

Expanding the Performance Envelope of Silyl-Modified Polymer Adhesives.

BALANCING STRENGTH, ELASTICITY AND CURE CONTROL FOR SEMI-STRUCTURAL BONDING

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ABSTRACT

Silyl-modified polymer (SMP) adhesives are valued for elastic bonding, broad substrate adhesion and isocyanate-free moisture-curing chemistry. Their use has traditionally concentrated on sealing and flexible bonding because increasing network density and cohesive strength can reduce extensibility, while moisture transport limits early strength development in thick bondlines.

This paper describes a formulation pathway that moves SMP technology into the semi-structural range while retaining high elongation. A-J930 development data report 7.3 MPa* tensile strength and 7.1 MPa* lap-shear strength on abraded aluminium. Elongation at break was measured at 525% by PC Labor and 543% by Molteni. On glass, the joint reached 4.6 MPa and failed in the substrate. A complementary 2K approach (A-J931) distributes a booster throughout the adhesive bead to accelerate strength build-up, supporting manufacturing concepts that require earlier handling strength.

The results show how polymer architecture, crosslinking functionality, adhesion promotion, filler selection and cure strategy can be treated as one system-level design problem.

*Performance results were obtained using material produced at micropilot scale in a 2 kg batch under the stated test conditions.



FROM FLEXIBLE BONDING TO SEMI-STRUCTURAL PERFORMANCE

Transportation structures need joints that can transfer meaningful load while accommodating differential movement, vibration, thermal expansion and manufacturing tolerances. That requirement sits between two traditional adhesive design spaces: highly elastic sealants, which tolerate movement but carry modest loads, and rigid structural adhesives, which deliver high strength but may offer less strain accommodation.

SMP chemistry is attractive in this intermediate space. The polyether-rich backbone provides flexibility; moisture-reactive silyl groups create a siloxane-crosslinked network; and the chemistry is isocyanate-free. Compared with pure silicone systems, the organic prepolymer backbone also offers higher surface energy, supporting wetting and adhesion. These attributes make SMPs well established in sealing and elastic bonding. The development question is whether the same platform can carry semi-structural loads without losing the large deformation capability that defines the technology.

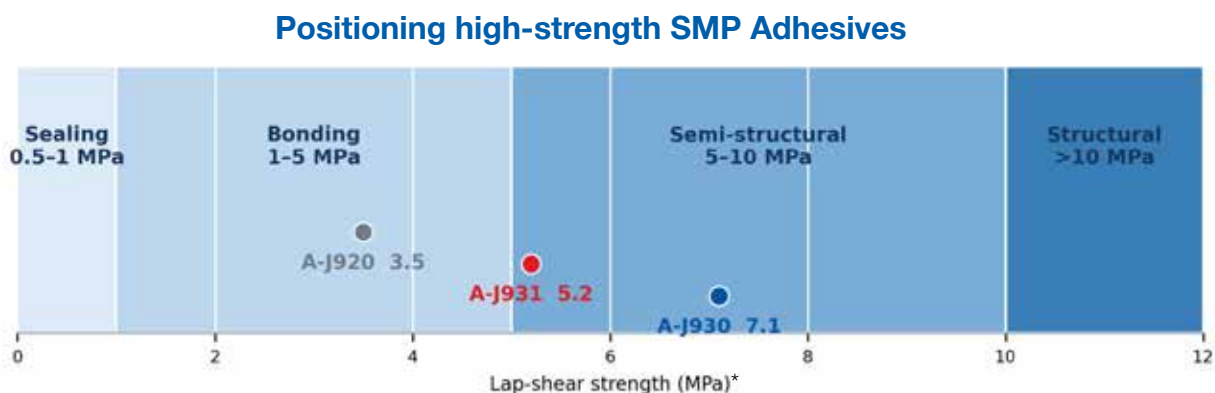


Figure 1. Application-oriented strength classes used in the WAC 2026 presentation, with reported lap-shear values for three L&L SMP developments.

FORMULATION ARCHITECTURE: BUILDING STRENGTH WITHOUT LOSING EXTENSIBILITY

An SMP adhesive is not defined by one ingredient. Its behavior emerges from a coupled network of telechelic silyl-modified prepolymers, catalysts, adhesion promoters, fillers, plasticizing components and water-management strategies. Each lever affects both the cured network and the uncured material's processability.

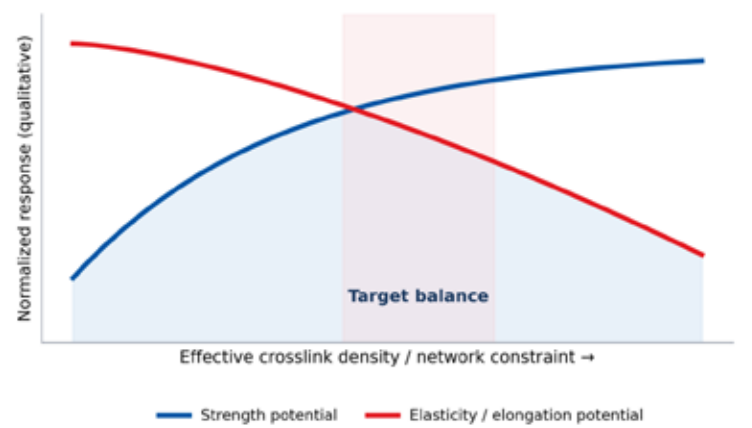


Figure 2. Qualitative representation of the central formulation trade-off between network constraint, strength and extensibility.

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Polymer backbone and reactive junctions

Polyether-based SMPs can be synthesized through several routes, and the spacer between the polymer backbone and the terminal silyl group influences hydrolysis and condensation reactivity. Trimethoxy- and dimethoxy-silyl telechelic groups provide different functionality and cure behavior. Additional silyl functionality distributed along the chain—for example through acrylate-containing architectures—can increase crosslink density. Alternative routes reported in the literature include thiol–ene coupling, nucleophilic substitution and olefin metathesis [1] .

NETWORK LEVERS

- Silyl functionality
- Spacer chemistry
- Catalyst package
- Backbone molecular architecture

SYSTEM RESPONSES

- Cure rate and depth
- Modulus and cohesive strength
- Elongation and stress relaxation
- Storage and processing stability

Interfaces and fillers are part of the network design

Aminosilane adhesion promoters must balance basicity, substituent chemistry, functionality and hydrolytic stability. The same molecule that promotes interfacial bonding can also alter cure kinetics or storage stability [2]. Carbon black and aluminosilicate fillers contribute reinforcement and rheology control through polymer–filler interactions; their surface chemistry and dispersion therefore influence both extrusion behavior and mechanical performance [3].

A-J930: EXTENDING THE SMP PERFORMANCE ENVELOPE

A-J930 was developed as a 1K, black, moisture-curing SMP adhesive with a 30-minute tack-free time.

A-J930 reports 300 Pa·s viscosity, 7.3 MPa* tensile strength, 1.6 MPa* tensile stress at 100% strain, approximately Shore A 60 hardness and 7.1 MPa* lap-shear strength on abraded aluminium. Elongation at break was measured at 525% by PC Labor and 543% by Molteni. On glass, lap-shear testing reached 4.6 MPa* and ended in substrate failure. The normal service-temperature range is reported as –40 to 100 °C, with short exposure to 120 °C.

In addition to its mechanical performance, A J930 is designed around practical assembly requirements. Its low-sag behaviour helps the applied bead maintain its position and geometry on vertical or overhead joints. Primerless adhesion on specified substrates can reduce surface-preparation steps, while paintability supports integration with downstream finishing processes. Surface preparation and paint compatibility should nevertheless be confirmed for the intended substrate, coating system and manufacturing conditions.

*Performance results were obtained using material produced at micropilot scale in a 2 kg batch under the stated test conditions.

A-J930 shifts the strength-elasticity envelope relative to A-J920

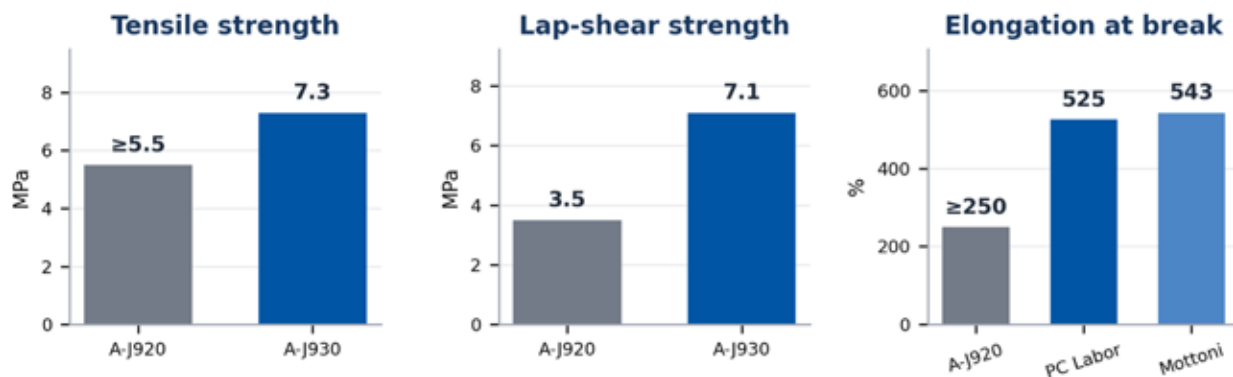


Figure 3. Properties reported for A-J920 and A-J930.

What changed in engineering terms

The relevant result is not simply that one strength value increased. The combination moved: lap-shear strength rose from 3.5 MPa* for A-J920 to 7.1 MPa* for A-J930, while elongation increased from a reported minimum of 250% for A-J920 to 525% and 543% in two A-J930 laboratory datasets. At the same time, A-J930 reached 7.3 MPa* tensile strength. This is the opposite of the simplest crosslink-density expectation, in which higher strength is purchased at the expense of extensibility. It indicates that the formulation architecture redistributes deformation and failure rather than merely making the network uniformly stiffer.

Primerless adhesion scope

The reported substrate scope includes cold-rolled steel, stainless steel, electro- and hot-dip-galvanized steel, abraded aluminium, glass, glass-fibre-reinforced polymer and ABS.

JOINT-LEVEL EVIDENCE ON ABRADED ALUMINIUM AND GLASS

Updated A-J930 testing reports 7.1 MPa* lap-shear strength on abraded aluminium. On glass, the joint reached 4.6 MPa and failure occurred in the substrate rather than within the adhesive or at the bonded interface. Because the glass specimen became the limiting element, the measured value demonstrates joint performance to 4.6 MPa but does not establish the adhesive-controlled limiting strength on glass.

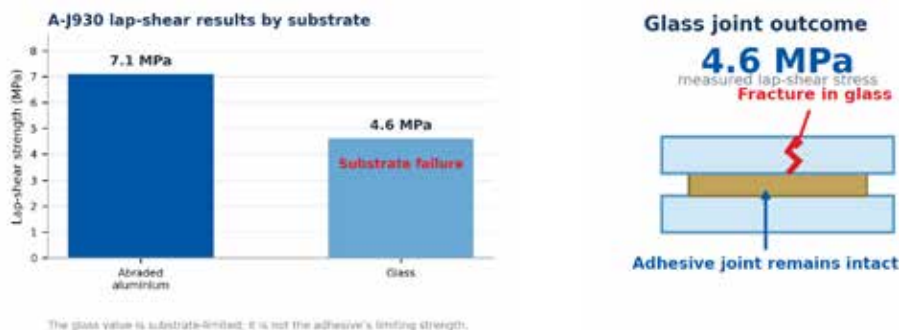


Figure 4. Current A-J930 lap-shear* results on abraded aluminium and glass, with the substrate-limited glass outcome illustrated at right.

*Performance results were obtained using material produced at micropilot scale in a 2 kg batch under the stated test conditions.

Elongation at break was measured at 525% by PC Labor and 543% by Molteni. Reporting both results shows the observed cross-laboratory range rather than selecting a single value. The final publication should identify the test standard, specimen geometry, test speed and conditioning used by each laboratory.

A 1K SMP cures as water from the environment reaches the adhesive surface, hydrolyses the alkoxy-silyl groups and enables condensation into siloxane junctions. For thin bondlines and accessible edges this mechanism is practical. For larger beads or enclosed joints, the diffusion path can delay through-cure and early strength.

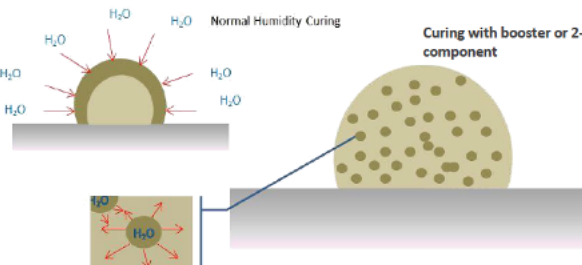
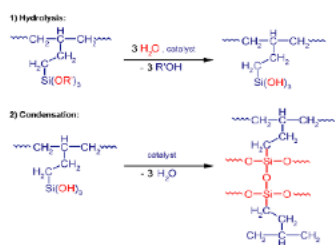


Figure 5. Conceptual cure pathways: moisture entering from the environment versus booster-distributed cure-enabling species throughout the bead.

*Performance results were obtained using material produced at micropilot scale in a 2 kg batch under the stated test conditions.

A-J931 uses a 10:1 two-component format. The booster distributes the cure-enabling species throughout the adhesive bead, reducing dependence on moisture transport from the exposed surface. The presentation reports greater early lap-shear* strength with A-J280 accelerator, with both systems converging toward a similar longer-time strength level. The graph legend states 1.2% A-J280, while its title states 1.5% accelerator; the loading therefore requires confirmation before publication.

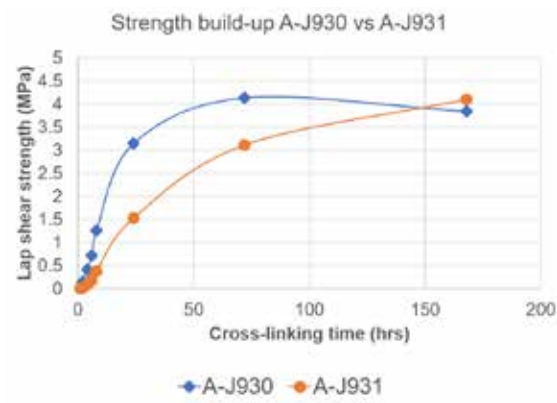


Figure 6. Reported lap-shear* strength development with and without accelerator (legend: 1.2% A-J280; chart title: 1.5%).

OVERALL PROPERTY PROFILE OF THE 2K SYSTEM

A-J931 is reported as a grey 2K SMP adhesive mixed at 10:1. Its property profile combines more rapid strength development with high extensibility and broad adhesion. The 225-minute tack-free time reported in the presentation should be distinguished from fixture time and from the earlier strength increase shown in the lap-shear* development plot.

Property	Reported Value	Engineering interpretation
Format	2K, 10:1	Distributed cure activation; metering and mixing required
Extrusion rate	62 g/min	Application-rate indicator; method and temperature to confirm
Tensile strength	>5.5 MPa*	High-strength elastic adhesive range
Stress at 100% strain	>2.2 MPa	Load transfer while accommodating deformation
Elongation at break	350%	Substantial ductility retained
Lap-shear strength	5.2 MPa* after 14 d at 23 °C	Semi-structural range in the presentation classification
Hardness	~60 Shore A	Elastic solid rather than rigid thermoset
Service temperature	–40 to 100 °C; 120 °C short exposure	Application-specific validation still required

Where the two systems fit

- A-J930 prioritizes the 1K handling model with a strong combination of lap-shear* strength and elongation.
- A-J931 adds metering and mixing complexity but is designed to reduce dependence on ambient moisture transport for early strength development.
- The selection should be made against the assembly process: bead size, joint exposure, takt time, fixture strategy, substrate set, temperature and durability requirements.

The most credible target applications are joints that benefit from elastic load transfer and movement accommodation but require more strength than a conventional sealant: large-panel bonding, mixed-material assemblies, glass and composite integration, and transportation structures with generous bondlines or thermal mismatch. Final suitability depends on joint design and validation; “semi-structural” describes a performance range, not a universal application approval.

*Performance results were obtained using material produced at micropilot scale in a 2 kg batch under the stated test conditions.

CONCLUSIONS

- SMP formulation can move beyond sealing and flexible bonding into the 5–10 MPa semi-structural range used in the presentation.
- A-J930 demonstrates that higher strength need not require the loss of high elongation: 7.3 MPa* tensile strength, 7.1 MPa* lap-shear strength on abraded aluminium and elongation values of 525% and 543% are reported together.
- On glass, the A-J930 joint reached 4.6 MPa and failed in the substrate, making the result substrate-limited rather than an adhesive-controlled failure value.
- A distributed 2K booster accelerates strength build-up by reducing dependence on moisture diffusion from exposed surfaces.
- The engineering opportunity is an isocyanate-free, highly elastic semi-structural adhesive platform; the next requirement is a harmonized durability, fracture and process-validation dataset.

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Dr Claudio Toncelli is an R&D Manager at L&L Products, where he leads the development of high-performance polymer materials and adhesive technologies. His work focuses on polymer synthesis, modification, blending and processing, supported by extensive expertise in formulation, rheology and structure–property relationships.

Claudio earned his PhD in Chemical Engineering from the University of Groningen, where his research encompassed thermally recyclable materials, environmentally responsible electrophoretic coatings for the automotive industry, rheology modifiers and metal-ion scavenging systems. He also holds a Master's degree in Industrial Chemistry from the University of Pisa, where he studied reactive compatibilization and the relationship between structure and mechanical performance in biodegradable polymer blends. His education is complemented by postgraduate training in scientific leadership, project management and intellectual property law.

With more than a decade of multidisciplinary research experience, Claudio has authored over 30 peer-reviewed publications, contributed to two patents and managed research programs.

His technical expertise spans polymer synthesis and processing, thermal and mechanical characterization, advanced rheology, spectroscopy, microscopy and chromatography. He combines fundamental polymer science with applied material engineering to address complex adhesive formulation and performance challenges.

Technical Data and Validation Statement

Unless otherwise stated, the performance values presented in this paper were obtained using material produced at micropilot scale in a 2 kg batch and tested under controlled laboratory conditions. These results describe development-stage material performance and should not be interpreted as production specifications, design allowables or guarantees of performance in a particular application.

Performance may vary according to production scale, substrate type and condition, surface preparation, bondline geometry, cure environment, test method and service exposure. Final material selection and joint design should therefore be validated using production-representative materials, substrates, manufacturing processes and service conditions.

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