THE PORTUGUESE EXPERIENCE IN COLD RECYCLING WITH FOAMED BITUMEN

CASES

Pragosa • FRANCISCO CASTRO & GONÇALO HENRIQUES

PRAGOSA

Infraestruturas de Portugal

Universidade do Minho
Escola de Engenharia

PRAGOSA

PRAGOSA is an international family-owned group with 48 years.

In three main business areas: **construction, environment**, and **industry**, with a solid international presence in Romania and Mozambique.

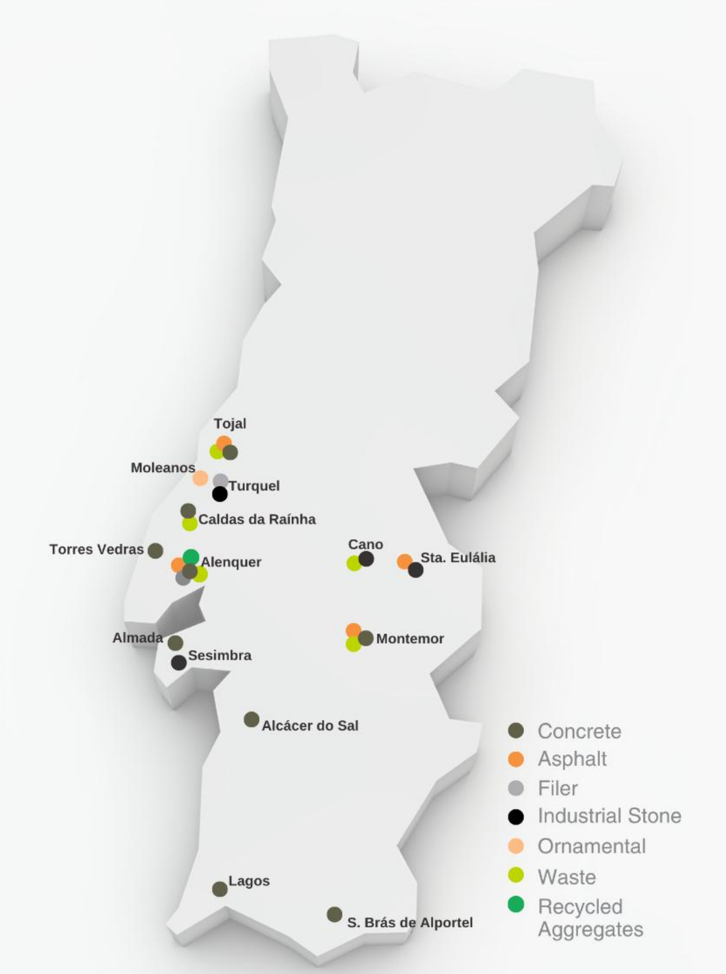
The group employs approximately **846 direct collaborators** and achieved a non-consolidated turnover of **€133 million in 2024.**

SUSTAINABILITY STRATEGY

- People – SDG 3 & 8
- Planet – SDG 9, 11, & 12
- Partnerships – SDG 17

Group objectives aligned with the United Nations Sustainable Development Goals.

CONSTRUCTION	TURN.: 83,8 M €
ENVIRONMENT	TURN.: 2,7 M €
INDUSTRY	TURN.: 46,8 M €



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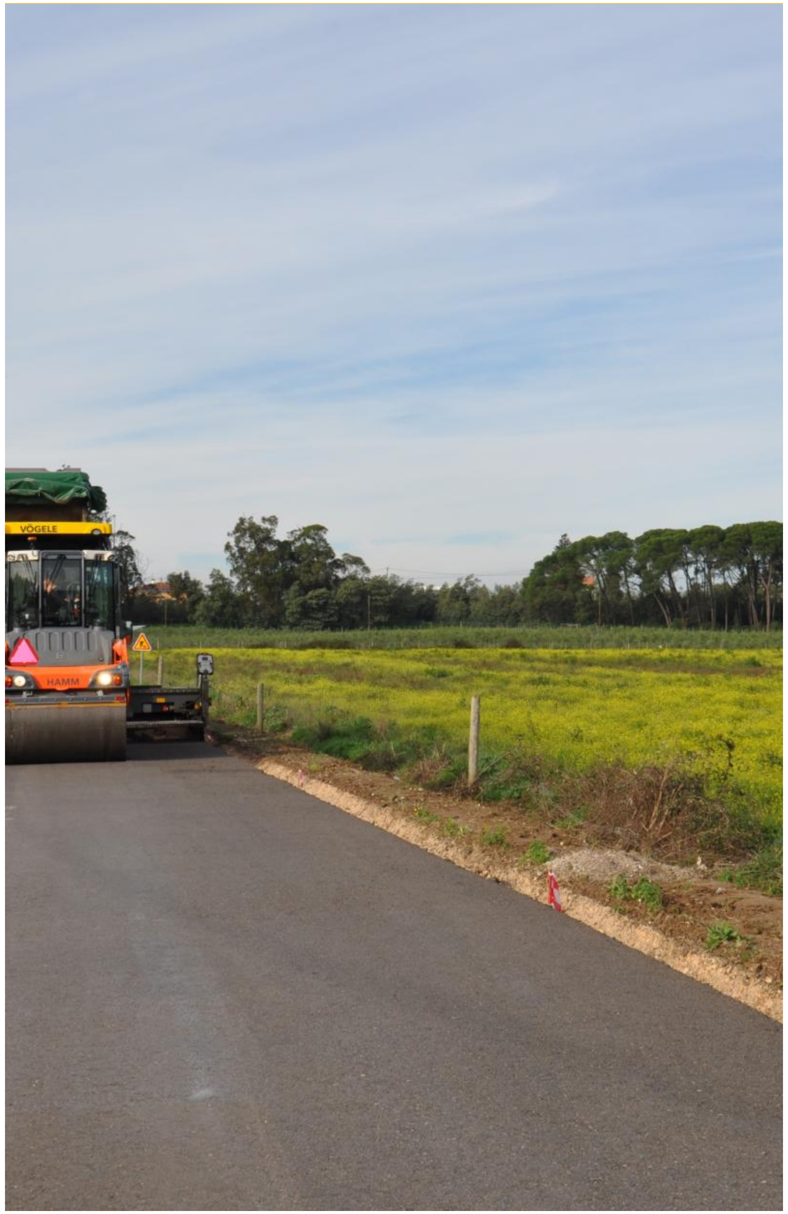


1. OUR MOTIVATION • WHY INNOVATE

1.

OUR MOTIVATION

WHY INNOVATE?

To find an environmentally sustainable alternative

2. THE APPROACH • "COLD RECYCLING"

2. THE APPROACH • "COLD RECYCLING"

PRAGOSA — Carried out construction, plant operation and on-site quality control.

Infraestruturas de Portugal — Responsible for managing Portugal's national road network.

Universidade do Minho, Escola de Engenharia — Technical lead: mix design, mechanical characterization and field validation.

Case 1 – Amiais

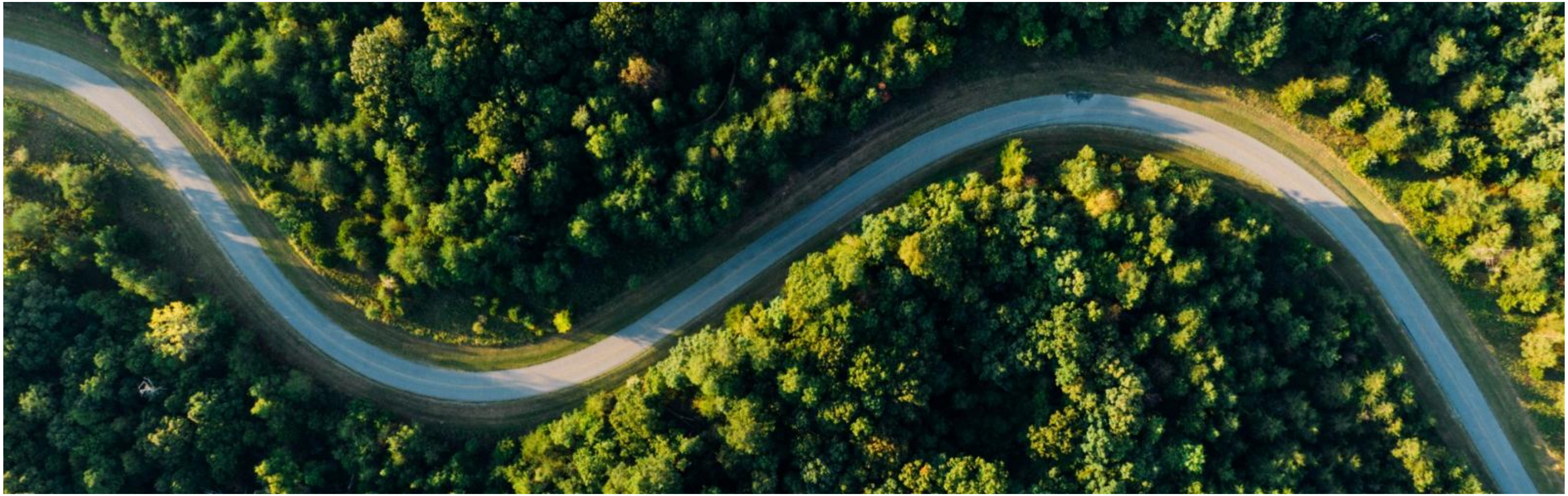
Cold in-situ recycling with foamed bitumen solution

[2020 – 2021]

Case 2 – Riachos

Cold in-plant recycling with foamed bitumen solution

[2023 – 2025]



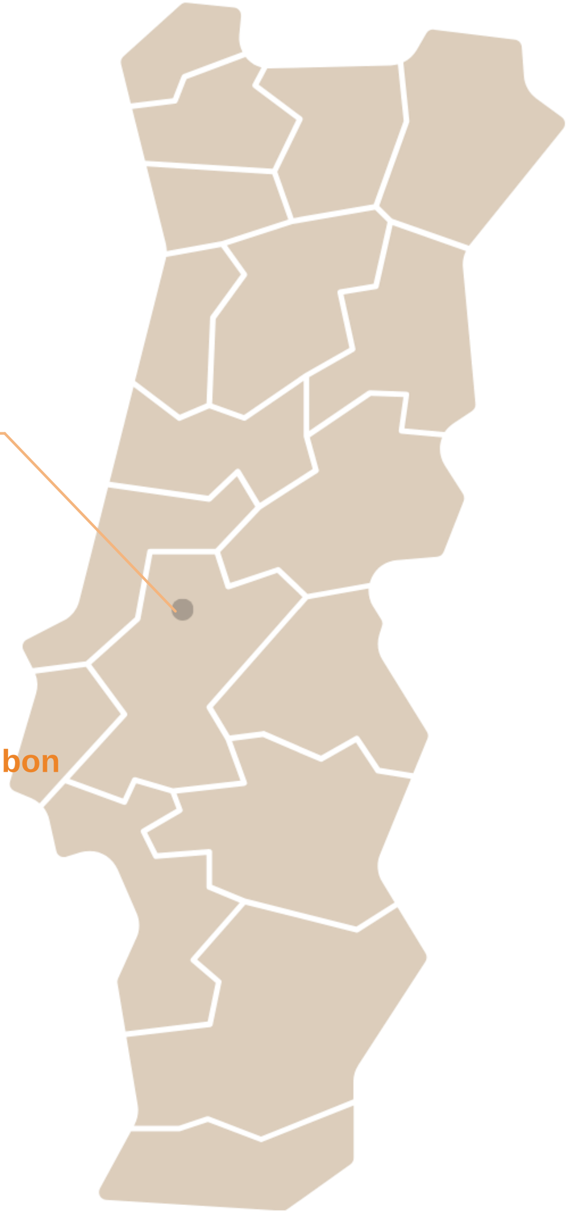
3. CASE 1 - AMIAIS • COLD IN-SITU RECYCLING

3.

CASE 1 - AMIAIS
COLD IN-SITU RECYCLING
LOCAL & EXTENSION

Total Extension:
2633 m

ER 361 – Amiais de Cima / Alcanena



3.

LABORATORY MIX DESIGN

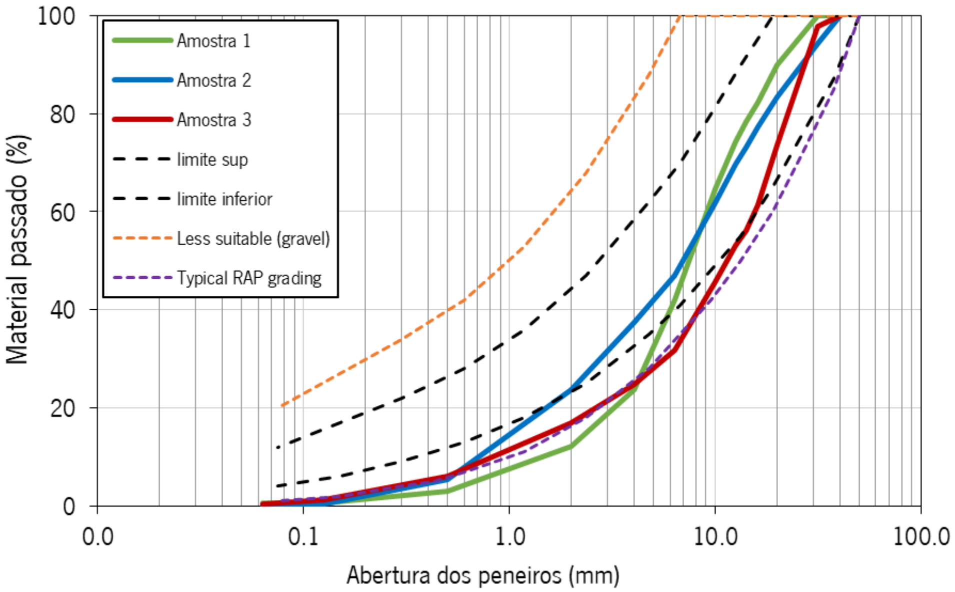
i. On-site sampling of reclaimed asphalt at multiple locations






3.

LABORATORY MIX DESIGN



ii. Deficit of fines in gradation curves — mitigated with lime/filler addition

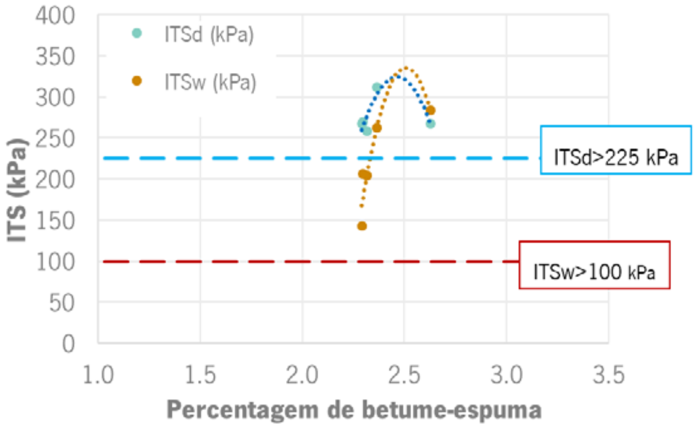
3.
LABORATORY MIX DESIGN

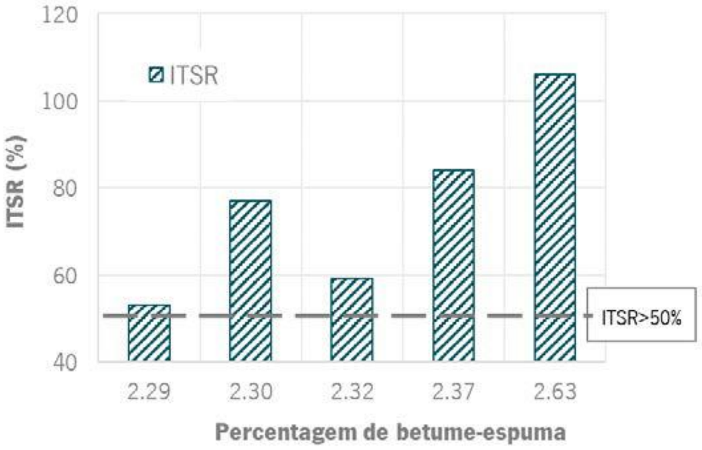
iii. Equipment: **Wirtgen WLB10S**

iv. Bitumen **70/100**

v. **Results & Mix Selection**

- All percentages met minimum ITS and ITSR requirements.
- **2.6% foamed bitumen**
- **2% hydrated lime**
- **5% water content**





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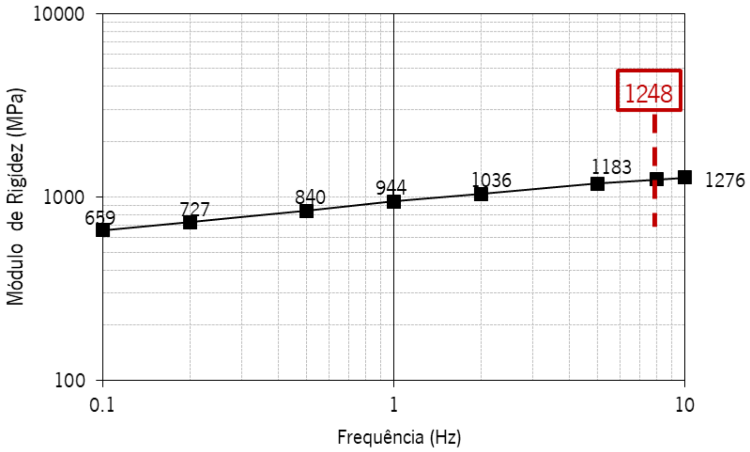
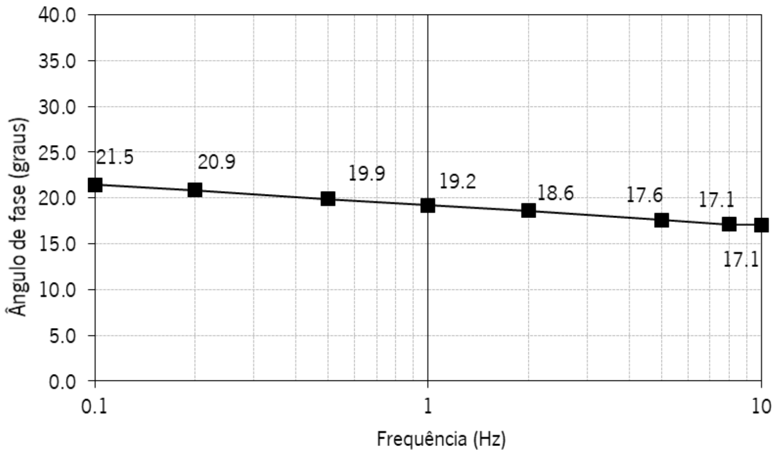
LABORATORY MIX DESIGN





10-day curing results

Resilient modulus within Wirtgen specification: 600–1500 MPa

3.
RECYCLED LAYER CONSTRUCTION

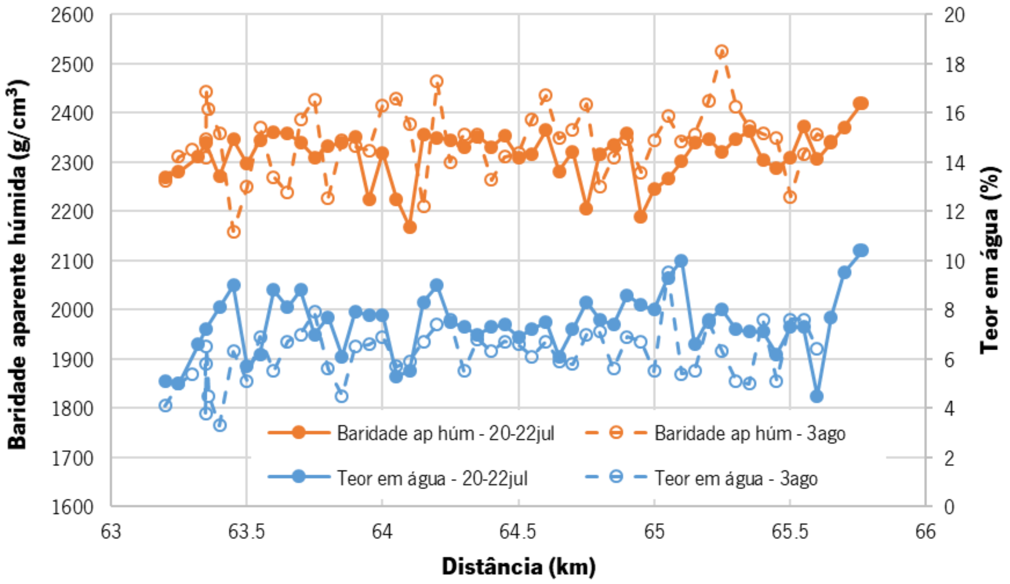
Case 1 – Amiais

Cold in-situ recycling with foamed bitumen solution
[2020 – 2021]


WIRTGEN

3.

QUALITY CONTROL AND PERFORMANCE VALIDATION

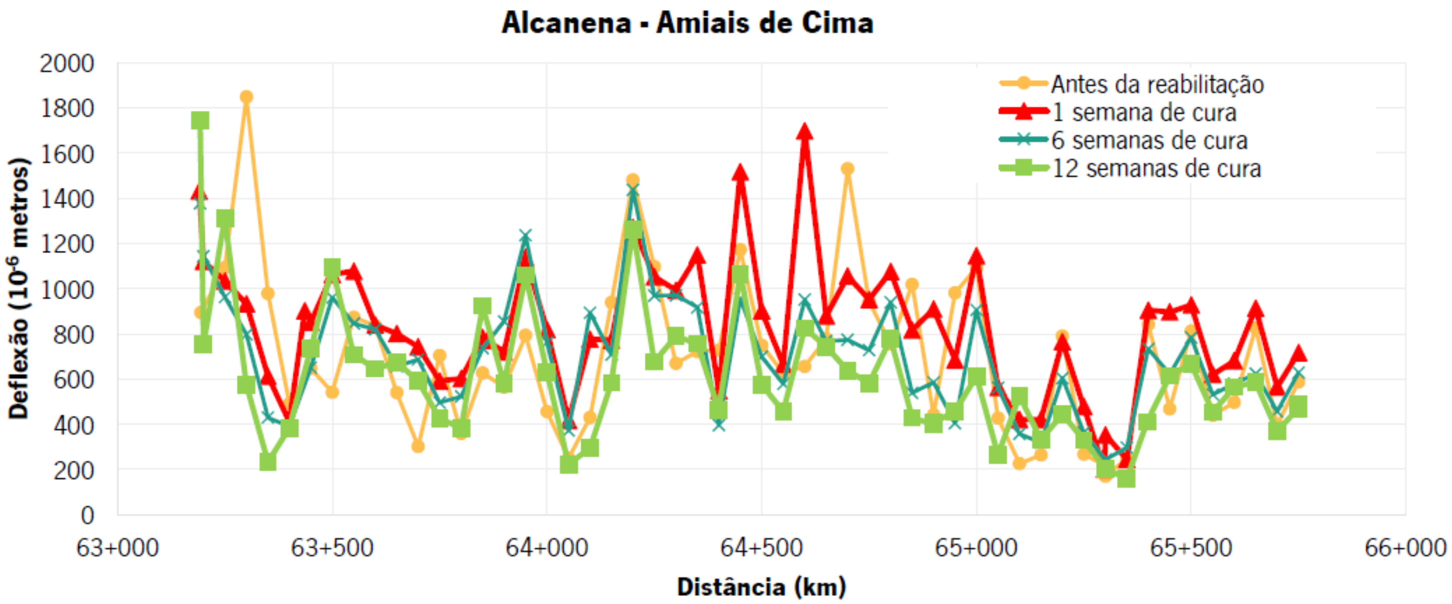


Compaction control and layer moisture-content

- After approximately two weeks' curing, the layer moisture content reduced by about 1%
- Representative rotary cores of the stabilised layer were only recoverable circa 6–7 weeks post-stabilisation

3.

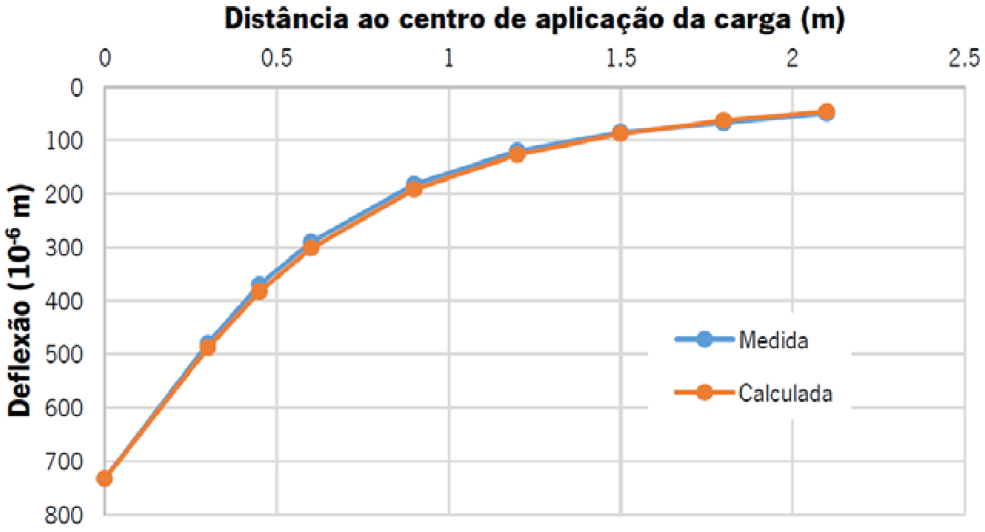
QUALITY CONTROL AND PERFORMANCE VALIDATION



Evolution of pavement load-bearing capacity

- Load-bearing capacity primarily determined by pavement structure and foundation
- Progressive increase in bearing capacity with curing time (reduced variability)

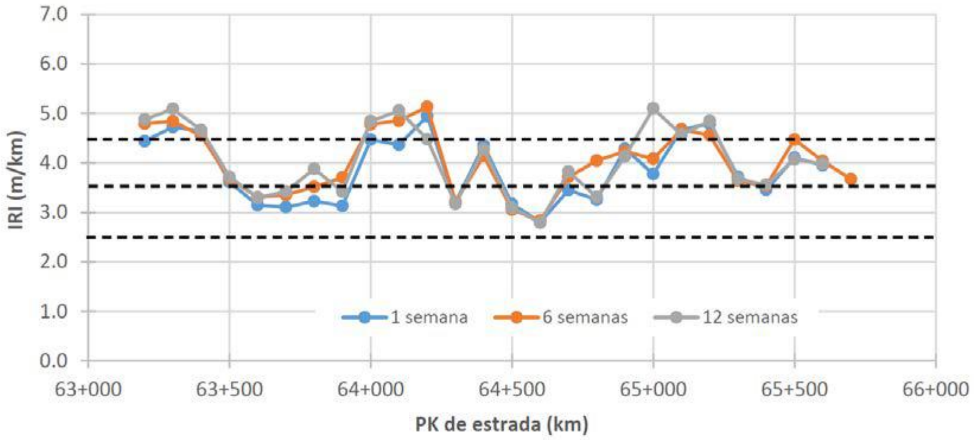
3.
QUALITY CONTROL AND PERFORMANCE VALIDATION



Type of material or layer	Pit 1 (thickness)	Pit 2 (thickness)	Pit 3 (thickness)	Pit 4 (thickness)	Pit 1 (modulus)	Pit 2 (modulus)	Pit 3 (modulus)	Pit 4 (modulus)
Foam bitumen stabilised layer	17 cm	15 cm	19 cm	18 cm	1200 MPa	2800 MPa	1600 MPa	900 MPa
Hydraulic macadam	7 cm	6 cm	8 cm	6 cm	190 MPa	250 MPa	180 MPa	150 MPa
Clayey soil mixture with crushed aggregates	21 cm	25 cm	14 cm	26 cm	160 MPa	210 MPa	150 MPa	120 MPa
Subgrade soil	-	-	-	-	89 MPa	120 MPa	85 MPa	63 MPa

3.

QUALITY CONTROL AND PERFORMANCE VALIDATION



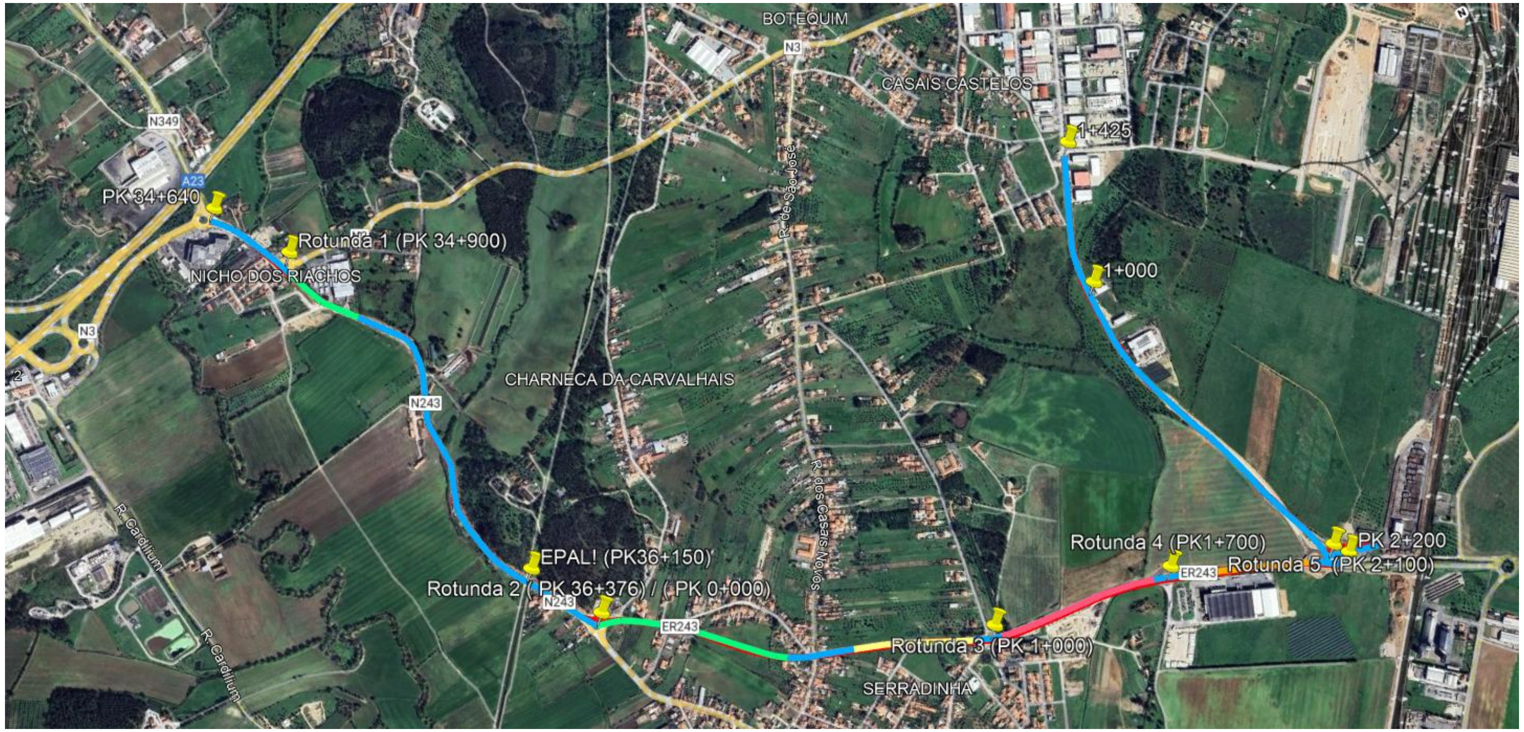
Longitudinal profile regularity and surface condition assessment

- The stabilized layer is more irregular than the HMA layers
- Layer without significant rutting, cracking or ravelling
- Localized areas exhibiting surface disintegration
- Irregularity caused by multiple manhole covers

4. CASE 2 - RIACHOS • COLD IN-PLANT RECYCLING

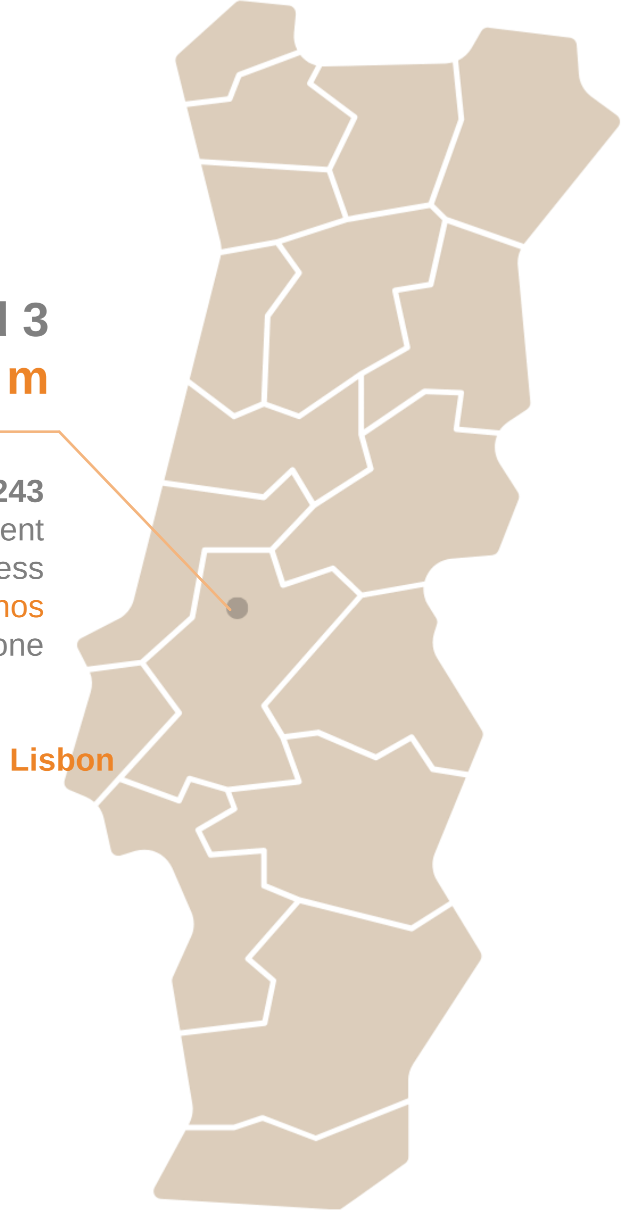
4.

CASE 2 - RIACHOS
COLD IN-PLANT RECYCLING
LOCAL & EXTENSION



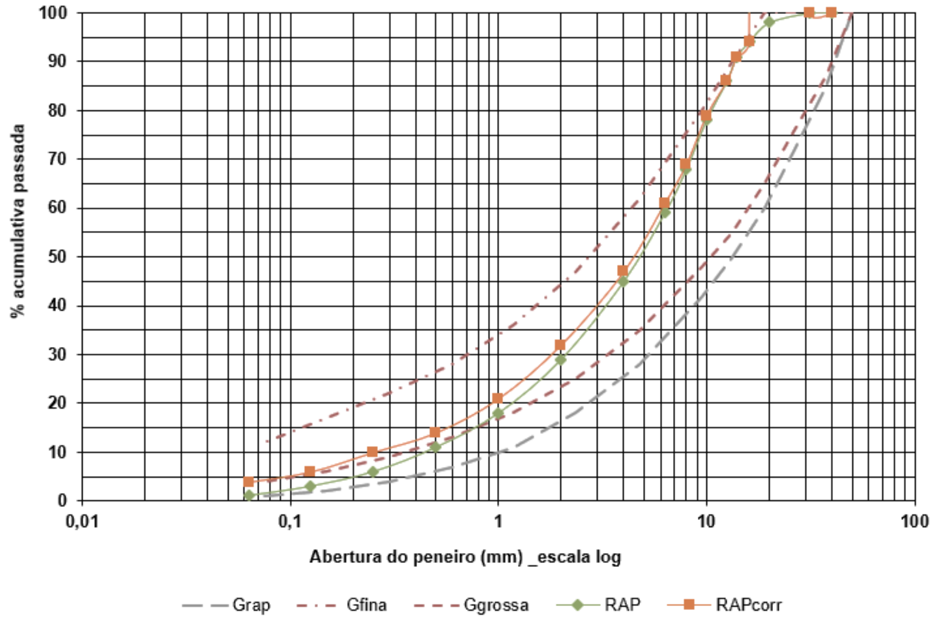
Section1, 2, and 3
Total Extension: **5362 m**

ER 243
Improvement works on access to the Riachos Industrial Zone



4.
LABORATORY MIX DESIGN

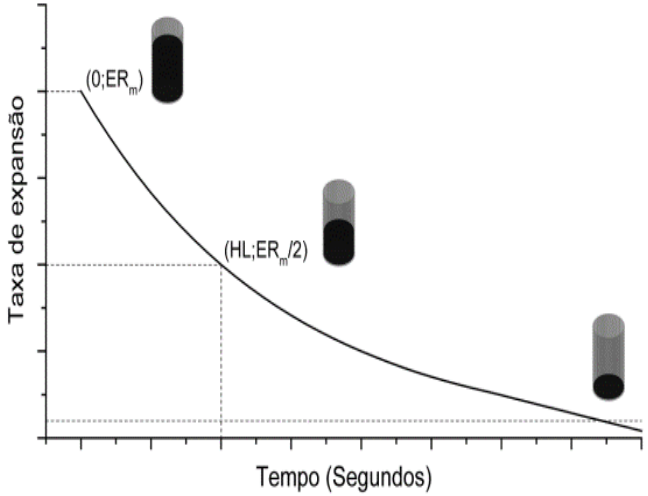
- Final mixture recycles 100% of the existing on-site material
- Improved quality control
- Milled material exhibits a low content of the finest fraction that bonds to the foamed bitumen — corrected by adding 4% commercial limestone filler



4.

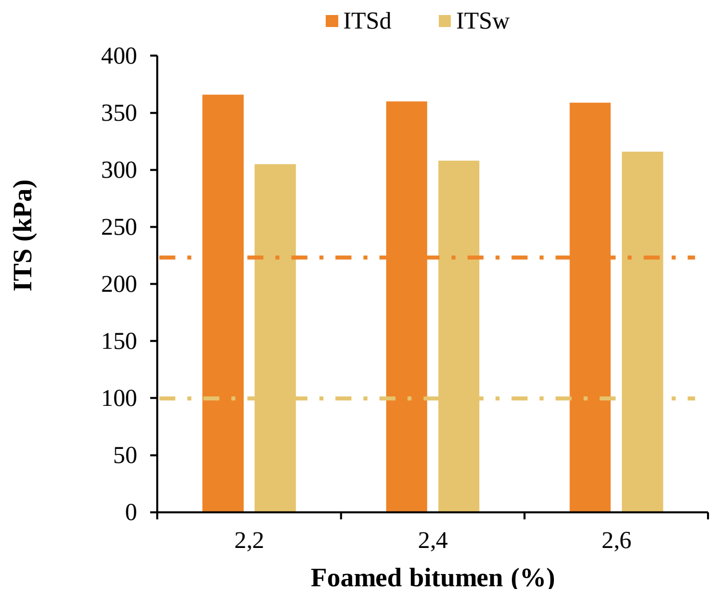
LABORATORY MIX DESIGN

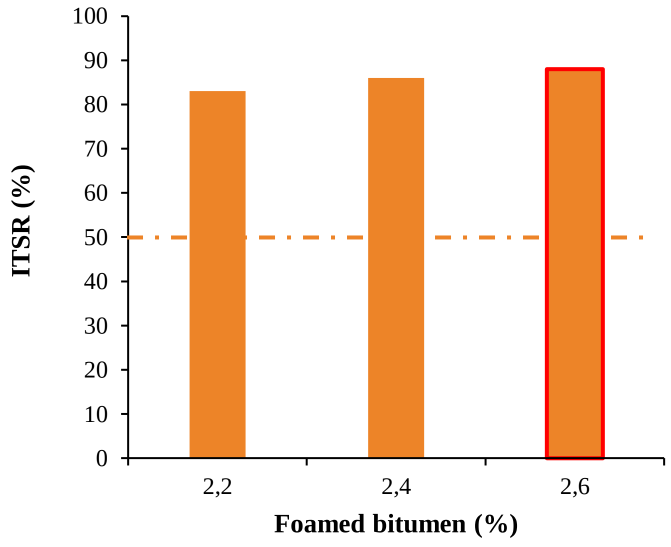
- **Optimal moisture content** for compaction using the modified Proctor method: **5.5 %**
- Optimal foamed bitumen content: between **2.2 % and 2.6 %**
- Foamed bitumen produced at 170 °C with **2.5 % water** and **70/100 bitumen**
- Addition of **2 % cement** as an active filler to increase modulus and accelerate curing



4.
LABORATORY MIX DESIGN

- **Indirect Tensile Strength** (ITS) is the key mechanical property used to evaluate cold-recycled mixtures
- Specimens were cured at 40 °C for 72 hours
- Tests were conducted at 25 °C after 24 hours of water conditioning at 25 °C
- **2.6 % foamed bitumen was selected**, providing the best overall performance
- The combination of foamed bitumen and cement produced a **hybrid mixture**, intermediate between granular and bound behaviour





4.

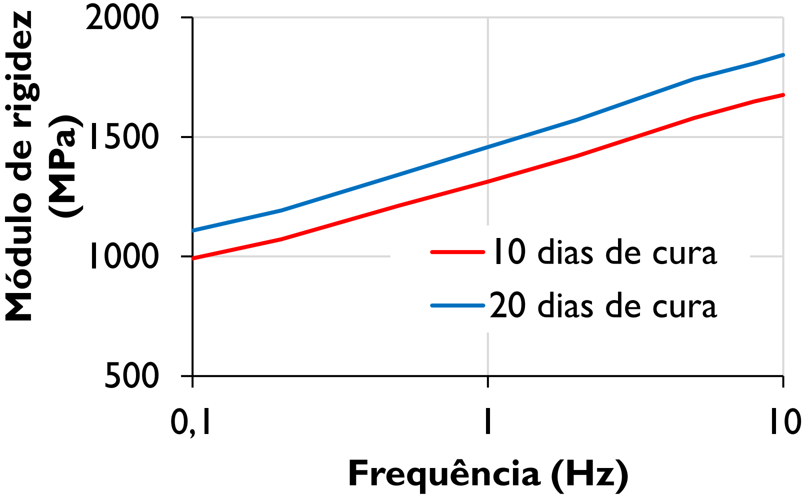
LABORATORY MIX DESIGN

STIFFNESS MODULUS ASSESSMENT FOR STRUCTURAL DESIGN

- Production of prismatic specimens under the selected conditions (2.6 % foamed bitumen)

- Stiffness modulus tests conducted using a four-point bending configuration

- Results confirmed modulus values between 1,500 MPa and 2,000 MPa, with an increase over curing time at room temperature

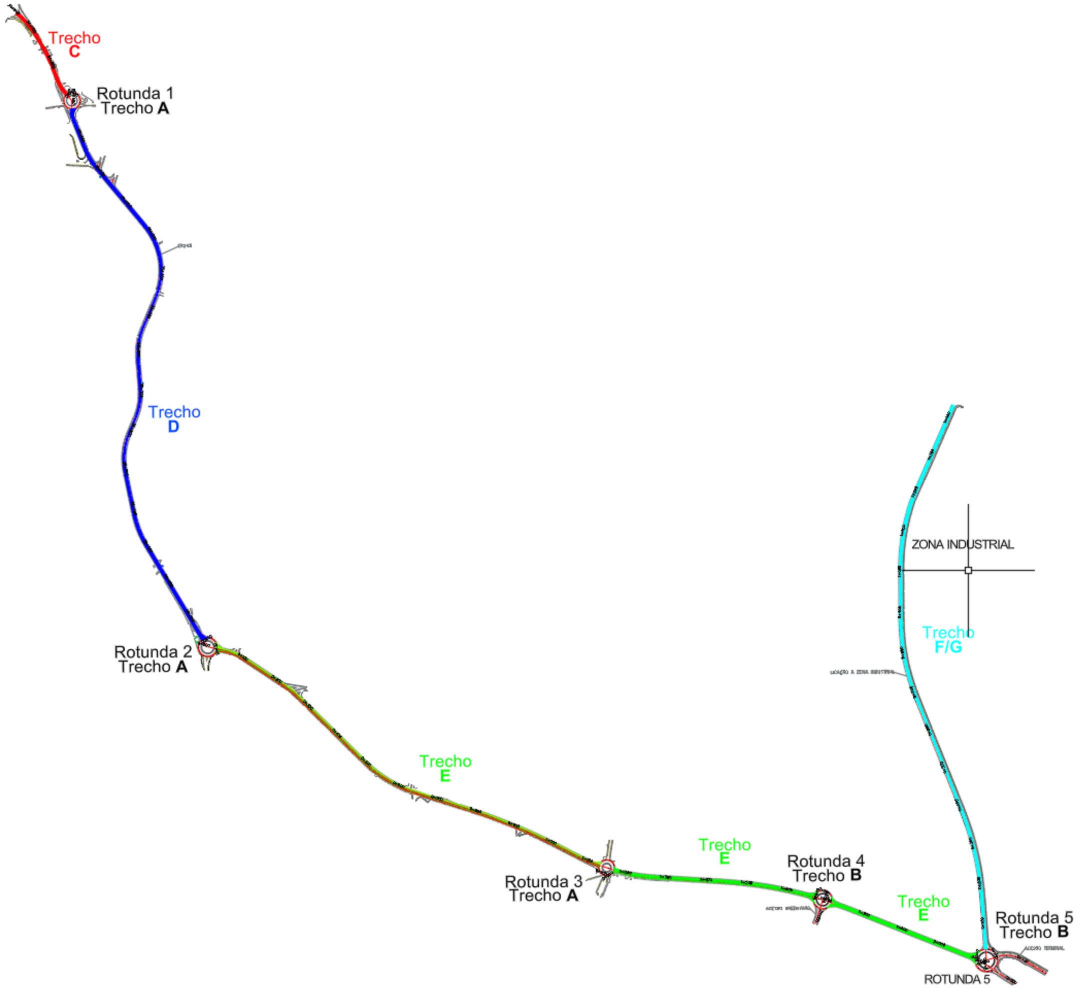


4.

LABORATORY MIX DESIGN

STRUCTURAL EVALUATION OF THE SOLUTION

- Cold recycling with foamed bitumen was applied in Section C to G (Traffic Classes T3 to T6) but was not used in the roundabouts — Sections A and B (Traffic Classes T1 and T
- Empirical–mechanistic design was performed using the Shell method
- The stiffness modulus of the cold-recycled layer with foamed bitumen was 2,500 MPa
- The recycled layer was considered bound, with a conservative bitumen content of 8 % by volume
- An overlay of two hot-mix asphalt layers improved surface regularity and resistance to disaggregation



4.

LABORATORY MIX DESIGN

STRUCTURAL EVALUATION OF THE SOLUTION

Local	Design Thicknesses of Pavement Layers					Ncal (millions 130 kN axles)	Damage (%)
	Surface (SMA)	Binder or Levelling (MBQ)	BSM (MEFBE)	Granular (Base)	Granular (Sub-base)		
[C]	4	5	15	-	30	4,5	81
[D]	4	4	15	-	25	4,2	67
[E]	4	4	15	-	40	3,7	76
[F]	4	3	11	-	20	0,5	50
[G]	4	3	11	20	20	3,6	7

4.
RECYCLED LAYER CONSTRUCTION

Case 2 – Riachos

Cold in-plant recycling with foamed bitumen solution **[2023 – 2025]**


RAP
WATER TANK (250M3)

4.

PERFORMANCE VALIDATION

CHARACTERIZATION OF THE STABILIZED MATERIAL APPLIED ON SITE

- After three months of curing, it was possible to extract three pavement slabs of approximately 1 m²

- The material remained cohesive throughout the full thickness

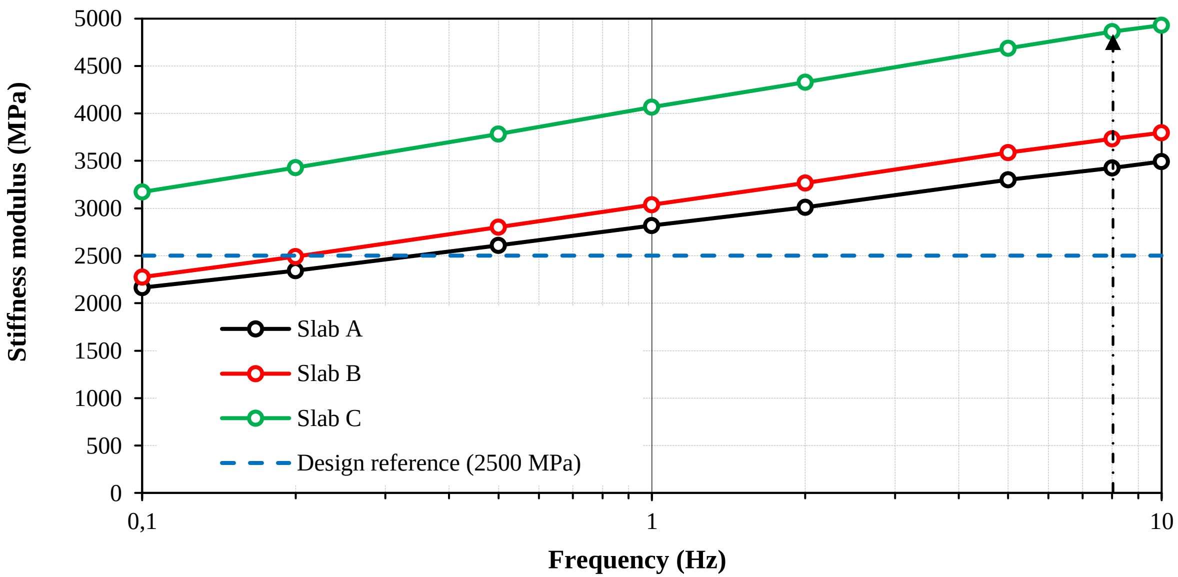
- Several specimens were obtained for laboratory characterisation of the stabilized material

4.

PERFORMANCE VALIDATION

STIFFNESS MODULUS, INDIRECT TENSILE STRENGTH

- Stiffness modulus of three slabs extracted in situ exceeded 2,500 MPa (at 8 Hz), as established in the design
- ITS was very high, ranging from 590 to 720 kPa, surpassing the values obtained in the initial study
- Water sensitivity (ITSR) exceeded 95 %

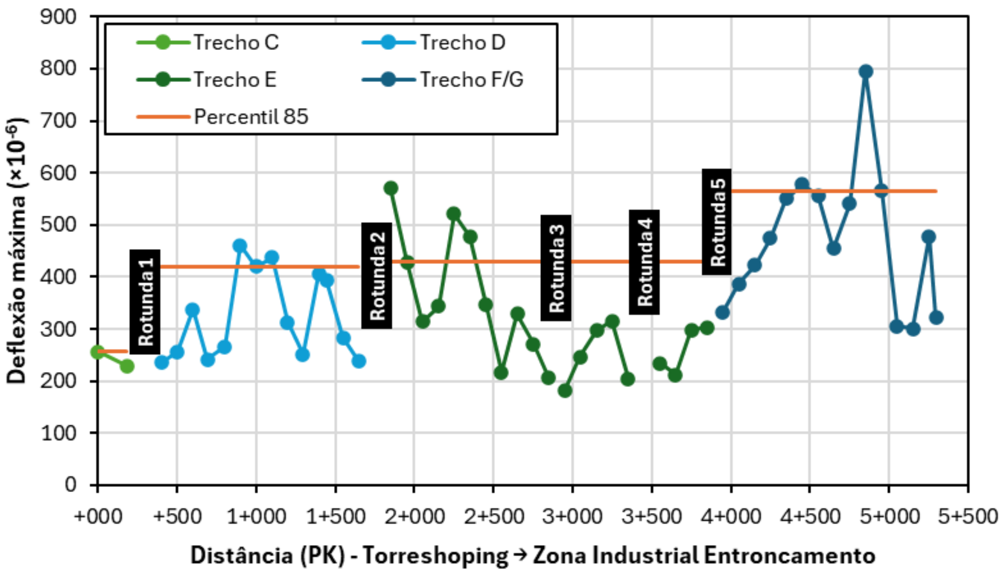


4.

PERFORMANCE VALIDATION

FIELD TEST WITH FALLING WEIGHT DEFLECTOMETER (FWD)

- Assessment of the pavement's load-bearing capacity after rehabilitation
- Inverse analysis of the results to determine the stiffness modulus of the recycled mixture
- Evaluation of characteristic deflections (85th percentile)
- Test conducted after the rainy season (when the subgrade exhibits its lowest load-bearing capacity)

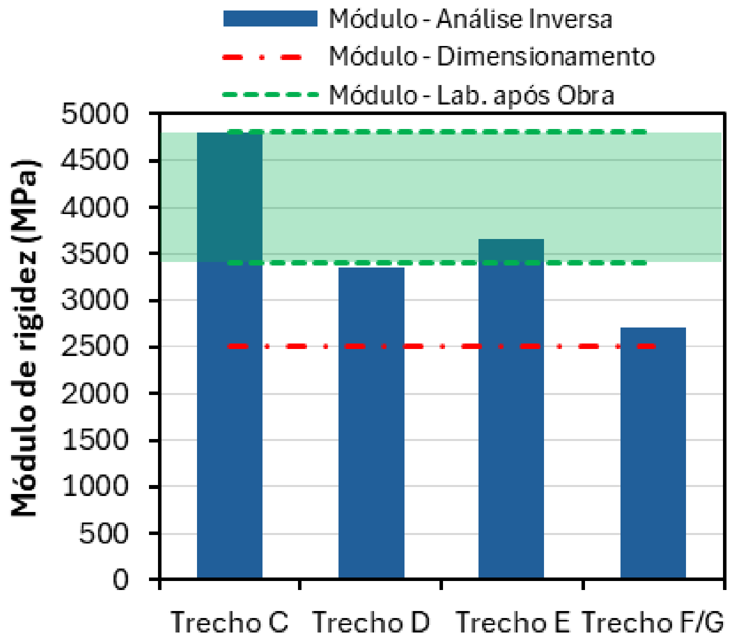


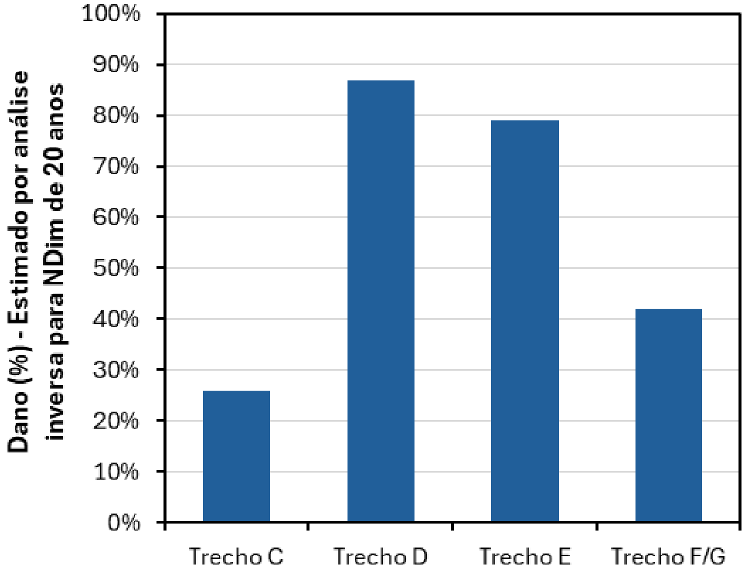
4.

PERFORMANCE VALIDATION

FIELD TEST WITH FALLING WEIGHT DEFLECTOMETER (FWD)

- Stiffness Modulus of the Cold-Recycled Mixture Determined by Inverse Analysis of Deflection Results
- The modulus values were higher than those used in the design (2,500 MPa) and similar to laboratory results (≈3,500 MPa)
- The estimated damage after 20 years is below 90 %



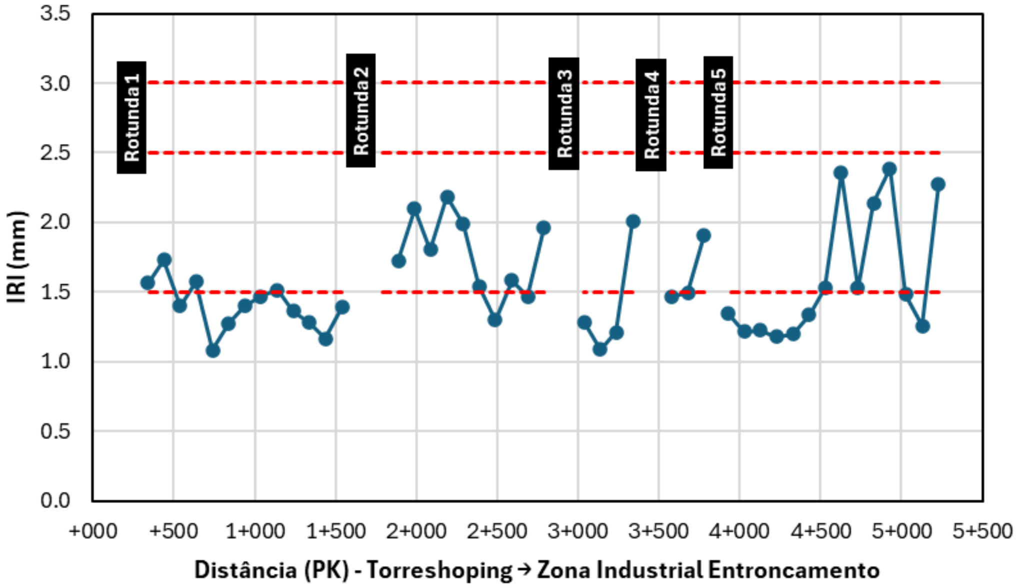


4.

PERFORMANCE VALIDATION

FIELD TEST WITH ROAD SURFACE PROFILOMETER (RSP)

- Assessment of pavement surface smoothness (IRI) after completion of the rehabilitation
- IRI values over 100 m sections were always below 2.5 m/km, and below 1.5 m/km in 55 % of the pavement, indicating very good smoothness



6. SUMMARY

6.
SUMMARY

i. **Cold in-plant recycling is viable** and a sustainable alternative to traditional pavement reconstruction.

ii. Contribution to the **decarbonization** of road networks and the transportation sector.

iii. Cold recycling techniques can be successfully implemented through proper RAP processing.

6.
SUMMARY

iv. There are many **benefits** of the in-plant recycling method:

- less raw material;
- less transportation and waste production;
- 100% reincorporation;
- high-quality end-product.

6.
SUMMARY

V. **Future challenges:**

- to establish quality control standards and end-product requirements;
- comprehensive studies (traffic loads, weather conditions).

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PRAGOSA

AUTHORS

Gonçalo Henriques
goncalo.henriques@pragosa.pt

Francisco Castro
francisco.castro@pragosa.pt

Joana Pragosa
joana.pragosa@pragosa.pt

REFERENCES:

pragosa.pt

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MOVITER