Center for Integration of Composites into Infrastructure

University of Miami

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UNIVERSITY OF MIAMI
COLLEGE of ENGINEERING

Status of the Site

List of Projects at Site

- Project 01: Durability Study of RC Seawalls Constructed with GFRP I-Bars and SIP Panels
- Project 02: Guide for Design and Use of Flexible Carbon Grid Reinforcement for the Repair and the Strengthening of Reinforced Concrete Slabs and of Masonry Walls
- Project 03: Large-Diameter Composite Hollow Rebars

List of Projects at Site

- Project 04: External Confinement of RC Columns by means of GFRP laminates
- Project 05: ICE Methodology for FRP Characterization
- Project 06: Safety Analysis of Composite Materials for Existing and New Construction

Durability Study of RC Seawalls Constructed with GFRP I-Bars and SIP Panels

Project Number: 01

GFRP RC seawalls represent an economically competitive alternative to conventional solutions, such as steel RC or timber seawalls, because of its resistance to corrosion, high strength to weight ratio and excellent fatigue performance.

This research intends to investigate the long-term performance of concrete seawalls using structural SIP panels. The project tasks include design of a prototype, construction, accelerated ageing and deployment at a waterfront site, and laboratory testing.

STRONGWELL

Overview

The main problem for existing RC seawall is the concrete cover spalling due to the corrosion of the internal steel reinforcement, mainly visible at the head of the foundation piles.

Old Cutler by Mathesan Hammark Park, Miami (FL)

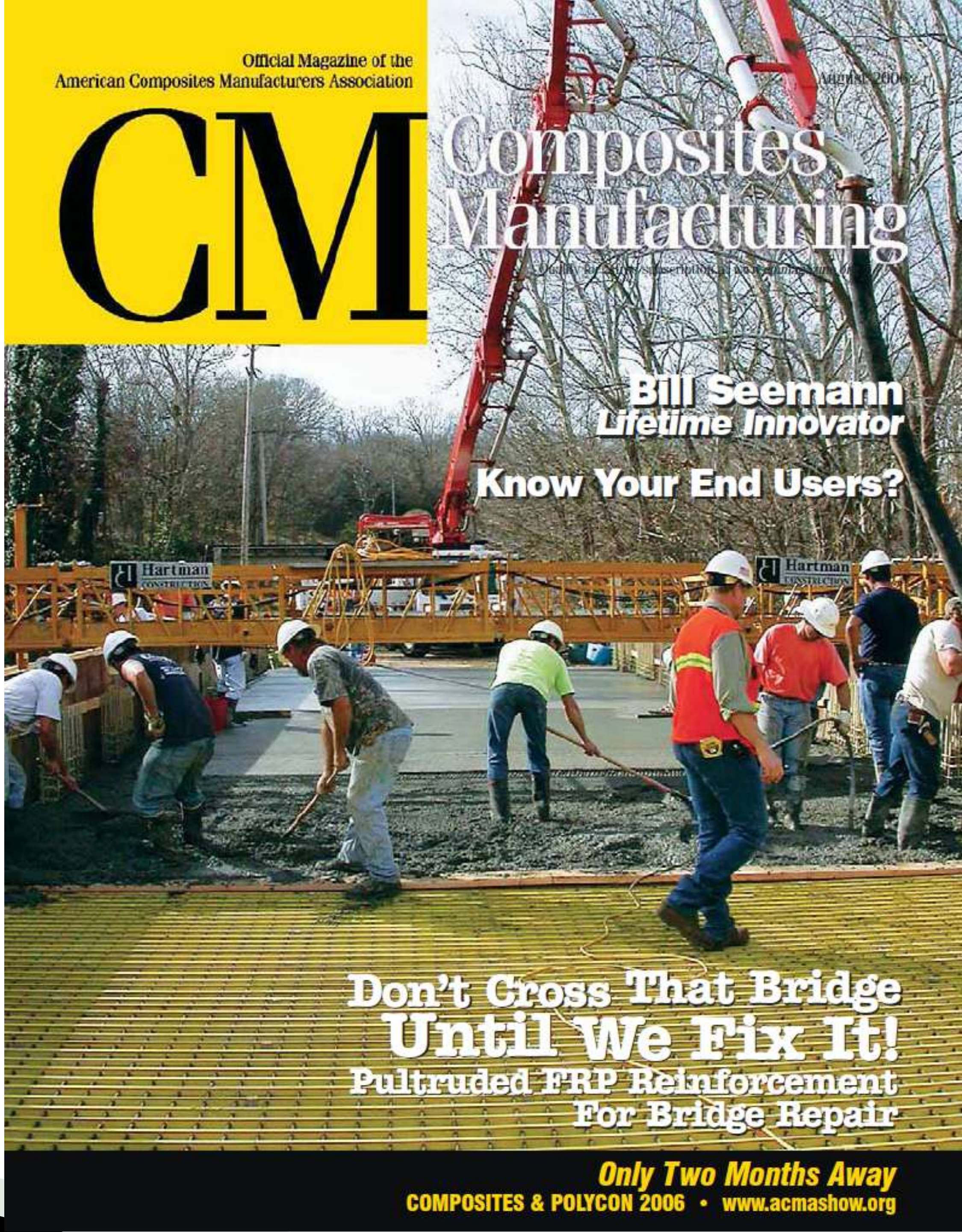
Overview

The main problem for existing RC seawall is the concrete cover spalling due to the corrosion of the internal steel reinforcement, mainly visible at the head of the foundation piles.

Williams Island, Aventura (FL)

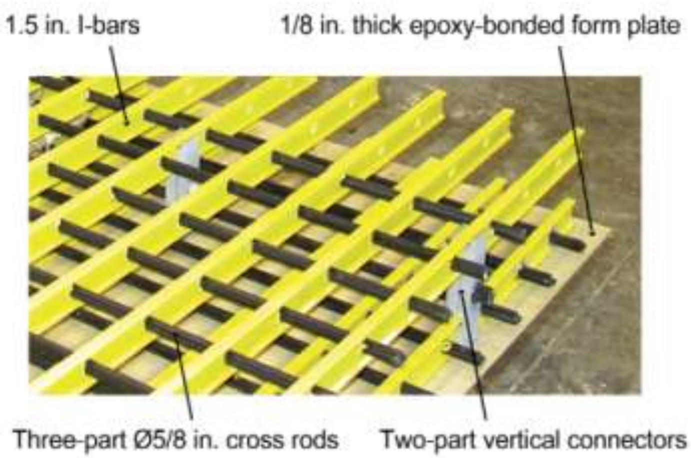
Introduction

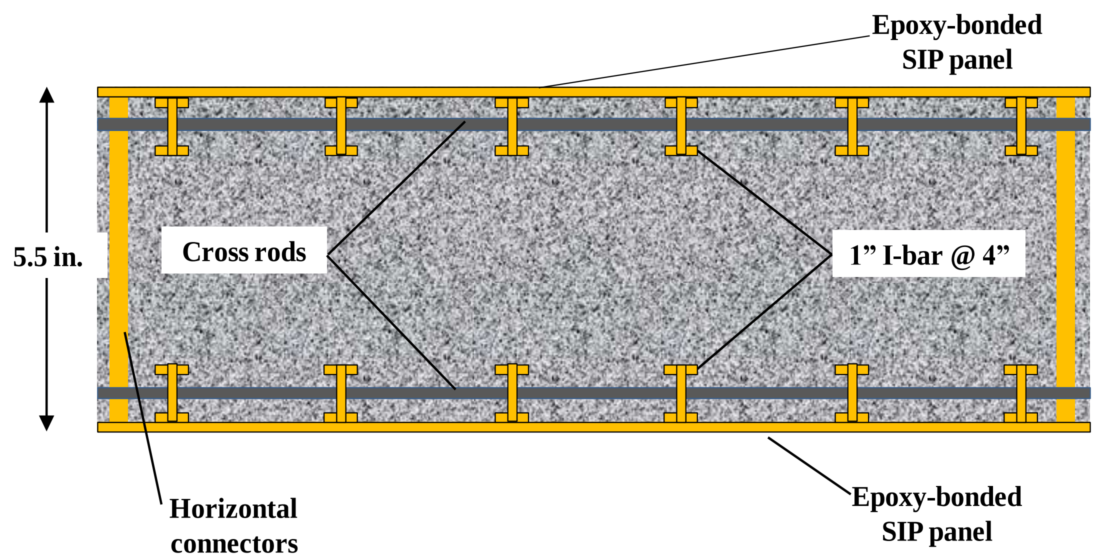
A combination of concrete and internal GFRP reinforcement represents a solution with high potential (no steel reinforcement corrosion) particularly when construction costs and completion time could be simultaneously reduced by introducing integrated GFRP structural reinforcement and stay-in-place (SIP) formwork



Objectives

- Investigate the longevity of concrete seawalls reinforced with GFRP SIP panels
- Provide the scientific community and practitioners with experimental data on the long term performance of GFRP SIP panels when exposed to harsh environment
- Provide the engineering community with new design tools to build long-lasting RC seawalls





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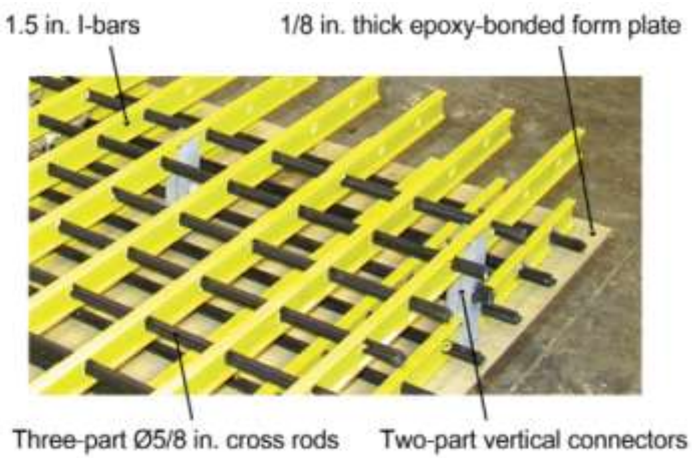
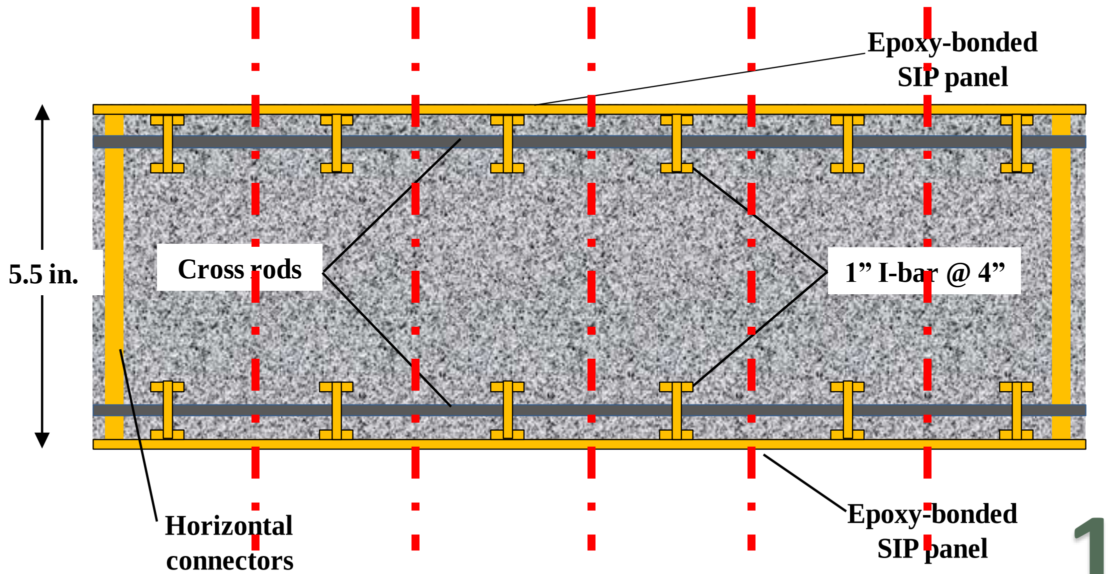
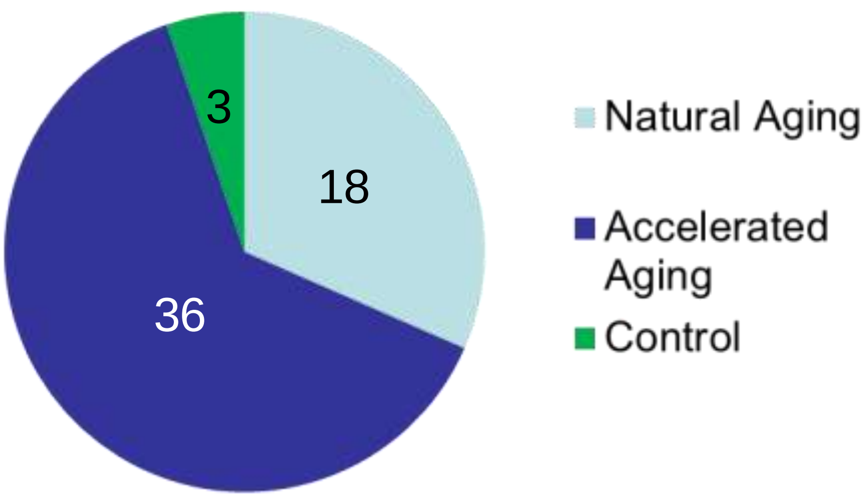




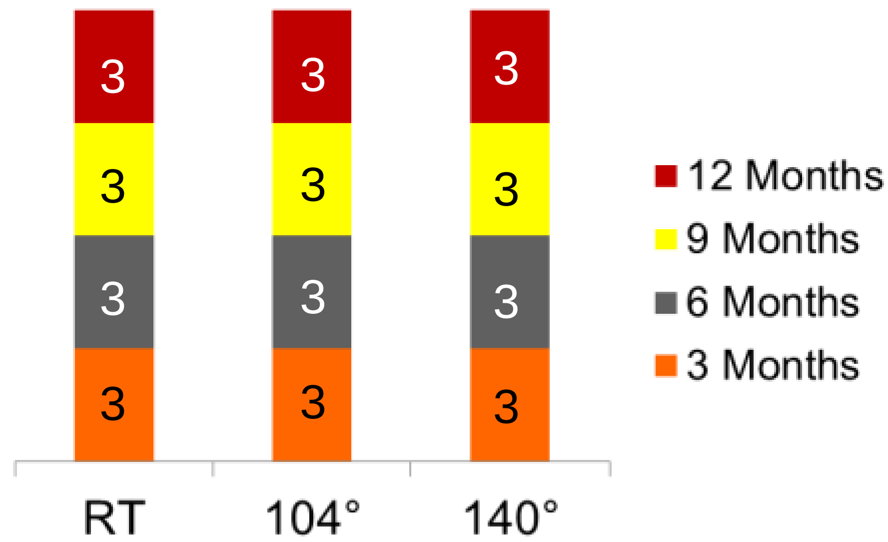
Test Matrix

Sample Distributions

Overall Sample Distribution

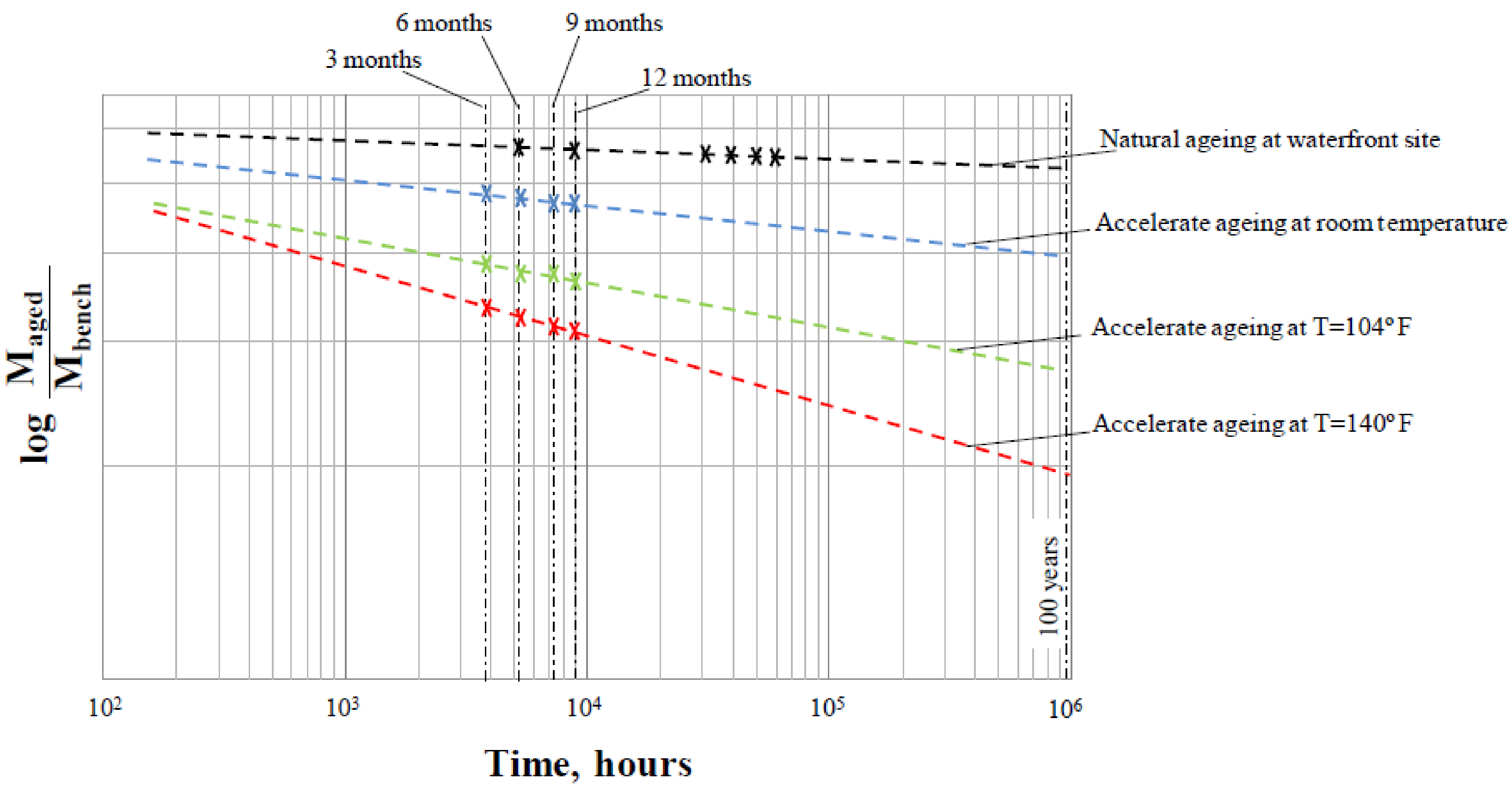


Accelerated Aging Sample Distribution

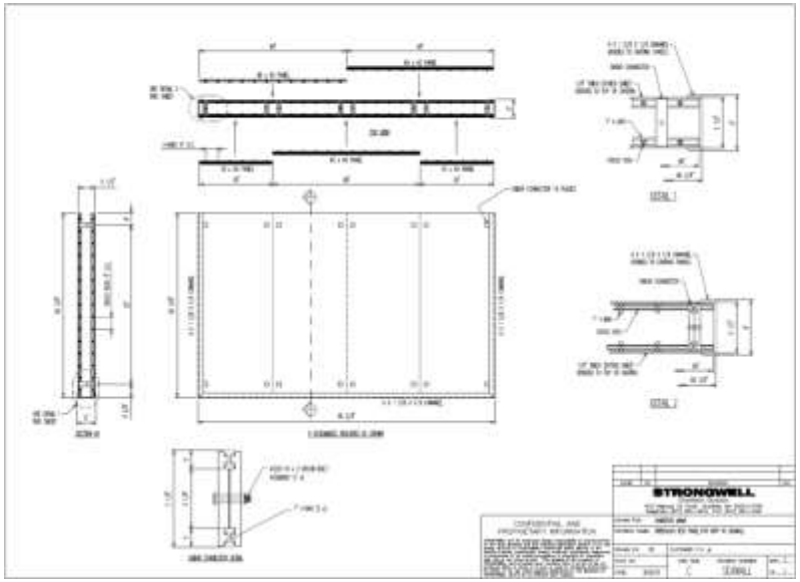


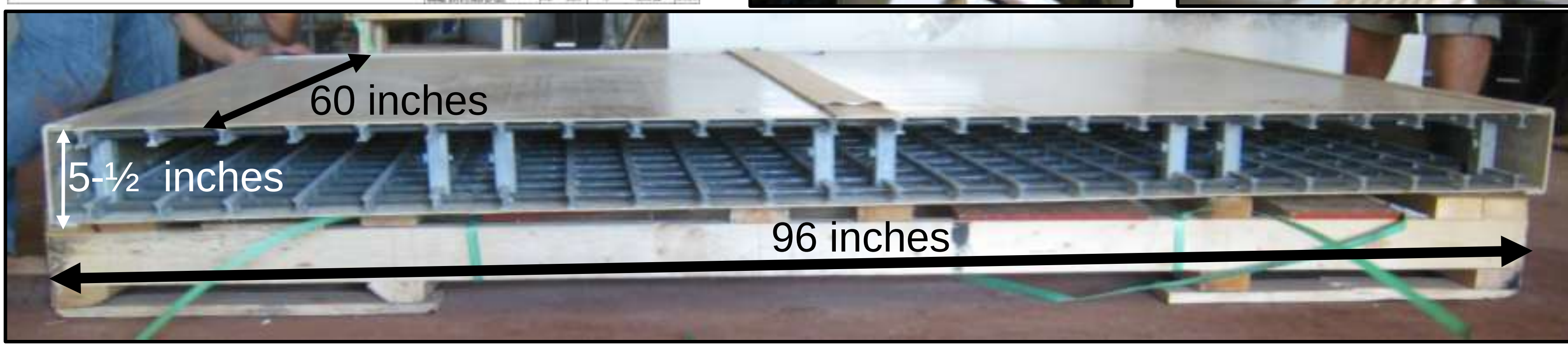
57 total samples are aged in the experiment. 36 samples are subjected to accelerated aging. They are separated into groups of three and aged for 3 months, 6 months, 9 months, and 12 months at room temperature, 104° F, and 140° F. In addition, 18 GFRP-RC beams are aged in a natural marine environment for 6 months, 12 months, two years, three years, four years, and five years.

Expected outcomes



Specimen preparation





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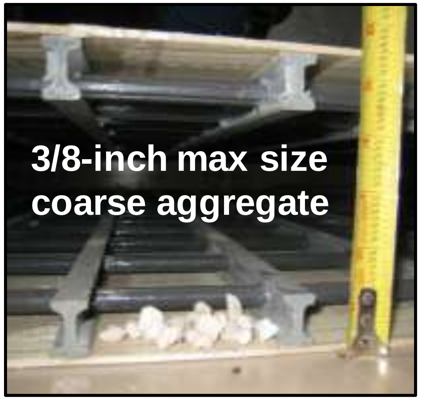


Guide for Design and Use of Flexible Carbon Grid Reinforcement for the Repair and Strengthening of Reinforced Concrete Slabs and Masonry Walls

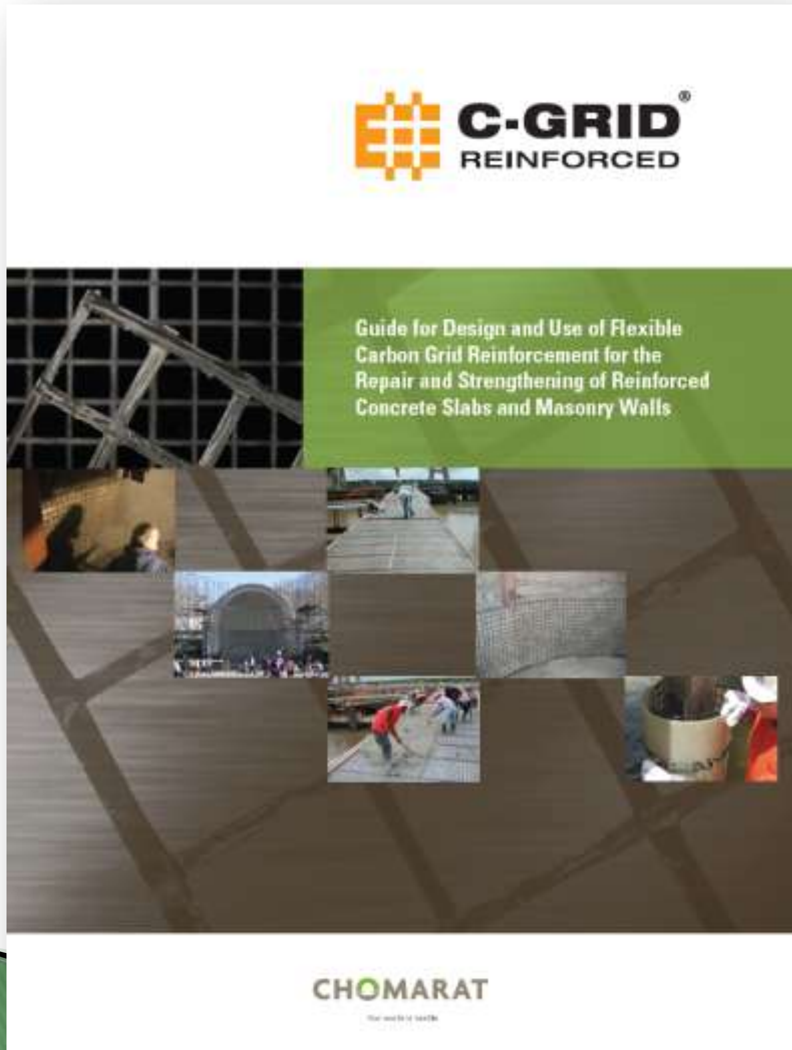
Project Number: 02

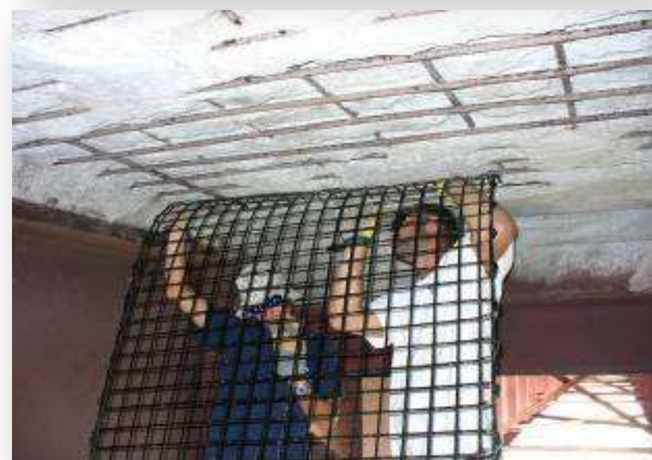
This document offers general information on the use of a specific product, named C-GRID and developed by Chomarat North America, for the repair and strengthening of reinforced concrete (RC) slabs and unreinforced masonry (URM) walls.

CHOMARAT

Overview

The document aims at providing a design guide with solved examples to assist designers and practitioners.





Large-Diameter Composite Hollow Rebars

Project Number: 03

Overview: The hollow core eliminates the inefficient solid core and, potentially, enables the rebar to carry data or electrical wiring, radiant heating, or sensors to make smart structures. Large-diameter, hollow composite rebar can provide distinct advantages for concrete construction application.

Experimental Plan: Hollow rebar specimens will be subjected to tensile tests. The experimental results will be used to validate an FE model.

Objectives: This project aims at investigating the mechanical behavior of hollow-core CFRP rebars.

Composite Rebar Technologies

External Confinement of RC Columns by means of GFRP laminates

Project Number: 04

De Luca, A., and A. Nanni, "**Single–Parameter Methodology for the Prediction of the Stress-Strain Behavior of FRP Confined RC Square Columns**," in press, *ASCE Journal of Composites for Construction*, 10.1061/(ASCE)CC.1943-5614.0000179

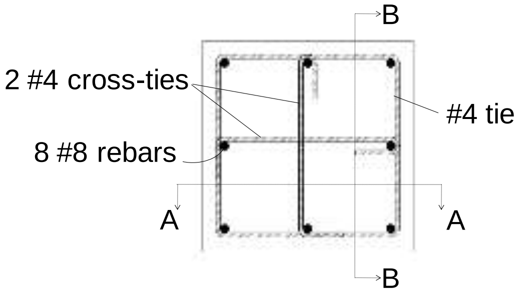
De Luca, A., F. Nardone, F. Matta, A. Nanni, G.P. Lignola, and A. Prota, "**Structural Evaluation of Full-Scale FRP-Confined Reinforced Concrete Columns**," *ASCE Journal of Composites for Construction*, Volume 15, Issue 1, pp. 112-123 (January/February 2011)

Previous research

Specimens were intended to represent real size building columns designed according to a dated ACI 318 code (i.e., prior to 1970) for gravity loads only

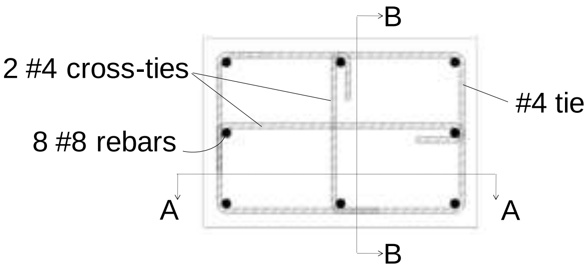
S-1 type

24 in. by 24 in.



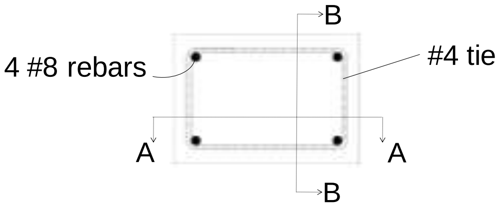
R-1 type

20 in. by 29 in.

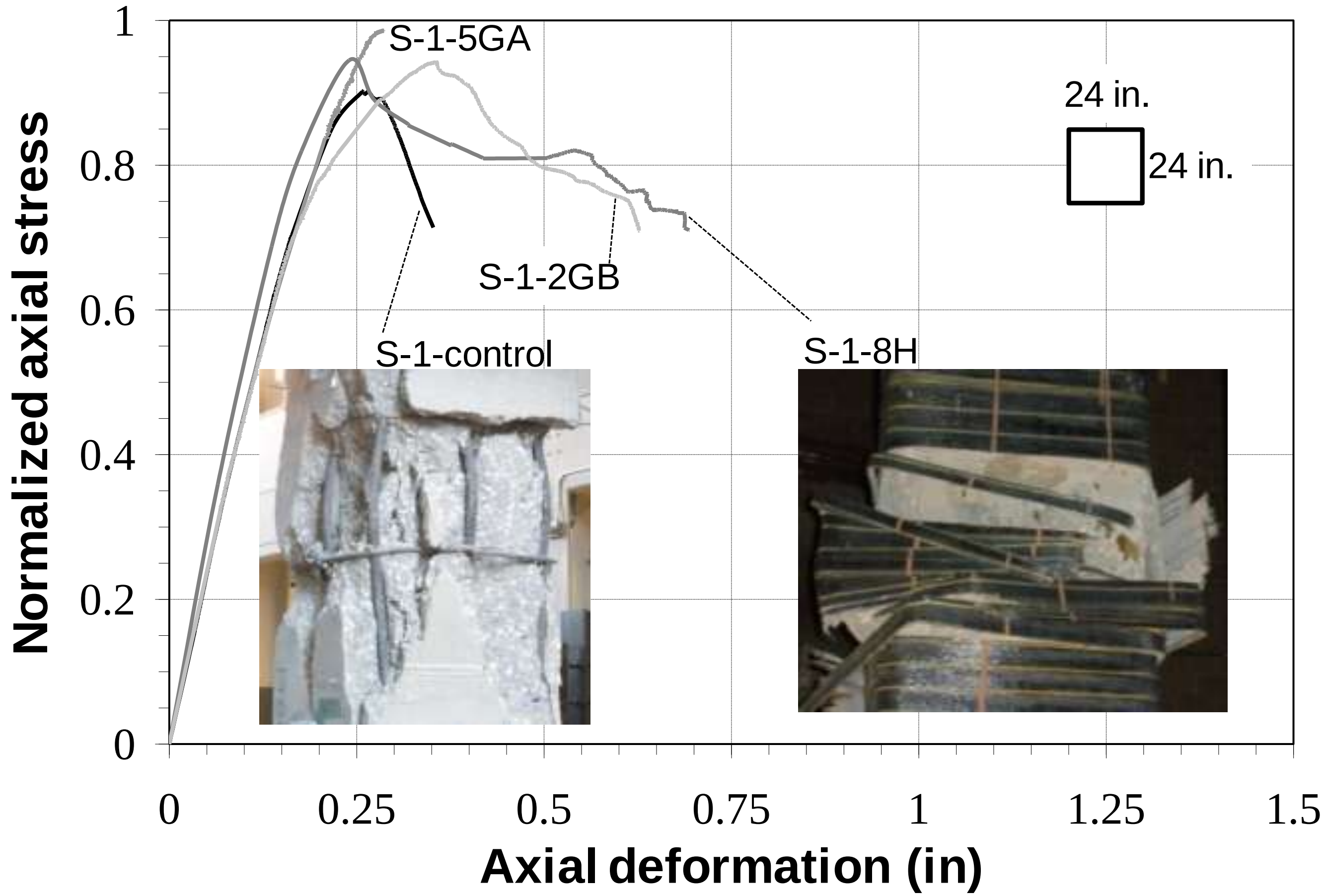


R-0.5 type

14 in. by 20 in.

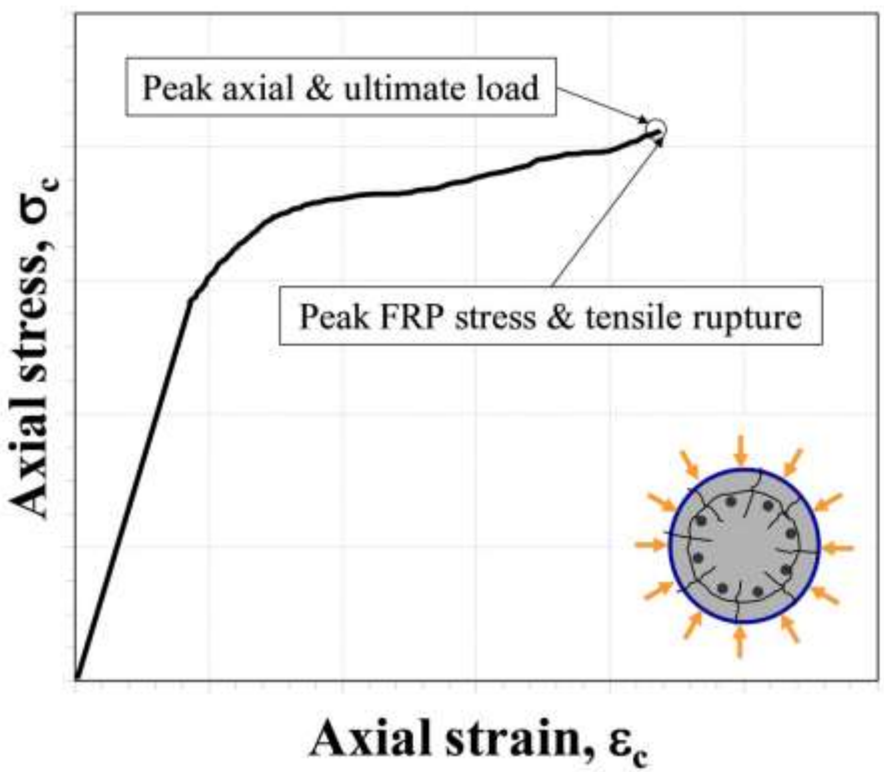


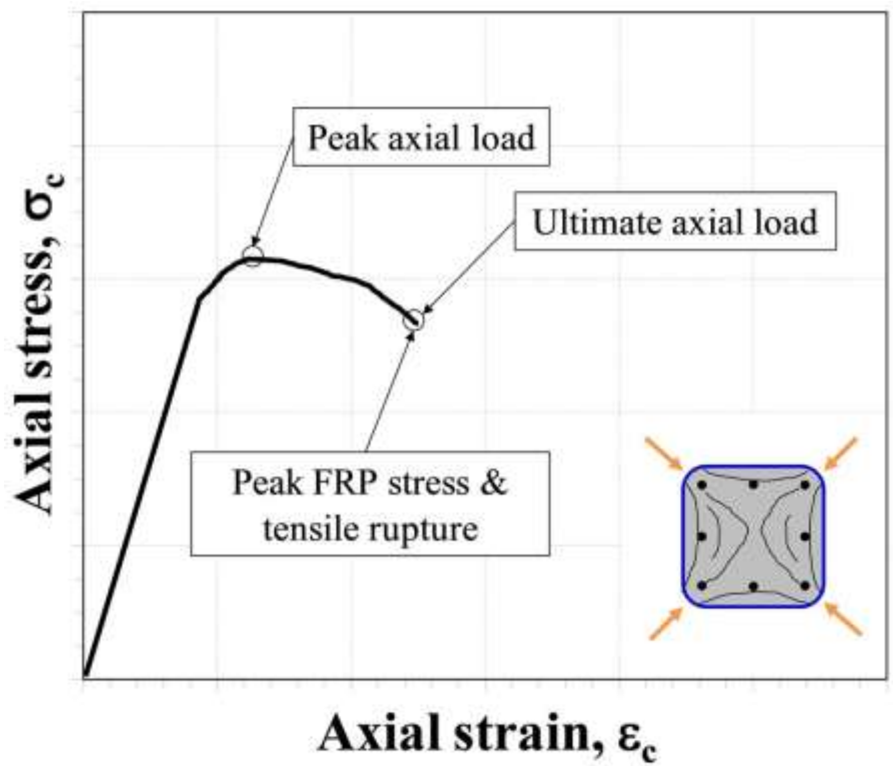
Research outcomes



Research outcomes

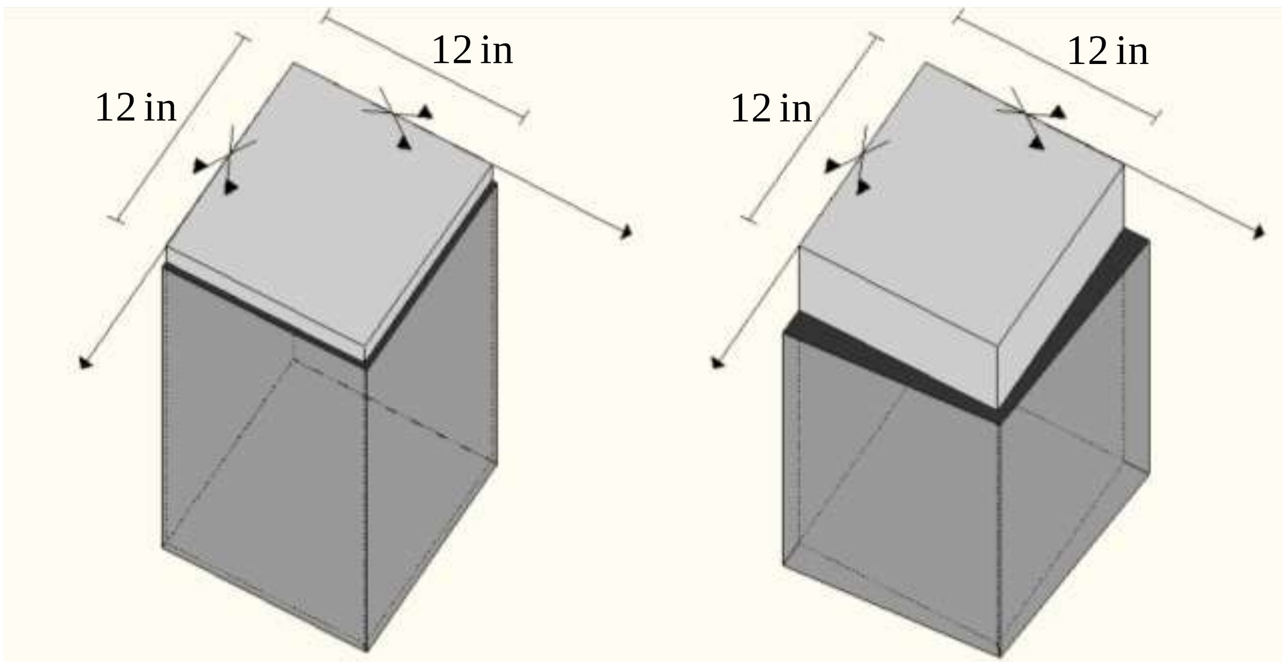
Circular vs. prismatic cross-sections





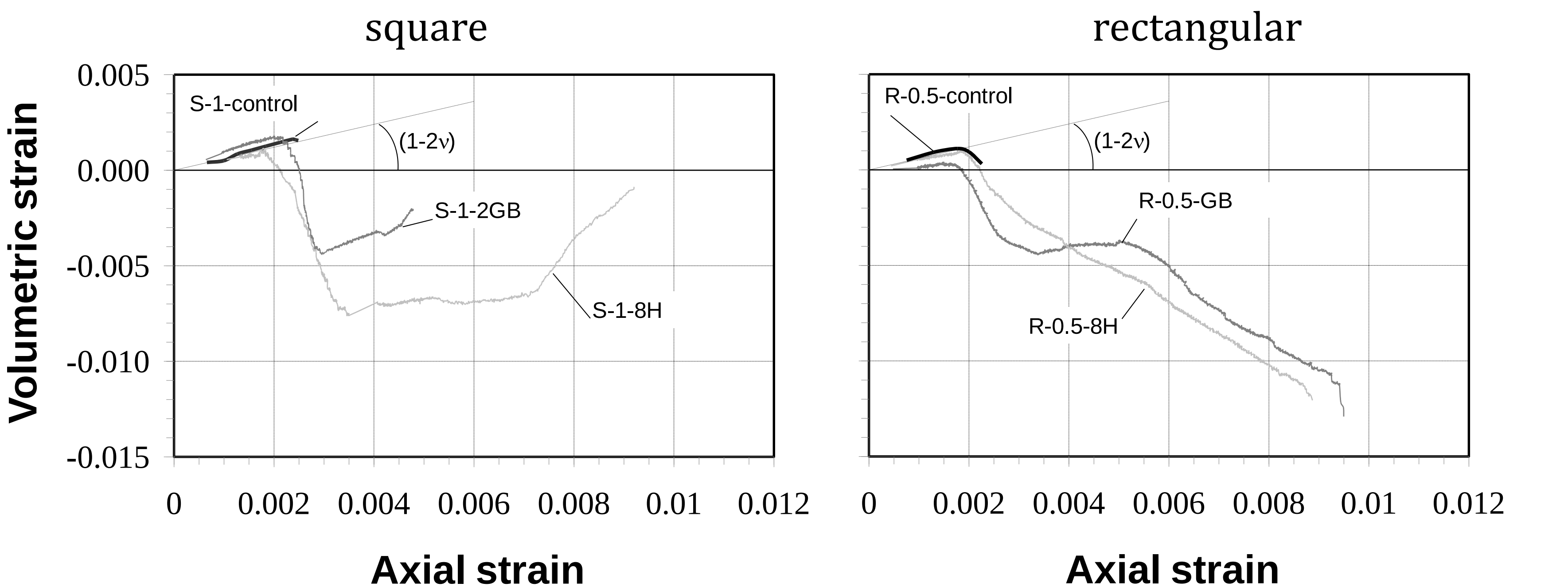
Research outcomes

Change in volume of a representative one-quarter unit element.



peak load failure

Research outcomes



Research outcomes

- In prismatic columns, the FRP confinement effectiveness is more significant in terms of enhancement of concrete axial deformation rather than increment in axial strength.

- The presence of the FRP jacket allows a "growth" in volume of the concrete core by offsetting buckling of the longitudinal bars and by delaying unstable crack propagation.

- The shape of the cross-section influences the effectiveness of the confinement.

- The maximum stress reached by concrete in columns is only about 85% of the cylinder strength, therefore, theoretical models should use $0.85 \cdot f'_c$, not just f'_c.

Future work

Future work

Small scale

Future work

1:5

Future work

- Size effect
- More experimental evidence

Small scale

ICE Methodology for FRP Characterization

Project Number: 05

- Current ultimate strain of FRP flat coupons based on direct tensile tests (ε_{fu}) do not correspond to experimental results of FRP jackets in the hoop direction ($\varepsilon_{\theta u}$).
- Develop a new test methodology to determine the ultimate circumferential properties of FRPs.
- Use the natural expansion of ice to apply an internal hydrostatic pressure to FRP cylindrical jackets for characterization.

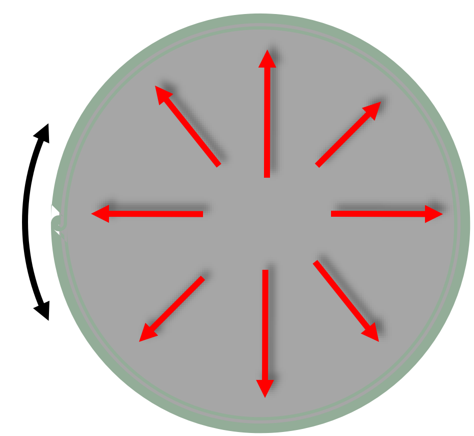
Direct tensile testing:

ε_{fu}

VS

"Hoop" tensile testing:

$\varepsilon_{\theta u}$



Novelty of ICE Methodology

Novelty originates from the lack of moving parts or complex fixtures to transfer load to the specimen, while applying a hydrostatic load…

…using the property of water that expands when it changes state of matter from liquid to solid, resulting on an applied load to test specimens.

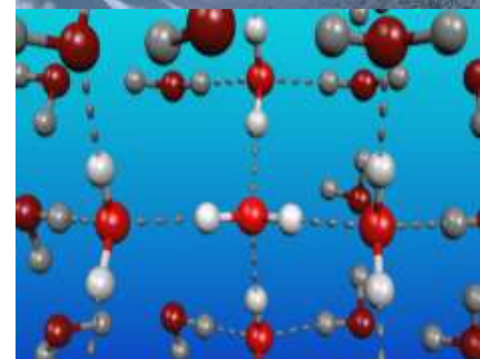
Objectives

1

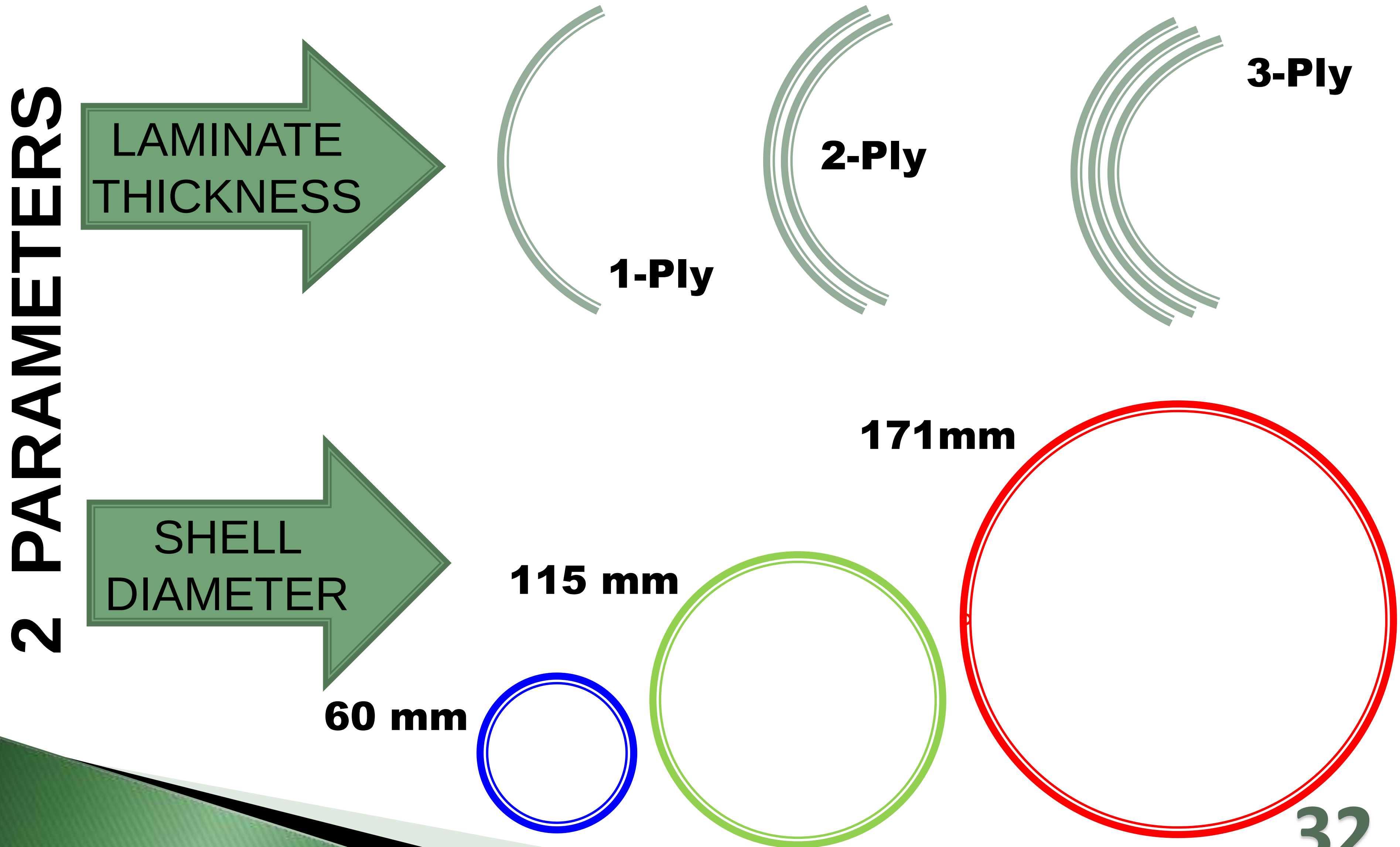
*To develop an **efficient** and **reliable** experimental technique to measure the ultimate **circumferential** (hoop) strain of FRP laminates, including specimens with different jacket diameters and laminate thicknesses.*

2

*To determine the effect of cylindrical FRP shell **curvature** and **laminate thickness** on the strain efficiency.*



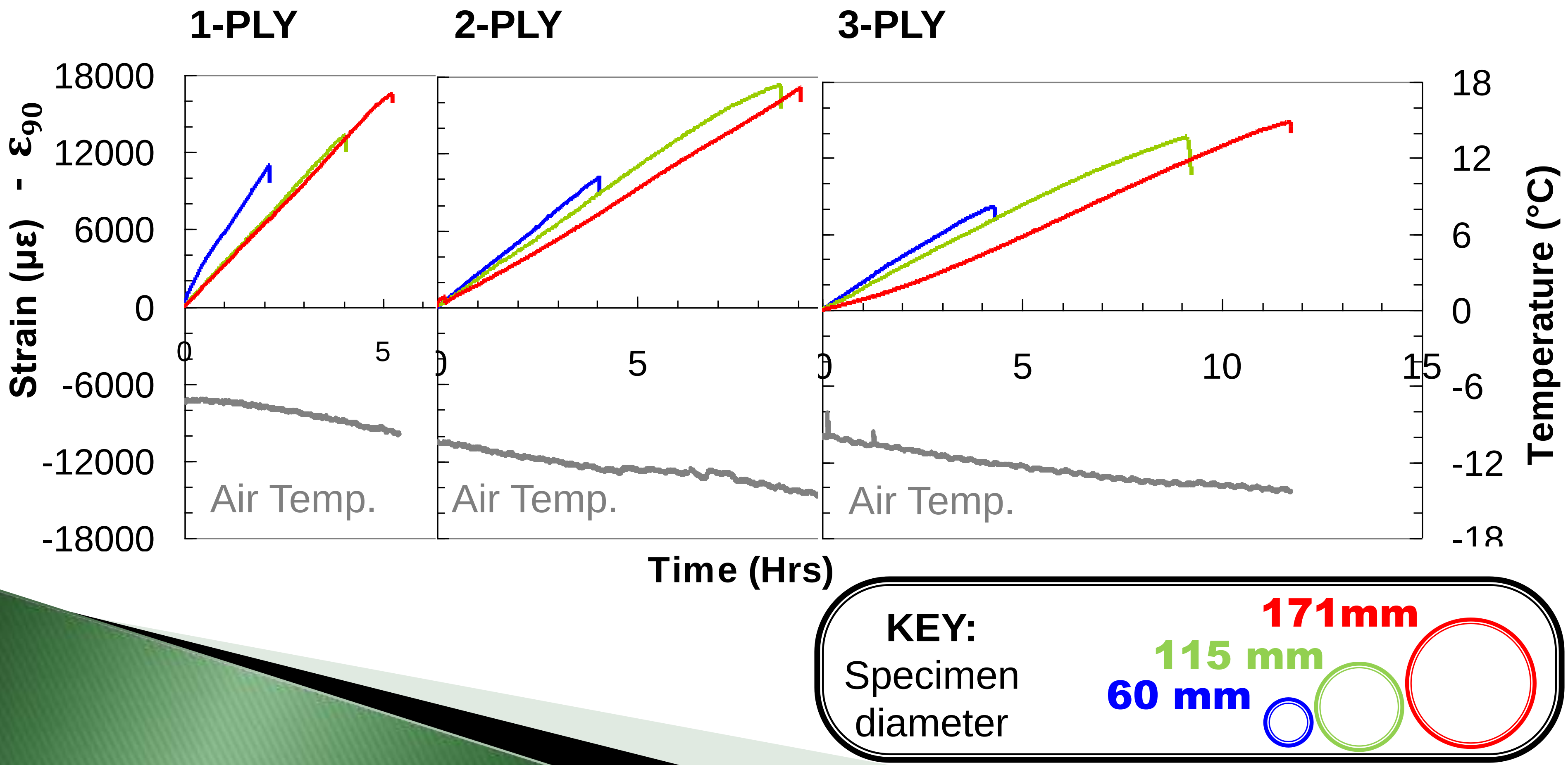
Experimental matrix



Specimen preparation

Experimental results

- **Behavior:**
  - Linear elastic to failure, constant gradient.
  - Increasing ultimate strain with increased diameter.



Experimental results

- Sudden brittle failure with rupture of the GFRP, in the middle third of the specimen height.
- With increasing reinforcement ratio, the failure occurred through the entire cross-section.
- Rupture zipped through the cross-section and migrated longitudinally in both directions.

Conclusions

- GFRP cylinders followed a linear elastic behavior till failure, where specimens failed in the middle third section in pure tension.
- The loading mode was successfully confirmed to be hydrostatic with video footage, as water busted out through the GFRP jacket at the instant of failure.
- Ultimate circumferential strain values increased with increasing diameter, while being consistently lower when compared to similar GFRP flat coupon specimens under the same environmental conditions.

Safety Analysis of Composite Materials for Existing and New Construction

Project Number: 06

This project aims at calibration of the safety factors of ACI 440 Code, particularly those pertinent to columns, by the process of reliability analysis. Furthermore this is an attempt to incorporate the expected life-time of a structure into design by introducing a methodology that relates life-time to safety factors. The latter goal is, of course, applicable to both existing (ACI 440.2) and new construction (ACI 318 and 440.1).

The structural types considered in this study include columns subject to pure axial load or shear and beams subject to shear.

Introduction

1 Knowing the suddenness of the failure of an FRP reinforced member they should be designed to be safer than steel reinforced members, but how much safer are they in reality?

2 Most rehabilitated structures have a shorter expected life-time than new structures, can we relax the safety rules for them?

Reliability Analysis is the methodology to address such questions…

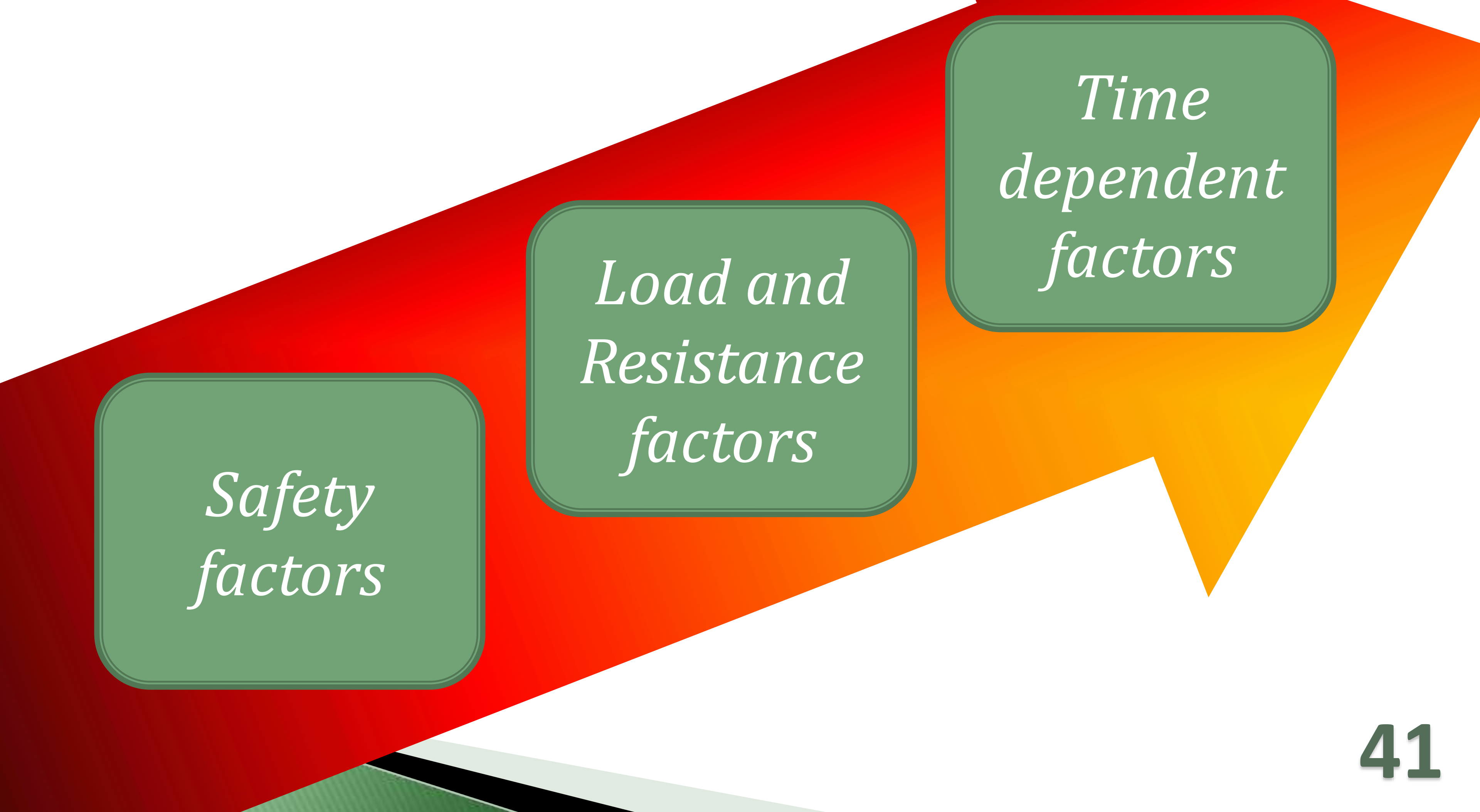
Background

Reliability Index, *β*, is a function of:

1. Safety factors
2. Load factors
3. Statistical parameters of resistance
4. Statistical parameters of loads
5. And is related to probability of failure

Overview

Development of safety factors:



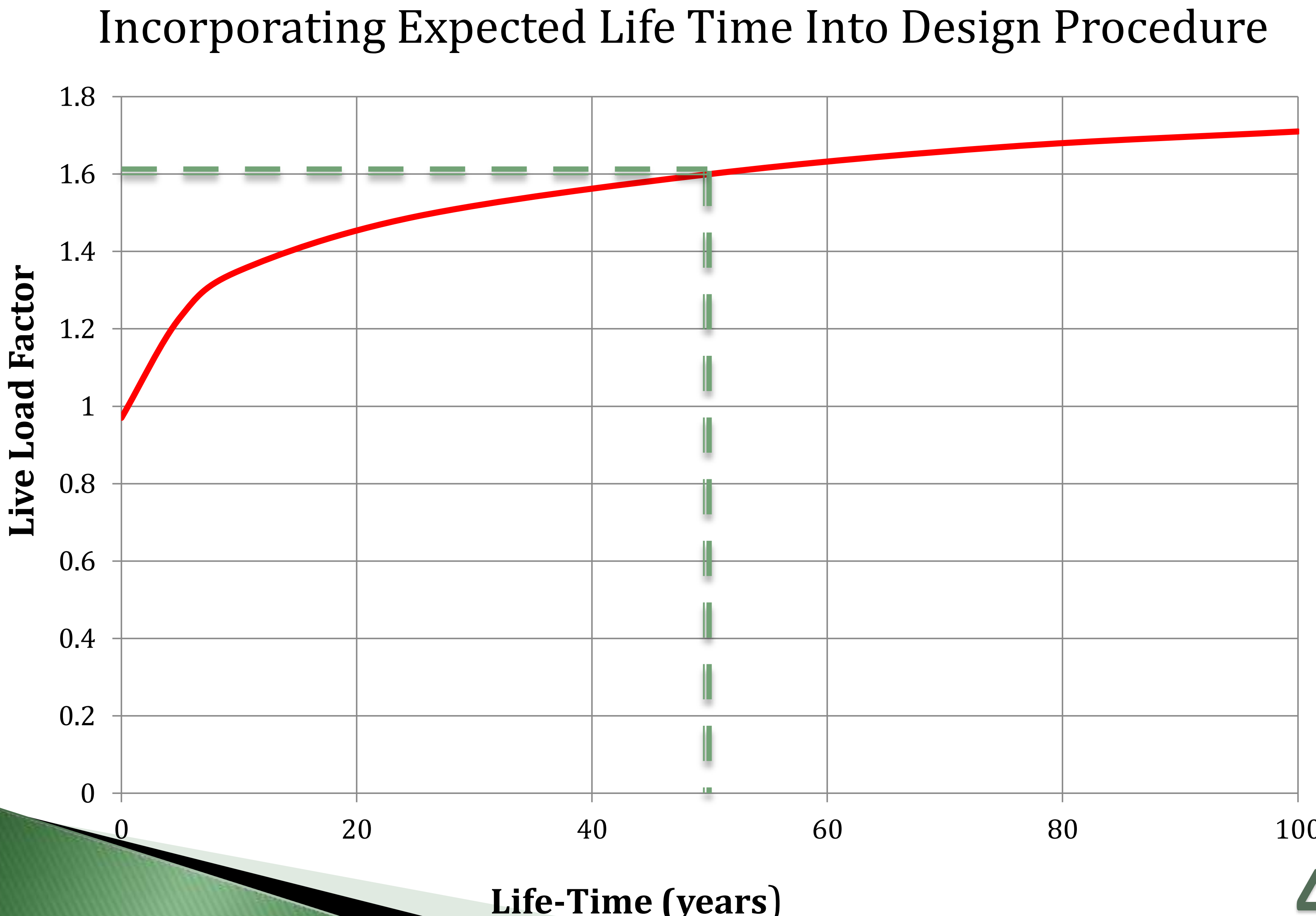
Overview

How life-time can play a role in design:

Live load statistical distribution is
Type I Extreme Value Distribution (EVD)

Life time(years)	Maximum/Nominal
25	0.86
50	1.0
100	1.13

Preliminary results



Scope of work

Calibration Procedure:

1
Focus is on columns under axial or shear force

2
Statistical model of resistance is selected.

3
Statistical model of load is selected, live load is modeled as a time dependent random variable.

Scope of work

Calibration Procedure:

4
The model is analyzed: Analytically or numerically.

5
Reliability is then compared to the target reliability.

6
The safety and load factors are then modified if needed so that the desirable reliability is achieved.

Thank U