THE T3.2 BENCHMARK

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How comparable are bentonite laboratory data between laboratories?
Status and first results — WP ANCHORS, Subtask 3.2

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Why a benchmark?

Bentonite is a safety barrier and a structural element of the repository

Its swelling pressure and hydraulic conductivity are safety-function indicators.

The safety case is built on models — models need measured parameters

Constitutive models are parametrised and validated from small-scale laboratory tests.

Parameters must be reproducible and vendor-agnostic

Part of QA/QC of the buffer: the number must not depend on who measured it.

Explicit SRA driver

Roadmap 3.3.1 — uncertainty management for buffer material characteristics; methodology for laboratory measurements is an ANCHORS outcome.

"Same material, two laboratories, 2 MPa and 5 MPa — which number enters the safety case?"

We have EN standards and accredited laboratories. Is that not enough?

Bentonite is an extreme soil

- Very fine, high-plasticity, strongly swelling — at the edge of the range the standards were written for
- Properties keep changing for months; standard tests assume equilibrium in days
- Interaction with water during the test is the process being measured, not a nuisance
- Not every parameter we need has a standard at all (swelling pressure at constant volume)

Standards leave room — and it matters

- Cell type and size, sample preparation, saturation logistics all differ between laboratories
- Every variant is legitimate — all of them sit inside the standard
- Several steps are known to be operator-sensitive
- Result: differences that look like material behaviour but are method effects

Following the same standard does not mean producing the same number.

The answer: a controlled benchmark — Milestone 32

Fixed for everybody

- Two reference materials, distributed centrally
- Target dry densities and tolerances
- Detailed step-by-step procedures, durations and solutions
- Common dismantling and error quantification

Deliberately left free

- The laboratory's own cell and equipment
- The laboratory's own operator and routine
- This is exactly what the benchmark measures
- Reporting format was not fully prescribed — it had to be defined in agreement with the database preparation team

Procedures were written to remove procedural variability — so that what is left is the laboratory effect. They had to be revised (R2) during the campaign, based on feedback from the participating laboratories.

Common materials + common procedures → what remains is the inter-laboratory scatter

The test programme in one slide

Path	Conditions	Sequence
CV1	Constant volume	Saturation with DI water (10 w) → kw → dismantling
CV2	Constant volume	CV1 + exposure to 0.02 / 0.1 / 1.0 M NaCl, kw after each step
CV3	Constant volume	CV1 + exposure to pH 13.5 & 13.0 (KOH) and pH 12.5 ($Ca(OH)_2$)
CS1	Constant axial stress	Saturation DI at 0.25 MPa → loading 0.5 / 1.0 / 2.5 MPa → unloading
CS2	Constant axial stress	CS1 + saline exposure at 0.25 MPa before loading
CS3	Constant axial stress	CS1 + alkaline exposure at 0.25 MPa before loading

Reference materials

- GB — Georgian Na-bentonite, 88 % smectite, CEC 1.07 eq/kg
- BCV — Czech Ca–Mg bentonite, 70 % smectite, CEC 0.61 eq/kg

Target dry densities

- GB 1400 / 1550 kg/m^3 · expected Ps 4.0 / 11.0 MPa
- BCV 1450 / 1650 kg/m^3 · expected Ps 2.5 / 8.0 MPa
- Tolerance ±25 kg/m^3 (35 mm cell) / ±15 kg/m^3 (50 mm cell)

Who delivered what

Partner	CS1	CS2	CS3	CV1	CV2	CV3
ASNR	1		1			
CIEMAT	2		1	2		
CLAYTECH	3			2	2	
CNRS-Navier	2	1	1			
CTU	2			2		
CU	1			4		
EPFL		2			2	
GI-BAS	1	1	1			
GRS				1	1	1
SKB				4	2	
TUBAF					2	
U. Lorraine				2		
Total	12	4	4	17	9	1

13
organisations reporting

47
specimens in this dataset

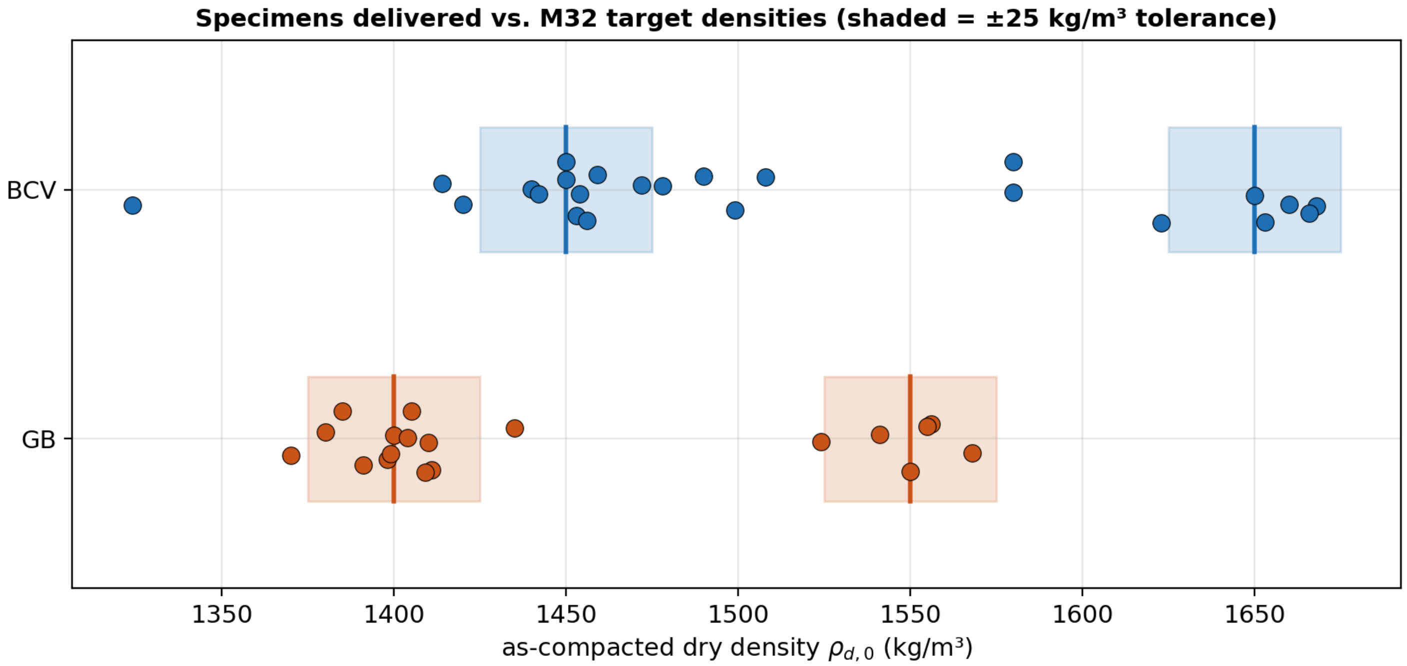
25 / 22
BCV / GB specimens

6
test paths covered

- CV1 and CS1 — the two core benchmark paths — carry most of the data
- CV3 has a single specimen so far; CS2 / CS3 remain thin
- Data are those reported in March 2026; an updated set is expected next month

Not every laboratory could follow M32 in full.

What was specified — and what actually arrived

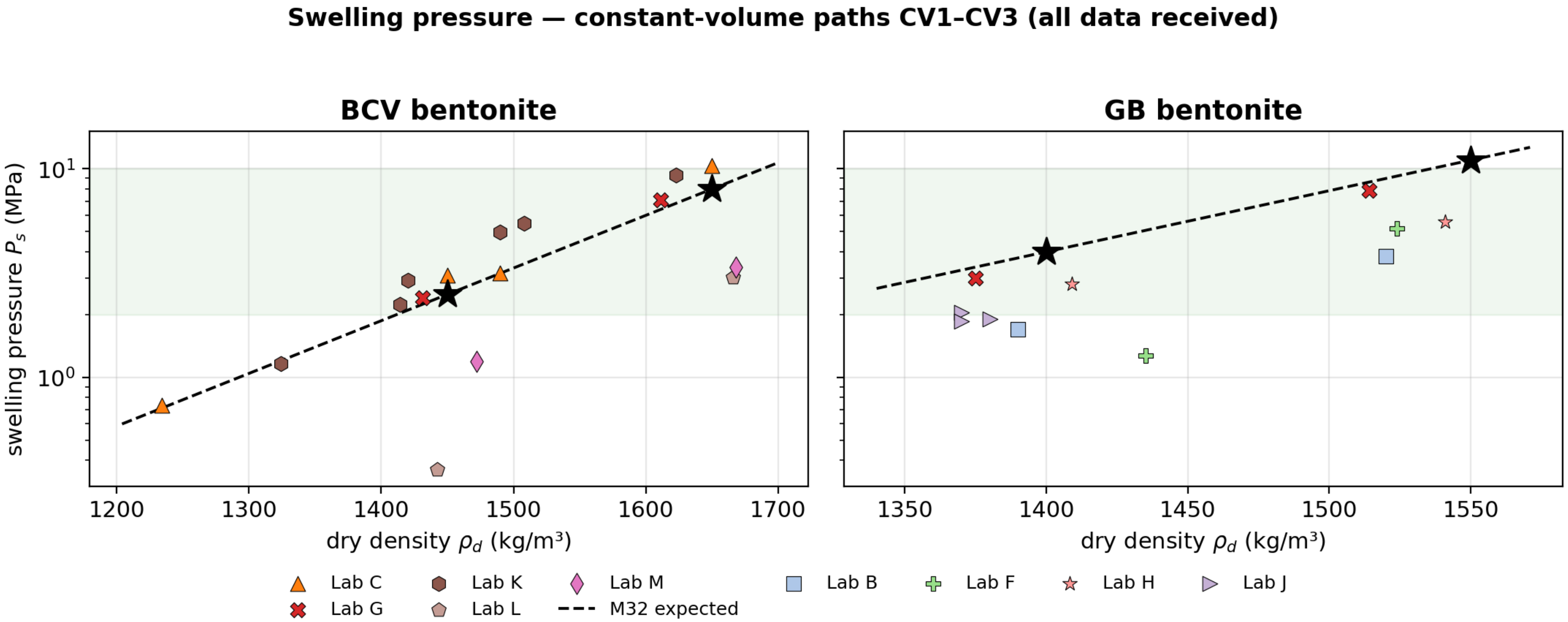


Deviations we can see in the data

- Only 69 % of specimens are inside the ±25 kg/m³ target window (BCV 60 %, GB 80 %)
- Cell diameters 30–120 mm and specimen heights 5–20 mm — a factor of 4 in height
- No CS test reached the specified 2.5 MPa; all stopped at 2.0 MPa
- One laboratory could only apply 0.04–0.17 MPa (large-diameter cell)
- Sign conventions and units for strain and density are not uniform in the reporting

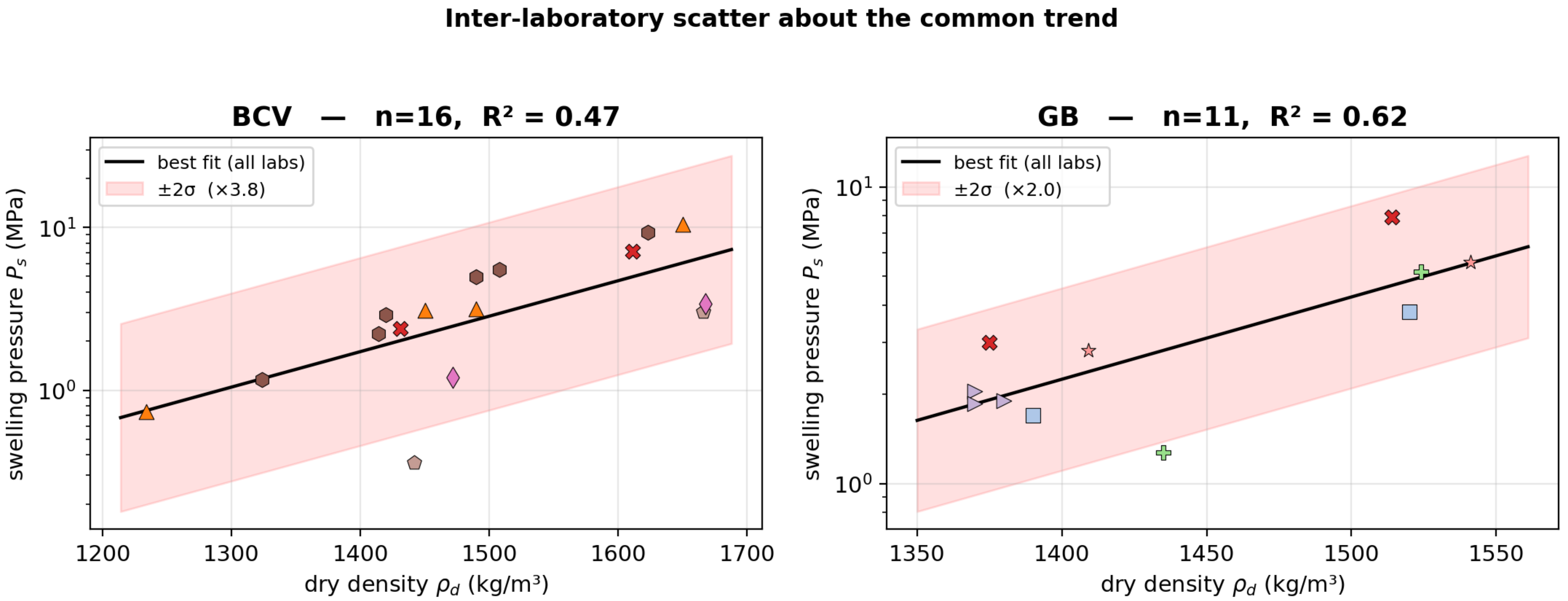
Part of the scatter is built in before the test starts.

Swelling pressure — the headline result



- The density dependence is reproduced by every laboratory — the physics is not in question
- BCV brackets the M32 expectation; GB sits systematically below it (median ≈ 0.55 × expected)
- Stars = M32 expected values at the target densities; green band = 2–10 MPa safety window

How large is the inter-laboratory scatter?



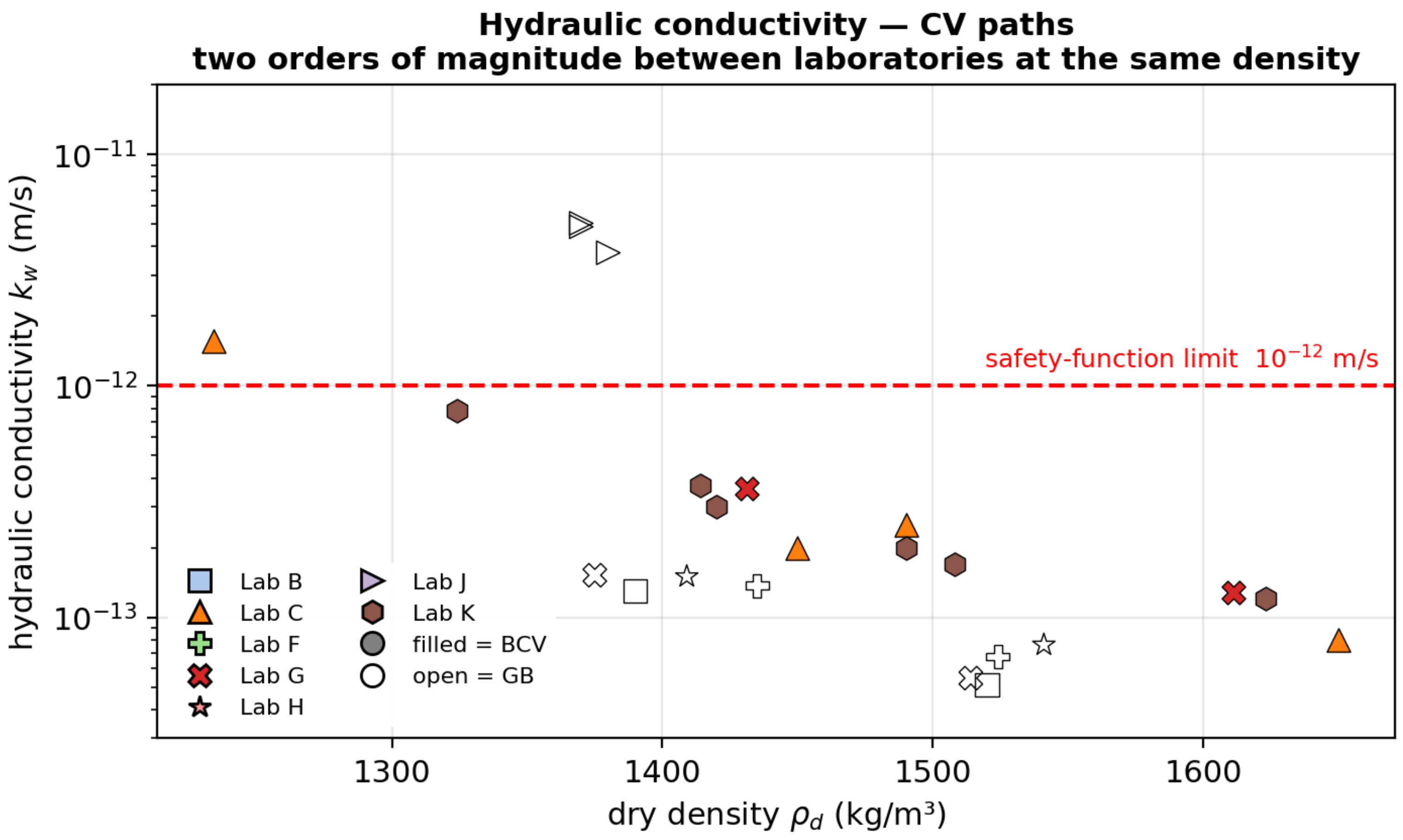
×3.8
BCV, ±2σ about the common trend

×2.0
GB, ±2σ about the common trend

×14
spread at the nominal BCV 1450 kg/m³ density

2–10
MPa safety window — narrower than our scatter

Hydraulic conductivity



What the data show

- Values span $5\cdot10^{-14}$ to $5\cdot10^{-12}$ m/s — two orders of magnitude
- Most laboratories agree within a factor of ~3 at the same density
- One set-up sits ~30× above the rest at every density — a method effect, not the material
- Four specimens plot above the 10^{-12} m/s safety-function limit

Excluding one set-up, kw is the better-behaved of the two parameters.

Conclusions and next steps

Where we stand

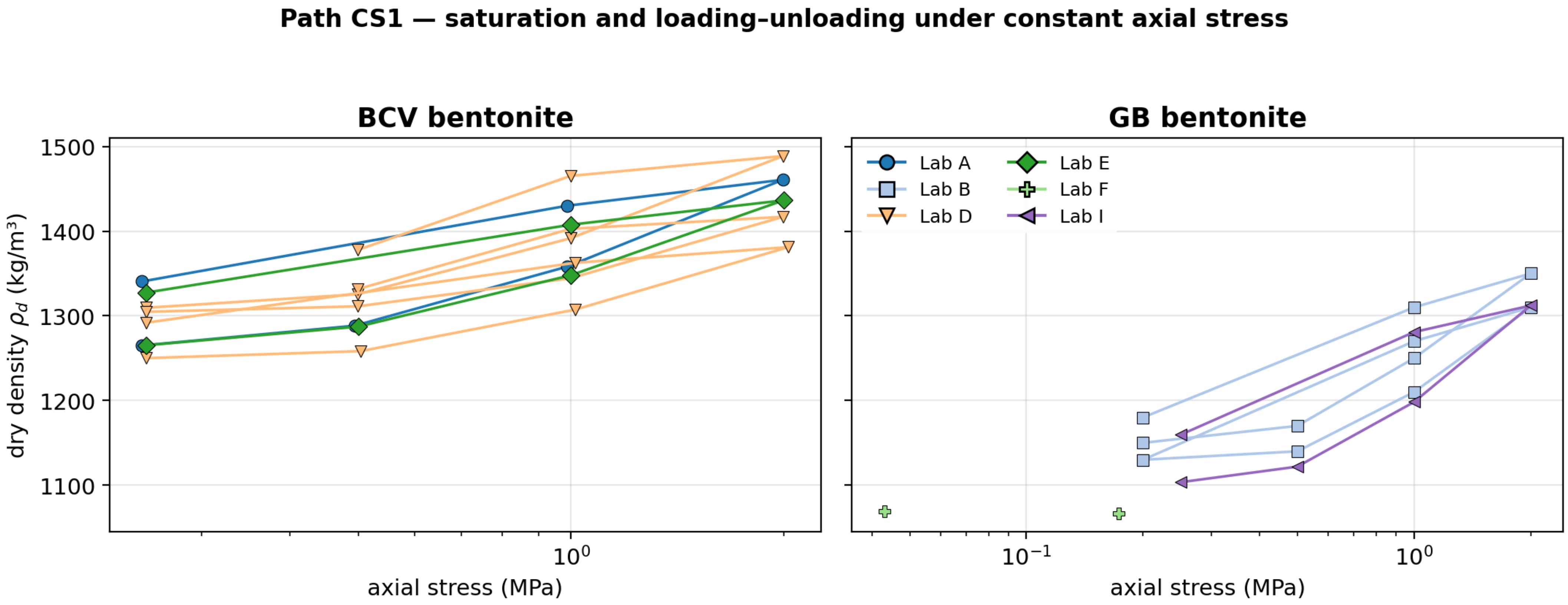
- First comparable dataset for two reference bentonites: 13 organisations, 47 specimens, 6 paths
- Density–swelling pressure trend is consistent everywhere
- Residual inter-laboratory scatter ×2 (GB) to ×4 (BCV) — the same order as the difference between the two bentonites
- kw spans two orders of magnitude, dominated by a few set-ups
- Deviations from M32 explain part of it — not all

Next steps

- Updated dataset expected next month — analysis will be repeated on it
- Complete CS2 / CS3 and CV3; they are still too thin to interpret
- Bilateral feedback to laboratories whose results sit outside the band
- Trace the scatter to specific procedural steps → input to the measurement methodology
- Post-mortem analysis with Subtask 3.1 on the dismantled specimens

Reminder: all benchmark results must be submitted to the project database.

Backup — oedometer path CS1



- Swelling strain on saturation at 0.25 MPa: 10–27 % across laboratories for comparable material and density
- One laboratory reports 46 % in a 120 mm cell and could not apply the loading stages