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Comparative Sustainability, LCA and Service Life Modeling for Repair vs. Rebuild – A Case Study

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Strategic Goal #2: Conserve Resources and Reduce Environmental Impact

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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

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

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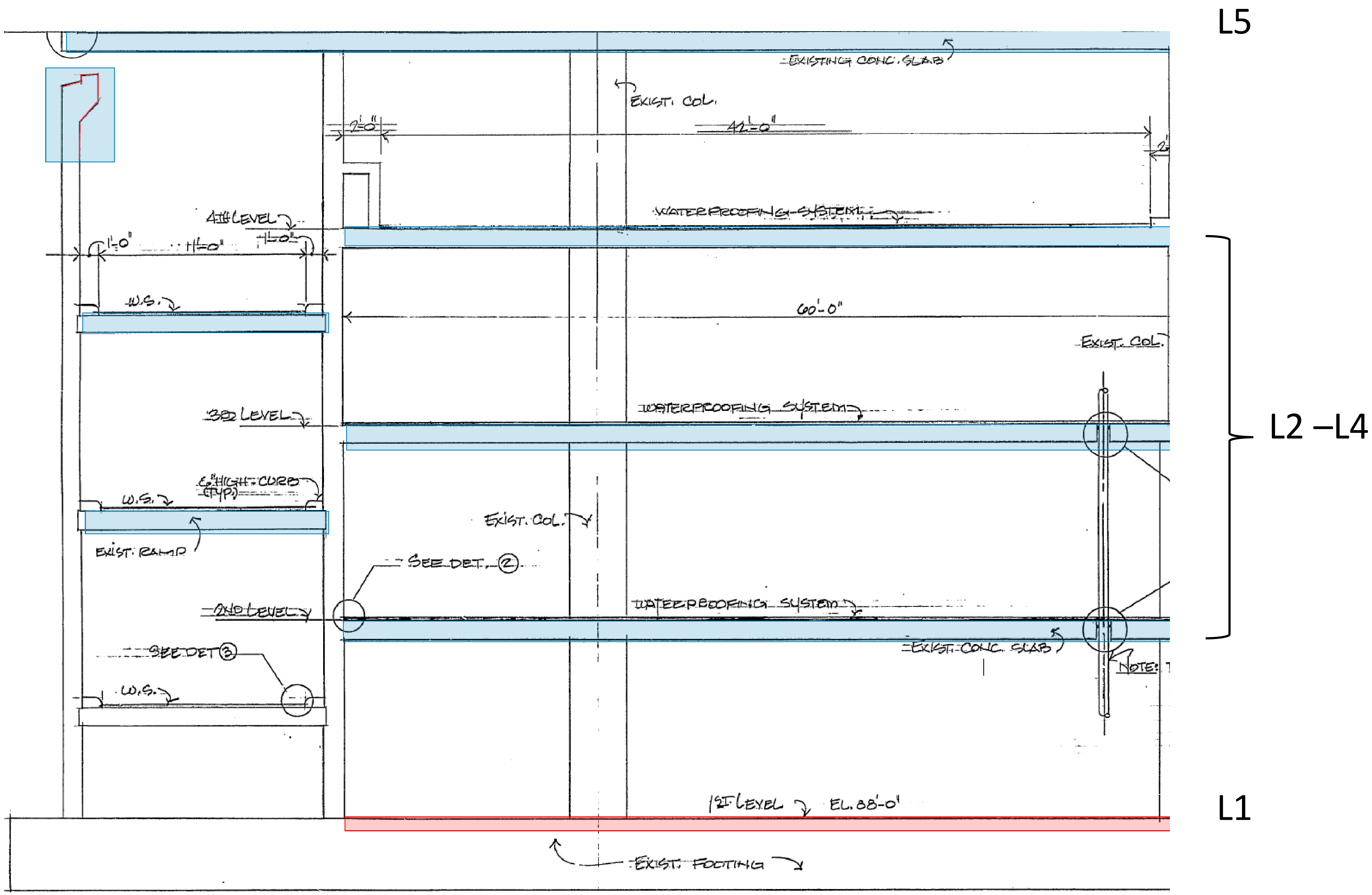
Background Info

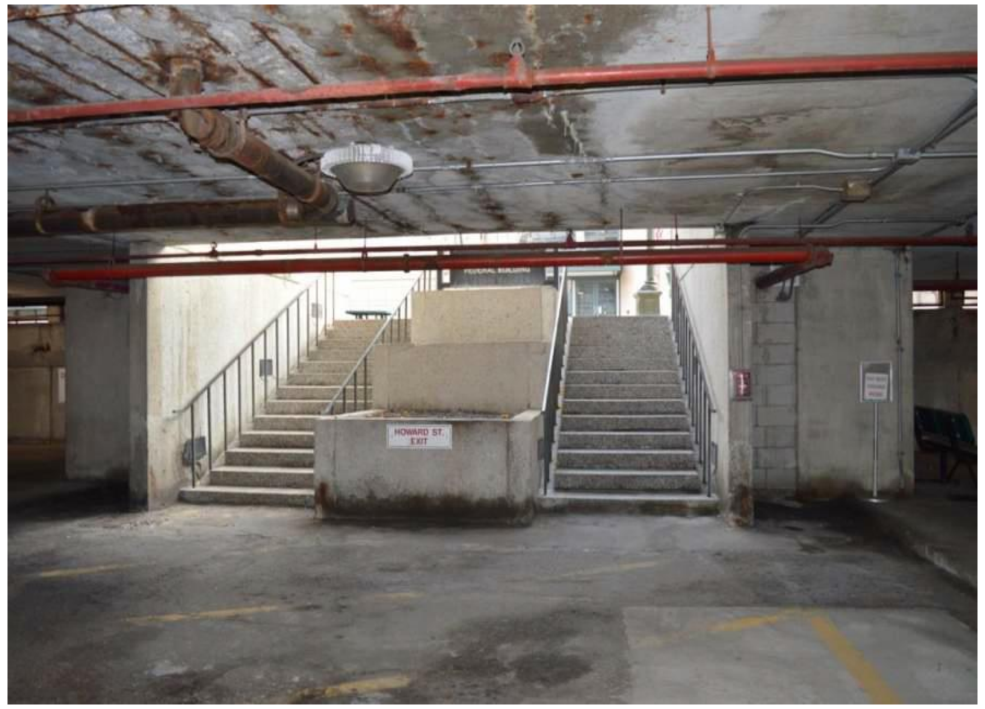
- Patrick V. McNamara (PVM) federal building located in Detroit, MI
- Built in 1973, this is an existing five-level reinforced concrete parking structure
  - 3 levels below grade (Levels 1-3),
  - 1 level at grade (Level 4), and 1 level above grade (Level 5).
- Major concrete repair work is ongoing
-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

General Parking Layout



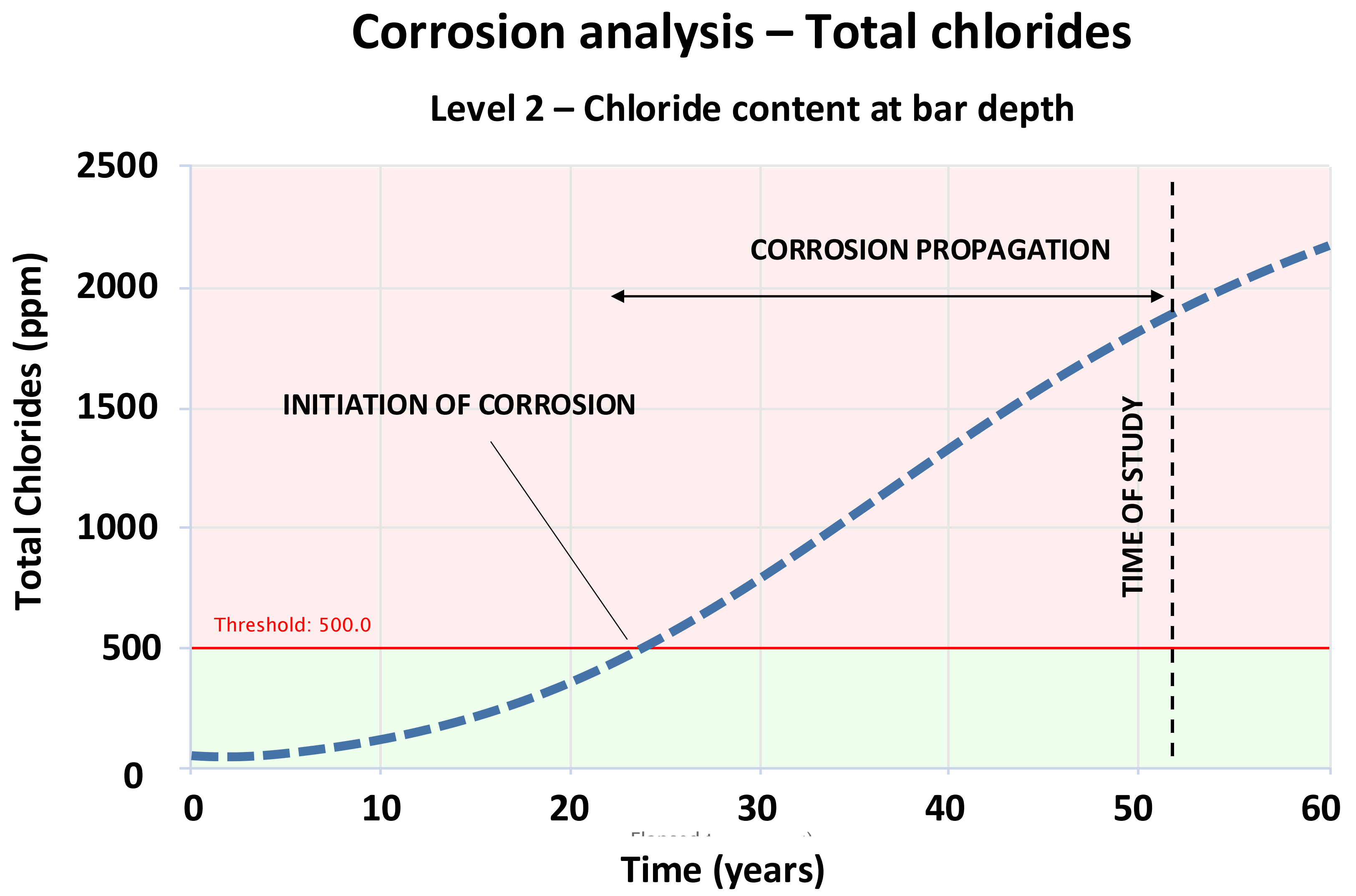
Main Assumptions

- 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 values 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 + 10yrs</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



Chloride Ingress Calculations

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



Concrete Repair Solutions vs. SLA Calculation

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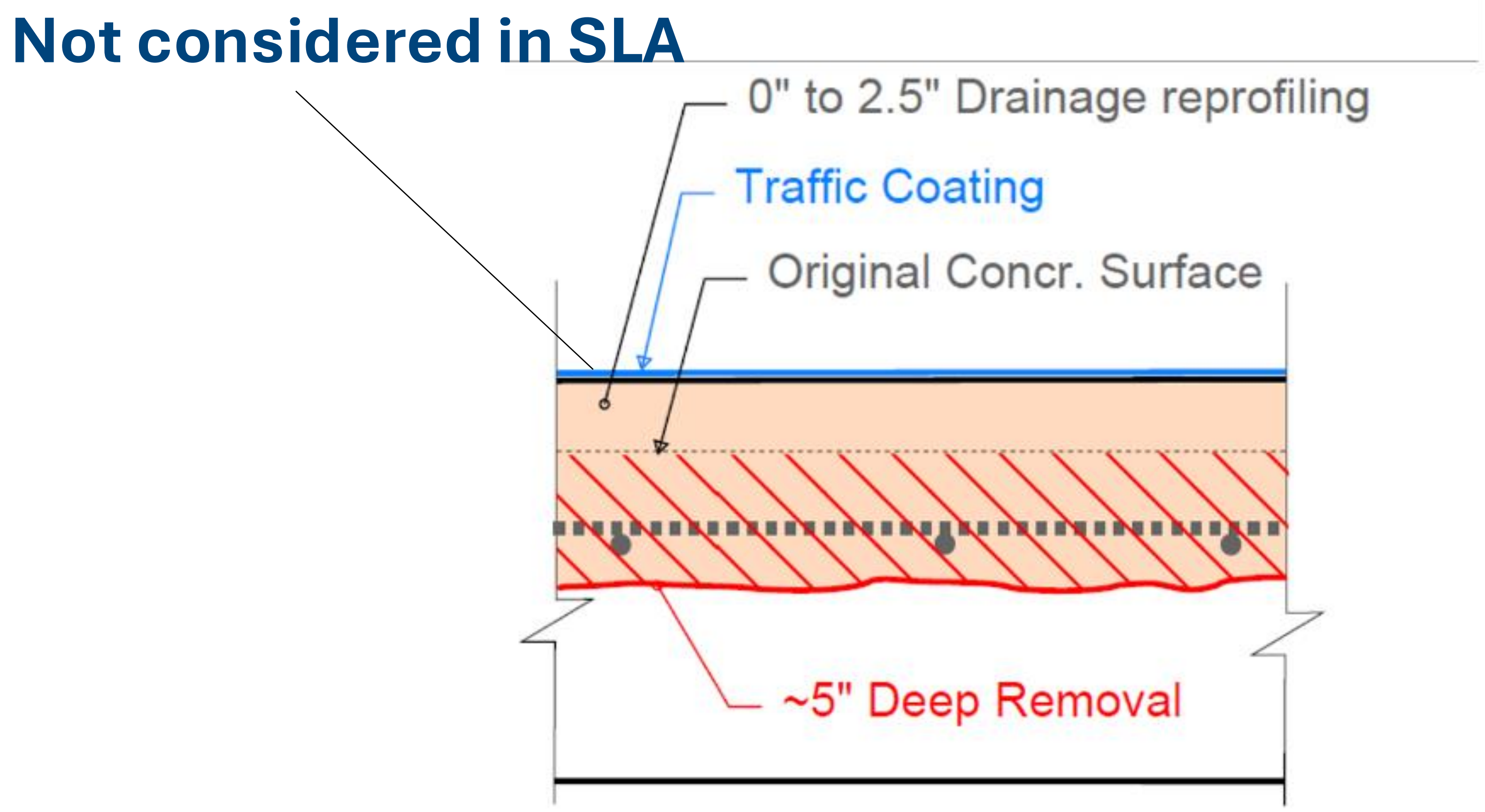
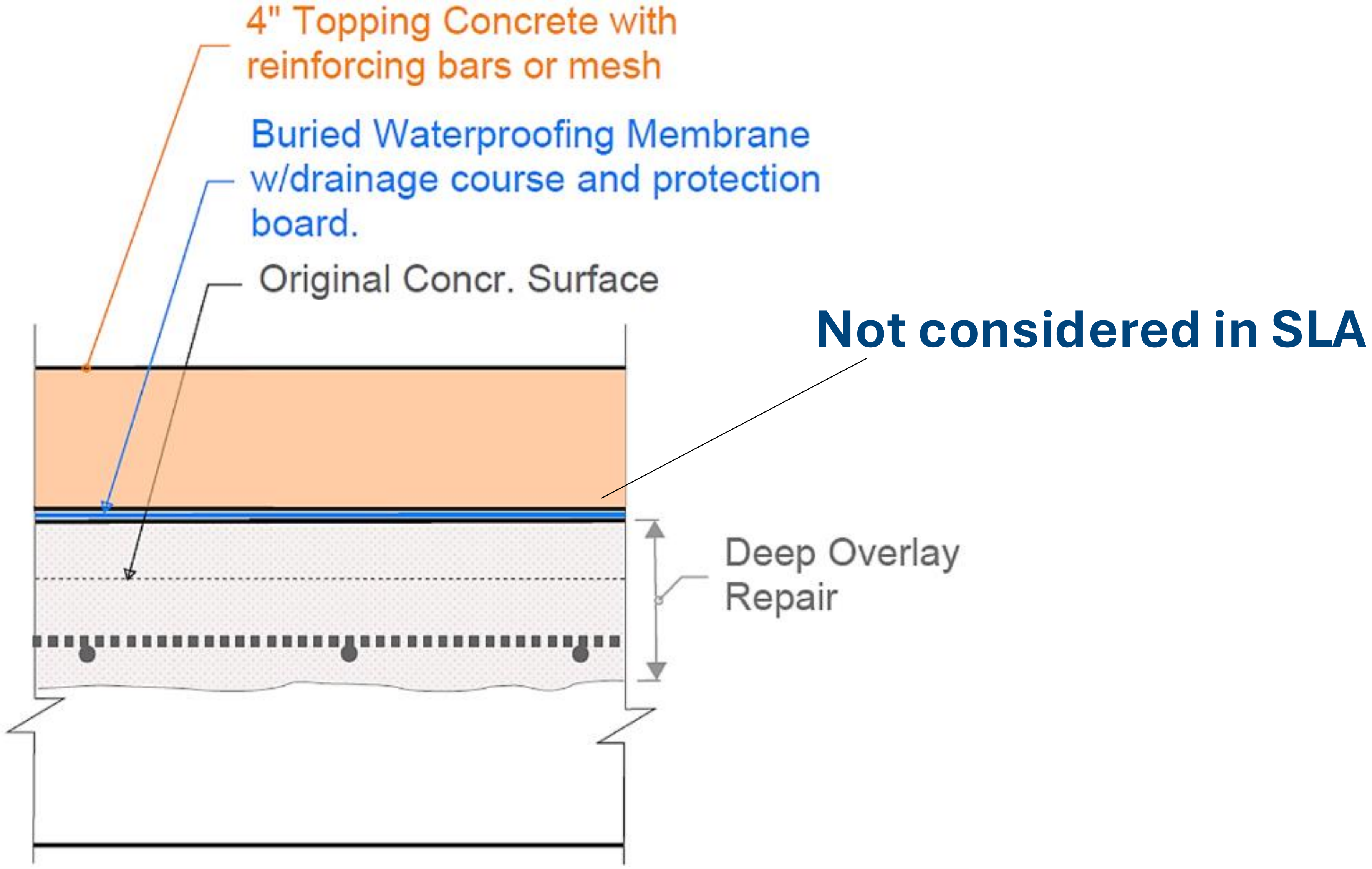


LEVEL 1-4: DEEP OVERLAY REPAIR



LEVEL 5: CONCRETE TOPPING

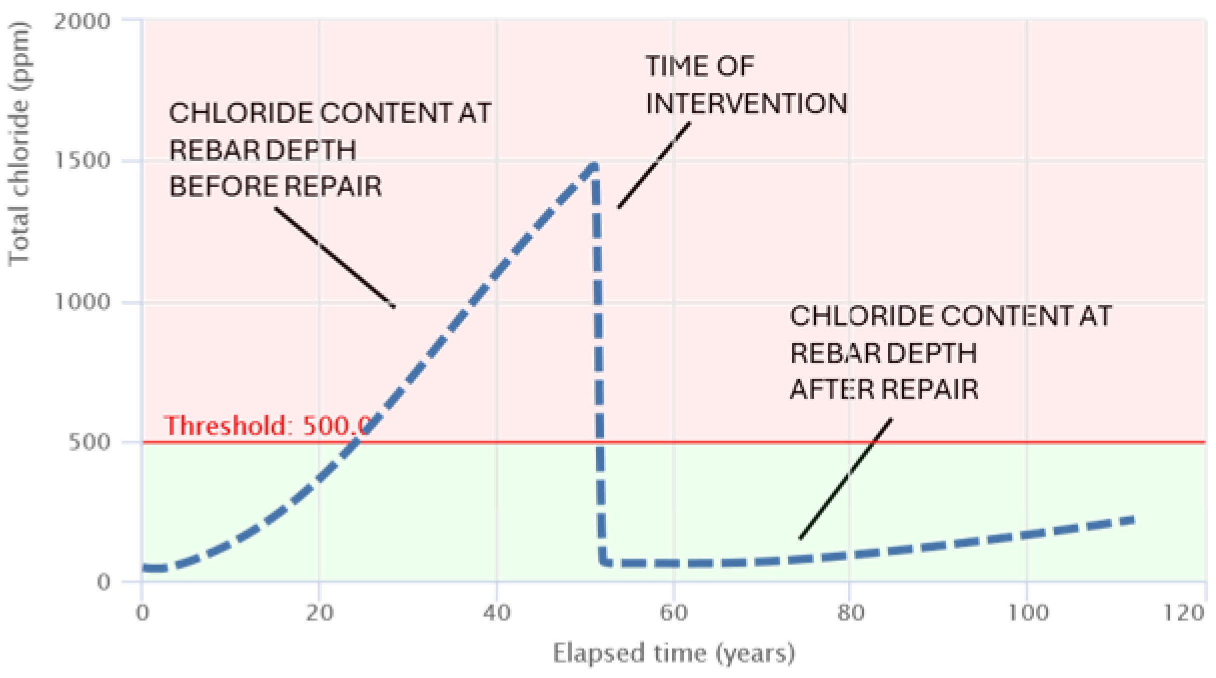
*ICCP system not considered in service-life evaluation

ACI Concrete Convention

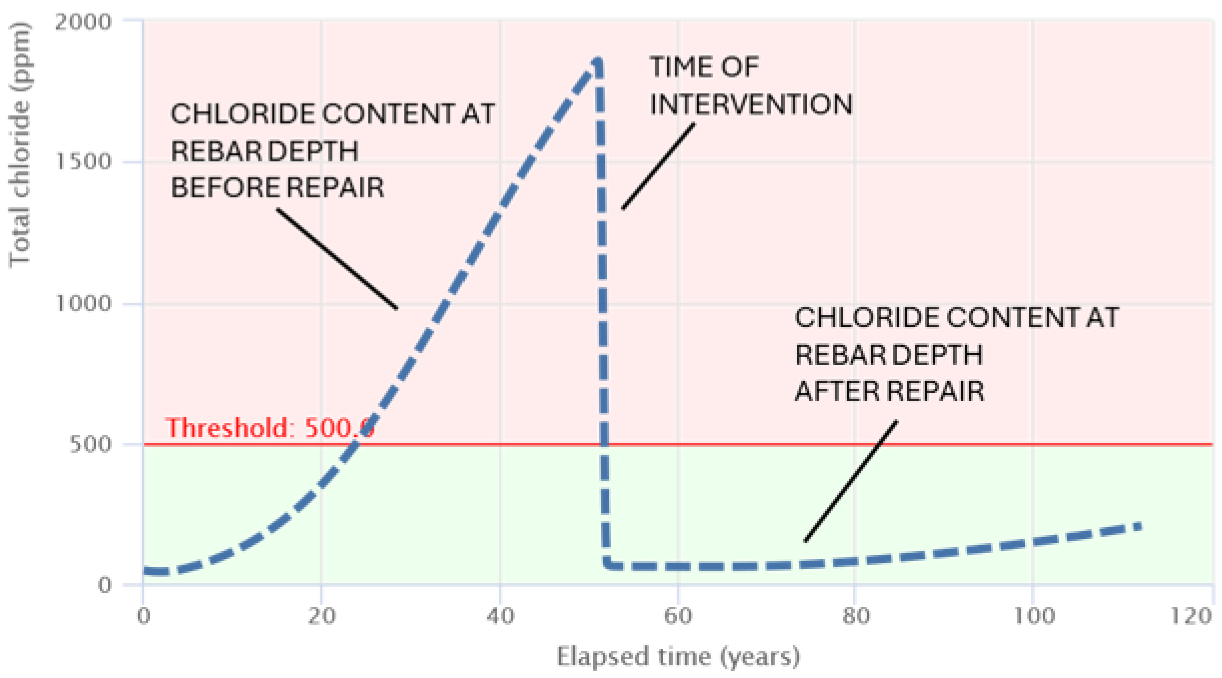
Concrete Repair Calculations

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

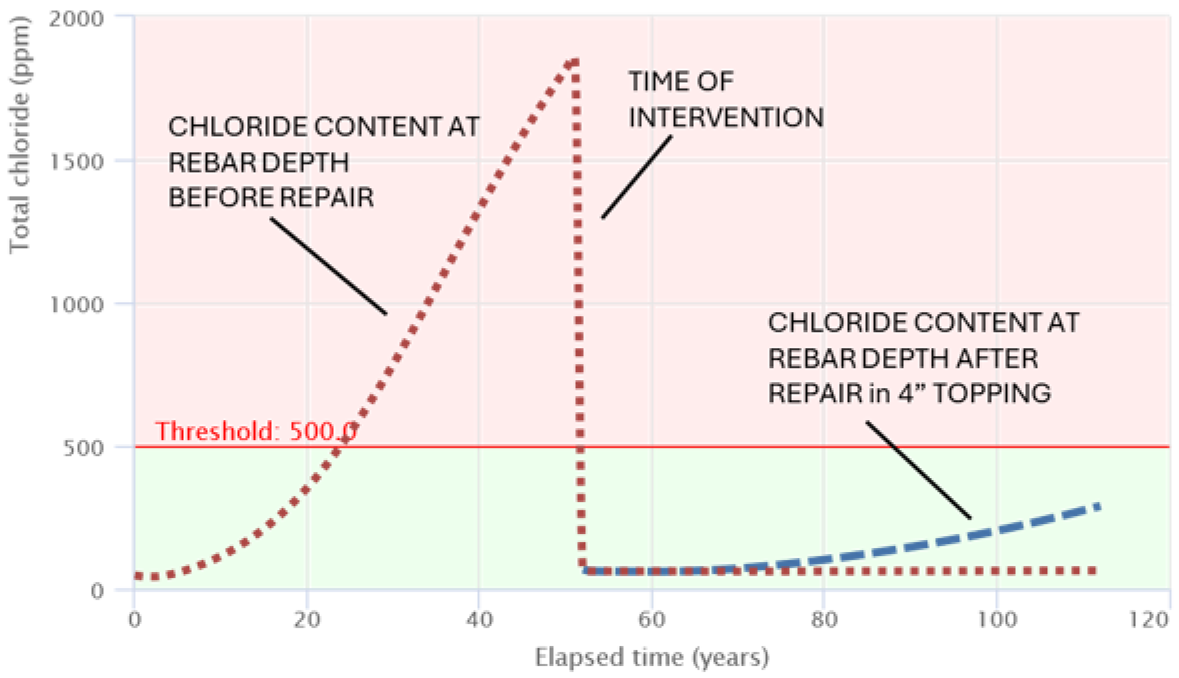
Level 1



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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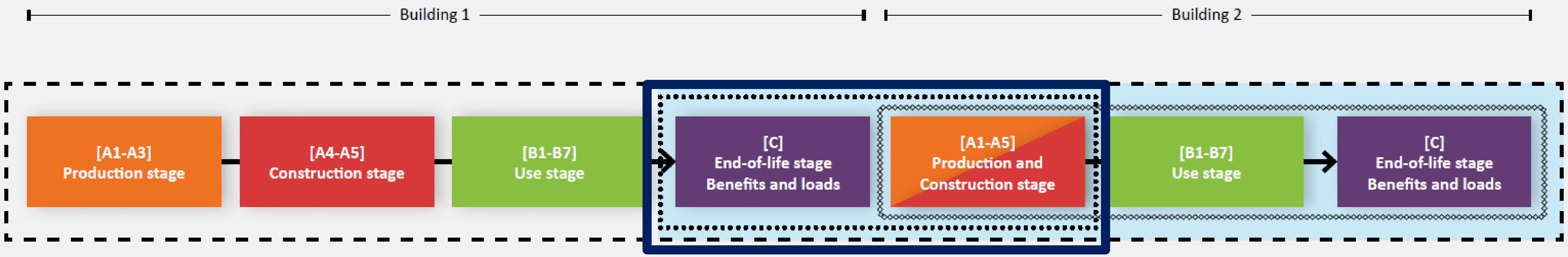
Proposed System Boundaries

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

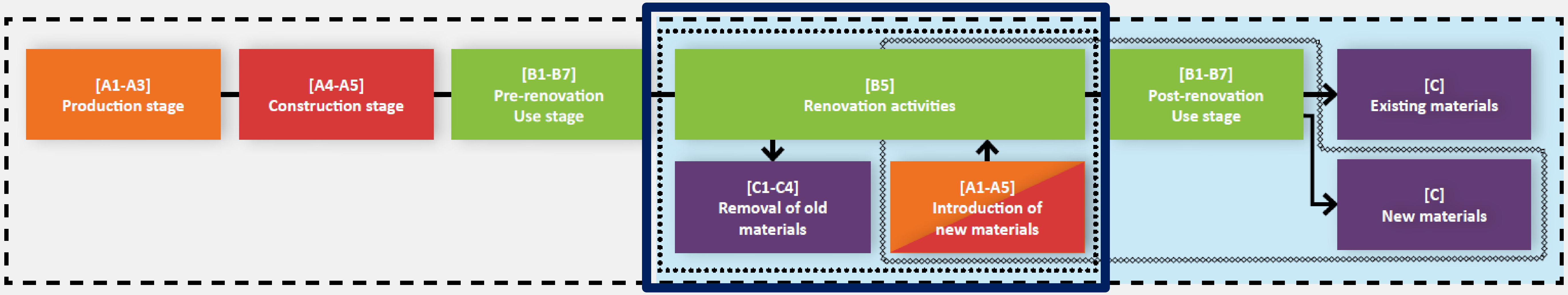
Four approaches to comparing renovation and new build scenarios:

	Reference	*Project system*
	– Life cycle of two buildings	– Entire lifespan of renovated structure
	– Full demolition – Life cycle of new building	– Partial demolition and renovation activities – Occupation and demolition of renovated building
	– Life cycle of new building	– Life cycle of new components
	– Demolition and reconstruction	– Partial demolition and renovation activities

Reference system: new building on same site



Project system: building undergoing renovation



Source: CERIEC 2024 Applying circularity in the LCA of buildings

Comparative Carbon Footprint

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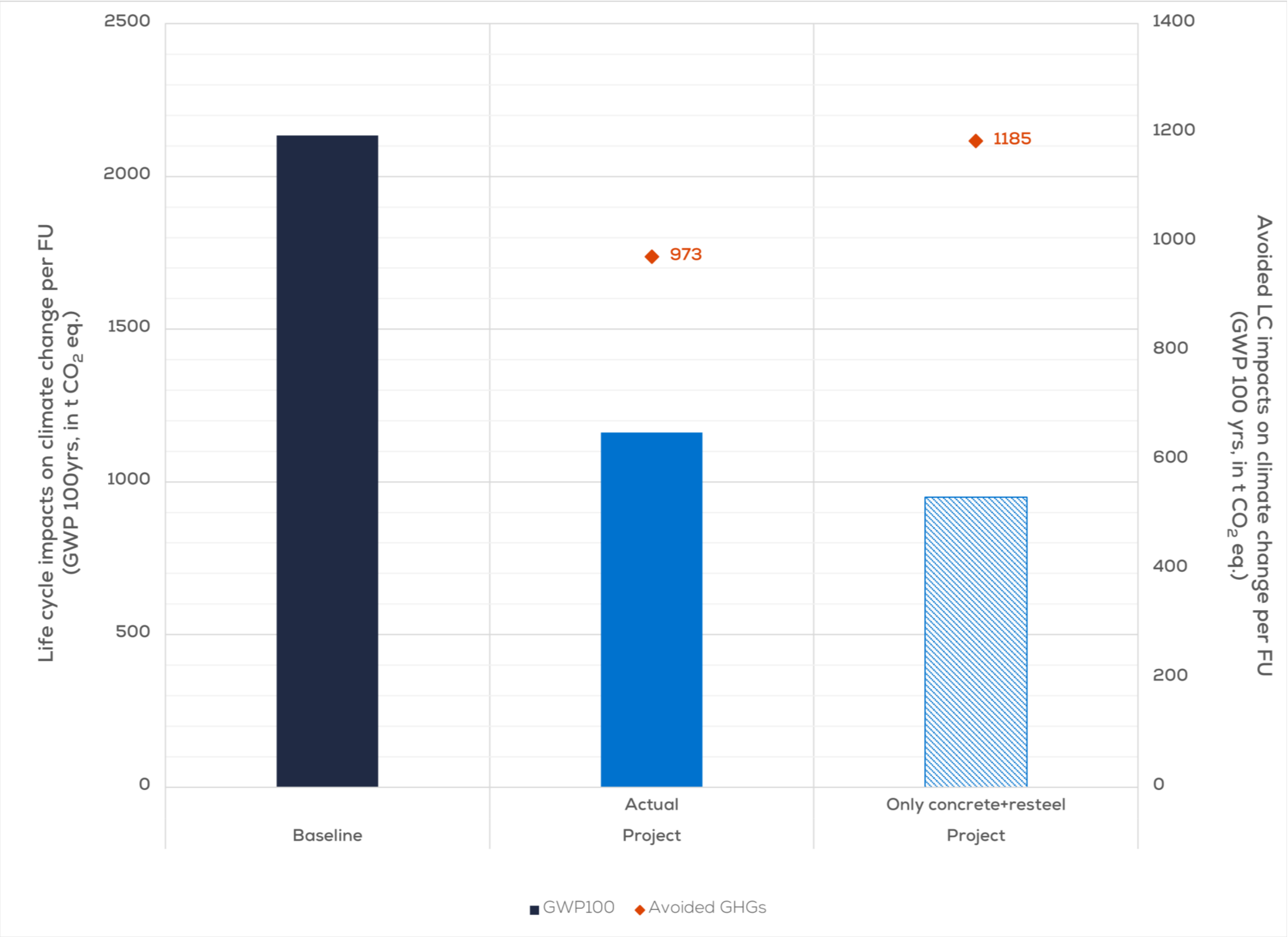
Functional unit (FU): Sustaining the use of the PVM building garage for an additional 60 years

- Carbon footprint of baseline scenario (new build, ESL 60 yrs):
  - 2135 t CO_2 eq. per FU
- Carbon footprint of project scenario (refurbishment, ESL 60 yrs):
  - 1162 t CO_2 eq. per FU
- Estimated avoided life cycle GHG emissions of PVM garage project:
  - **~ 973 t CO_2 eq. (~1185 t CO_2 eq., if only consider concrete & steel)**



ESL: Estimated service life

Breakdown of Project Carbon Footprint

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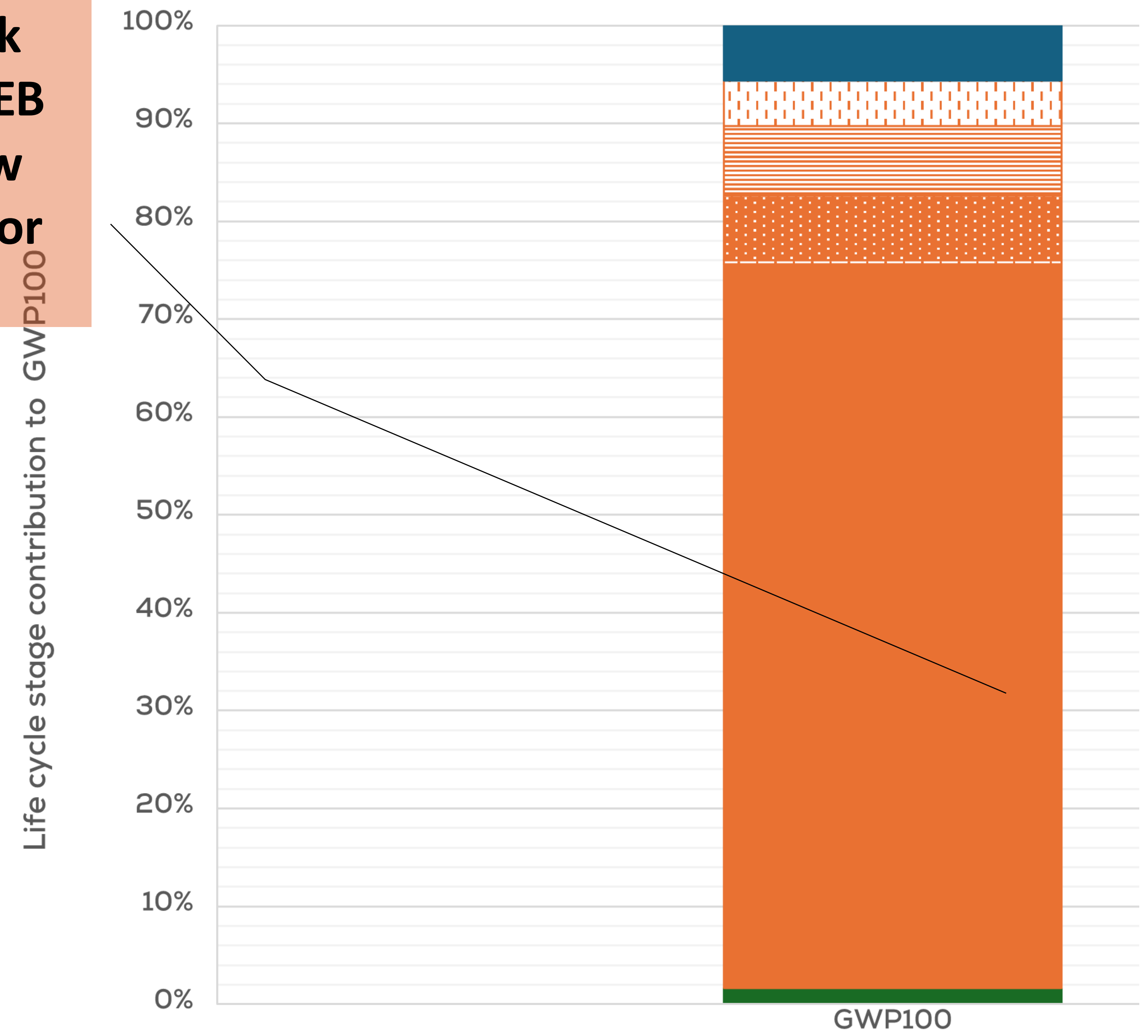
- CF of project scenario per FU: 1162 t CO_2 eq.

Life cycle stages	Contribution to CF
Partial demolition	5.6%
MR_Concrete*	74.0%
MR_Reinforcing steel	0.4%
MR_Traffic coating	6.6%
MR_ICCP system	7.1%
MR_sealants	4.6%
Maintenance	1.6%

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



	GWP100
B5 Partial demolition and waste management	5.6%
B5 Sealants	4.6%
B5 ICCP system	7.1%
B5 Traffic coating/silane sealer_level 1	0.1%
B5 Traffic coating_levels 2 to 5	6.6%
B5 Reinforcing steel	0.4%
B5 Concrete	74.0%
B4 Replacement of skylights	1.6%

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Summary and Next steps


2026-01-19

PROJECT REPORT

SIMCO

SIMCO TECHNOLOGIES

P+EX PVM GARAGE PROJECT

PARTIAL CARBON FOOTPRINT

O/Ref.: n/a

Y/Ref.: 125628.001

NORDA STELO

- PVM Parking Garage repair project study showed
  - **~973 tons of CO_2 eq.* avoidance** compared to new build
  - Results reviewed and verified to conform with ISO 14044:2006 & 14071:2024
- Achieving the maximum carbon benefit depends on:
  - Type of repair solutions and their carbon intensities
  - Service life of repair solutions
- When considered early in the design process and aligned with <u>specific service life objectives</u>, these parameters can guide decision-making similarly to a cost-benefit analysis
- P+Ex plans to publish the PVM parking garage case study and to assemble more case studies using standardized Life Cycle Analysis methods

aci CONCRETE CONVENTION

Questions?

P+Ex
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