Center of Excellence for Preservation and Service Life Extension

Strategic Plan Progress Update

@ICRI Fall Convention

10/20/2025

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Introduction to P+Ex

CO_2 Impact of Extending Service Life

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- **380 Million CY** of new RMX concrete placed each year in USA
  - Material production only, contributes 69 Million Tons of CO_2 to the atmosphere (~*0.18 Ton CO_2/CY)**

- **12 Billion CY** current inventory of existing concrete in USA
  - 12 Billion CY = 2.2 Billion Tons of CO_2
  - Repairing , Protecting, Rehabilitating, Preserving
  - Extending the Service Life
  - Everyday we extend the service life of existing concrete inventory

  = ***Savings of 6 Million tons of CO_2*** *

* *source PCA, 400lb CO_2/CY*

**less the CO_2 required to preserve the existing concrete which is generally minimal

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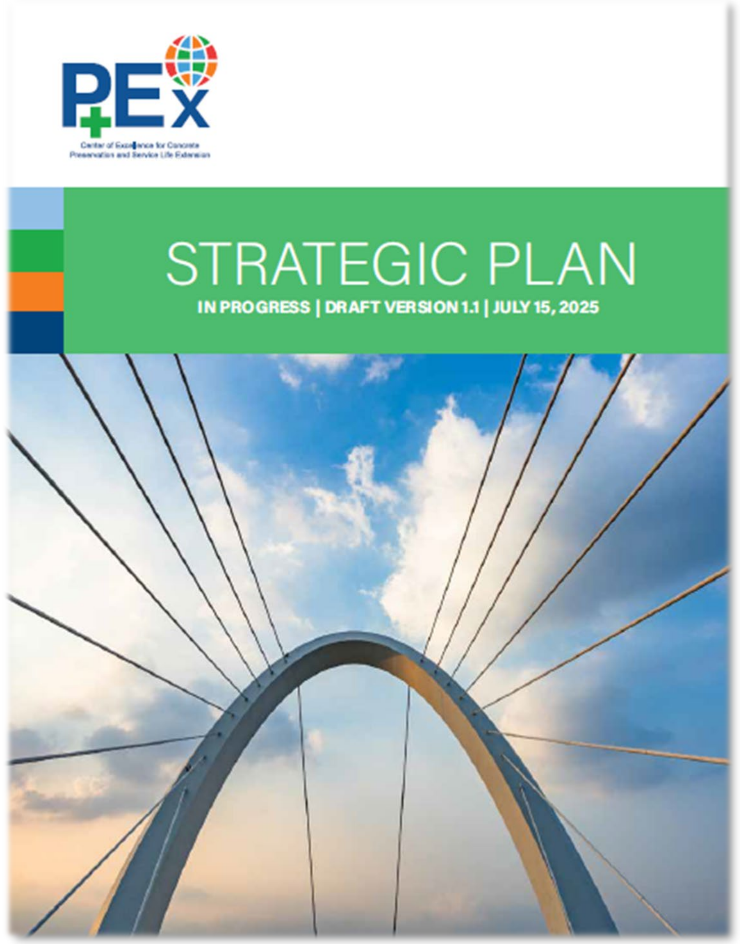
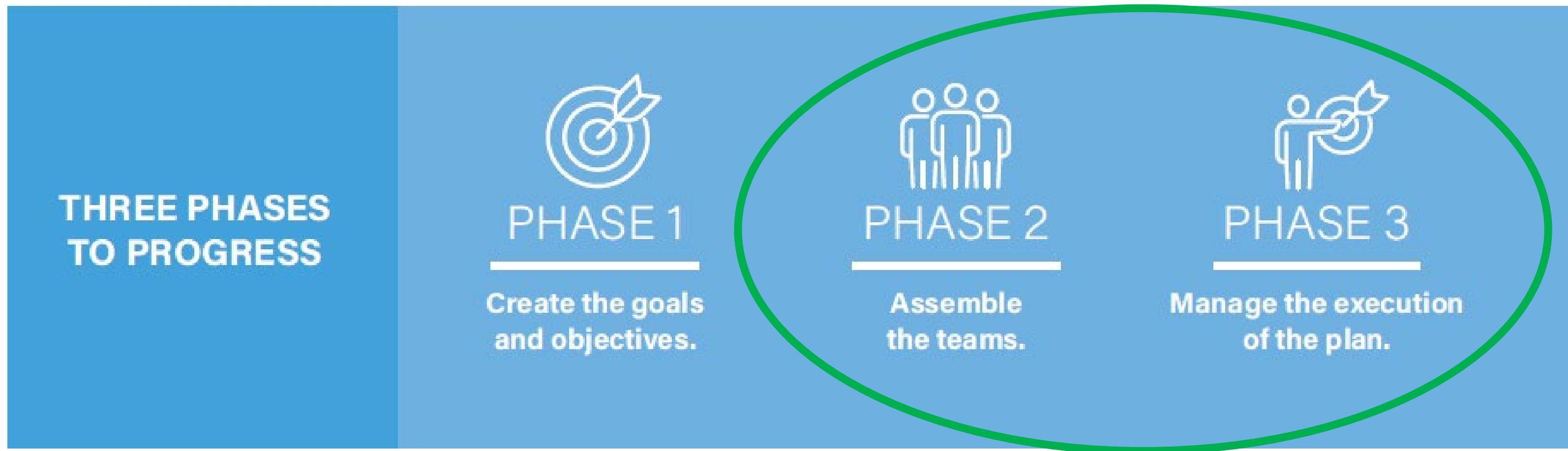
Progress Made in the Last 6 Months

- Strategic Plan has been approved by the Board; and is published the P+Ex website
- P+Ex is supported by ICRI and NEx (ACI Center of Excellence)
- Memorandums of Understanding are pending with ACI, ACA, NCBC, ASBI and PTI
- We are moving forward with implementation
    - Assemble working groups
    - Organize workshops and meetings to execute the plan





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P+Ex Goals

PROGRESSIVE FOCUS

- GOAL 1: Highlight the societal benefits of enhanced service life for new and existing structures.
- GOAL 2: Develop strategies to conserve resources and reduce environmental impact through proper concrete asset management.
- GOAL 3: Raise awareness of the financial benefits of durability design and service life extension.

- GOAL 4: Advocate for responsible stewardship of the built concrete environment.
- GOAL 5: Serve as a knowledge hub for tools and techniques to extend service life.
- GOAL 6: Publish periodic sustainability reports on the repair industry's efforts and set future goals as needed.

PEX

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GOAL 1: Highlight the societal benefits of enhanced service life for new and existing structures

Objectives:

- ***Support the inclusion of durability requirements in codes and standards, such as ACI 318 and ASCE 7.*** Follow international guidelines like ISO 2394, which specifies min. 50-year service life for buildings.
- Educate owners on the importance of regular maintenance of concrete structures to prevent deterioration and keep them safe.
- Develop a guide for owners regarding inspection and maintenance of concrete facilities.
- Protect public safety by utilizing available technologies to enhance and protect concrete structures against aggressive environments.

Task Group & Timeline

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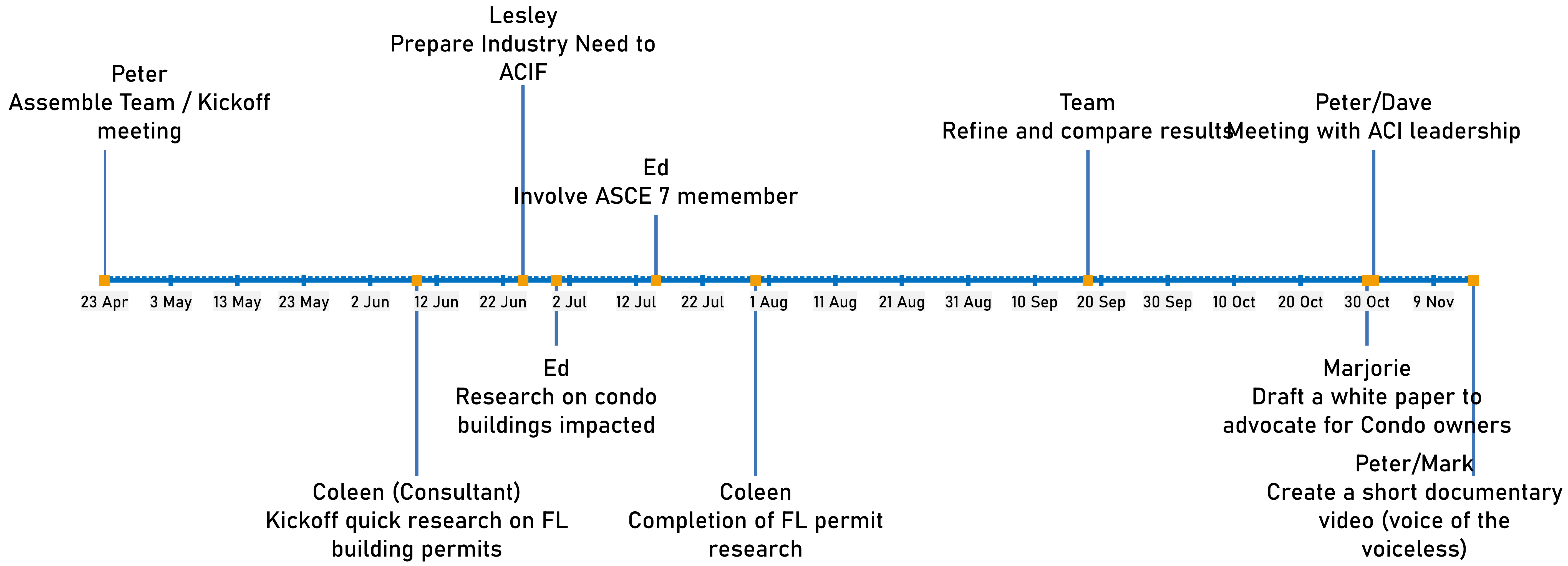
Case Study

- **Peter Emmons (Structural) – lead**
- Mark Geraghty (Structural)
- Ed Kluckowski (Mapei)
- Marjorie Lynch (Structural)
- Coleen Holding (Consultant)

Collaborate with ACI

- Peter Emmons (Structural)
- Dave Whitmore (Vector)
- Ed Kluckowski (Mapei)
- Lesley Ko (P+Ex)



Florida Buildings within 1 Mile of Coastline

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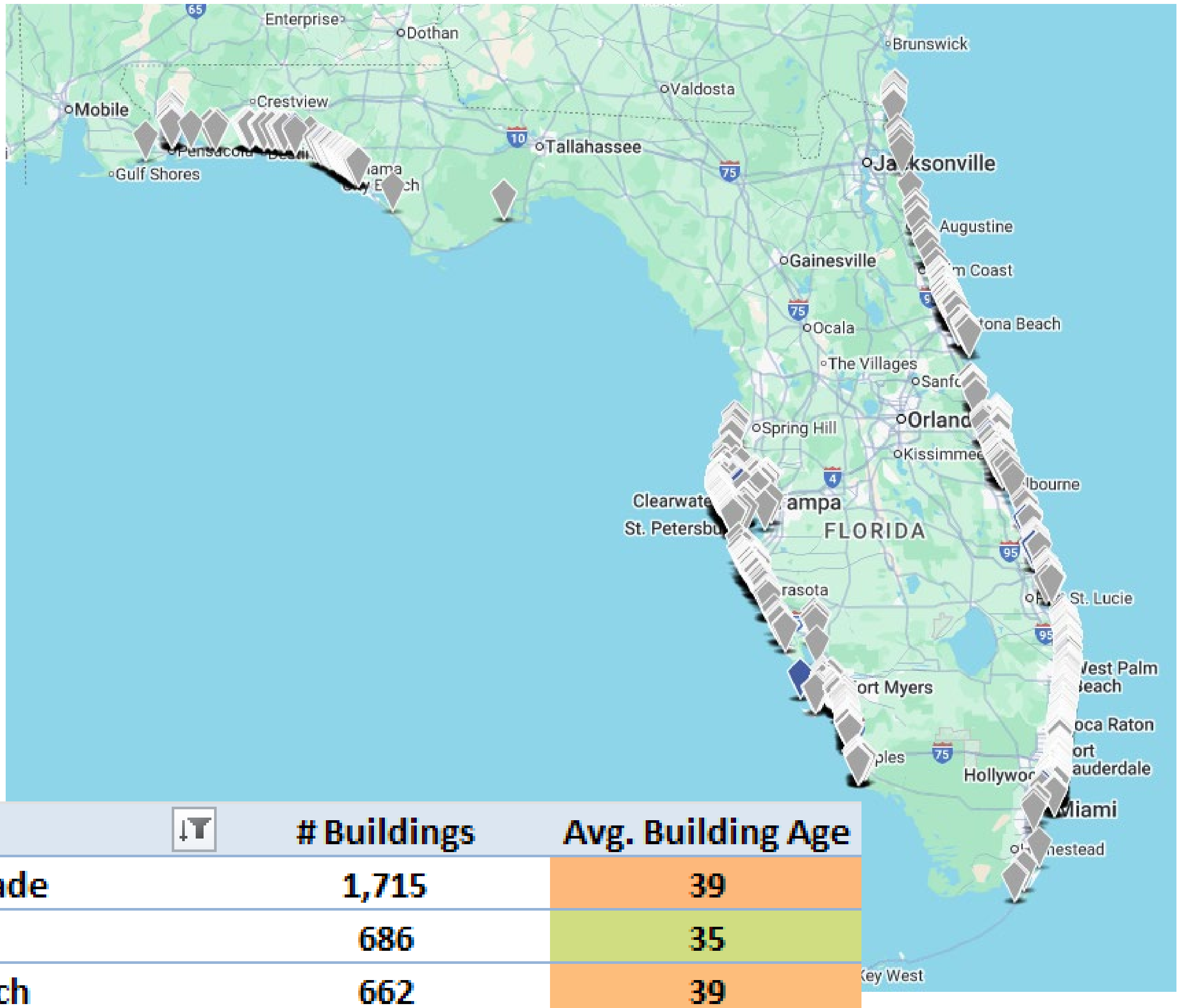
✚ Existing buildings

- 5,886 properties (≥ 4 stories)
- Considered top 10 Counties (by # Buildings)
- Average building age - ***38 years***



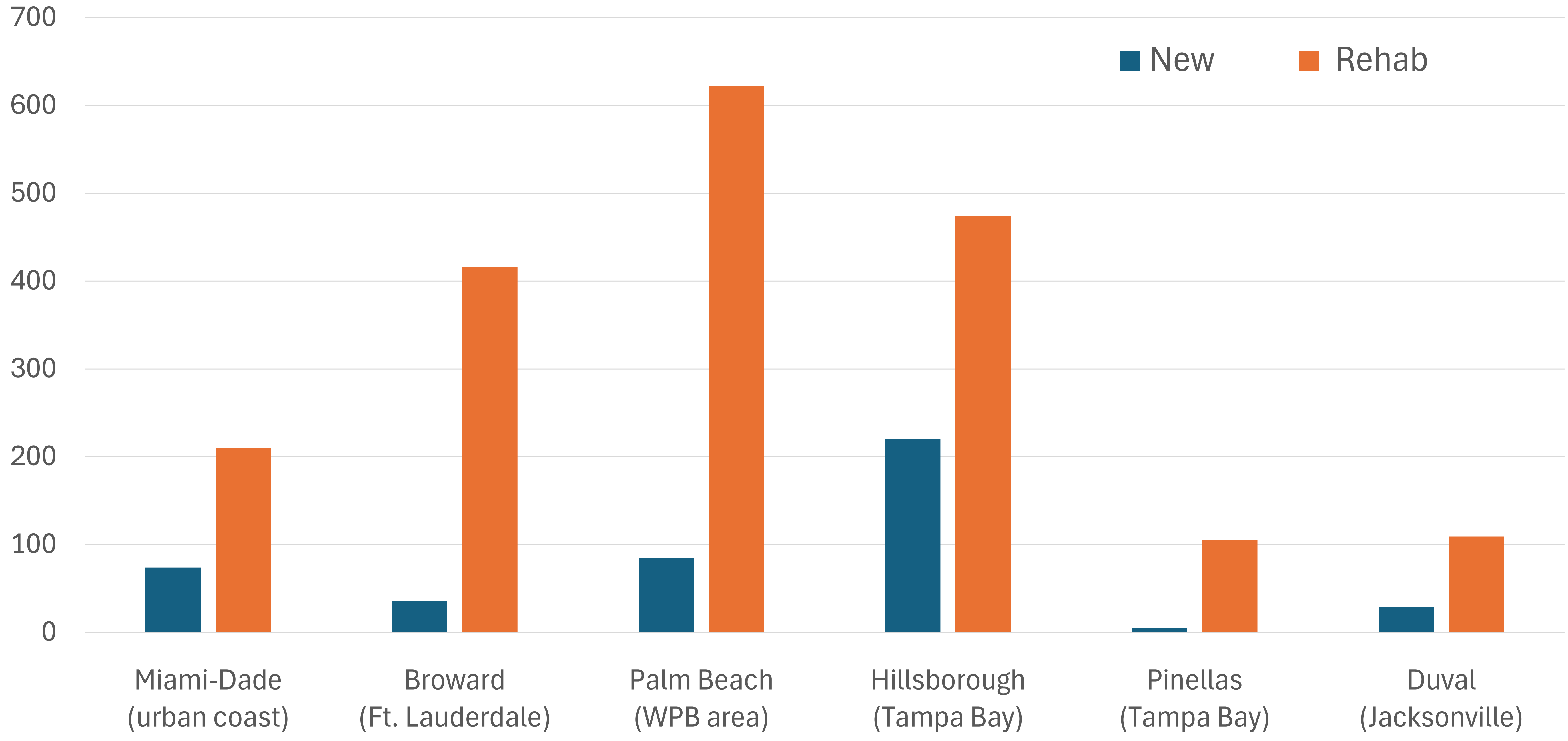
County	# Buildings	Avg. Building Age
Miami/Dade	1,715	39
Pinellas	686	35
Palm Beach	662	39
Broward	525	43
Sarasota	322	35
Collier	300	38
Brevard	277	32
Volusia	264	41
Hillsborough	251	33
Lee	157	36
Grand Total	5,159	38

✚ Total 1422 building permits issued in 2024

- 1140 permits (80%) for restoration or alteration
- 282 permits for new constructions

Data Source: 2025 CoStar Group (8/10/2025 inventory

Florida Coast Permits
Rehabilitation vs. New Build



- **Rehabilitation permits far exceed new construction permits (2023 & 2024)**

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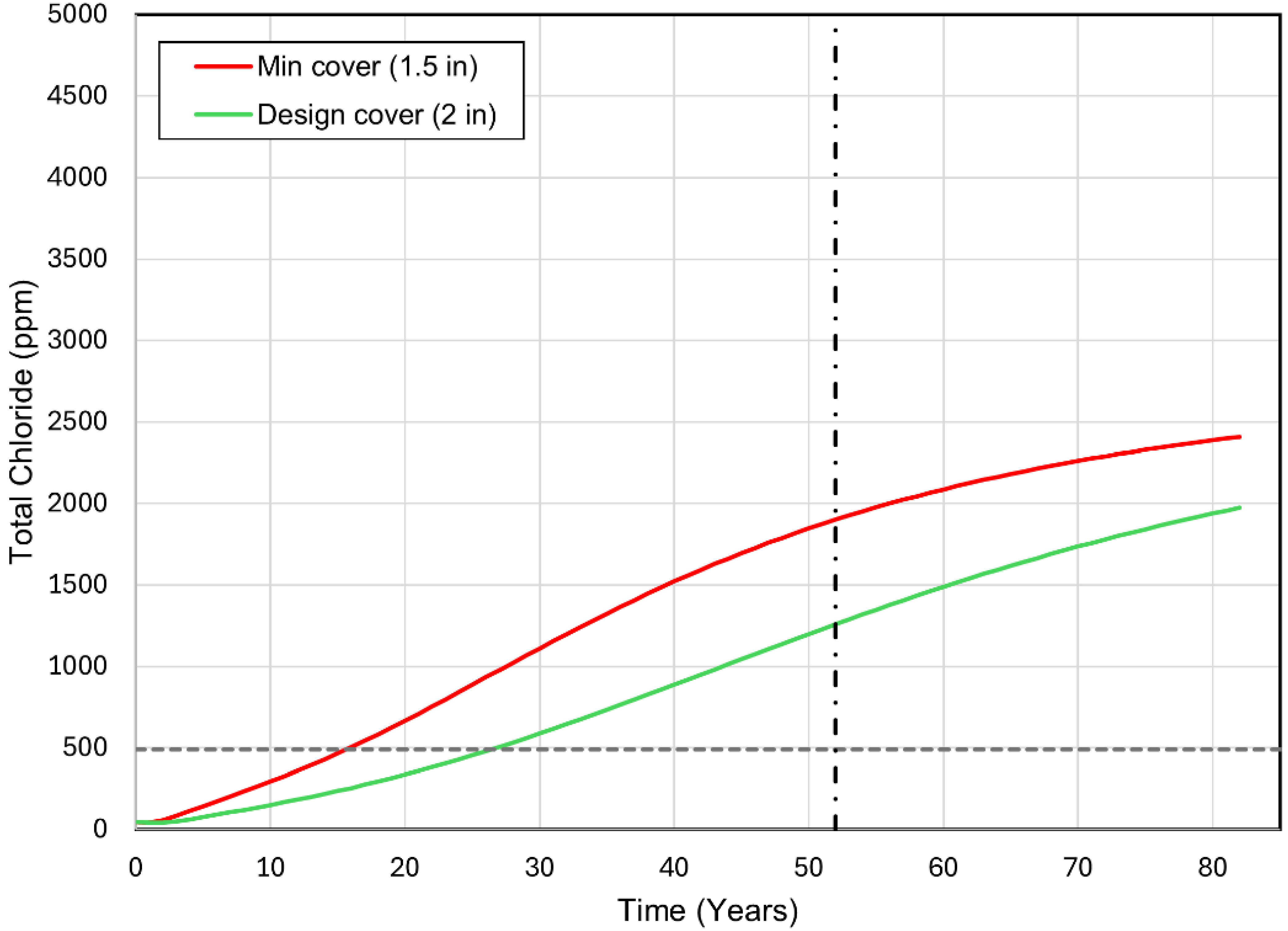
Drivers of Coastal Structure Rehabilitation

- **Concrete structures are not always designed/ constructed to resist aggressive chloride ingress**
  - Chloride-induced rebar corrosion in concrete
    - Low concrete cover
    - Minimal waterproofing
    - Lack of maintenance
- **Aging infrastructure & deferred maintenance**

Chloride Ingress and Corrosion



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Key Categories of Coastal Rehabilitation Projects

Structural concrete repair

- Repair spalling concrete and corroded rebars
- Balconies, parking garages, columns, beams, structural walls

Building envelope & waterproofing

- Coatings, waterproofing and sealants to block water and salt ingress

Impact windows & doors

- Installing hurricane-rated openings to meet FBC 2023 wind standards

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P+Ex Recommendation for More Durable Structures

- **Incorporate additional durability requirements (not just strength) to make concrete structures more resistant to aggressive chloride exposure**
  - "Promote Design for Service Life", e.g. 50, 75, 100 years (?)
  - In FL, many of the coastal buildings are condominiums. Condominium owners typically take possession of the building shortly after construction, but they do not have a say in what durability measures are incorporated in the building, and they are ultimately responsible for the high cost of fixing deteriorated concrete.
  - In FL, nearly one new building along the coast is breaking ground every day utilizing the current building code (not designed with specific durability code requirements)

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P+Ex Recommendation for More Durable Structures (cont.)

- Implement maintenance planning as part of original design
- Need to include more durability requirements in ACI 318 (ref. ACI 321, ASCE 7)
- ASCE 7 – create environmental loading chart
  - Zones of marine and airborne chloride (e.g. coastal buildings)
  - Zones of road salt chloride (e.g. parking structures)

Summary and Next Steps

- We recommend **inclusion of mandatory durability requirements in the building code to enhance the service life of concrete structures**
- Write a white paper on Florida coastal building repair to help inform stakeholders
- Educate owners on the importance of:
  - Durable design and the need for regular maintenance to prevent deterioration and keep them safe
- Develop an inspection and maintenance guide for owners of concrete facilities

GOAL 2: Develop strategies to conserve resources and reduce environmental impact through proper concrete asset management

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Objectives:

- **Assess and recommend methodologies** and procedures to quantify the environmental and resource consumption benefit of extending the service life of concrete structures vs. replacement
- Assemble case studies using standardized LCA methods
  - PVM Parking Garage Case Study
- Develop **repair system environmental declarations** to calculate and verify the repair system's environmental impact (i.e. membrane on a parking deck)

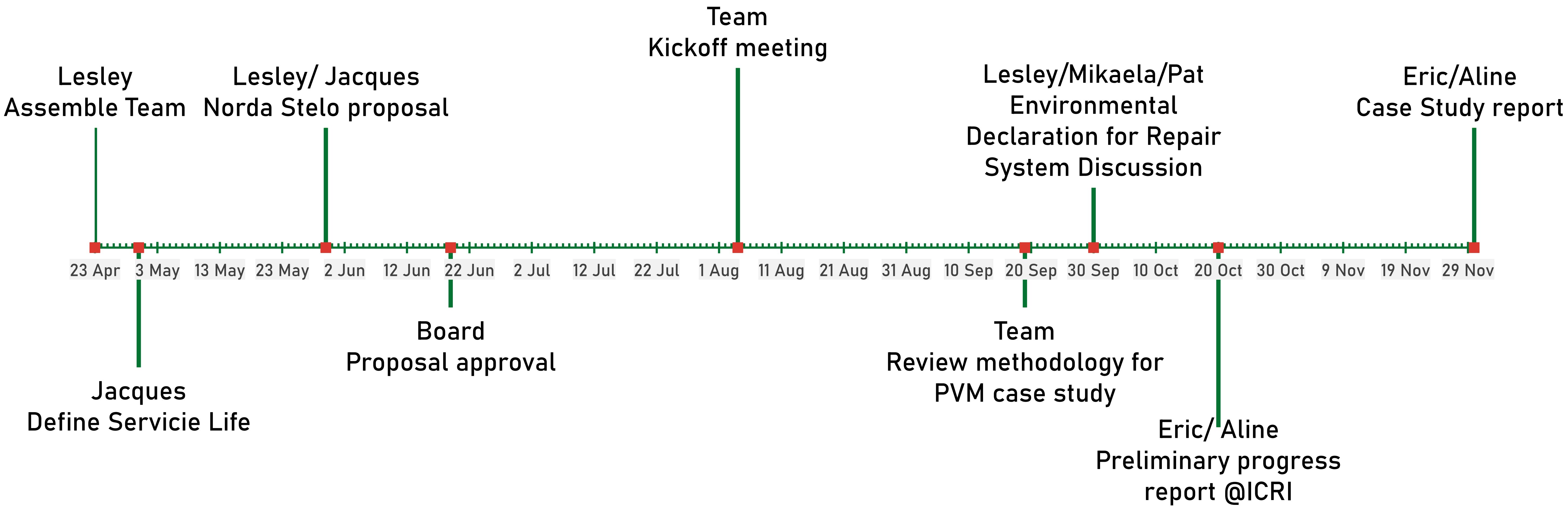
Task Group & Timeline

Case Study 1:

- **Lesley Ko (Structural) – lead**
- Jacques Marchant; Eric Samson (SIMCO)
- Alex Brisson, Aline Cobut, Vincent Blanchard (Norda Stelo)

Methodologies and additional case studies:

- Mikaela Decio, Brittany Storm (Mapei)
- Patrick McConnell (Atlantis Fibers)



PVM Parking Garage

A case study combines service-life analysis (SLA) and carbon footprint calculation

- Parking Layout
- Main Assumptions
- Service-Life Analysis
- Carbon footprint Calculations

Background Info

- Patrick V. McNamara (PVM) federal building located in Detroit, MI
- Built in 1973, this is an existing five-level reinforced concrete parking structure
  - 3 levels below grade (Levels 1-3),
  - 1 level at grade (Level 4), and 1 level above grade (Level 5).
- Major concrete repair work is ongoing
- Data from past inspections and reports were used.
- Frequent exposure to deicing salt led to rebar corrosion.
- Breakout windows showed extensive corrosion damage.

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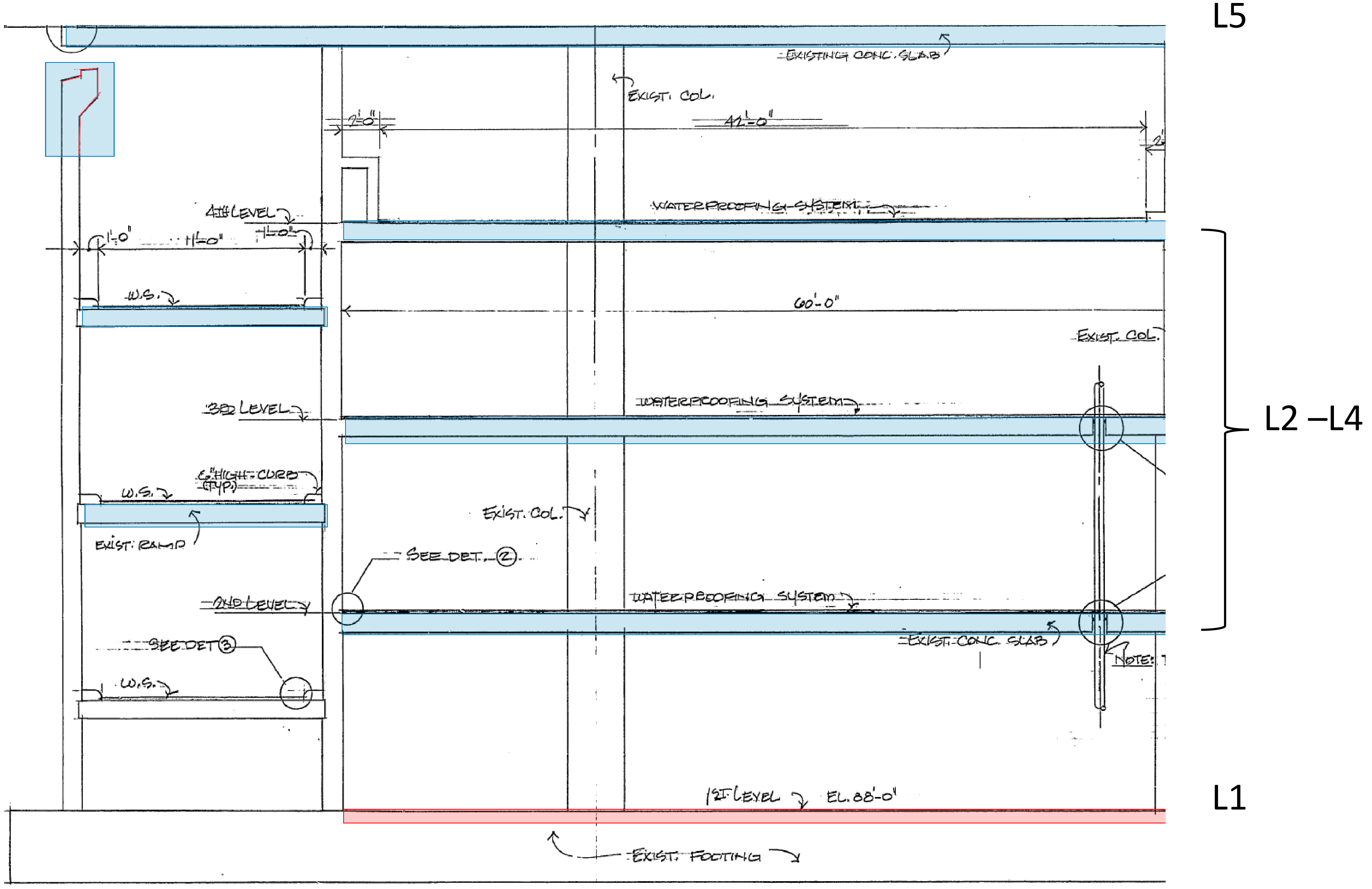
General Parking Layout



Main Assumptions

- Concrete properties estimated based on similar projects executed by SIMCO:
  - OPC with 375 kg/m3, 0.45 w/c
  - Physical properties: porosity, diffusion coefficient, permeability
- Cover depth: design value and GPR data were used:
  - L1: Design = 4”, GPR = [3” – 5”]
  - L2 – L5: Design = 2”, GPR = [1.5” – 2”]
- Main degradation mechanism: chloride ingress causing reinforcement corrosion. End of service-life: <u>initiation + 10 years</u>
- Chloride loading: per ACI 362.1R-12, Detroit falls within Zone III - regions subject to frequent freezing and the regular use of de-icing salts

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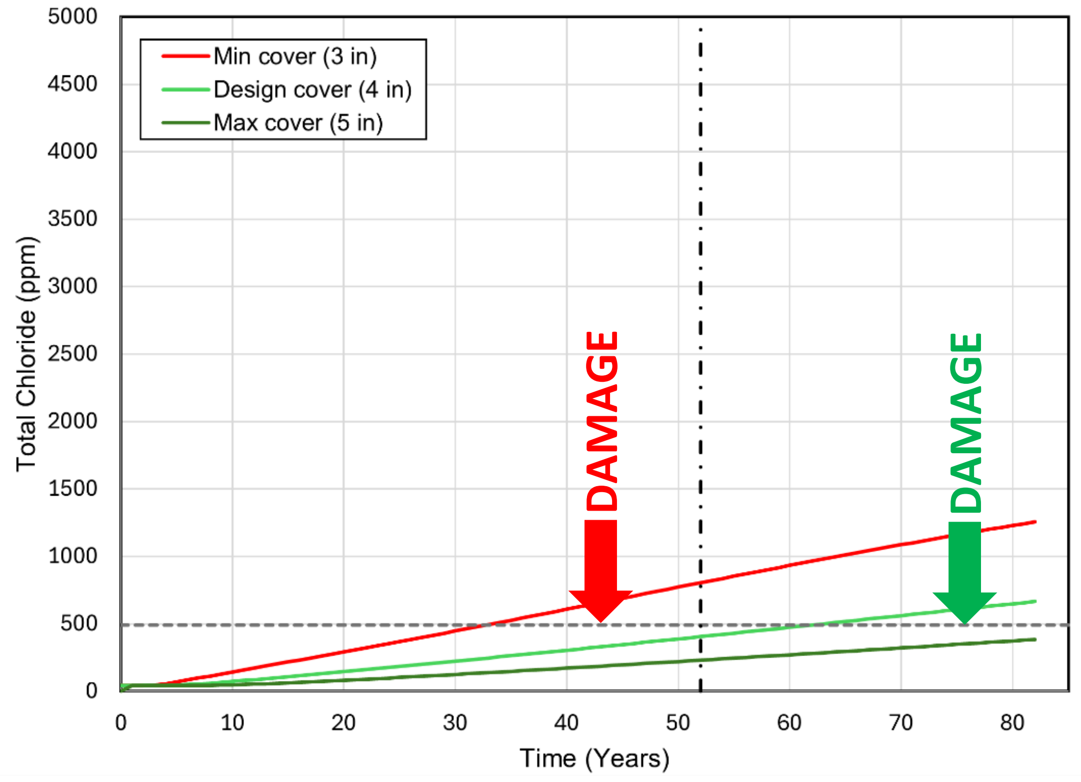
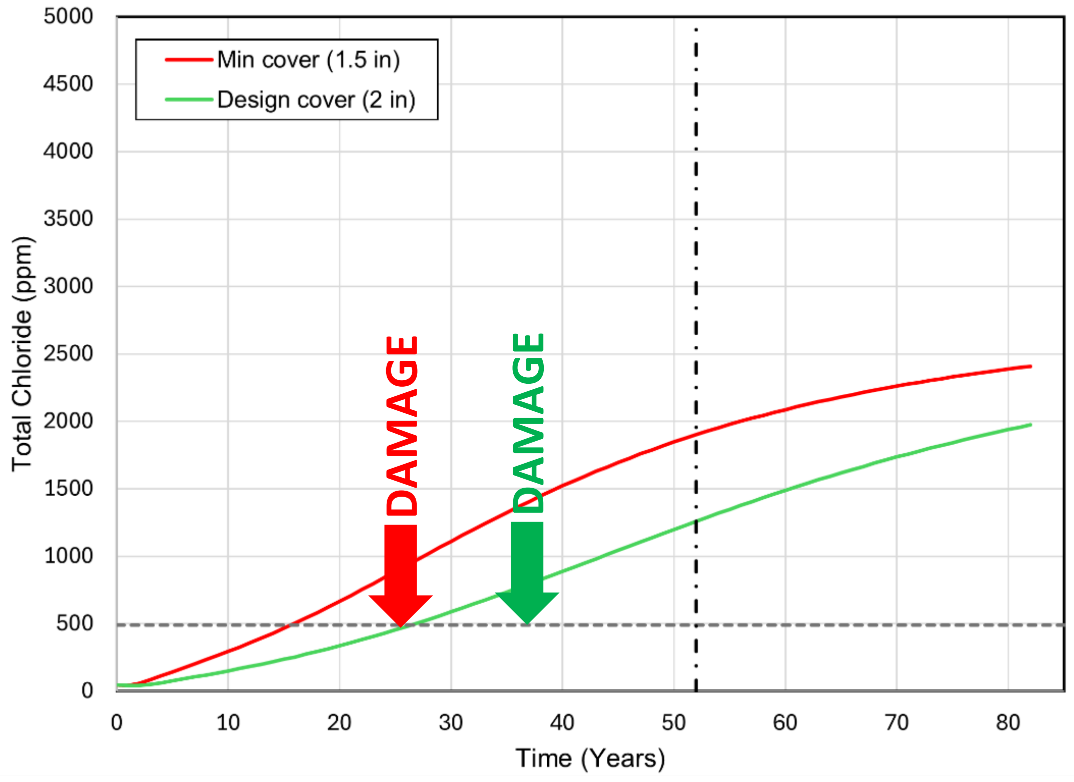
Chloride Ingress Calculations

- All calculations show chloride has reached rebars
- For the most part, it matches with observations
- However, a finer analysis would be needed to reproduce corrosion underneath the slabs

Level 1



Level 2-4



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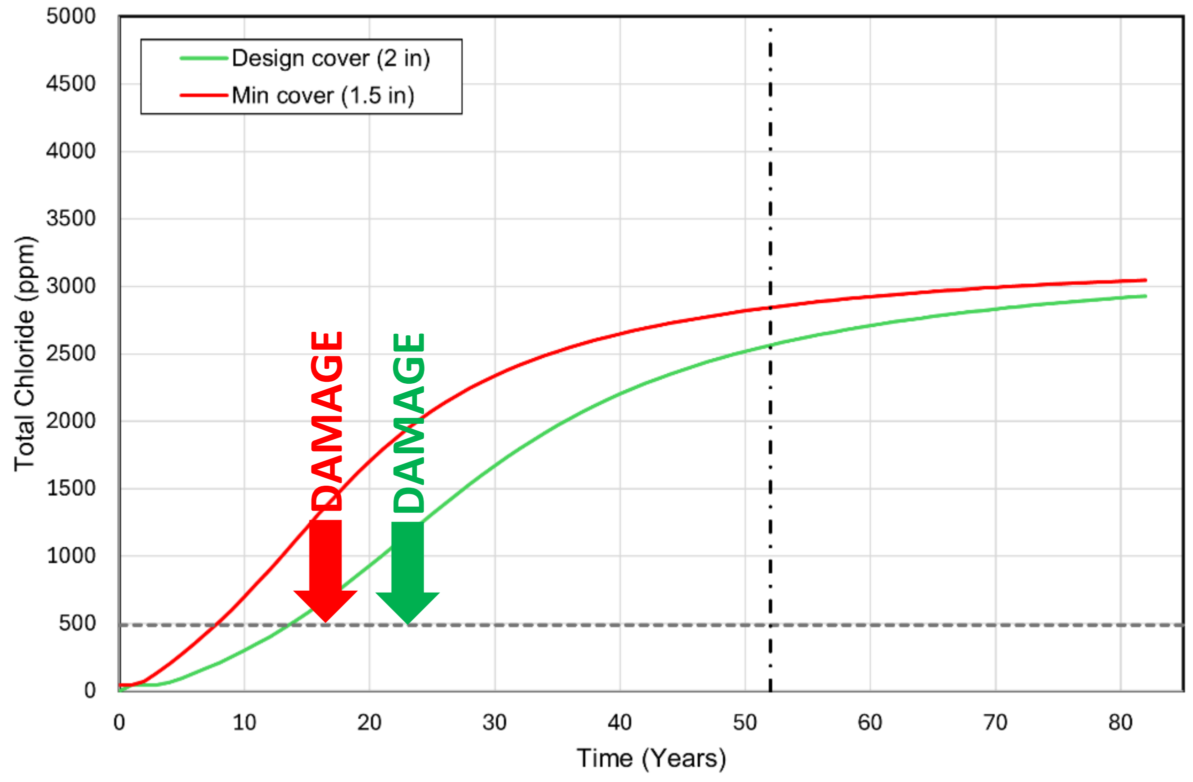

Concrete Repair Solutions vs. SLA Calculation

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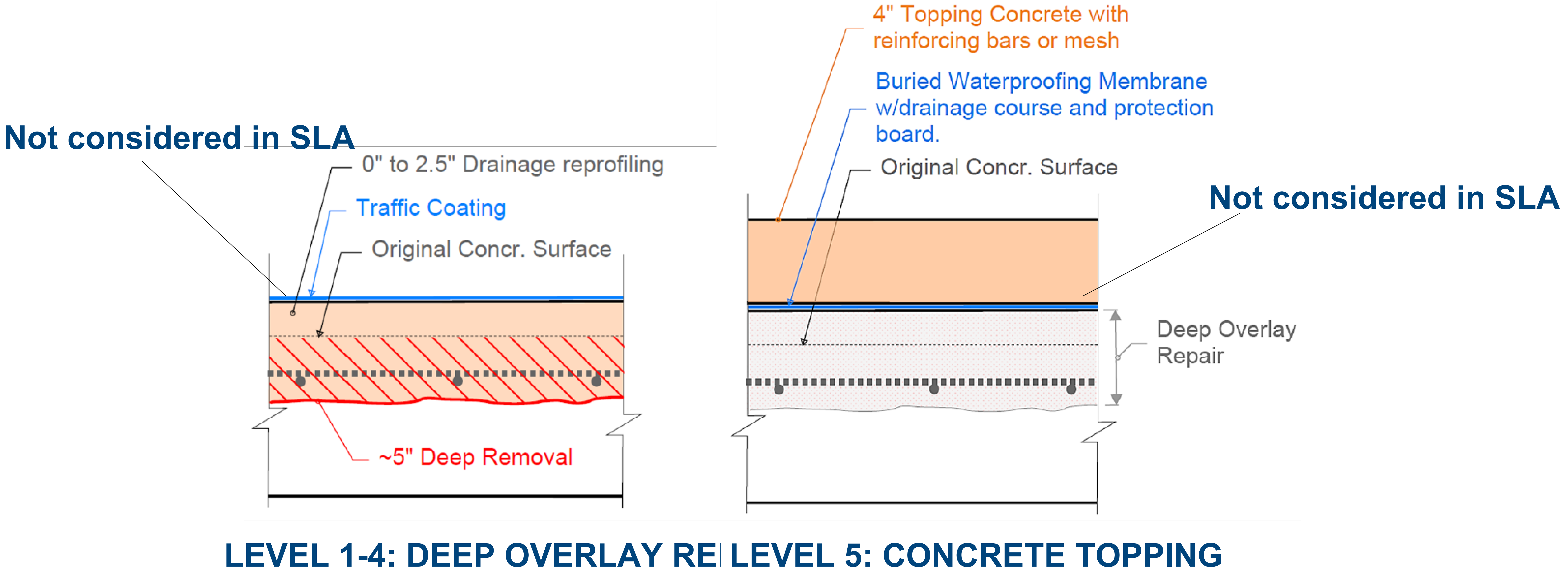
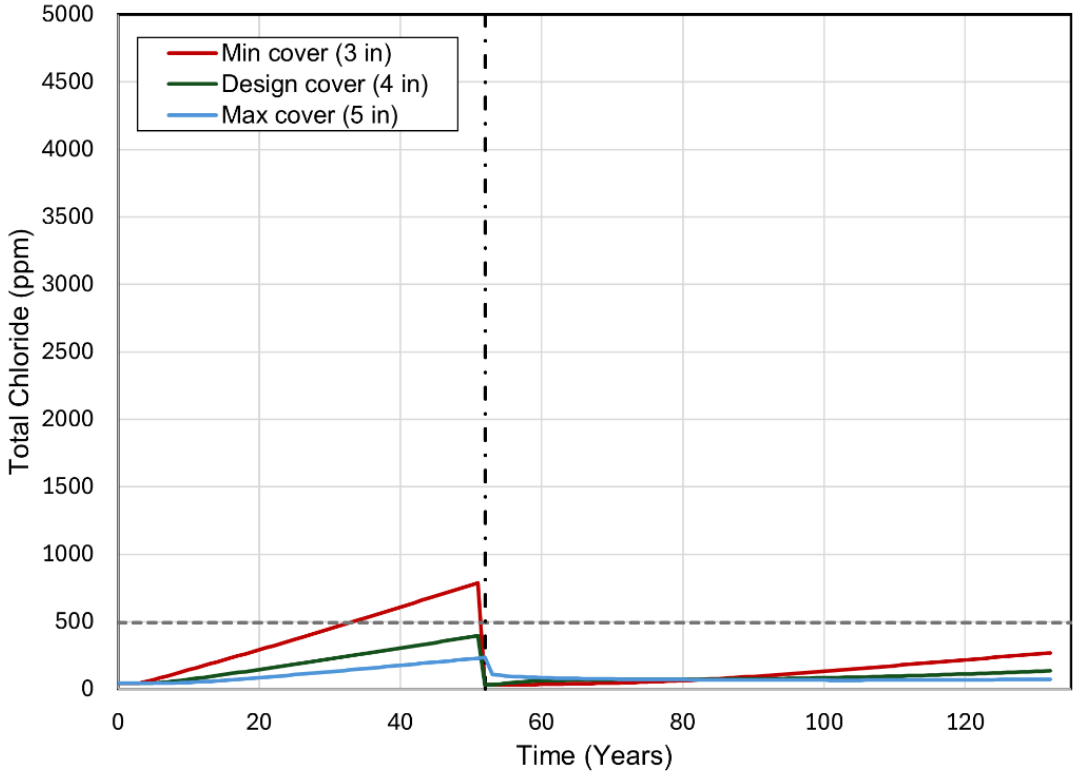


ICCP system not considered in service-life evaluation

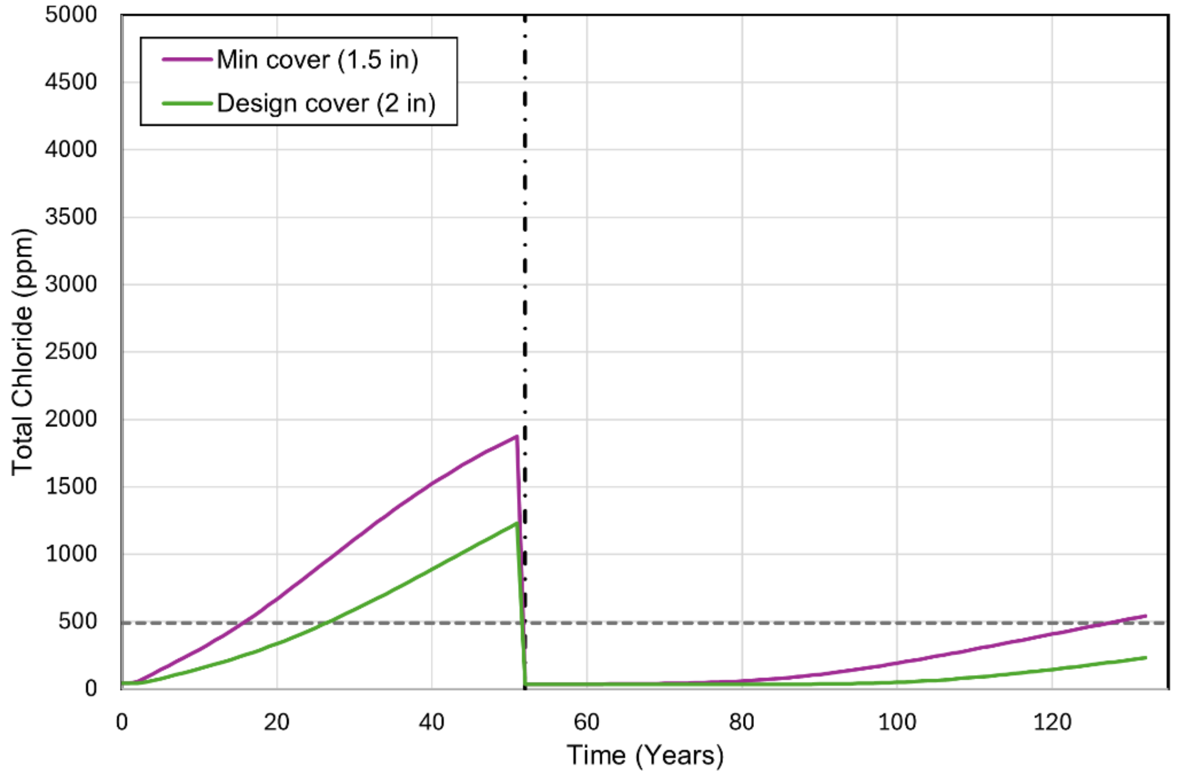
Concrete Repair Calculations

- All repairs assume that corroded rebars are exposed and cleaned before new concrete is placed.
- Calculation results: 0.5 in. reprofiling (above initial level)

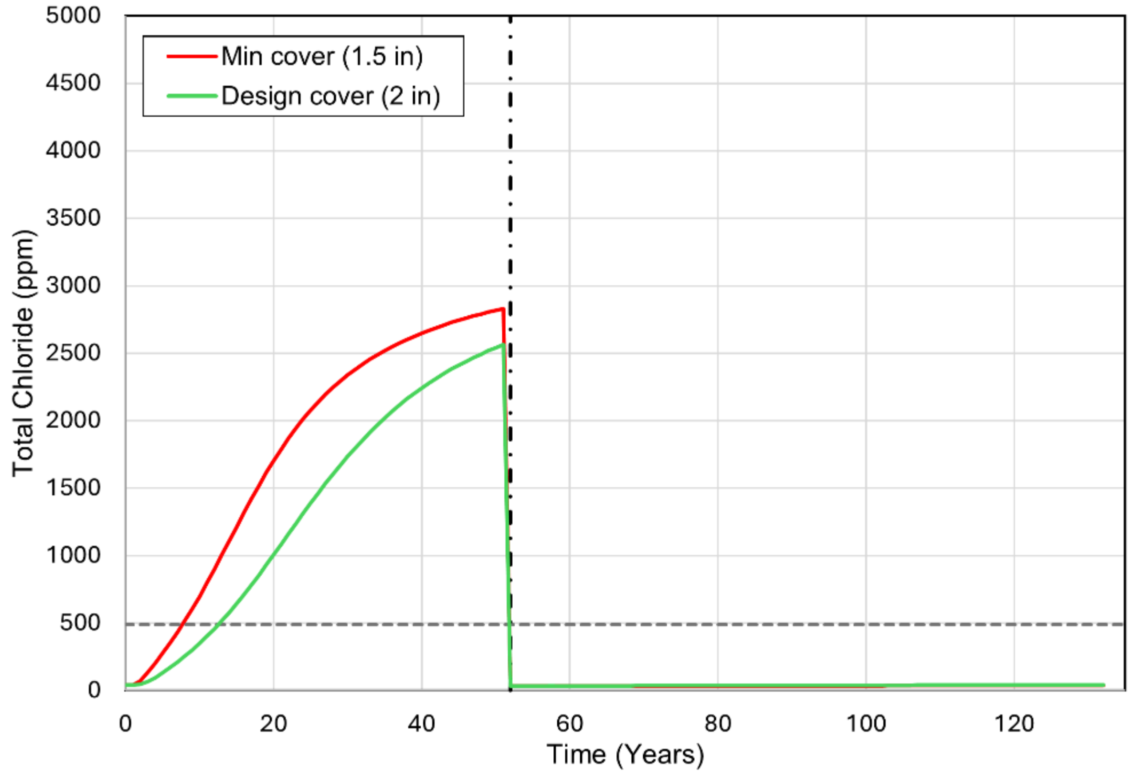
Level 1



Level 2-4



Level 5



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Carbon Footprint Methodology

Goal and scope definition → Functional unit (basis for analysis) → Life cycle inventory (LCI) data collection → Modeling in LCA software (SimaPro, openLCA, etc.) → Preliminary results and interpretation / data quality → Sensitivity analysis → Conclusions / recommendations

ISO 14040:2006 (principles, framework)

ISO 14044:2006 (requirements, guidelines)

Iterative process

Identification of main contributors to impact scores

Decision support tool

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Building Life Cycle Stages

Example: Construction (ISO 21930:2016, EN 15804/15978)

Building life cycle stage																Supplementary information
Product			Construction process		Use							End of life				
Raw material supply	Transport	Manufacturing	Transport	Construction - installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction/demolition	Transport	Waste processing	Disposal	Benefits and loads beyond the system boundary (Reuse, recovery, recycling)
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

Cradle to Gate (partial life cycle) (A1–A3)

Cradle to Gate with options (partial life cycle) (A1–A3, optionally A4–C4)

Cradle to Grave (whole life cycle) (A1–C4)

Source: https://www.mdpi.com/2071-1050/12/20/8442

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Applicable Standards and Guides

- NRC National Whole-Building LCA Practitioner's Guide (2024)
- CERIEC report on Applying Circularity in the Life Cycle Assessment of Buildings (2024)
- ISO 21930:2017. Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services. Ed. 2.
- ISO 14064-2:2019. Greenhouse gases - Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. Ed. 2.
- ASCE Guide (2017)
- AIA Guide to Building Life Cycle Assessment in Practice (2010)

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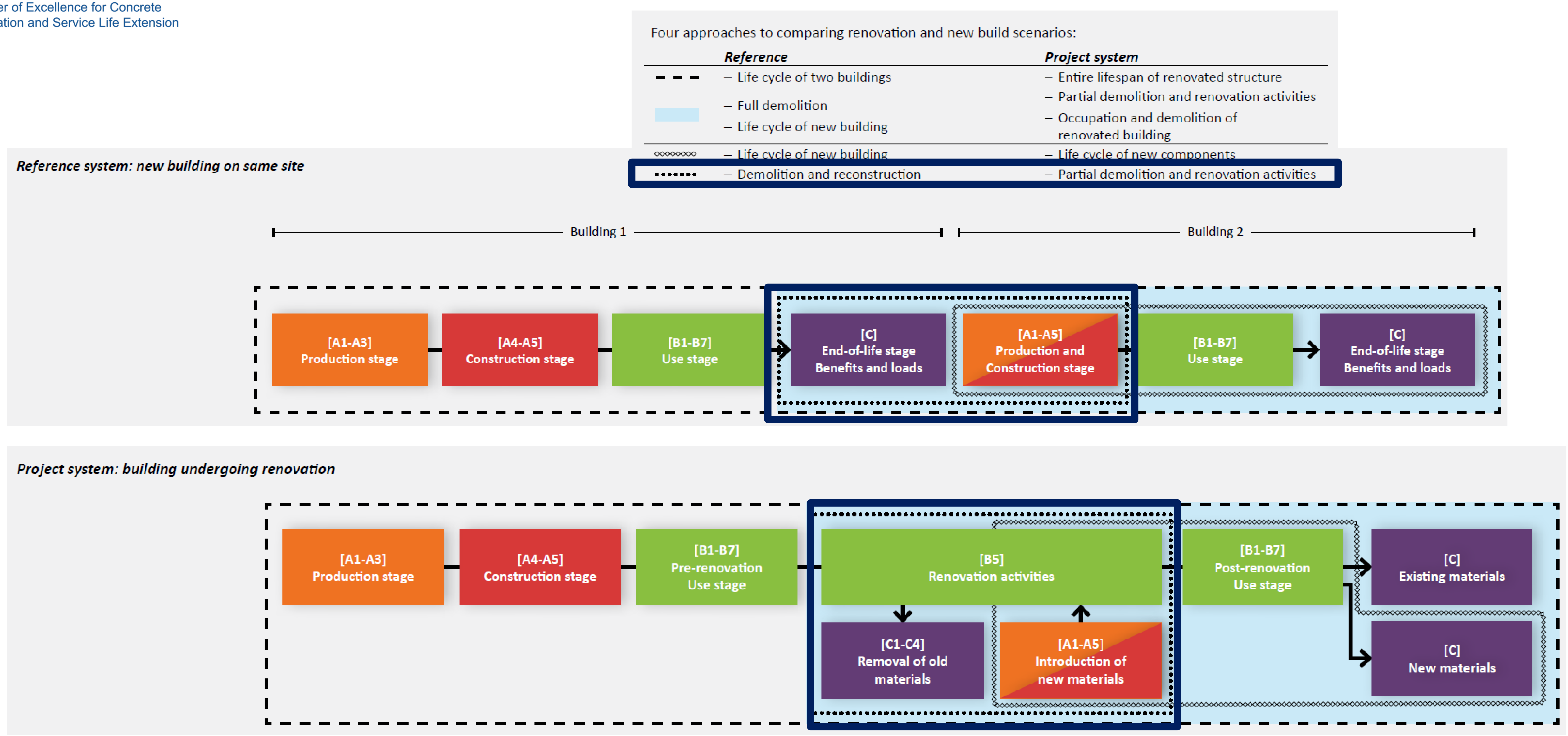
Proposed System Boundaries

*(Note areas outlined in **dark blue**)*



Source: CERIEC 2024 Applying circularity in the LCA of buildings

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Comparative LCA of Two Scenarios

Project scenario

- Partial demolition
- Major renovation

Included	Excluded

- Repairs (B3-B5)
  - Waste generated and treatment (C1-C4)
  - New material input (A1-A5)
- Maintenance, repair after project (B3-B5)
	- Operational water & energy (B6-B7)

Baseline scenario

- Demolition of existing asset
- Reconstruction of similar underground parking
  - Identical to current parking but with current building products

Included	Excluded
- Waste generated from demolition and its treatment (C1-C4) - New building materials + installation (A1-A5) - Maintenance, repair of new garage (B3-B5)	- Operational water & energy (B6-B7)

Breakdown of Project Carbon Footprint

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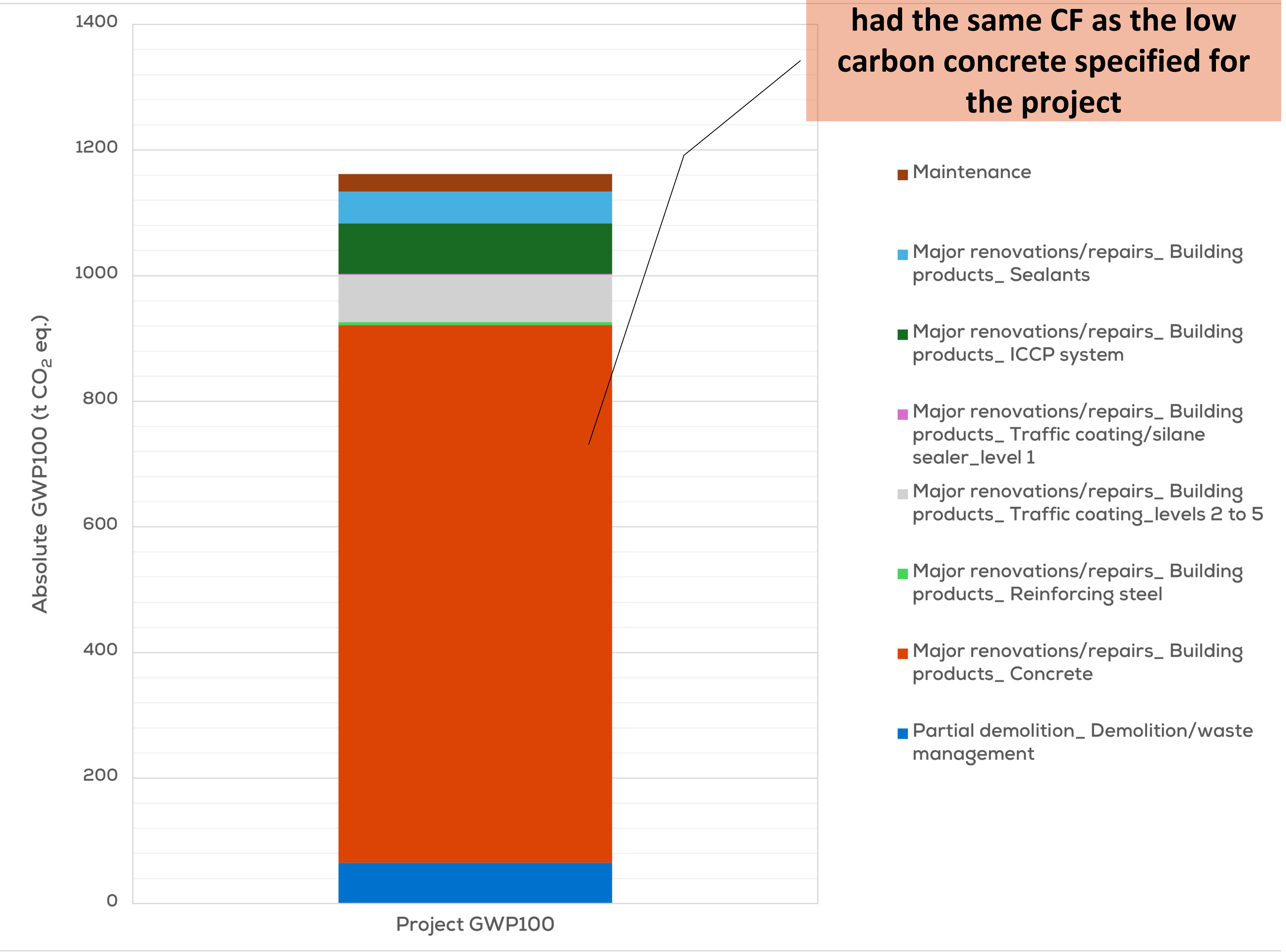
Functional unit (FU): Sustaining the use of the PVM building garage for an additional 30 years

- Absolute CF of project scenario: 1162 t CO_2 eq. (per FU, 441 t CO_2 eq.)

Life cycle stages	Contribution to CF
Partial demolition	5.6%
MR_Concrete*	73.7%
MR_Reinforcing steel	0.4%
MR_Traffic coating	6.6%
MR_ICCP system	7.0%
MR_sealants	4.3%
Maintenance	2.4%

*« Concrete US Benchmark 5000 psi » used in Athena IEB had the same CF as the low carbon concrete specified for the project



Comparative Carbon Footprint

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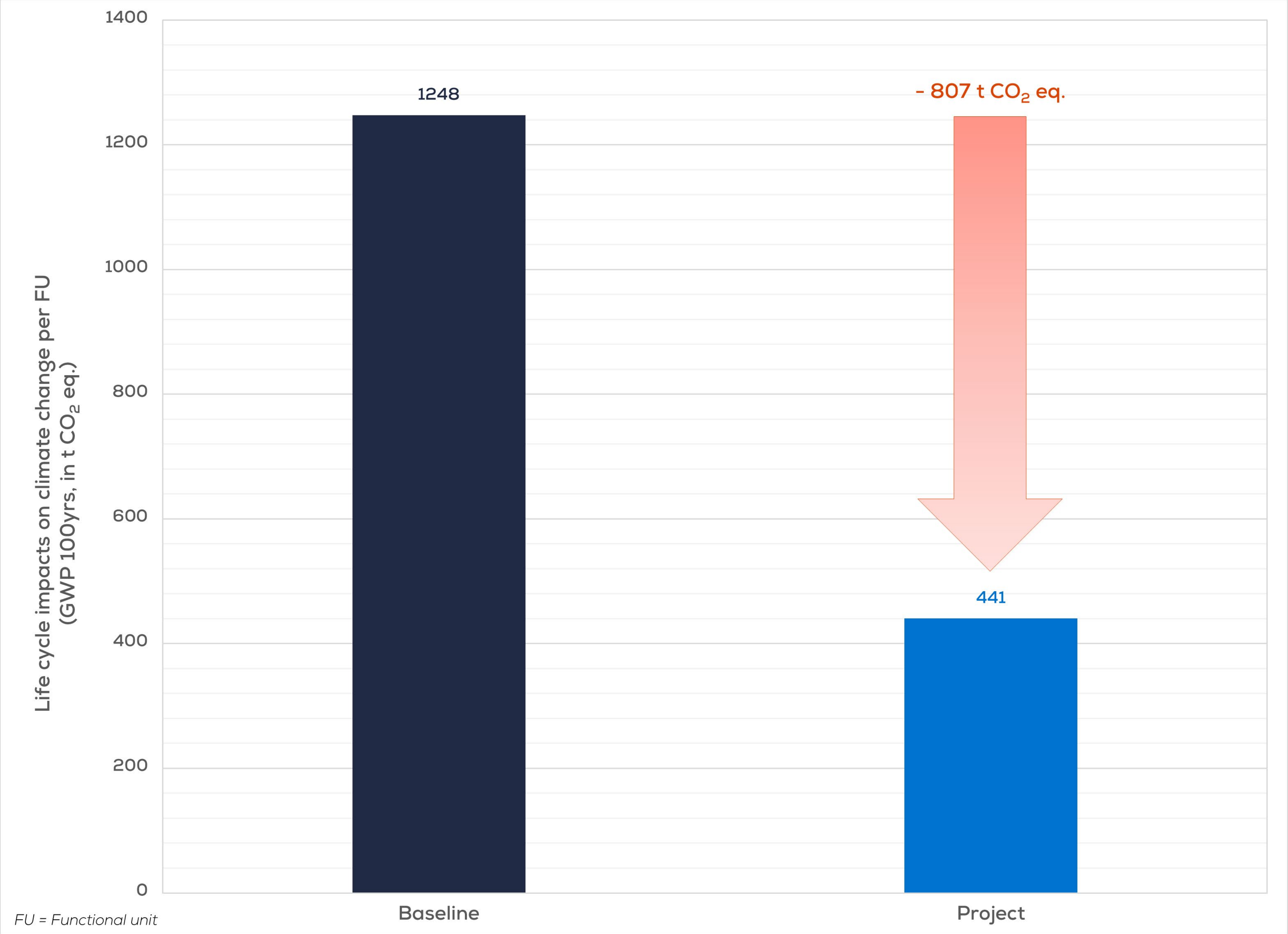
Functional unit (FU): Sustaining the use of the PVM building garage for an additional 30 years

- Carbon footprint of baseline scenario (new build, 60 yrs life):
  - 1248 t CO_2 eq. per FU
- Carbon footprint of project scenario (repair, 75 yrs SL):
  - 441 t CO_2 eq. per FU
- Estimated avoided life cycle GHG emissions of PVM garage project:
  - **ca. 807 t CO_2 eq.**



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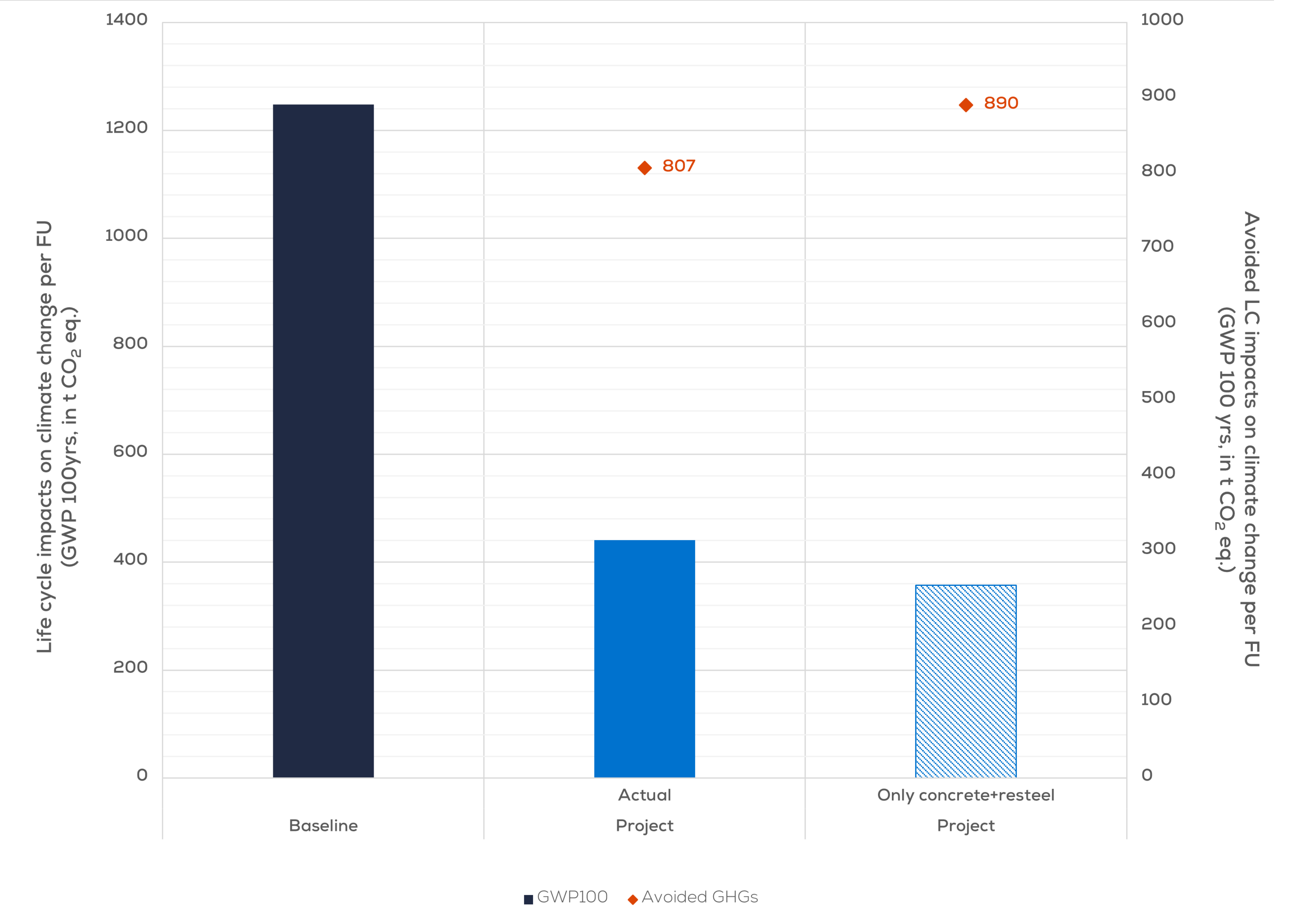
Comparative Carbon Footprint

Functional unit (FU): Sustaining the use of the PVM building garage for an additional 30 years

- Carbon footprint of baseline scenario (new build, 60 yrs life):
  - 1248 t CO_2 eq. per FU
- Carbon footprint of project scenario (repair, 75 yrs SL) only consider concrete + rebarsteel:
  - 358 t CO_2 eq. per FU
- Estimated avoided life cycle GHG emissions of PVM garage project:
  - **ca. 890 t CO_2 eq.**



Comparative Carbon Footprint

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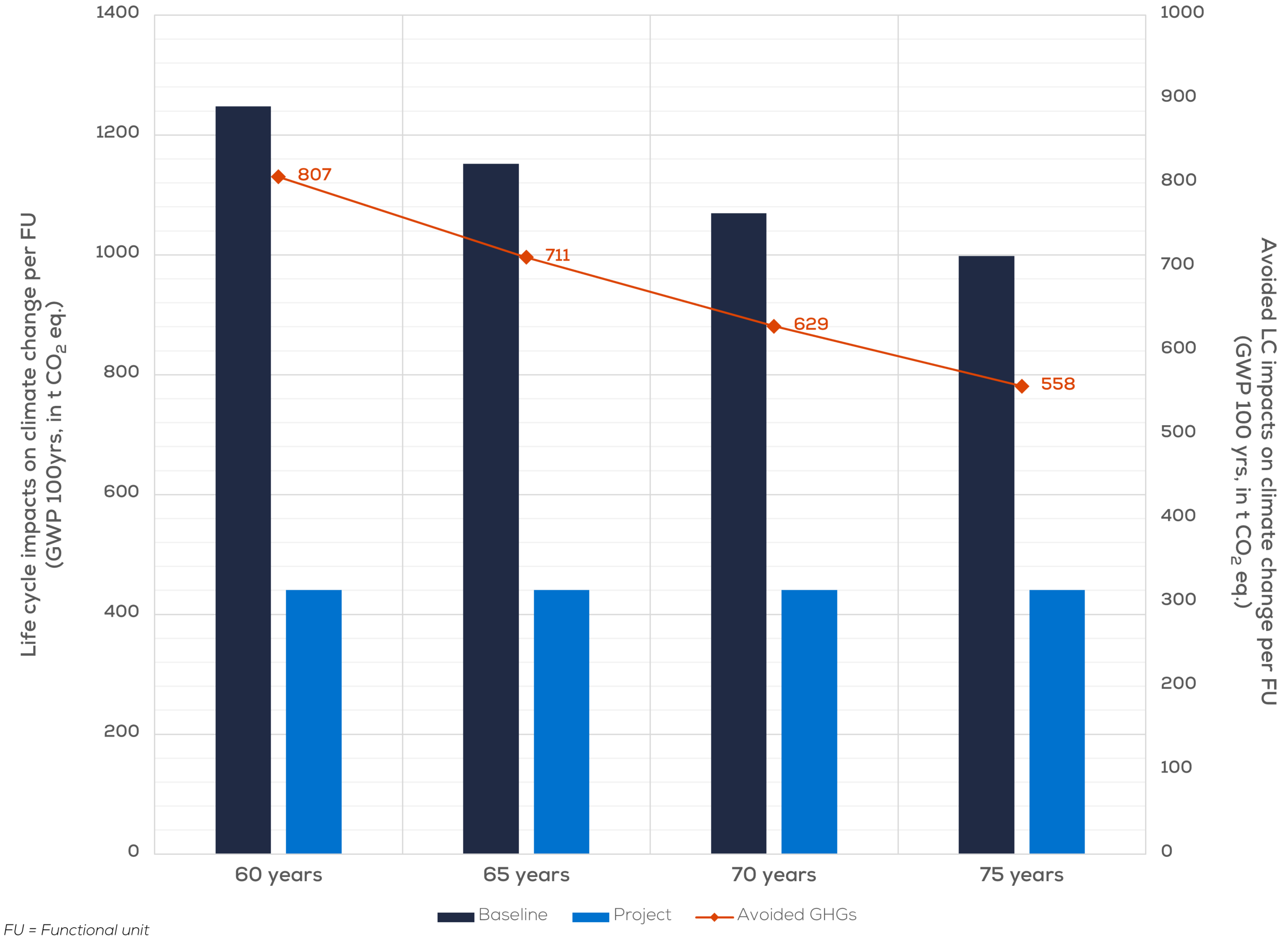
- **Sensitivity analysis** on reference service life (RSL) chosen for the baseline scenario.
- Carbon footprint of project scenario 441 t CO_2 eq.

RSL of baseline garage	Avoided life cycle GHG emissions per FU (t CO_2 eq.)
60 years	807
65 years	711
70 years	629
75 years	558



FU = Functional unit

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Industrial Column Retrofit Project

Objective:

Restore and preserve the original load-carrying performance of deteriorated industrial concrete columns

Approaches:

- Applied cementitious ductile overlay to reconstitute surface integrity.
- Arrested crack propagation and minimized moisture/chemical ingress.
- Re-established confinement effects lost due to spalling.
- Did not alter flexural or axial design capacity — focused solely on system capacity maintenance.

Outcomes:

- Performance retained: ~95% of original design capacity
- Service life extension: +25 years
- Material & carbon input: <2% of rebuild scenario

Preliminary Global Warming Potential (GWP, kg CO_2eq) estimation showed minimal footprint of retrofit project compared to demolition and new construction

Summary and Next steps

- PVM Parking Garage repair project study showed
  - **~800 tons of CO_2 eq.* avoidance** compared to New Build
  - Sensitivity analysis showed design for longer service life in new construction (e.g. from 60 to 75 years) can save ~250 tons of CO_2 eq.
- P+Ex plans to publish the PVM parking garage case study and to assemble more case studies using standardized Life Cycle Analysis methods
- Develop repair system environmental declarations to calculate and verify the environmental impact of different repair approaches

*Based on EPD of OPC & RMX (by PCA & NRMCA); 800 tons of CO2 eq. is ~1000 ton OPC emission; or ~4000 CY RMX concrete emission)

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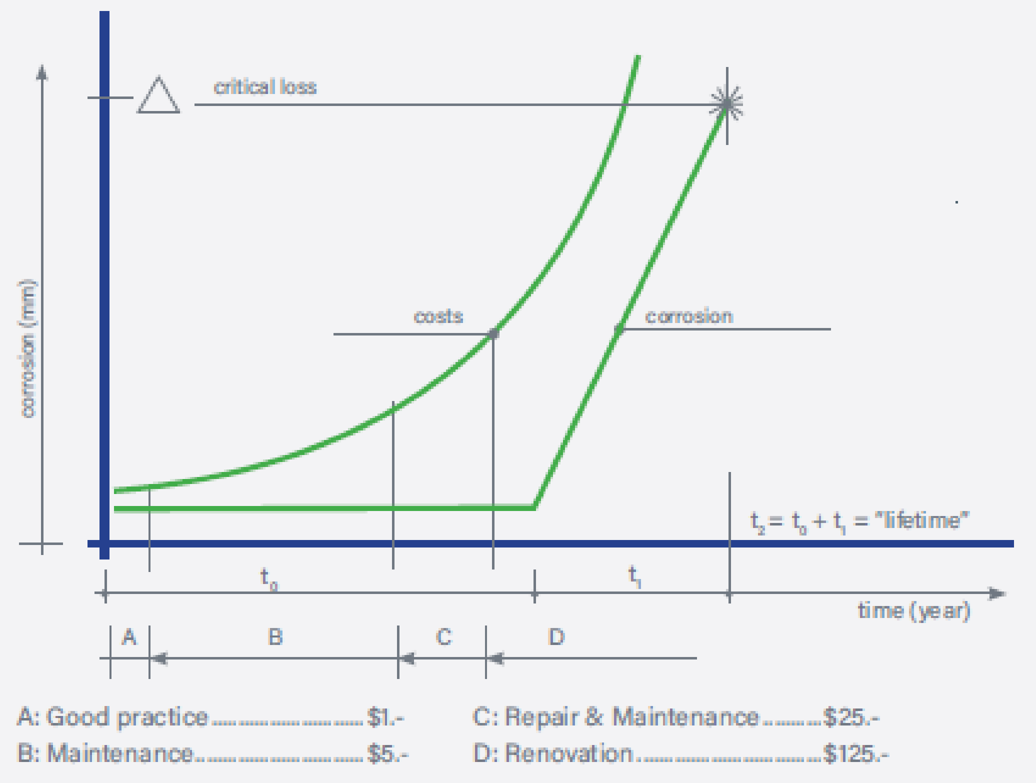
GOAL 3: Raise awareness of the financial benefits of durability design and service life extension

Objectives:

- **Conduct market research to determine the MAGNITUDE of the concrete repair market (How much effort is being expended on extending the service life of concrete structures?)**
- Assemble asset management best practices for extending the service life of concrete structures.
- Assemble case studies of financial benefits based on Sitter's "Law of Fives."

FOUR PHASES OF CONSTRUCTION
(W.R. DE SITTER, 1983)



Repair Market Size Estimation

- 3 Approaches:
  - Materials – Centric
  - Contractor – Centric
  - Industry Data – Centric
- Work independently to estimate the size of the Concrete Repair, Protection, and Strengthening market.
- Compare estimates and reach consensus on the size of the concrete repair market

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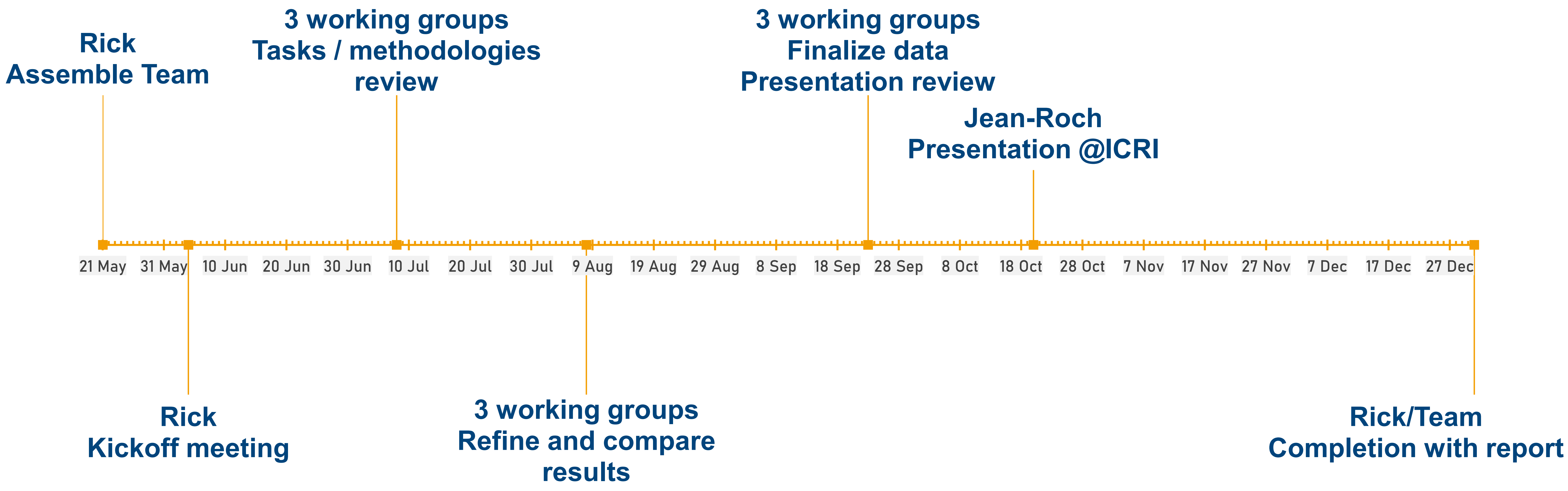
Task Group & Timeline

Material Centric:
- **Rick Montani (Sika) – lead**
- Jean-Roch Lucas (Freyssinet)
- Dave Sweetland (Mapei)

Contractor Centric:
- Peter Emmons (Structural)
- Nicole Dupiton (Structural)
- Mark Geraghty (Structural)

Industry Data:
- Dave Whitmore (Vector)
- Lesley Ko (Structural)
- Mark Geraghty (Structural)
- Stephen Stacey (Durability Engineers)



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Materials-Centric Approach

Use the value of concrete repair material sales to estimate the overall repair market)

- Identify applications and materials involved
- For each material, use estimate of US Material Sales $. Add estimates for construction labor, equipment, supervision, design, overhead, and profit
- Sum up to estimate overall US market
- Extrapolate for rest of world to estimate Global market

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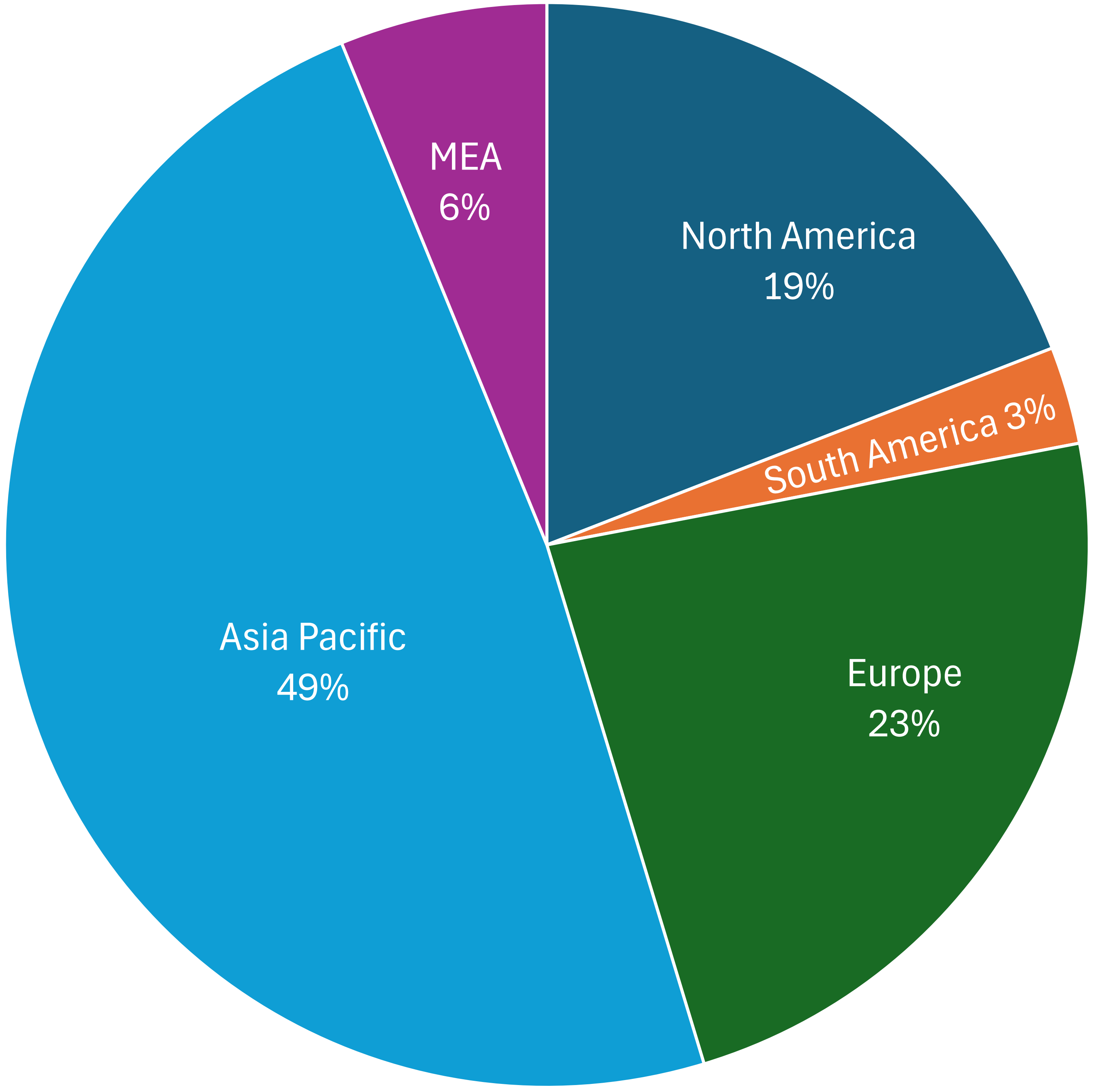
US Market Estimation

Material Categories	Material (Billion)	Labor (Billion)
Cementitious Materials (**RMX**, Precast, Packaged Repair Materials, Cementitious Overlay)	$ 8.2	$ 10.8
Steel (Rebar & PT)	$ 3.3	$ 5.8
Resin & Polymer (Coatings/Sealers/Waterproofing, Grout/Resin, Chemical Anchoring)	$ 2.1	$ 2.9
Manufactured Product & Systems (Strengthening, Pile Jacket, Cathodic Protection, Expansion Joints, etc.)	$ 0.2	$0.2
Total Cost of material & labor	$ 33.5	
Estimated Total Repair Market Value (incl. construction labor, equipment, supervision, management, design, overhead and profit)	**$ 67.1**	

Repair Market Size by Region



- Using the US market size as a reference, regional markets were estimated using local material and labor costs
- Asia Pacific Region, despite being focused on new construction, represents ~50% of global Concrete Repair Market

Global Market Value ~$ 450 Billion

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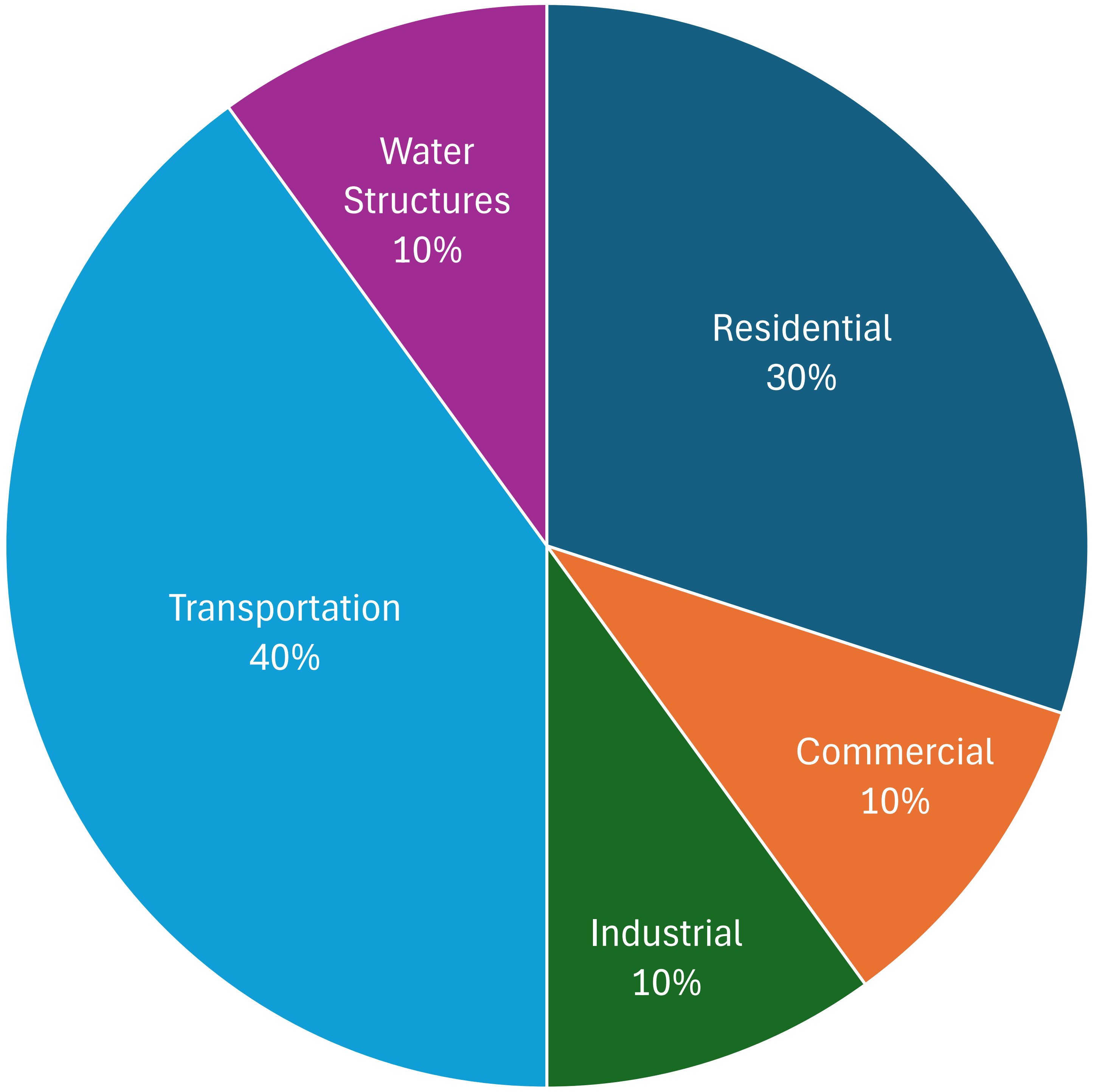
Repair Market Share per Segment



- Residential is the biggest share although not well tracked due to many small and private stakeholders
- Buildings repair (residential, commercial) attract the majority of the repair market due to intense urbanization
- Discrepancy between investment need and actual spending in transportation and infrastructures and what is effectively spent on project.
- Globally aging infrastructures will inevitably force public entities to invest more in the future.

Contractor-Centric Approach

Key assumptions:

- Market size estimated based upon actual data set of 5 years of project opportunities from large repair contractor
- Project opportunities were divided into market segments
- Market segments were added together to get an overall market size estimate

Estimated US Repair Market

Macro Categories	Annual Value (Billion)
Transportation (Bridges, Roadways, Aviation, etc.)	$ 29.4
Water/Wastewater	$ 7.2
Water Transportation (Piers, Docks, Dams, etc.)	$ 1.7
Industrial & Energy	$ 6.0
Buildings (Commercial, Residential*)	$ 15.2
Total	$ 59.5

* Residential buildings underestimated as it's outside company's project scope

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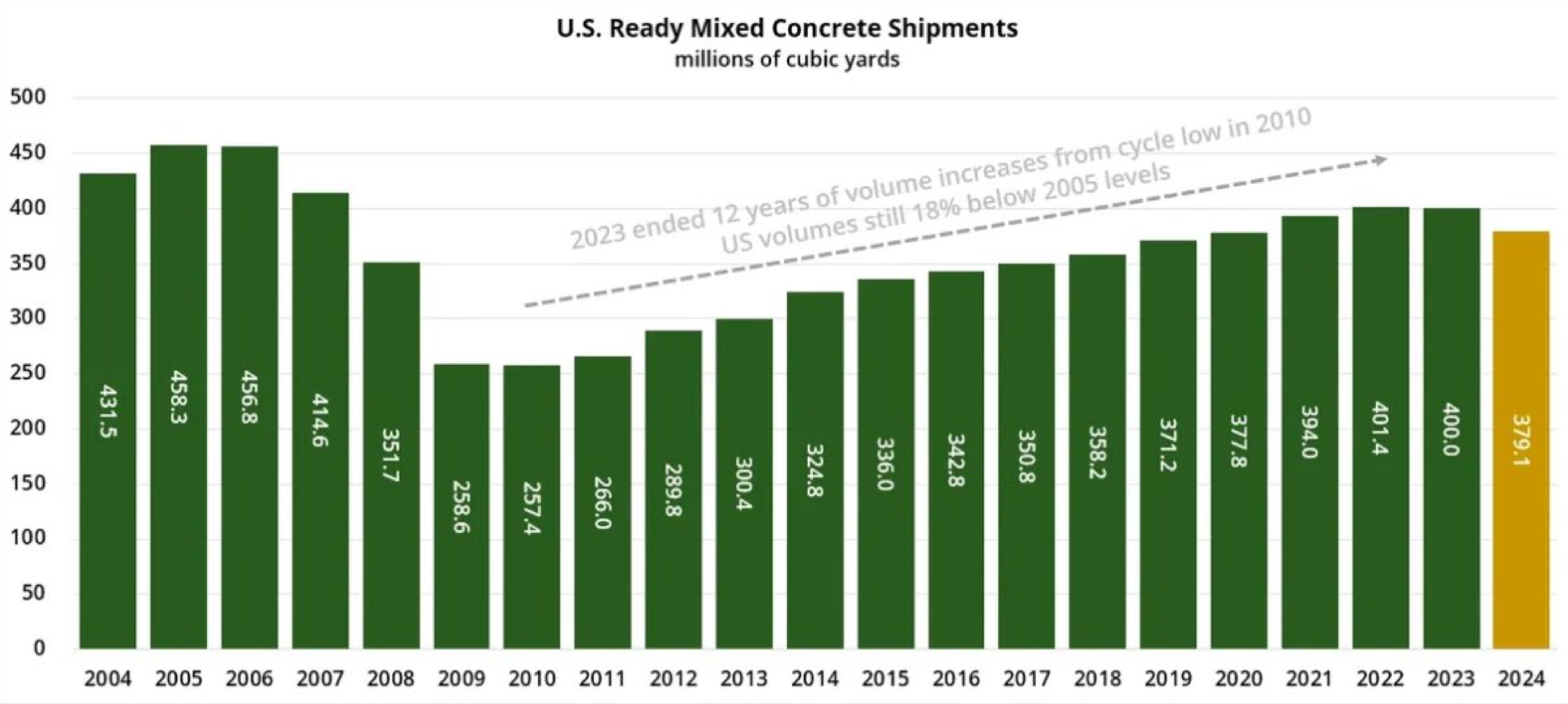
Industry Data – ASCE Report Card 2025

		2024-2033 funded (bn)	
Transportation	Aviation	$	197
	Bridge	$	165
	Road	$	1,549
	Rail	$	113
	Transit	$	466
Sub total		$	2,490
Water/wastewater	Drinking water	$	361
	Wastewater/stormwater	$	293
Sub total		$	654
Energy (industrial)		$	1,308
Water transportation	Inland waterways & ports	$	32
	Dams	$	20
	Levees	$	7
Sub total		$	59
Buildings	Schools	$	671
Total		**$**	**5,182**

- Covers Infrastructure and non-residential buildings
- Federal investment continues for next 10 years*
- Average investment in repair per year ~ $500B

*Assumes investments continue at levels shown by public data and based on authorized amounts set by Infrastructure Investments and Jobs Act, and Inflation Reduction Act, and other legislation.

Industry Data – US Ready Mix Concrete Shipments



Source: NRMCA utilizing US Geological Survey data – updated June 2025

- ~380 million CY RMX shipped in 2024; av. price $169/CY

→ Total concrete sold $64 B (material only)

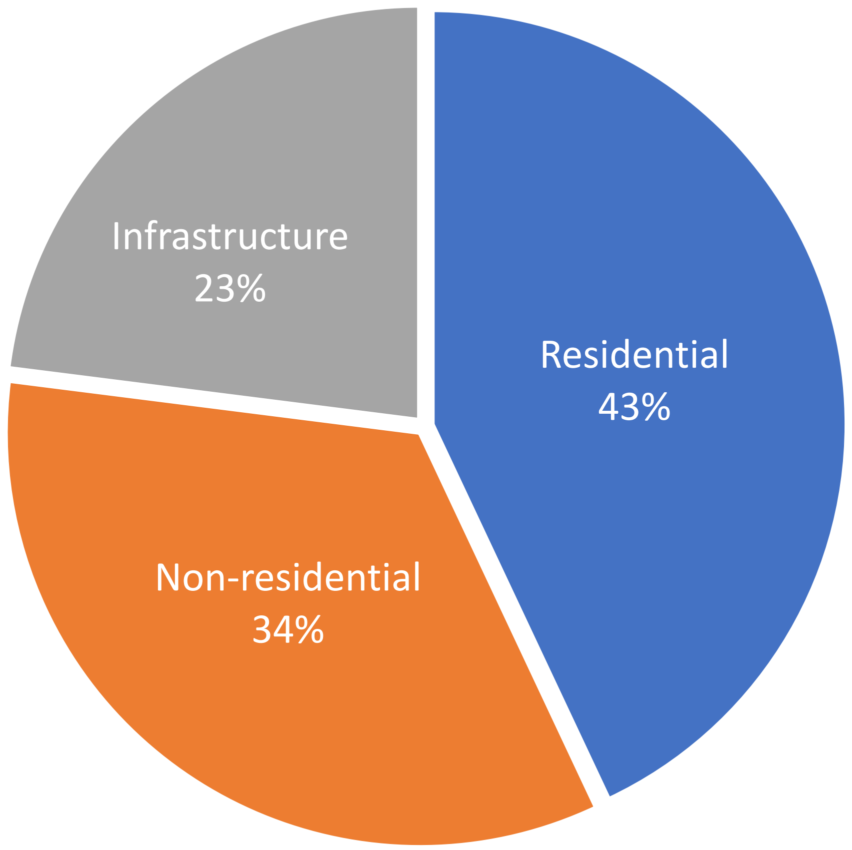
Source: USGS, NRMCA, US Concrete Industry Data

Public information – US GDP and Construction Spending 2024

GDP 2024 USA (B)	Total Construction (4.5%) (B)
$ 28,780	$ 1,295

Source: source: U.S. Bureau of Economic Analysis (BEA)

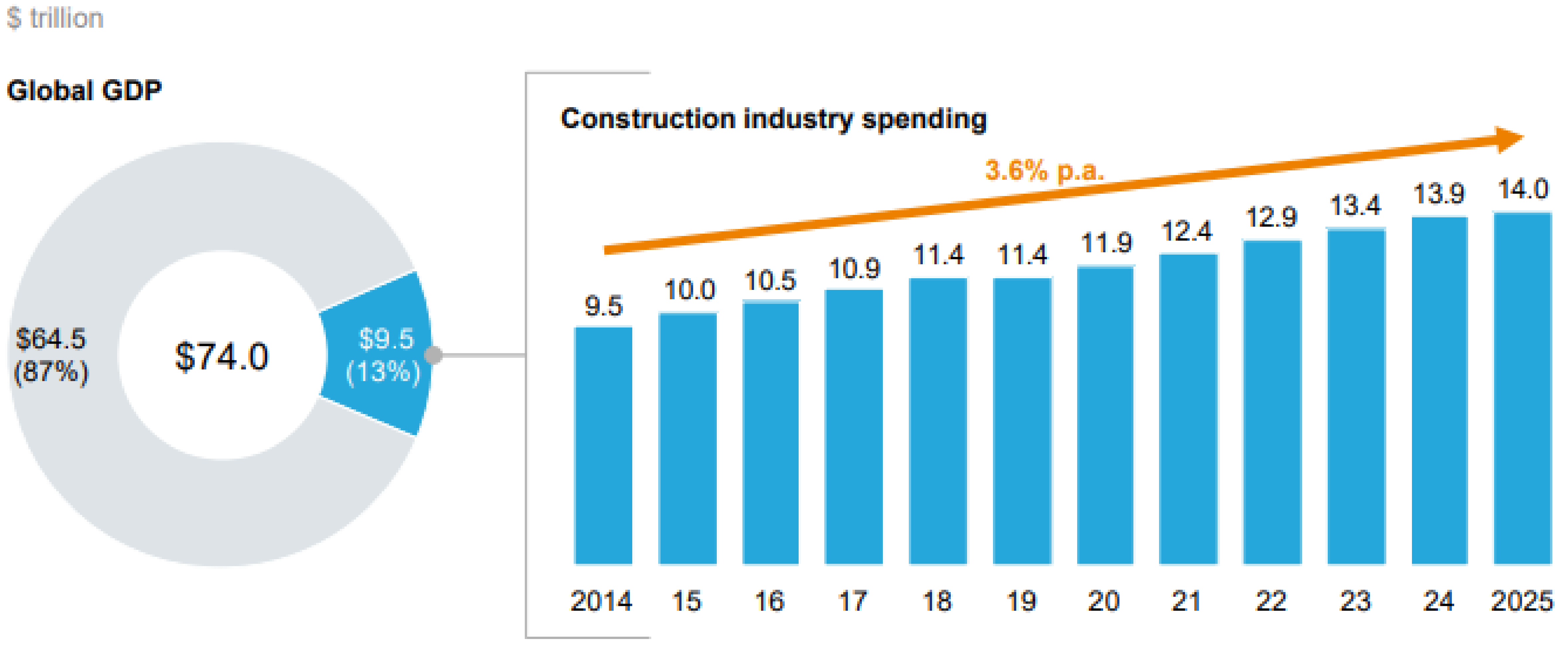
Category	**Spending (B)**
Residential	$ 930
Non-residential	$ 732
Infrastructure	$ 493*
Total	$ 2,155



Source: U.S. Census Bureau Economic Indicators
Total Public Construction Spending: Total Construction in the United States (TLPBLCONS) | FRED | St. Louis Fed
ConstructConnect, FMI, and FRED
*: Federal spending in transportation ~$135 B (2% of total spending)

Public Information – Global GDP and Construction Spending 2024

- Global GDP ~ $ 110,000 billion (World Bank - GDP (current US$) | Data)
- Construction industry spending @ ~ 13% (McKinsey Global Inst.)



SOURCE: World Bank; IHS; ISSA; McKinsey Global Institute analysis

Summary and Next Steps

- Based on the material and contractor-centric approaches and cross-check with industry and public data
  - US repair market is estimated to be ~ $ 65 B
  - Global repair market ~ $ 450 B
- **Concrete repair industry is the one to extend the service life of concrete structures**
- Establish framework/methodology for asset management best practices for extending the service life of concrete structures

Closing Remarks

- Preliminary results from case studies are very encouraging
  - FL coastline building permits show repair vs. new build (80/20); ave. building age 38 yrs; ~1 new building breaks ground per day; stronger building codes and durable design matter. Time is of the essence.
  - PVM parking garage LCA study shows ~800 tons of $CO_{2eq.}$ avoidance compared to demolition and replacement
  - Repair market size estimated for US ~$65 B; world ~$450 B; Concrete repair industry is well positioned to extend the service life of concrete structures
- Exciting journey has just begun
- Join P+Ex in shaping the future of concrete preservation (https://www.pexcoe.org/roadmapping/#member)

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Acknowledgements

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