement coating over all rebar
- Apply migrating corrosion inhibitor
- GFRP reinforcement over bottom and sides
- Install formwork and place self-consolidating concrete

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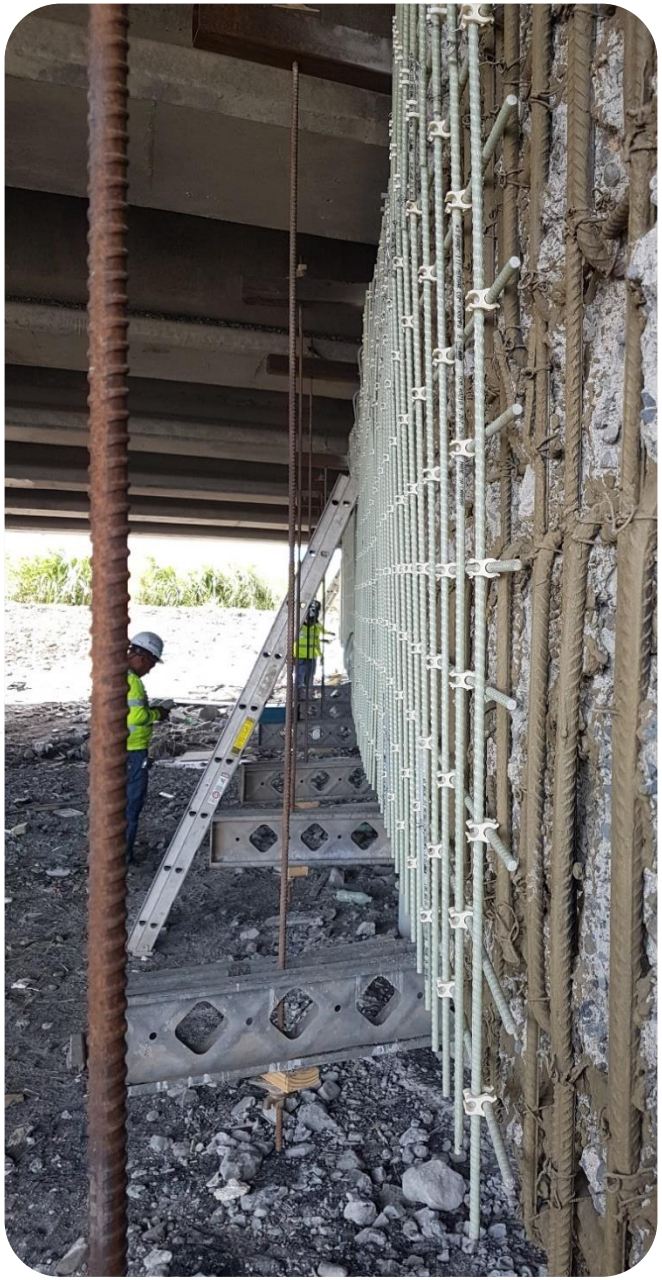

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Conclusion

- GFRP was used cost-effectively in combination with self-consolidating concrete as a means to extend the service life of a critical bridge structure.
- Pre-bent GFRP allows for a fast installation of reinforcement around columns. Pre-bent L-shaped anchors were successfully used to maintain the GFRP meshes in place and provide structural support by dowel action.
- Material transportation cost to Panama was relatively inexpensive due to lighter weight of bar compare to conventional metallic bar.


THANK YOU!

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(Floor discussion – No presentation)

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- **2.3 – GFRP Quality Control of Continuous Processes** *(Xavier Seynave)*

Discussion 2.4 (90 mins)

Quality control of continuous processes

2nd International Workshop on GFRP bars for Concrete Structures

Assets and challenges of continuous manufacturing processes

The automotive approach:

- Description of the process(es)
- Risk-based analysis
- Monitoring, inspections and controls

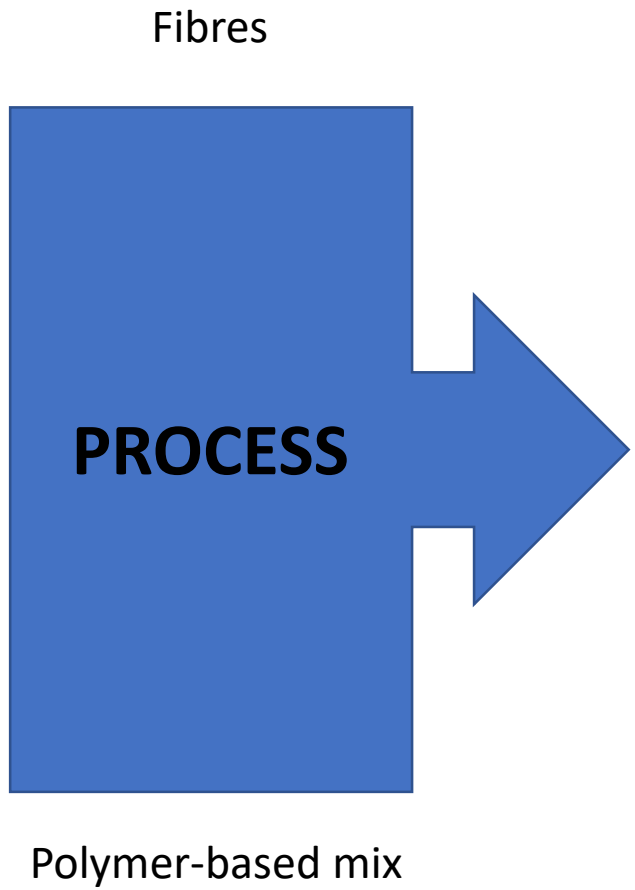
Beyond quality control: improvement

Conclusion

Continuous flow of material at different stages of transformation

Machine(s) always on

Several sensors and feedback loops



Failure of the process can result in failure of the product, failure of the product hints at an out-of-control process.

Process parameters and product properties are tied.

product

stability

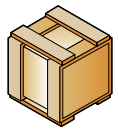
process

Inspired by the automotive industry: flow chart

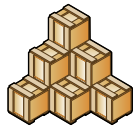
- List of the steps in chronological order
- Characteristic of the flow of material
- Useful to plan a plant layout
- Birds-eye view (but nothing is missing)

	action	inspection	transport	delay	storage	operation
1.1						
1.2						
1.3						
1.4						
1.5						
1.6						
1.7						









Inspired by the automotive industry: FMEA

Potential **F**ailure **M**ode and **E**ffect **A**nalysis

Process Functions / Requirements	Potential Failure Mode	Potential Effects of Failure	Potential Causes / Mechanisms of Failure	Current Process Controls	
				Prevention	Detection

Inspired by the automotive industry: FMEA

Process Functions / Requirements	Potential Failure Mode
cutting	variable length
	displt. errors
	non-functional

Inspired by the automotive industry: control plan

Actions taken based on the RPN: the greater the risk, the more frequent the inspections, the more accurate the measurements, etc…

Operation	Characteristics		Method					Records	Corr. Action
	Product	Process	Spec./Tol.	Instr.	Sample		Method of Ctrl.		
					Size	Freq.			
production	cure ratio	(stability)	≥95%	DSC	1	1/shift	ASTM E2160	computer	scrap bars adjust process param.
	T_g	(stability)	≥100°C	DSC	1	1/shift	ASTM E1356	computer	

Road map to explain QC as logical and justified activities supported by a risk analysis of the manufacturing process(es)

Using a flow chart, FMEA and control plan opens several doors:

- Facilitating process reviews
- Planning of maintenance (preventive, predictive)
- Raising H&S concerns
- Prioritizing and implementing improvements
- Identifying weaknesses

Objective: stay in control

Tools are available and field-tested to plan the quality of the product.

The setting parameters of a continuous process guarantee the performances of the product.

Deep analysis of the process help to ensure the consistency of the product batch after batch.

Thank you!