







LIFE CYCLE ASSESSMENT OF UNDERGROUND CAR PARKS. CASE STUDY – BRAZIL

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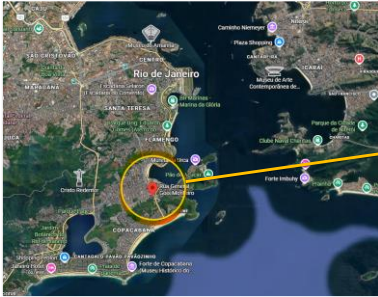
Challenges of (comparative) case studies

- Comparison of several alternatives (with different materials)
- Cost & environmental impact ⇒ most environmental solution?
- Avoid “bias”
 - select independent & experienced consultants
⇒ freedom to design according to their own experience (optimization?)
 - find peer-reviewers (LCA) with expertise in the specific field
- Level-playing field comparison? Impact of
 - Design: select structure (geometry) / loads / location / soil conditions
 - LCA: environmental data (standards, EPDs, software, database,...)
 - Period of assessment (prices variability)





Location – Botafogo | Rio de Janeiro



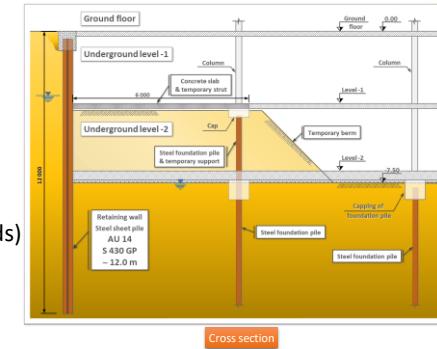
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Design

- Brazilian design engineer
- 2 levels below ground (no vertical loads from superstructure)
- dimensions: 50 x 50 m
- typical soil conditions (sands)
- R 90 fire resistance
- design: FEM (Plaxis)
- service life: 50 years

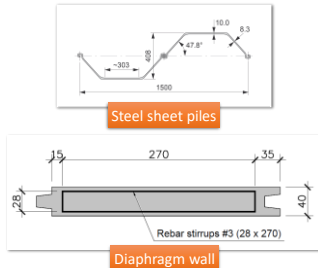


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Design



2 alternatives

- **steel sheet piles**
AU 14, 12.0 m, S 430 GP
- **diaphragm wall**
(reinforced concrete)
40 cm thick, 12.0 m long, C 30/37

⇒ Same length = optimized length?

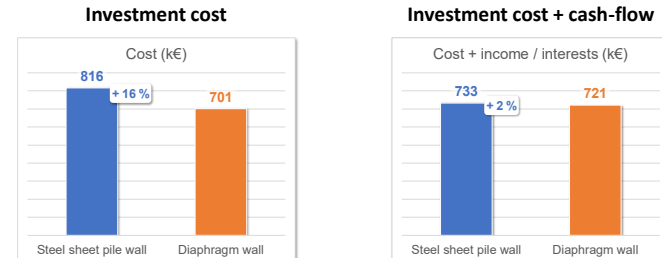
Note: sketches with different scales

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Cost analysis – retaining wall

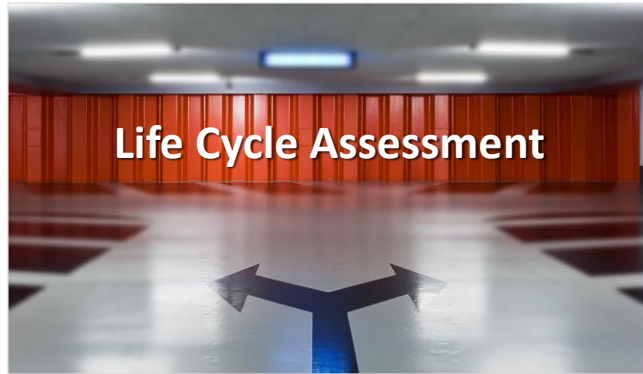


Cash flow: difference in construction time (14 weeks shorter for ssp) ⇒ more revenue / less interests

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Life Cycle Assessment – challenges



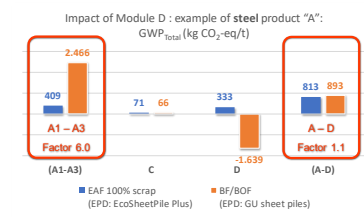
- Software
- LCIA Databases
- EPD Standards (EN 15804+A1 / +A2) / Programme operators / PCR versions
- LCA Modules (whole life cycle): production, installation, reuse / recycling (Module D)
- Corrosion (steel), maintenance
- Steel – concrete: which quality (low carbon emissions ?)
- Dismantling: possible / economically viable ?
- Module D: adapt EoL scenario?
- Peer-reviewers: panel of X experts (construction / infrastructure ?)
- Which environmental indicators?

Note: EPD = Environmental Product Declaration, PCR = Product Category Rules, EoL = End of Life

LCA steel & concrete specificities



- EPDs / databases – offsetting & CCUS not accepted!
- Steel : Worldsteel association. BF/BOF vs EAF – transfer of burden
⇒ Module D (“Value of scrap”)
- Concrete: low carbon concrete – GGBS (slags) / fly ash / exposure classes – recycled aggregates

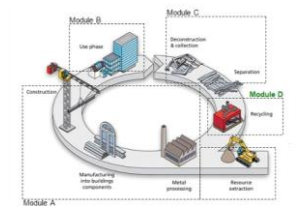


Notes: "BF/BOF" = "Blast Furnace / Basic Oxygen Furnace", primary steel manufactured from iron ore
"EAF" = "Electric Arc Furnace", secondary steel manufactured from almost 100 % of steel scrap

Life Cycle Assessment – Key data



- Software: *OneClickLCA*
- Functional unit: 50 x 50 m wall
- Modules (A-C) & (A-D)



- Transport (A4) & installation (A5)
- End of Life scenario (in %):

Solution	Product	Recycle %	Reuse %	Landfill %	Left in place %
SSP-Wall	Rebars	85		15	
SSP-Wall	Steel sheet pile	99		1	
SSP-Wall	Steel - corroded			100	
D-Wall	Concrete				100
D-Wall	Rebars				100
D-Wall	Formwork – OSB			100	
D-Wall	Bentonite			100	



Life Cycle Assessment – Key data



Product		GWP		Source	Low carbon emissions material
Steel	Reinforcement steel (rebar) – XCarb*	300	kg CO ₂ -eq./t	EPD (+A1)	Yes
Steel	EcoSheetPile™ Plus – XCarb*	370	kg CO ₂ -eq./t	EPD (+A1)	Yes
Steel	Welding (filler material)	1.850	kg CO ₂ -eq./t	EPD (+A1)	No
Concrete	Ready-mix concrete C 12/15	196.1	kg CO ₂ -eq./m ³	One Click LCA	No
Concrete	Ready-mix concrete C 30/37 CEM II/A	247.5	kg CO ₂ -eq./m ³	One Click LCA	No
Wood	Formwork – OSB	200.6	kg CO ₂ -eq./m ³	One Click LCA	No
Misc.	Bentonite, activated	0.48	kg CO ₂ -eq./kg	One Click LCA	No
Misc.	Sealing tapes	0.14	kg CO ₂ -eq./m	EPD (+A1)	No
Misc.	Gypsum based fire resistant mortar	2.45	kg CO ₂ -eq./m ²	EPD (+A1)	No

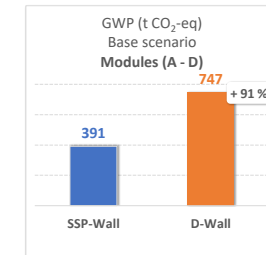
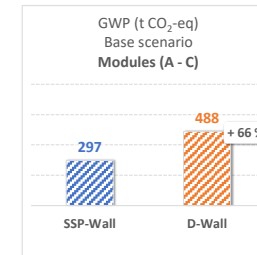
Notes: GWP = Global Warming Potential
 *EPD (+A1) = EPD according to standard EN 15804 +A1

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LCA results – Base scenario



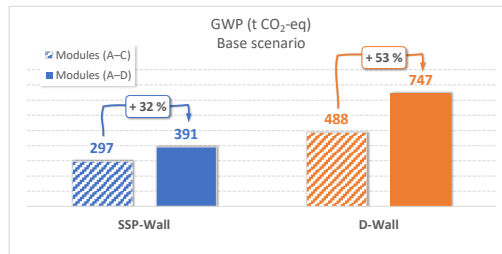
Note: GWP = Global Warming Potential

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Base scenario – Impact of Module D



- **D-Wall:** mainly due to **rebars** not recovered after service life
- **SSP-Wall:** predominantly due to steel's **net scrap value** (EAF steel with almost 100 % scrap)

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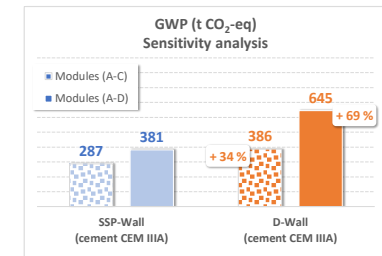
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LCA results – Sensitivity analysis



Different scenarios

- Scenario with
 - “low carbon concrete” (Brazilian EPD)
- Scenario with
 - “standard” steel sheet piles (European EPD)
 - without corrosion
- ...



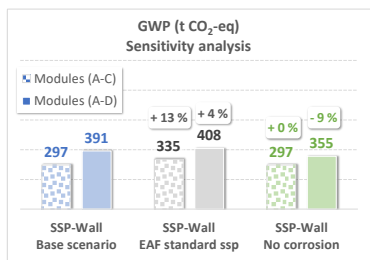
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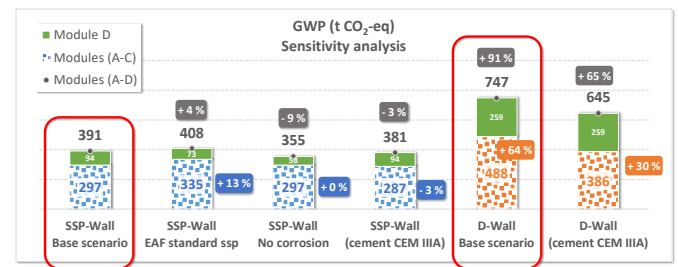
LCA results – Sensitivity analysis



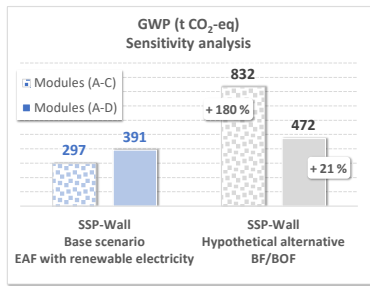
Different scenarios

- Scenario with
 - “low carbon concrete” (Brazilian EPD)
- Scenario with
 - “standard” EAF steel sheet piles (European EPD)
 - without corrosion
- ...

LCA results – Sensitivity analysis



LCA results – Sensitivity analysis



Scenario not included in the peer-reviewed report

- same sheet pile section, but from **BF/BOF steel** (European EPD)

Conclusion

- significant difference for Mod. (A-C)
- small difference for Mod. (A-D)

Note: "BF/BOF" = "Blast Furnace / Basic Oxygen Furnace", primary steel manufactured from iron ore
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Impact of transport A4 & installation A5

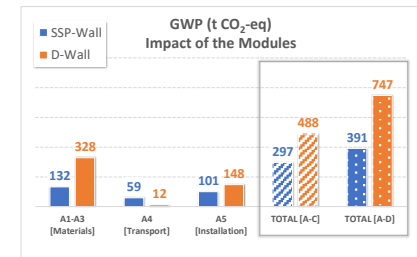


SSP-Wall

- Mod. A4 45 % of A1-A3
- Mod. A5 77 % of A1-A3

D-Wall

- Mod. A4 4 % of A1-A3
- Mod. A5 45 % of A1-A3



Note: Transport of steel (sheet piles, rebars, plates,...) from Luxembourg to Rio de Janeiro by train / ship / truck (long distances)
 Transport of concrete & other materials from local suppliers (short distances)



Conclusions



- Large difference of environmental impact (# scenarios)
- Sensitivity analysis very important
- Results cannot be simply transposed to other structures / locations
 - Design: soil conditions, national design codes & habits
 - Cost: variability of material costs / installation method
 - LCA: software / local databases / EPDs
- Perform LCA per project (feasibility to design stages)
 - ⇒ product specific EPDs, renowned databases, adequate software,...
- Add environmental criteria (i.e. Dutch monetization method)

