Discussion of FRP Design Codes and Guidelines in Brazil and South America

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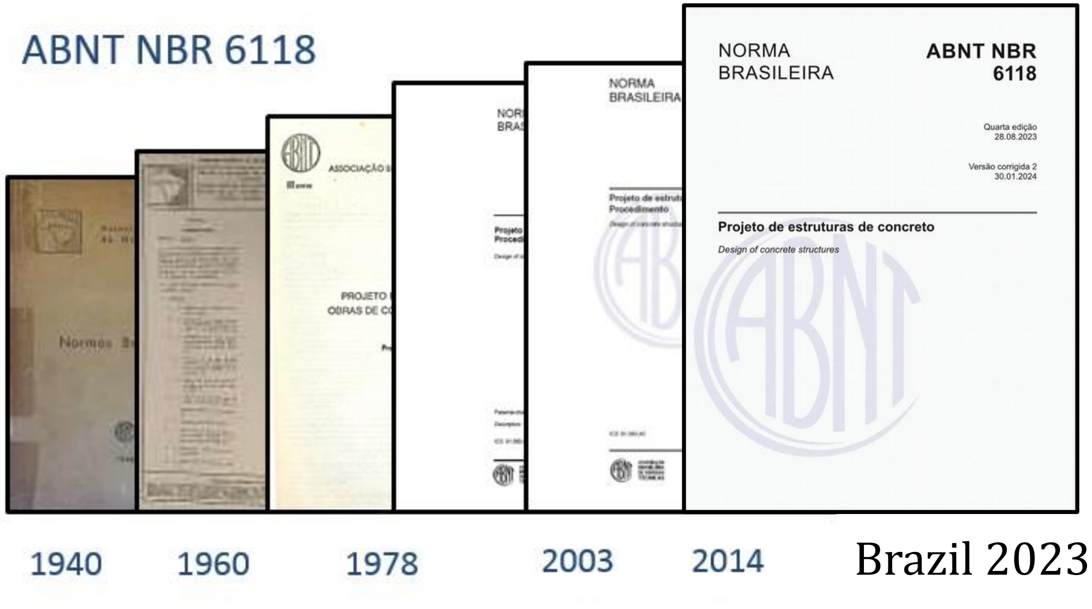
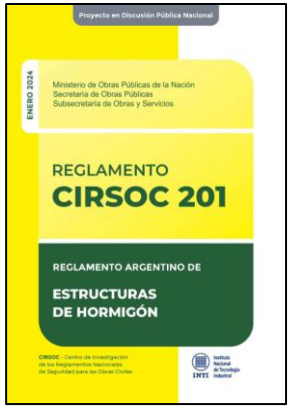
South American Codes for Concrete Structures



Brazil 2023

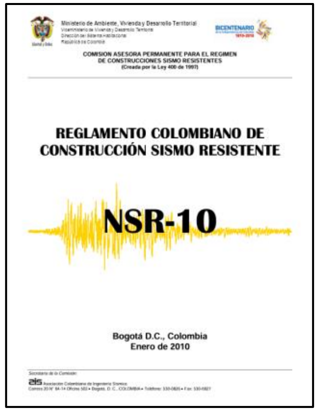
Pretty modern codes… of course, there are exceptions…

For FRP RC, only Brazil has active TCs…



Argentina 2024

Peru 2020



Colombia 2010

Chile 2008

Use of FRP RC in South America

Before 2018

1 manufacturer | bar used in soft-eyes and eventually on industrial projects

In 2018

Many suppliers bringing bars from Russia

After 2018

Pandemic: cost of steel bars increased
Ukraine War: reduction of importation from Russia
Growth of national companies
Limited knowledge and qualified personnel
Main application: grids for slabs-on-grade
but we see even in lintels!

Haizer Building Solutions

Timeline

2015: Installation of the IBRACON/ABECE TC 303
Non-conventional materials for concrete structures
WG3: Concrete structures with non-conventional internal reinforcement

2019: WG3 Activities restarted after a long break

2021: Manual of Practice published

2022: Reactivation of ABNT TC
CE-002 124.026 – Structural design
CEE 193 – Material specification, qualification and tests

2024: Released for public review

Main Non-Technical Challenges

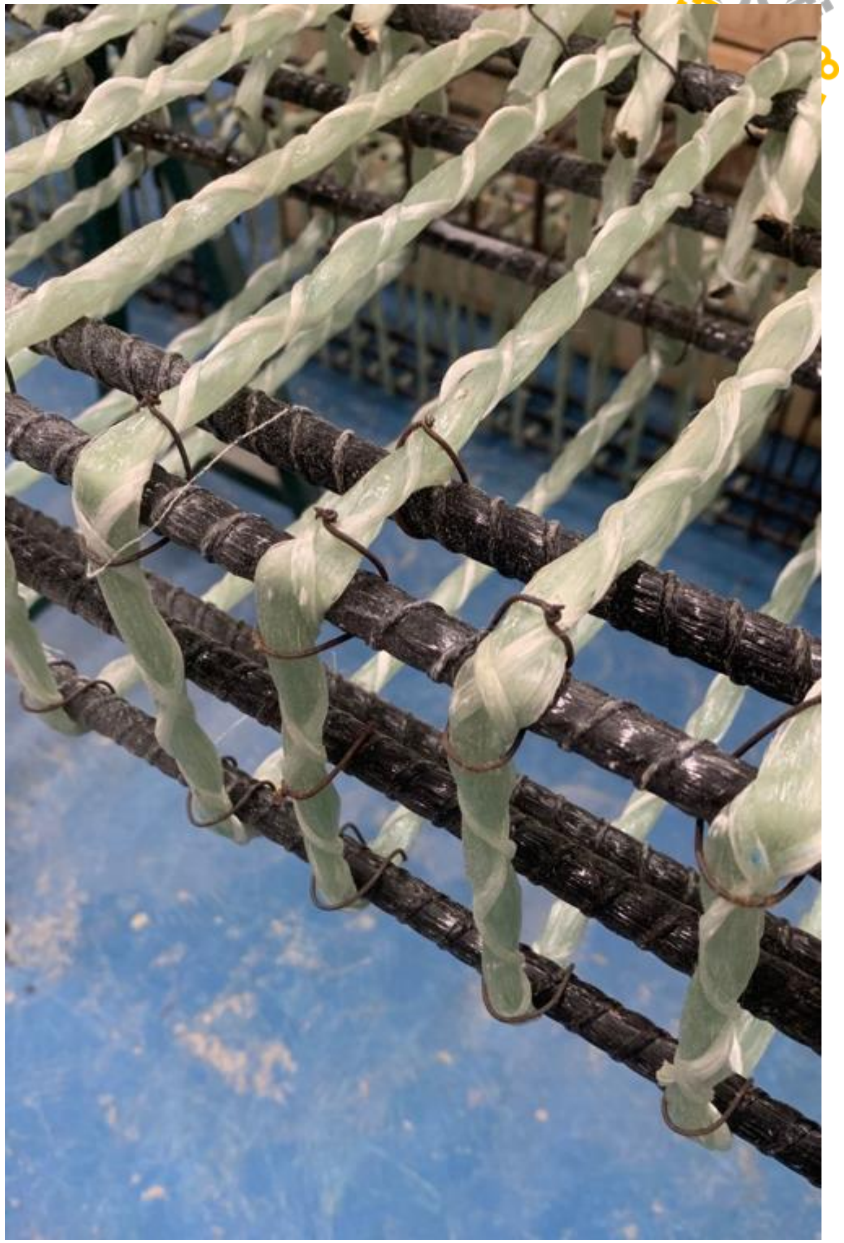
Few researchers involved with FRP composites for concrete

Limited technical data available in the country

Lack of knowledge of the community about composites

Industry flagship: grids and dowel bars (even less data)

Variability of materials
- graphene
- polyester



Courtesy: Luiz Otávio (UERJ)

Scope

Concrete strength up to 50 MPa, w/ or w/out fibers

VE or EP-based bars with glass or basalt fibers

Bars with surface treatment meeting minimum physical and mechanical requirements

Combination of steel and FRP

Temperatures below 80 °C

- No pre-stressing
- No bundles
- No hollow bars or w/ split cross-section (grids)
- No fire, earthquake, impact or other exceptional limit states
- No waffle slabs, flat slabs, punching shear

Material Specification, Qualification and Testing
(coordinated by Prof. Nadia Forti)

1 Main document with specification and minimum requirements

12 Parts describing physical and mechanical characterization tests

Original aspects:

Tg and degree of cure for qualification, but not for regular quality control...
... Instead: water absorption and apparent longitudinal shear

Tensile tests with reduced free and anchorage lengths

Structural Design
Original Developments

Concrete strength and cover minimum requirements

Aggressive Environment Class	Description	w/c ratio	Minimum Concrete characteristic strength (MPa)	Minimum concrete cover (mm)
CAA-FRP-I (weak)	- Structures not exposed to the external environment (dry) - Structures in contact with water or soil with low sulfate content)	≤ 0.60	20	30 (20 for slabs)
CAA-FRP-II (moderate)	- Structures in contact with water or soil with moderate sulfate content - Structures in contact with sea water.	≤ 0.50	30	40
CAA-FRP-III (Strong)	- Structures in contact with water or soil with a high sulfate content.	≤ 0.40	45	55

Structural Design
Original Developments

Partial factors

R1: don't change load factors

R2: don't change concrete strength factor

R3: β > 3.8

Load:

$$F_d = \gamma_n \left(\gamma_g F_{gk} + \gamma_q F_{q1k} + \gamma_q \sum_{j=2}^{n} \psi_{0j} F_{qjk} \right)$$

Adjustment factor to account for the consequences of a brittle failure (=1.1)

Resistance:

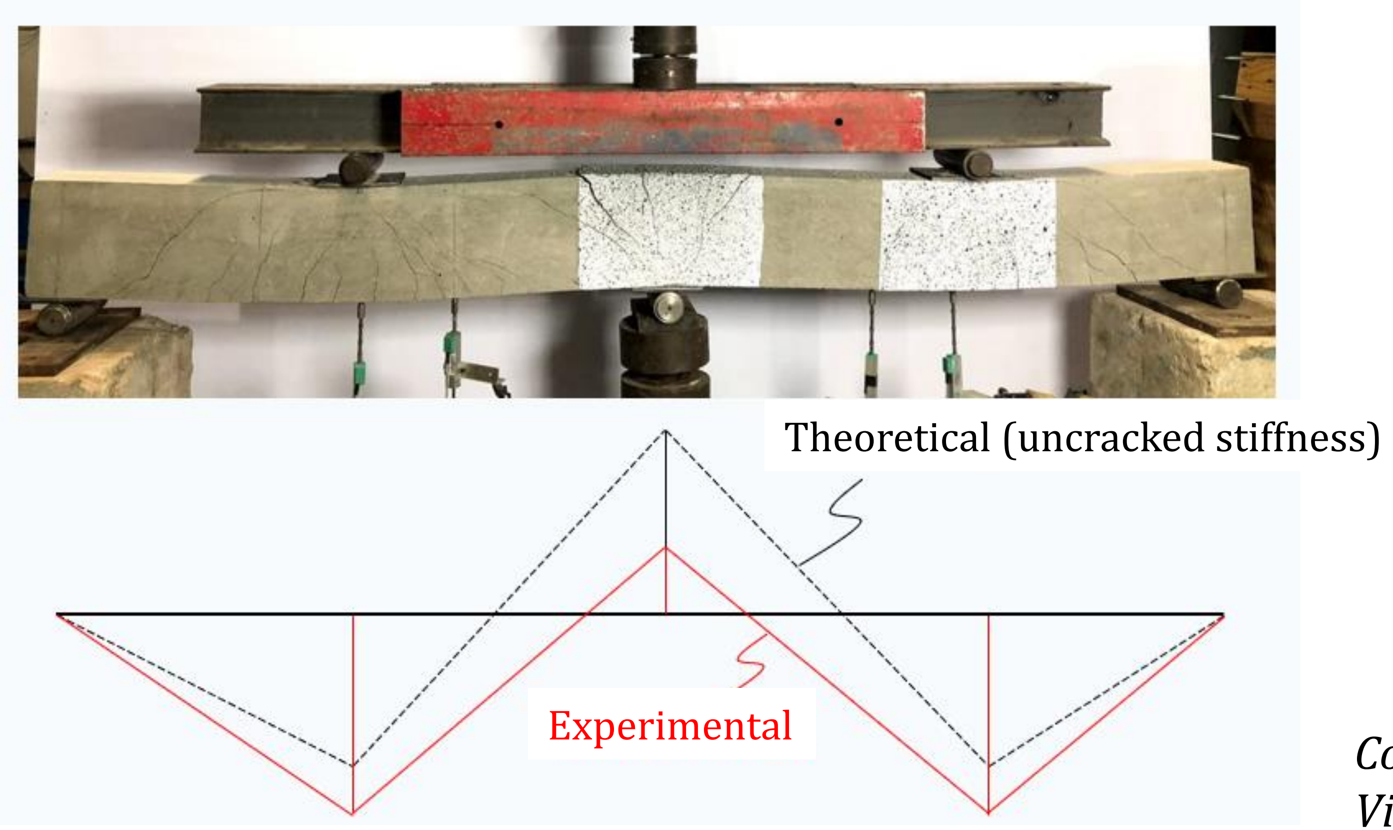
$$f_d = C_E \frac{f_k}{\gamma_{FRP}}$$

______ =1.3

$$F_{Rd} = \text{function}(f_d)$$

Structural Design
Original Developments

Uncracked x cracked stiffness in structural analysis
Recommendations for beams and slabs



Courtesy:
Vitor Carvalho (PUC-Rio)

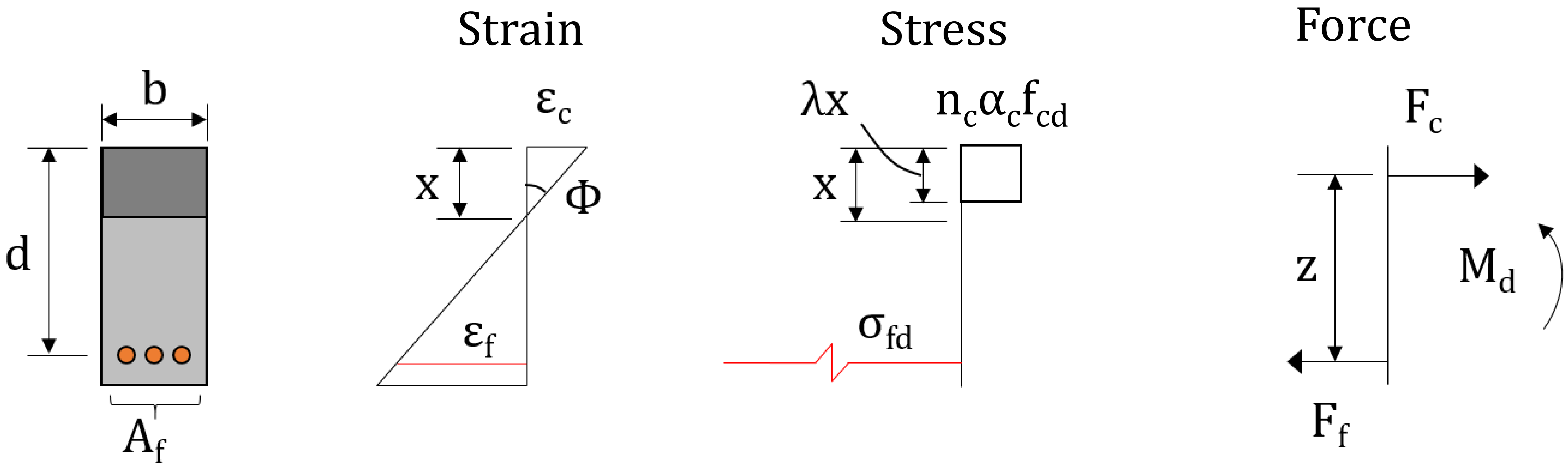
Structural Design
Original Developments

Strategies for ductility
- concrete confinement
- use of fibers (in compression)
- hybrid reinforcement
- FRP bars in compression

Courtesy:
Vitor Carvalho (PUC-Rio)

Structural Design
Original Developments

ULS-Bending



*Limitations for hybrid reinforcement and multiple layers

Structural Design
Original Developments

ULS-Shear

$$V_{Sd} \leq V_{Rd2}$$

$$V_c = 0,6\, f_{ctd}\, b_w\, x_{II}$$

$$V_{Sd} \leq V_{Rd3} = V_c + V_f$$

$$V_f = 0,9\, d\, f_{fVd} \left(\frac{A_{ft}}{s}\right)$$

*Fibers not considered (yet)

Structural Design
Original Developments

SLS-Deflection

Bischoff method (similar to ACI)

Lower moment at cracking

Long-term: steel in compression

$$\alpha_f = \frac{\xi(t) - \xi(t_0)}{1 + 50\rho_s'}$$

SLS-Cracking

Model Code 2010 approach

Accounts for fibers

$$w_k = \frac{2}{E_f}\left[1{,}5c_{nom} + \frac{1}{4}\frac{f_{ctm}}{\tau_b}\frac{\phi}{\rho_{ef}}\right]\left[\sigma_f - \frac{1}{2}\frac{f_{ctm}}{\rho_{ef}}\left(1 + \frac{E_f}{E_{cs}}\rho_{ef}\right)\right]$$

Concluding Remarks and Next Steps

- The Brazilian code results from a 5- to 6-year work.
- Modern code, original in many aspects, but not perfect...
- Code will be really important to spread the knowledge about FRP RC and its safe use
- TC303 IBRACON will reunite after July 2024 to continue the work (grids, dowel bars, fire, punching shear, etc)

Merits of a small group with very limited resources, but focused, highly motivated and hardworking.

OBRIGADO!