LL-TEQ

FREEZE-THAW PERFORMANCE

77 winters · 9 sites · 0 defects

A record signed by an independent Engineer of Record

REV. B

Proudly made in Québec

THE RECORD IN NUMBERS

LL-TEQ™ freeze-thaw performance

9 reference sites in real service, across 4 climate regimes comparable to Québec

77	**Cumulative winters** across 9 sites in real service
6,730	**Cumulative freeze-thaw cycles** inspected by the *Engineer of Record*
0	**Freeze-thaw defect observed** across all 9 sites
3 M+	**Cumulative ESALs** from local roads to heavy haul
59 m	**Cumulative snowfall** 27 documented weather events
4	**Köppen climate regimes** Dfa, Dsb, Cfa, Csb — neighbours of Québec's Dfb

01 The Québec freeze-thaw challenge

The dominant pavement-degradation mechanism in Québec

In Québec, conventional bituminous pavement ages under two compounding pressures: **thermal fatigue** from repeated freeze-thaw cycles around 0 °C, and **structural heave** caused by the formation of ice lenses in the frost-susceptible clay soils of the St. Lawrence Lowlands.

Under a **humid continental Dfb** climate — roughly **75 freeze-thaw cycles per year** and more than **2 metres of snow** — shrinkage cracks, alligator cracking, potholes and rutting advance season after season. Corrective maintenance becomes the dominant road-spending line item.

The question put to LL-TEQ

Can a pavement system that delivers both the wearing course and the structural function at once, formed in place as a single monolith, withstand Québec winter conditions **durably**?

✓ The dossier's answer

9 reference sites in real service across the United States, under 4 climate regimes comparable to Québec's Dfb, totalling 77 cumulative winters and roughly 6,730 freeze-thaw cycles: **no defect attributable to the freeze-thaw cycle** was observed by the *Engineer of Record* in April 2026.

02 The dossier at a glance

An empirical performance record signed by an independent engineer

This document is the **marketing summary** of the technical dossier *"LL-TEQ — Freeze-Thaw Performance,"* dated May 19, 2026 and prepared by an independent engineer at LL-TEQ's request.

AUTHOR

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METHOD

In-service visual inspection

Methodical assessment over the full treated length of all 9 sites, aligned with the principles of *ASTM D6433*. Inspections completed in April 2026.

SCOPE

Documentary record

An empirical record of observed performance. Project-by-project design remains the responsibility of the design engineer.

The question asked of each site

On in-service visual inspection by a qualified engineer, is any pavement defect **attributable to freeze-thaw** observed — cracking, alligator cracking, heave, potholes, rutting or slippage cracking?

03

Why LL-TEQ does not crack under freeze-thaw

A cohesive layer with no bituminous matrix, no interface, no connected pores

Freeze-thaw degradation of a flexible pavement relies on specific physical enablers. **LL-TEQ provides none of them.**

NO BITUMINOUS MATRIX

Nothing to harden, nothing to crack

LL-TEQ uses no bituminous binder subject to ageing and hardening. Cyclic thermal stresses find no brittle matrix to act upon.

NO CONNECTED PORES

Water does not enter, freezing does not start

The layer's dense cohesion eliminates connected porosity and capillary retention. With no free water in the matrix, no ice lens can form inside the layer.

NO INTERFACE

One structure, one monolith

The layer is formed in place as a unified whole, with no stratification or adhesive plane. No interface where differential stresses could concentrate.

NATIVE SOIL INTEGRATED

The fine fraction enters the monolith

The upper fraction of the native soil is integrated into the cohesive matrix. The mass of fine soil able to form ice lenses in direct contact with the layer is reduced at the source.

04 The two freeze-thaw degradation mechanisms*

M1 — cyclic thermal fatigue · M2 — structural heave from deep frost

** Two-mechanism framework established by the Engineer of Record in the technical dossier's scoping note (§3.3), aligned with the ASTM D6433 inspection grid.*

Mechanism 1 (M1) — Cyclic thermal fatigue

Governed by the number of air-temperature transitions around 0 °C. Each cycle subjects the pavement to a contraction then an expansion that promote the formation of thermal cracks in the asphalt matrix. Through water infiltration and the combined action of frost and traffic, these cracks can evolve into potholes.

Mechanism 2 (M2) — Structural heave from deep frost

Triggered when the seasonal frost front penetrates the underlying native soil and produces, in frost-susceptible soils, the formation of ice lenses by segregation. These lenses heave the pavement and can generate structural cracking through its full thickness.

✓ LL-TEQ neutralizes both at the source

M1 — no bituminous matrix to harden, no interface where stress concentrates. M2 — no internal slip plane, and the upper fraction of the native soil is integrated into the cohesive monolith. Both mechanisms remain **without physical support** in the LL-TEQ structure.

05 How it is built

Two cold-application techniques, conventional road equipment

The dossier's 9 sites were built using two distinct techniques, both of which produce a **unified cohesive layer** delivering both the wearing surface and the structural function.

Cold recycling in place (*Cold Recycling*)

Four sites treated: Benton Harbor, Alexandria, Glenview, Bessemer. The reclaimer integrates the existing degraded bituminous mix and the underlying granular gravel base into a cohesive layer of ≈150 mm (6 in), with no interface or stratification.

Use case: rehabilitation of an existing degraded pavement.

In-place native-soil stabilization (*In-place Soil Stabilization*)

Five sites treated: Rockford, East Chicago, Elgin, Bridgeport, Big Bear Lake. The LL-TEQ layer alone constitutes the pavement, at ≈150 mm (≈200 mm at Bridgeport for the dossier's most demanding load). No added granular base or sub-base.

Use case: new pavements with no prior conventional structure.

06

The 9 reference sites — 77 winters, 0 defects

Visual inspections signed by the *Engineer of Record* in April 2026

#	SITE, STATE	KÖPPEN	WINTERS	ROAD CATEGORY	FREEZE-THAW VERDICT
1	Benton Harbor, MI	Dfa	9	Local (municipal, lake effect)	**0 defects**
2	Alexandria, VA	Cfa	9	Local (Potomac marine clay)	**0 defects**
3	Rockford, IL	Dfa	8	Collector (heavy haul)	**0 defects**
4	Glenview, IL	Dfa	8	Local (park access, silty soil)	**0 defects**
5	East Chicago, IN	Dfa	8	Arterial (industrial corridor)	**0 defects**
6	Elgin, IL	Dfa	8	Collector (heavy haul)	**0 defects**
7	Bridgeport, CA	Dsb	10	Arterial (military airstrip, 2,070 m)	**0 defects**
8	Big Bear Lake, CA	Csb	7	Local (mountain access, 2,050 m)	**0 defects**
9	Bessemer, AL	Cfa	10	Local (the oldest — 10 winters)	**0 defects**

Site-by-site detail (climate, soil, weather events endured, cumulative ESALs, documented interventions) in the full technical dossier, available on request.

07 Flagship site — Bessemer, Alabama

10 winters of service — the oldest site in the dossier

Why this site matters

Placed in service in **April 2016** by cold recycling in place. **10 cumulative winters**, humid subtropical climate (*Cfa*), ~1,300 mm/yr rainfall and silty native soil. The pairing of moisture + fine soil documents LL-TEQ's long-term durability under a regime with frequent oscillations around 0 °C.

Events endured

- EF3 tornado, January 2021 (~240 km/h, Jefferson County)
- Flash flooding, March 2022 (~130 mm in a few hours)
- Arctic cold snap, December 2022

April 2026 finding (10 winters)

No cracking, no alligator cracking, no heave, no potholes, no rutting. Surface wear *"slight for ten winters of exposure."*

08

Flagship site — Glenview, Illinois

8 winters — silty soil comparable to the loose deposits of the Lowlands

Why this site matters

Placed in service **August 2018**. Access infrastructure in a wooded riverside recreational area, Cook County. **8 winters**, humid continental climate (*Dfa*), **silty floodplain soil** — comparable to the loose deposits of the St. Lawrence Lowlands.

Relevance to Québec

The site documents LL-TEQ's performance on a fine substrate susceptible to frost heave and to bearing-capacity loss on thaw — exactly the soil profile that troubles conventional pavements in the Lowlands.

April 2026 finding (8 winters)

No cracking, no alligator cracking, no heave, no potholes, no rutting. Cohesion intact over the full treated length.

09

Flagship site — Bridgeport, California

Military airstrip, C-17 Globemaster III, 265 tonnes — with no conventional structure

Why this site matters

Placed in service **July 2016** by in-place native-soil stabilization over ≈200 mm (8 in), **with no prior conventional structure whatsoever**. Airstrip at 2,070 m elevation, eastern slope of the Sierra Nevada, *Dsb* climate — **~172 freeze-thaw cycles/yr**, more than double the Québec regime.

The documented load

Hosts in real service the **C-17 Globemaster III** — maximum takeoff mass **~265,000 kg**. A load regime that exceeds, by a substantial margin, any load encountered on civilian road networks.

April 2026 finding (10 winters, 1,720 cumulative cycles)

No defect attributable to the freeze-thaw cycle. Integrity preserved under military aviation loading and prolonged mountain winters.

10 Climates compared to Québec

4 Köppen regimes neighbouring the Dfb of the St. Lawrence Lowlands

The dossier's 9 sites span four distinct *Köppen* climate regimes, all comparable — on the dominant parameters of freeze-thaw degradation — to the **Dfb** regime of the St. Lawrence Lowlands (Montréal reference).

KÖPPEN REGIME	DOSSIER SITES	RELEVANCE TO QUÉBEC
Dfa — humid continental	Benton Harbor, Rockford, Glenview, East Chicago, Elgin	Direct neighbour of Québec's Dfb; comparable freeze-thaw cycles and winters, frost-susceptible fine soils
Cfa — humid subtropical	Alexandria (VA), Bessemer (AL)	Heavy rainfall + expansive clay soils (Alexandria: Potomac marine clay, analogous to Champlain clays)
Dsb — high-altitude continental	Bridgeport (CA)	~172 freeze-thaw cycles/yr — more than double Québec's Dfb regime
Csb — mountain Mediterranean	Big Bear Lake (CA)	~153 freeze-thaw cycles/yr, high-mountain daily thermal swing

Dfb reference — Montréal

≈75 freeze-thaw cycles per year, ≈210 cm of annual snowfall. Five dossier sites **exceed** that annual cycle count; two exceed it by a wide margin (Bridgeport, Big Bear Lake).

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Empirical corroboration — 11 years of continuous exposure

10 LL-TEQ Proctor specimens, Highland Park (Illinois), July 2015 → April 2026

In July 2015, ten LL-TEQ-treated Proctor specimens — split across four distinct matrices (asphalt, limestone, clay, sand) — were placed in continuous open-air exposure at **Highland Park (Illinois)**, in a humid continental *Dfa* climate.

✓ 11 years later — April 2026 visual examination

None of the ten specimens shows any cracking, whether thermal, structural or shrinkage. Under climatic loading alone — freeze-thaw cycles, seasonal thermal variations, precipitation, radiation — the LL-TEQ layer develops no cracking.

This observation corroborates the finding from the 9 in-service sites: **the surface wear noted on in-service pavements is attributable to operational loading** (traffic, winter-maintenance equipment, studded tires), and not to the freeze-thaw cycle.

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Statement of the *Engineer of Record*

Mark D. Hardy, P.E. — Hardy Engineering, Santa Monica, California

"I, the undersigned, Mark D. Hardy, engineer, in my capacity as *Engineer of Record* for Hardy Engineering, attest that I prepared or supervised the preparation of this master freeze-thaw performance dossier for the LL-TEQ system. The dossier brings together **9 reference sites in real service**, spread across 6 US states and 4 Köppen climate regimes (Dfa, Dsb, Csb, Cfa) comparable to the Dfb regime of the St. Lawrence Lowlands, totalling **77 cumulative winters and 6,730 freeze-thaw cycles**."

"The assessments rest on the in-service visual inspection of each pavement, conducted by a qualified engineer per the principles of *ASTM D6433*. **No defect attributable to the freeze-thaw cycle** under the six-category grid was observed on any of the 9 sites."

Mark D. Hardy, P.E. — *Engineer of Record, Hardy Engineering · Professional licence PE 36538 · Statement dated May 19, 2026.*

The English version, signed and sealed by the Engineer of Record*, is the official document of record.*

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Going further

The full technical dossier, on request

This summary gives the result. The **full technical dossier** is available on request for evaluation by your engineering team: signed scoping note, 9 detailed site sheets (climate, soil, weather events, ESALs, interventions, finding), behavioural synthesis by mechanism, Highland Park empirical corroboration, and the statement of the *Engineer of Record* (signed official English version).

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