Reducing Carbon Footprint in Deep Foundations

From Uncertainty to Measured Performance

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The Problem: Systematic Overdesign

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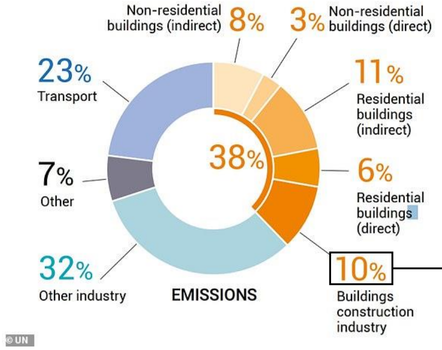
- Uncertainty in soil response → conservative design → excess CO_2
- Design based on correlations and limited data → conservative assumptions → excess CO_2
- High safety factors → unnecessary material use → excess CO_2
- Systematic overdesign → avoidable carbon footprint

CO_2 in the Construction Industry



Phase of use: 28%

Construction Phase: 10%
The 30 % of this phase is the foundation cosntruction. It means that the foundations represent the 3% of total emisisons

Carbon Reduction Strategy

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- 1. Reduce materials
- 2. Increase resistance
- 3. Reduce uncertainty
- 4. Measure during construction
- 5. Reduce waste
- 6. Increase execution speed

Key Actions for Carbon Reduction

1. Reduce materials → Increase capacity of piles using new technologies. Increase allowable resistance of reinforced concrete.

2 Reduce uncertainty → Measuring parameters during construction with new technology equipment, devices measuring resistance parameters like EB and TIC, measuring performance in 100% of the piles

3. Reduce waste → Higher resistance per pile, (less, shorter or slenderer piles), installation technology (e.g. FDP instead of CFA), improvement devices (TIC, EB), higher fck in concrete.

4. Increase execution speed → Less piles, shorter piles, slenderer piles

Underlying Mechanism

- Soil shear resistance improved before service loading
- Shaft resistance improved with new technologies like FDP and others.
- Toe resistance improved with new technologies like EB and TIC so the toe resistance can be mobilized at lower displacement. Movements compatibility with the shaft

Field Experience (South America)

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New Technologies:

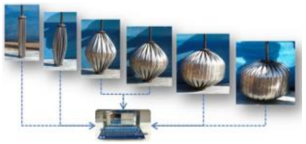
- Bauer BTronic
- Full displacement piles, with or without EB
- EB, Expander Body
- TIC, Toe injection cell in drilled and CFA piles

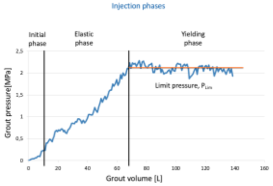
Technology Overview

Expander Body (EB)

A folded steel tube that expands under pressure at the pile tip.

Enhances density and stiffness of the surrounding soil.





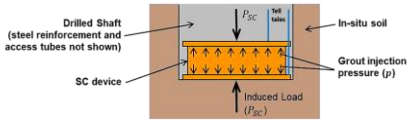
Collects stress-strain data in real time during expansion.

Increases tip resistance and reduces settlement.

Toe Injection Cell (TIC)

Installed at the pile base, it allows controlled injection of pressurized grout.

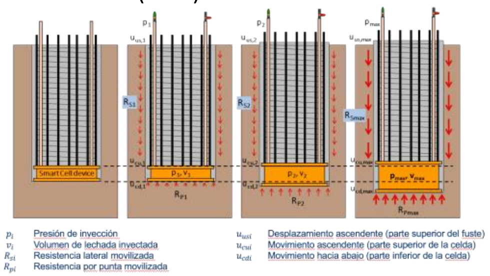
It acts as a hydraulic jack, generating a bidirectional load.



Both resistances are activated simultaneously through post-injection, ensuring uniform load distribution from the beginning of service.

The pile toe no longer starts soft. It starts already mobilized..

Toe Injection Cell (TIC)

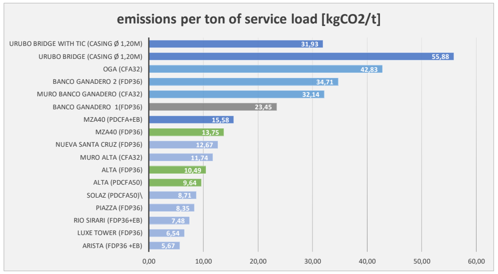


Mobilizes both lateral and tip resistance simultaneously via controlled grout injection.

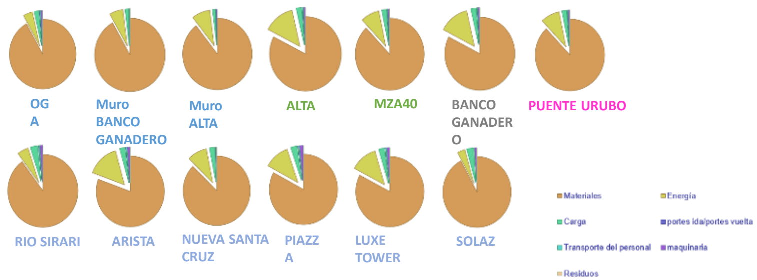
Measures real-time deformations to optimize pile design.

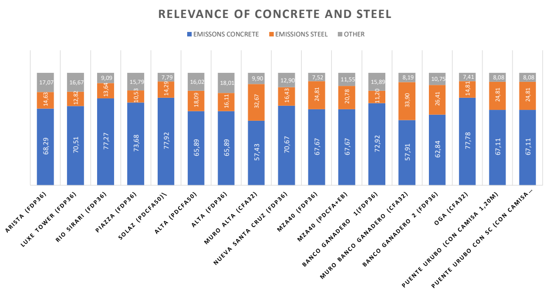
Measured CO_2 per Unit of Service Load ($kgCO_2/t$)

CO_2 Emissions vs Installation Technology



Distribution of CO2 emissions





Analysis of alternatives

CO2 EMISSIONS: COMPARISSON BETWEEN TECHNOLOGICAL ALTERNATIVES

		QUANTITY OF CO2 PER T OF SERVICE LOAD (T/CO2)							
Item		PILE 1, Ø 1 m, L = 20 m	PiLe 2, Ø 1 m, L = 20 m with TIC	Pile 3, Ø 0.40 m, L = 12 m	Pile 4, Ø 0.40 m, L = 12 m with EB	Pile 5, FDP Ø 0.36 m, L = 12 m	Piles , FDP Ø 0.36 m, L = 12 m with EB	Piles 7, DCFA (Partial Displacement CFA) Ø 0.50 m, L = 24 m	Piles 8, DCFA (Partial Displacement CFA) Ø 0.50 m, L = 24 m with EB
Diameter (m)		1	1	0,4	0,4	0,36	0,36	0,5	0,5
Length (m)		20	20	12	12	12	12	18	18
Volumen + overconsumption (m3)	m³	19,635	19,635	1,885	1,885	1,368	1,368	4,064	4,064
CO2 EMISSIONS (t)									
Concrete production	m³	4,453	4,453	0,428	0,428	0,310	0,310	0,922	0,922
Concrete transportation	h	0,105	0,105	0,010	0,010	0,007	0,007	0,022	0,022
Steel	t	1,508	1,508	0,014	0,014	0,014	0,014	0,014	0,014
Truck 250 HP	h	0,158	0,158	0,015	0,015	-	-	0,022	0,022
Drilling machine 350HP	h	2,680	2,680	0,168	0,168	0,084	0,084	0,335	0,335
Support equipments 150 HP	h	0,080	0,080	0,010	0,010	0,006	0,006	0,040	0,040
Electricity	kW	2,454	2,454	0,236	0,236	0,171	0,171	0,508	0,508
EB's Steel	t				0,048		0,048		0,048
SC's steel	t		0,192						
Cement for EB	t				0,027		0,027		0,027
Cement for SC SC	t		0,018						
Total CO2 (t)		**11,44**	**11,65**	**0,88**	**0,96**	**0,59**	**0,67**	**1,86**	**1,94**
Normalizing CO2 Value Relative to Pile 1		1,00	1,02	0,08	0,08	0,05	0,06	0,16	0,17
Service Load (kN)		3500	7000	450	1100	750	1500	2000	3000
t of CO2/kN Service		0,00327	0,00166	0,00196	0,00087	0,00079	0,00044	0,00093	0,00065
Normalized t/CO2 Value Relative to Pile 1		**100,00%**	**50,92%**	**59,91%**	**26,59%**	**24,15%**	**13,61%**	**28,50%**	**19,77%**

Key Conclusions

Uncertainty Reduction

- Measured resistance parameters in 100% of the piles
- Real stiffness known
- Reduced safety factors
- Measure → Verify → Optimize → Reduce

Optimization Chain (Measured Design)

- In situ parameters measurement (100% of piles) → lower uncertainty
- Lower uncertainty → lower FS
- Lower FS → smaller piles
- Smaller piles → less CO2
- Less CO2 →Higher efficiency

CO_2 reduction is fundamentally a design problem

GEOEXPAND Solutions

Thank you!

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