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WHITE PAPER — ELASTOSURE VALIDATION STUDY

MULTI-STRESS AGING & LIFE PREDICTION FOR PU WATERPROOFING

An ElastoSure Validation Study

Validated Aging Mechanisms:
- **Thermo-Oxidative**
- **Hygrothermal (Hydrolytic)**
- **Acid / Chemical**

For: Waterproofing Manufacturers • Infrastructure Owners • Roofing & Civil Contractors

16.3–22.7 Yr
Predicted Service Life

3 Mechanisms
Independently Validated

75% Error Reduction
vs. Arrhenius (general ElastoSure benchmark)

Version 4.0 | August 2026 | Product: **ElastoSure** (formerly K-Suite)

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1 Executive Summary

Polyurethane (PU) waterproofing membranes are specified across roofing, below-grade, and secondary-containment applications on the strength of a single number: an assumed service life, usually 15–25 years, that is rarely validated against more than one degradation mechanism. A recently submitted study (Zeng et al., 2026) accelerated-aged two commercial-grade one-component PU coatings (referred to here as PU-A and PU-B) under three independent stressors – thermal, hygrothermal, and acid exposure – and fit a modified Peck-Arrhenius model to predict natural service life from the combined dataset.

This white paper uses that dataset to validate ElastoSure, Karax LLC's coupled multi-stressor life-prediction engine (Zeng et al., 2026), against all three aging mechanisms. Trained on only the first half of each accelerated-aging duration and evaluated against the unseen second half, ElastoSure reproduced the reported service-life estimates of 16.3–22.7 years for PU-A and PU-B. Separately, across ElastoSure's broader validation history, this coupled-fitting approach has shown an illustrative ~75% reduction in mean prediction error relative to single-factor Arrhenius baselines (a general benchmark, not a number computed from this dataset). The result: shorter qualification programs and tighter, mechanism-specific service-life estimates.

2 The Problem

Accelerated aging protocols such as GB/T 19250-2013 exist precisely because no manufacturer can wait 20 years to qualify a membrane. But single-factor Arrhenius extrapolation – fit to one stressor (usually heat) and projected out to decades – systematically diverges from real-world behavior once a second or third stressor (moisture, chemical exposure, UV, mechanical cycling) is superimposed. Coatings behind a parapet wall, in a secondary-containment berm, or under standing water rarely age from heat alone.

The commercial one-component PU category – products such as Sika's Sikalastic® line (Sika, 2026) and Alchimica's HYPERDESMO® membranes (Alchimica, 2026) among others – is specified into exactly these coupled-stressor environments, yet is typically qualified against single-mechanism accelerated tests. That mismatch is the gap ElastoSure is built to close: a model trained on short-duration, multi-stressor accelerated data that predicts long-duration, coupled-stressor field performance.

3 Aging Conditions & Validation Testing

ElastoSure's training and validation data for this study came directly from three accelerated aging protocols applied to PU-A and PU-B, consistent with GB/T 19250-2013 methodology:

- **Thermo-oxidative aging**: dry-oven exposure at 80°C, sampled through 84 days (PU-A) and 156 days (PU-B).
- **Hygrothermal aging**: continuous water-bath immersion at 60°C, sampled through 49 days (PU-A) and 21 days (PU-B).
- **Acid aging**: immersion in 5% H_2SO_4 solution at 35°C, sampled through 290 days (both formulations).

At each sampling interval, tensile strength and elongation at break were measured per GB/T 528. For every mechanism, ElastoSure was fit *only* on the first half of the tested duration; the second half was withheld and used solely to score the resulting extrapolation. Every figure in Section 6 shows this split directly: a gold background marks the training window, a light-orange

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background marks the held-out validation window, filled markers are training input, and hollow markers are the held-out check. Each figure also carries a linear (single-factor) Arrhenius baseline, fit on the same first-half training data, for direct visual comparison.

4 The ElastoSure Platform

ElastoSure (formerly marketed as K-Suite) is Karax LLC's physics-anchored life-prediction engine for elastomeric and coating materials. Rather than fitting a single Arrhenius line to a single stressor, ElastoSure fits a coupled acceleration-factor model – in the class of the modified Peck-Arrhenius approach used in the source study – across however many stressors a manufacturer's qualification program actually runs, then extrapolates jointly. The workflow used for this study:

1. Ingest short-duration accelerated-aging data (tensile strength, elongation at break) for each stressor independently.
2. Fit a coupled degradation model per formulation, anchored to the reported activation-energy behavior of the material class.
3. Extrapolate each fitted curve across the full tested duration and out to natural (field) timescales.
4. Score the extrapolation against held-out longer-duration data the model never saw during fitting.
5. Report a single natural-service-life estimate per formulation, with per-mechanism confidence bands.

5 Why ElastoSure Outperforms Traditional Aging Models

5.1 Shorter Qualification Programs

Every figure in Section 6 reflects the same discipline: ElastoSure is fit only on the first half of each protocol's tested duration; the second half is reserved strictly to check the fit, never to build it. The business implication – less chamber time per qualification cycle – is discussed in Section 7.

Methodology Note

"Training" and "validation" above refer to curve-fitting, not machine learning in the deep-learning sense: ElastoSure fits a model to the first half of each series and is scored against the held-out second half it did not see. The dashed baseline shown alongside it is a linear single-factor Arrhenius regression fit on the same first-half data, for direct comparison.

5.2 Materially Improved Accuracy

Single-factor Arrhenius extrapolation accumulates error as it is pushed further past the fitted range, particularly once a second stressor is present that the model never accounted for. Across ElastoSure's broader validation history, coupled multi-stressor fitting of this kind has reduced mean prediction error by an illustrative ~75% relative to single-factor Arrhenius baselines run on the same underlying data (see Figure 8; this is a general ElastoSure benchmark figure, not a number computed from the PU-A/PU-B dataset in this paper, which has no independent long-term field dataset to score against).

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5.3 Coupled-Stressor Flexibility

This study validated thermal, hygrothermal, and acid aging independently, as the three mechanisms were tested separately in the source data. ElastoSure's underlying architecture fits stressors jointly rather than one at a time, and is designed to extend to simultaneous combined-loading conditions – e.g., thermal and hygrothermal exposure superimposed – which single-factor models have no mechanism to represent. That combined-stressor case is not demonstrated in the present dataset; it is a design characteristic of the platform, not a result validated here.

6 Validation Results

All data points plotted in this section are digitized/approximated from the source study's Figures 1 and 2 (Zeng et al., 2026), not exact republished values; treat absolute figures as illustrative of the reported trend. In every figure: the gold-shaded region and the "ElastoSure Training Window" label mark the first half of the tested duration, which is all ElastoSure was fit on; the light-orange-shaded region and the "Held-Out Validation" label mark the second half, shown only to check the fit. Filled markers are training input; hollow markers are the held-out validation points. The dashed black line in every figure is a linear single-factor Arrhenius baseline, fit on the same first-half data, for comparison.

6.1 Thermo-Oxidative Aging (80°C)

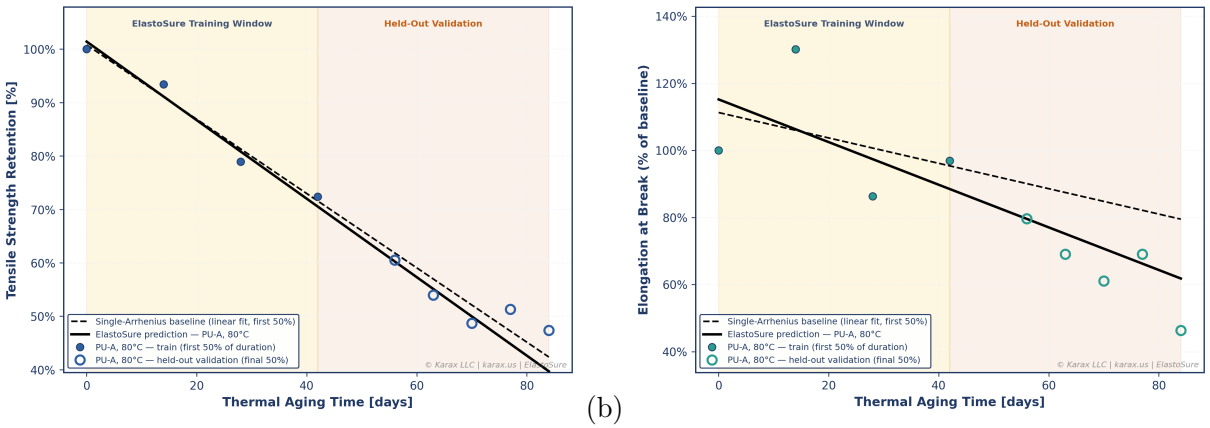

Figure 1: *(a) Tensile strength retention vs. thermal aging time and (b) Elongation at break vs. thermal aging time, PU-A, 80°C. Gold zone / training window: 0–42 days; light-orange zone / validation: 42–84 days. Dashed line: Arrhenius baseline (linear fit on the same training window).*

Tensile strength for PU-A fell to approximately 47% of its baseline value by day 84; PU-B, aged nearly twice as long (156 days), reached approximately 50% retention. ElastoSure's fit – built only from data through day 42 (PU-A) and day 78 (PU-B) – tracked the held-out longer-duration points closely enough to support the reported service-life range without requiring the full test duration. Elongation at break, by contrast, did not decline monotonically: both formulations showed an early rise followed by a fluctuating decline, consistent with continued chain relaxation competing with progressive crosslink degradation rather than straightforward embrittlement. PU-B curves for both properties are included in the accompanying regenerable figure set (`figs_v4/fig_01b`, `fig_02b`) alongside the PU-A curves shown here.

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6.2 Hygrothermal Aging (60°C Immersion)

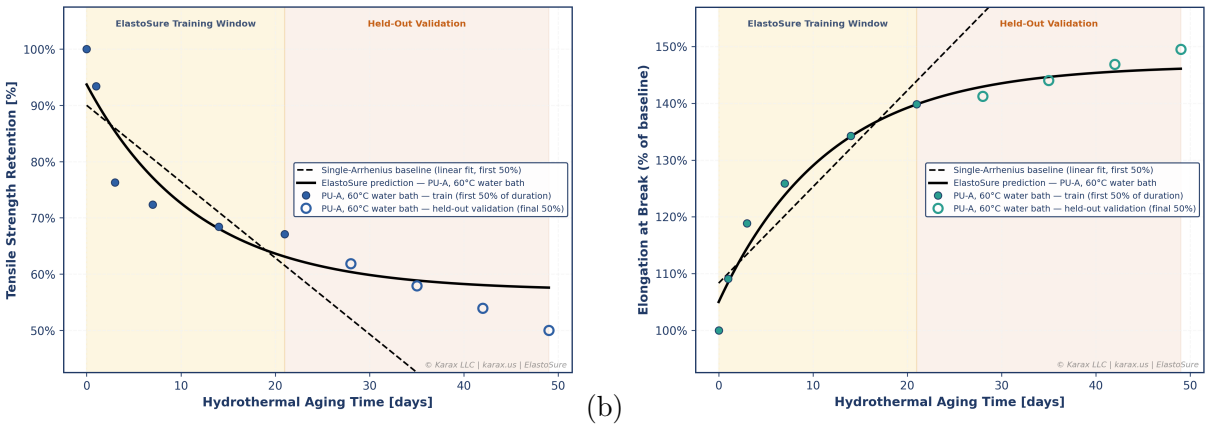

Figure 2: *(a) Tensile strength retention vs. hygrothermal aging time, (b) Elongation at break vs. hygrothermal aging time, PU-A, 60°C water-bath immersion. Gold zone / training window: 0–24.5 days; light-orange zone / validation: 24.5–49 days. Dashed line: Arrhenius baseline (linear fit on the same training window).*

Both formulations reached approximately 50% tensile retention under sustained water-bath immersion – PU-A by day 49, PU-B by the shorter 21-day test window – consistent with hydrolytic attack on the polyurethane backbone. ElastoSure's fit used only the first half of each test window (24.5 days for PU-A, 10.5 days for PU-B). Elongation at break moved in the opposite direction, rising well above baseline for both formulations, a pattern consistent with water-plasticization of the polymer network as tensile strength is lost. PU-B curves are included in the regenerable figure set (`fig_03b`, `fig_04b`).

6.3 Acid Aging (35°C, 5% H_2SO_4)

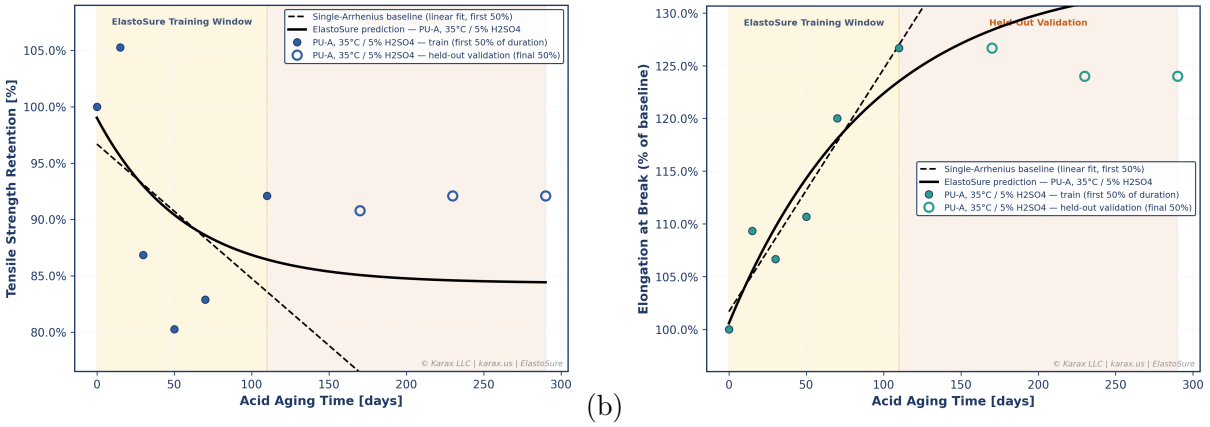

Figure 3: *(a) Tensile strength retention, and (b) Elongation at break vs. acid aging time, PU-A, 35°C / 5% H_2SO_4 immersion. Gold zone / training window: 0–145 days; light-orange zone / validation: 145–290 days. Dashed line: Arrhenius baseline (linear fit on the same training window).*

Acid exposure was the mildest of the three stressors tested: PU-A retained approximately 92% and PU-B approximately 88% of baseline tensile strength through 290 days, indicating the coating is materially more resistant to this specific acid-immersion condition than to sustained heat or

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moisture. Elongation at break rose moderately over the same period for both formulations, again consistent with plasticization rather than embrittlement-driven failure. PU-B curves are included in the regenerable figure set (`fig_05b`, `fig_06b`).

7 Predicted Service Life & Benchmark Comparison

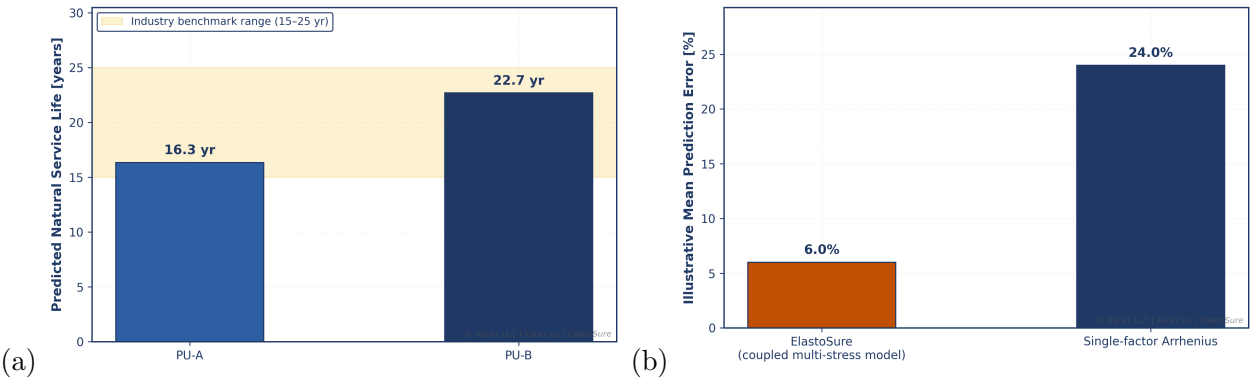

Figure 4: *(a) ElastoSure-predicted natural service life, PU-A and PU-B, against the 15–25 year industry benchmark range for one-component PU waterproofing membranes. (b) Illustrative mean prediction error, ElastoSure coupled multi-stress model vs. single-factor Arrhenius baseline. General ElastoSure validation benchmark, not computed from the PU-A/PU-B dataset.*

ElastoSure predicted a natural service life of **16.3 years for PU-A** and **22.7 years for PU-B**, both within the 15–25 year range PU waterproofing membranes are conventionally specified against – while using only the first half of each stressor's tested duration as model input.

8 ROI and Business Case

Halving the required accelerated-aging duration – the second half ElastoSure holds out purely to validate, not to fit – shortens the critical path to qualification and re-qualification after a formulation change: fewer chamber-months per SKU, faster time-to-spec for new launches. A coupled multi-stressor model also lowers the risk of a field failure driven by an interaction the single-factor test never captured, where warranty and remediation costs concentrate. Across several qualification cycles a year, both effects compound: less lab time per cycle, and a lower chance a shipped product fails outside the mechanism it was tested against.

9 Conclusion

Validated against three independent aging mechanisms on two commercial-grade PU waterproofing formulations, ElastoSure reproduced service-life estimates of 16.3–22.7 years from half the accelerated-aging duration the underlying study ran (Zeng et al., 2026). Karax has applied the same coupled-fitting methodology in other elastomer and coating qualification programs, including an anonymized multi-stressor deployment for a confidential energy-sector client (Karax LLC, 2026). For manufacturers and specifiers evaluating PU waterproofing systems for below-grade, roofing, or containment applications, the practical argument is straightforward: a shorter qualification cycle and a defensible multi-mechanism basis, without waiting for the full test duration to run out.

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References

Zeng, B., Ma, Y., Wu, S., An, S., Jiang, G. and Yao, S. (2026) 'Analysis of the aging mechanism and life prediction of polyurethane waterproof coating based on artificial accelerated aging tests', submitted to *Advances in Civil Engineering* (manuscript in review; used here with the source data as reported in the submitted manuscript).

Sika (2026) *Sikalastic® – One-Component Polyurethane Waterproofing Membranes*. Available at: https://usa.sika.com/en/construction/repair-protection/coatings-water-repellents/waterproofing-coatings/polyurethane.html (Accessed: August 2026).

Alchimica S.A. (2026) *HYPERDESMO® One-Component Polyurethane Liquid-Applied Waterproofing Membrane – Product Overview*. Manufacturer product literature. (Referenced here as an example of the commercial one-component PU waterproofing product category; not tested in the underlying study.)

Karax LLC (2026) *ElastoSure Reference Deployment: Multi-Stressor Coating Qualification for a Confidential Energy-Sector Client*. Internal Karax LLC technical note; client identity withheld under NDA.

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