The Latest Developments in Polyurethane Structural Adhesives

Structural adhesives play a key role in creating strong and reliable bonds between a wide range of substrates in a variety of industries ranging from manufacturing to construction. These adhesives are based on polyurethane (PUR) and, because of their exceptional properties, can be used for many different purposes.

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A description of the typical mechanical properties and applications of structural PUR adhesives highlights their importance in an industrial context. Industries that produce consumer goods, capital equipment and vehicles of all kinds and the construction of buildings and infrastructure sectors all benefit from the versatile and adaptable mechanical and adhesive properties of these adhesives (*Figure 1*). They offer a combination of chemical cross-linking by forming covalent bonds and physical cross-linking as a result of the attractive interaction of the polymer chain segments. This combination of networks and interactions creates three-dimensionally crosslinked superstructures, a crucial feature for achieving the required structural strength and stability.

Structural PUR adhesives are reactive adhesives that are created by mixing two chemically reacting components directly at the site of application. Mixing and dosing equipment is generally used to combine the components and process the adhesive. The success of the bonding process depends on the ideal wetting of the substrates, which can be optimized accordingly with the help of a pretreatment, and a curing reaction that is as controlled and specific as possible. The aim is to achieve a balance between the cohesive forces within the adhesive and the adhesion forces between the adhesive and the various substrates.

The application determines the choice of raw materials

A characteristic feature of PUR adhesives is that the structure-property relationships can be systematically controlled by the choice of the chemical raw materials used. The chemical building blocks include monomeric and polymeric isocyanates and chemical substances with low and high molecular weight that react with these isocyanates. Additional raw materials in PUR adhesives are catalysts, fillers and additives. The majority of the conventional, commercially available PUR adhesives and sealants are two-component systems whereby alcohols and polyols which react with the isocyanates form the basis for the A component. The component containing the isocyanate-functional hardener molecules is referred to as the B component.

The cured adhesive formulations are subjected to specific mechanical tests to determine their practical suitability. These tests

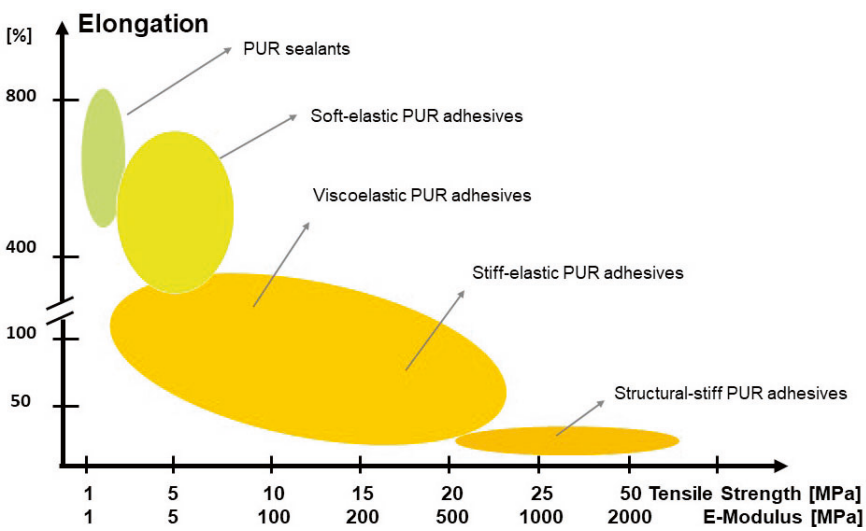

Figure 1 The range of typical types of PUR adhesives and their mechanical properties.

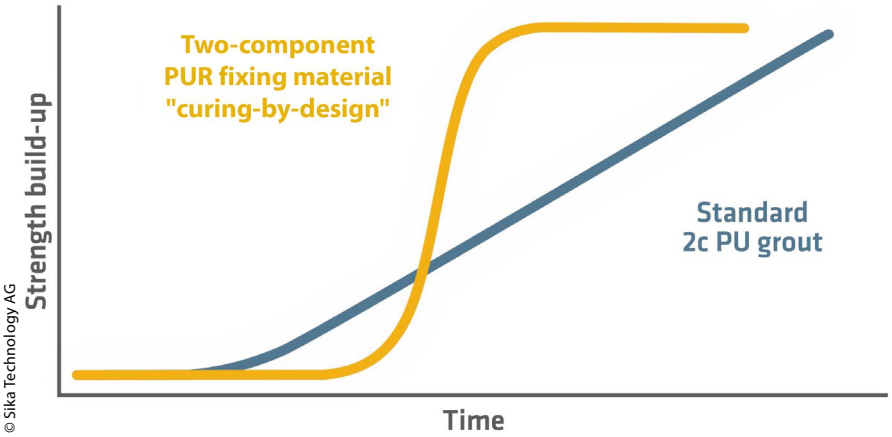

Figure 2 Curing behavior of conventional and chemically modified "curing-by-design" rail fixing materials.

evaluate properties such as bond strength, impact strength and resistance to the influence of dynamic mechanical stresses or climate conditions such as cold, heat and moisture. These are crucial factors that allow the assessment of durability and reliability of composite structures. In addition, identifying the thermomechanical characteristics of PUR adhesives provides insights into their microscopic structure and allows to predict their behavior at different temperatures and under different load.

Figure 3 Mechanical (top) and manual application (bottom) of rail casting material on a transport infrastructure construction site.

Product innovation

The latest PUR adhesives are sustainable products made from renewable raw materials and thermoreversible systems that provide the option of debonding by dissolution of the adhesive bonds. In addition, concepts for controlling the curing reaction allow for the targeted formation of an adhesive matrix. By controlling the curing kinetics, it is possible to ensure very fast curing of adhesives with long processing times. This results in fast cycle times in industrial production or faster recommissioning of infrastructure systems (*Figure 2*). Special curing catalysts are used to achieve this effect.

Rail casting materials: Improved processing

One practical example of this is stiff-elastic, two-component, PUR rail casting materials with tailor-made curing kinetics which are used to install and repair all types of rail infrastructure. Materials based on "curing-by-design" or "snapcure" technology with individual curing mechanisms have an extended open time and at the same time an accelerated curing time (*Figure 2*).
The modified procedure makes working time more effective, because the longer open time for processing and application leads to more application safety. The shorter curing time means that the infrastructure can be returned to operation more quickly. As a result, waiting times during the curing phase of the adhesive can be kept to a minimum or dispensed, which is often one of the key arguments in favor of using these systems. The elastic rail casting materials can either be mixed and applied using an automated mixing and dosing system or processed by hand like a type of casting compound (*Figure 3*). The use of automated systems allows for faster application rates, which is advantageous in the context of larger construction projects.
The shorter curing phase means that these new products can be exposed to dynamic loads around five times more quickly, which enables transport systems to come back into operation in a shorter time. The two-component PUR products previously used for these applications have spe-

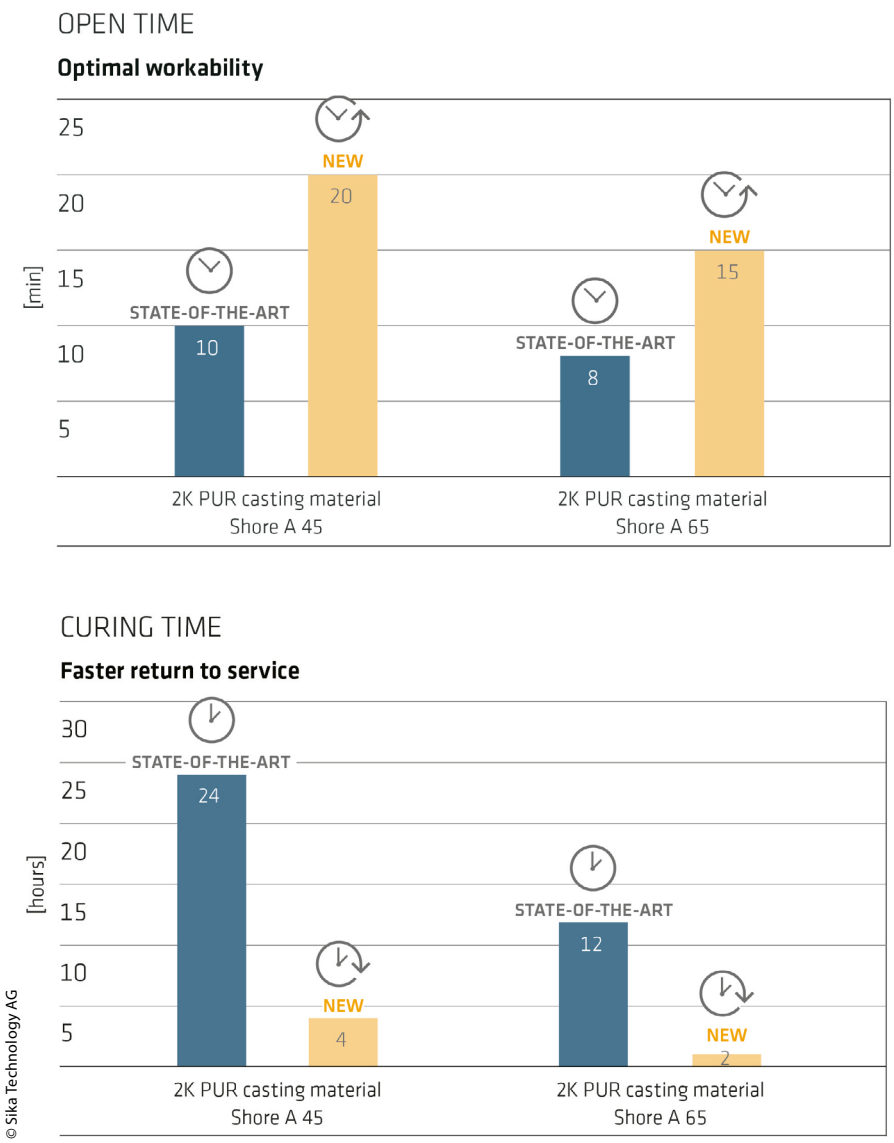

Figure 4 Open time or processing time and curing time after the application of conventional and chemically modified "curing-by-design" rail fixing materials.

cific requirements relating to the working methods, such as additional equipment and tools for cleaning the rails. In addition, applying and curing the casting material takes longer than the usual period for maintenance of one night shift (*Figure 4*).

Optimum product properties

Further modifications of these products have resulted in improved tolerance to a range of weather conditions during the application process. For example, it is possible to apply these products onto a damp substrate. The rail casting systems are designed as vibration-damping, load-bearing, flexible materials for fastening grooved rails or T-rails in solid trackways on steel or concrete substrates on tram, subway and rail tracks. They are also suitable for use on bridges, in tunnels or in road construction.

The properties of the products allow the reduction of vibration and structure-borne noise. This reduces the stresses on rolling stock and gives rail passengers a more comfortable ride. The excellent electrical insulation improves the management of leakage currents in accordance with the regulations in DIN EN 50122. The durability of the fixing material and, in particular, its high fatigue strength allow for longer maintenance intervals, resulting in very low-maintenance track systems. The use of these materials allows the construction height and weight of the structure to be reduced, which is important for tunnels and bridges.

Summary

Users of PUR structural adhesives should get a comprehensive overview of the current status and find out about the latest advances in this area of adhesive technology [1]. The most recent innovations in both academic and industrial settings will lay the foundations for future developments in this area of adhesive technology. Users are increasingly demanding ecologically sustainable, robust or reversible adhesive products and the properties described here will support developments in structural adhesives and make further advances possible. //

References

[1] Choffat, F.; Corsaro, A.; Di Fratta, C.; Kelch, S.: Advances in Polyurethane Structural Adhesives. In: Advances in Structural Adhesive Bonding (2023). Elsevier, 2nd edition, p. 103–136

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