AN ELASTIC ADHESION SYSTEM FOR STRUCTURAL BONDING OF FACADE PANELS

EIN ELASTISCHES KLEBESYSTEM ZUR TRAGENDEN BEFESTIGUNG VON FASSADENPLATTEN

UN SYSTEME ADHESIVE ELASTIQUE POUR LA FIXATION PORTANTE DE PANNEAUX DE FACADE

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SUMMARY

Concerning design and construction the application of elastic adhesive technique improves the potential in construction and design of facades. The Sika-Tack-Panel system having achieved the first technical approval in Germany is described with test results and an example of application.

ZUSAMMENFASSUNG

Der Einsatz der elastischen Klebetechnik eröffnet neue Möglichkeiten in der Konstruktion und der Gestaltung von Fassaden. Anhand von Versuchsergebnissen und einem Anwendungsbeispiel werden die Eigenschaften des Sika-Tack-Panel Klebesystems beschrieben, das als erstes System in Deutschland eine allgemeine bauaufsichtliche Zulassung erhalten hat.

RESUME

L’utilisation de la technique adhésive élastique offre des possibilités nouvelles pour la construction et le dessin de façades. Sur la base de résultats d’essais et à l’aide d’un exemple d’application les caractères du système Sika-Tack-Panel, qui comme premier système a obtenu un agrément, sont décrits.

KEYWORDS: elastic adhesion system, facade panel

1. INTRODUCTION

For a couple of years the use of decorative plates in ventilated curtain walls has become an integral part of new buildings and renovation projects in the private, commercial and public domain (Fig. 1). The bonding of facade plates on the support frame by an elastic adhesive joint represents a new technique in Germany comprising several advantages in comparison to conventional fixing systems (screws, rivets, cramps ,anchors, etc.).

Fig. 1. *Single-storey building as an example for the use of decorative facade panels*

The elastic adhesive technique allows an invisible back-panel fixing without any weakening of the cross-section of the plate. Due to an extensive bonding area along the edges of the panels, the loads resulting from wind, temperature and the self-weight of the plate are carried out uniformly. A stress concentration as produced i.e. by anchors is avoided. In the case of failure of a facade plate the adhesive joint is able to hold large fragments in place. Quite different types of plates, i.e. HPL (high pressure laminate), ceramic, aluminium-compounds or cement bonded plates can be used with the same adhesion system. In particular the elastic adhesion technique is suitable for the use of thin and large-size plates. Therefore a number of new design possibilities and a potential for cost reduction is presented.

The Sika Tack-Panel system is the first system in Germany having achieved a technical approval (approval number Z-36.4-18). As yet, the approval is valid for the use of aluminium support frames and the following ceramic or HPL (high pressure laminate) facade plates: Megaceram 650, Trespa Meteon / FR, Resoplan, Isovolta Max Exterior.

As the adhesive acts as a structural connection between the facade plate and the support frame without any additional devices to carry the self-weight of the plate or to retain the plate in case of complete mechanical failure of the adhesive joint, the system performance has to fulfil high requirements. To guarantee durable safety in use, the adhesive itself and the adhesion to the substrates has to possess a sufficient resistance to worst surrounding conditions. Furthermore, a particular attention has to be paid to the practical installation of the adhesive system.

The test program carried out for verification of the system performance was mostly following the EOTA draft guideline for structural adhesive glazing systems. The program comprised tests for the identification of the adhesive (thermo-gravimetric analysis, specific weight, etc.), tests for the determination of tensile and shear properties and tests to study the resistance to special environmental conditions (temperature, water, chemical and biological affect). As the system can be applied in the workshop as well as on the building site, the effects of non-observance of the application instructions was tested.

In the following the properties of the system are described by the most important test results and a building project in Sindelfingen near Stuttgart.

2. STRUCTURE AND APPLICATION

Fig. 2 serves as illustration for the assembly of facade plates to a T-shaped aluminium support frame. To put a certain quantity of the adhesive to the supporting frame, a cartridge with a V-shaped nozzle (Fig. 3) is used for the application. The fresh adhesive is a non-sagging paste. Attaching the facade panel, the V-shaped nozzle is distorted to a joint of b = 12 mm width and t = 3 mm thickness.

The double-side adhesive mounting tape consisting of polyethylene-foam (see Fig. 1) acts as a spacer to adjust the joint thickness. Additionally the tape is responsible to hold the plate until the adhesive has cured completely.

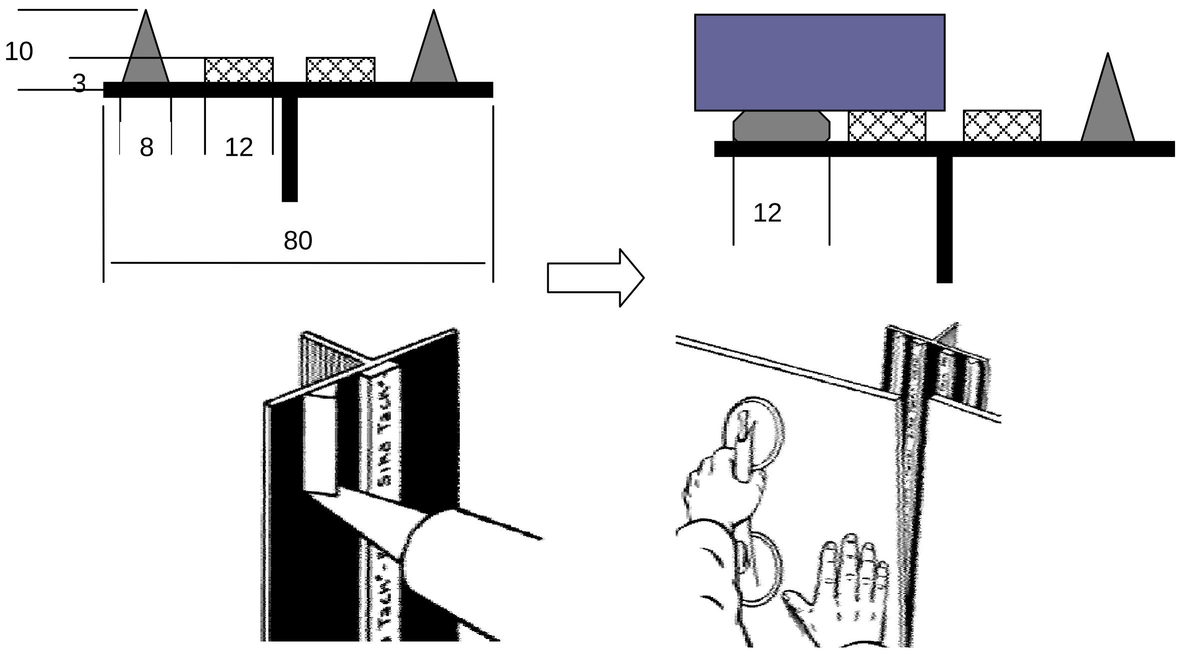


Fig. 2. *Assembly of the facade plates on a T-shaped support frame*

The substrate surfaces have always to be treated. Dust, dirt, surface oxidation, drawing grease and depositions from transportation and storing have to be removed. By grinding and cleaning with special Sika products clean, dry and grease-free surfaces are created. Afterwards a primer has to be applied. The treatment is specified in detail and serves for a good adhesion of the adhesive to the support frame and the back-side of the facade plate.

3. CHEMICAL REACTION SCHEME DURING ADHESIVE CURING

The adhesive is a one-component product based on polyurethane. Reacting with the air humidity it turns into an elastic adhesive. The chemical reaction takes place in two steps.

In a first step the isocyanate group reacts with water and turns into a carbamin-acid. This compound is not - stable and decays to an amin with the release of CO_2.

$$R{-}N{=}C{=}O + H{-}O{-}H \longrightarrow [R{-}NH{-}CO{-}O{-}H] \longrightarrow R{-}NH_2 + CO_2$$

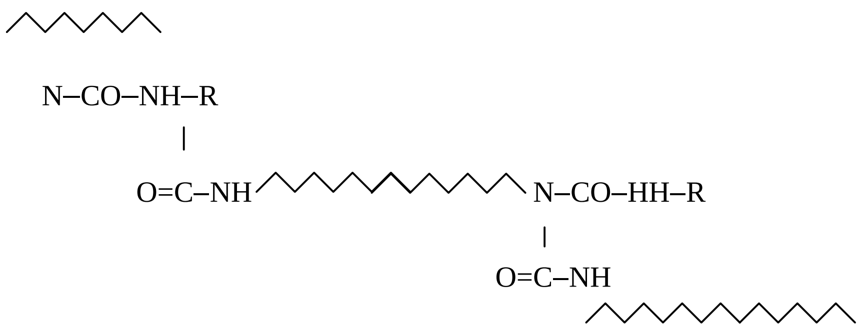
Isocyanate-group — carbamin- acid — amin

In the second step the amin reacts with an isocyanate-group; two prepolymeres molecules are connected.

$$R{-}N{=}C{=}O + R{-}NH_2 \xrightarrow{\text{amin}} R{-}NH{-}CO{-}NH{-}R$$

Isocyanate-group — urea-group

Additional cross-links are formed by the reaction of further isocyanate-groups with urea-groups. The biurethane structure is produced.



The reaction velocity and the curing time depend on the temperature and the air humidity. At T = +23°C and RF = 50 % skinning of the adhesive surface starts after an assembly open time of 20 minutes. From the surface the curing reaction continues into adhesive volume.

The optimum temperature range for adhesive hardening is between +5°C and +35°C. The relative humidity should be below RF = 75 %. Under these conditions a adhesive joint of 12 mm width and 3 mm thickness has cured completely within 24 h.

4. TEST RESULTS

The following Table 1 gives an overview of the most important mechanical properties of the structural adhesive determined according to German, European or international standards.

Table 1. *Adhesive properties*

density	ISO 1183, method A	2,05 g/cm^3
shrinkage	ISO 10563	-8,47 % (mass) -7,93 % (volume)
tensile strength, elongation at break	DIN EN 28 339	2,48 N/mm^2 350 %
tensile shear strength, elongation at break	DIN 53 283	2,52 N/mm^2 540 %
shore A hardness	DIN 53 505	55
elastic recovery	EN 27 389	92 %

In addition the mechanical properties of the structural adhesive were studied using test samples with a joint cross-section b x t (see Fig. 2) according to realistic facade application. Stresses and strains in tension and shear were calculated on the basis of the measured displacements and forces and these nominal geometric dimensions. To obtain a defined adhesive curing and ageing, all test samples were conditioned for 2 weeks at a temperature T = 23°C and a humidity RF = 50 %, followed by further 3 weeks according to DIN EN 28 339, method B.

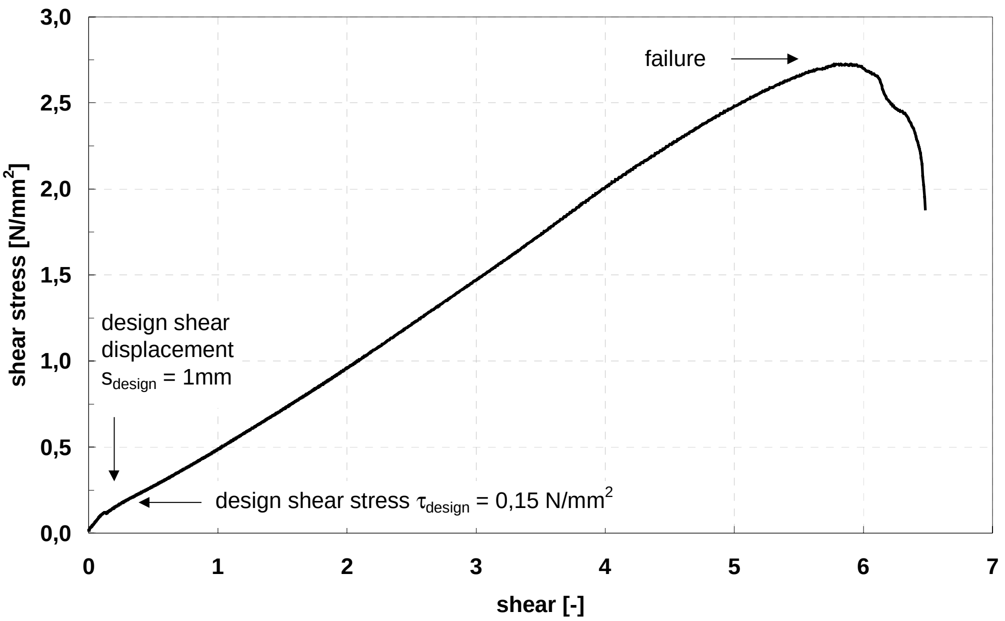


Fig. 3. *Shear test*

Fig. 3 shows a typical stress strain curve observed in a shear test with the samples described above. The type of failure was cohesive at stresses of about 2,7 N/mm^2. The design stress and displacement for practical applications was limited by the approval to 0,15 N/mm^2 and 1 mm, respectively.

The mechanical property of the structural adhesive subjected to steady loads at room temperature (T = +20°C) and at T = +60°C is shown in Fig. 5. The shear force applied was 0.018 N/mm^2, coming up to about three times the self-weight of the facade plate in the example showed below.

The elastic shear displacement that recovers after stress removal, is overlied by an irreversible creep. At the end of the test after about 3 weeks the measured creep velocity was about 0.01 mm/week. With additional temperature loading a reduction of the shear stiffness and an increasing tendency to creep was observed.

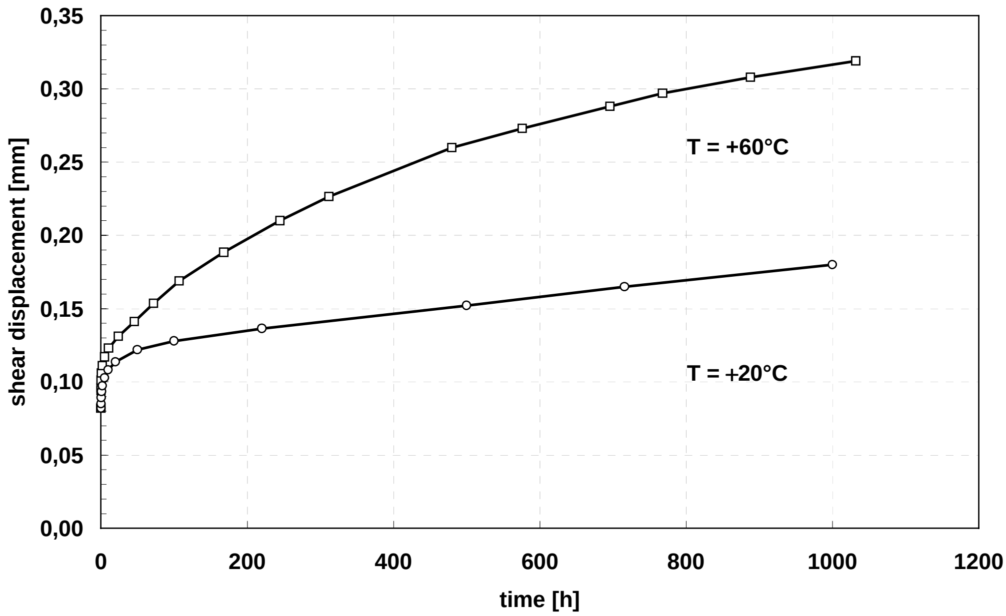


Fig. 4. *Fatigue stress test at temperatures T = +20°C and T= +60°C*

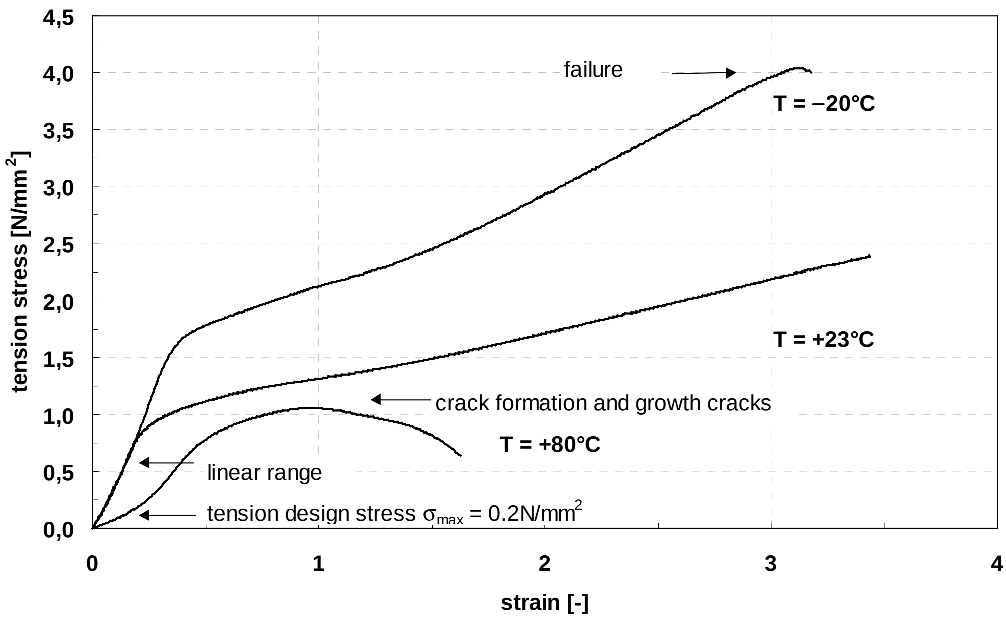


Fig. 5. *Results of tensile tests at temperatures T = -20°C , T = +23°C and T= +80°C*

Exemplary Fig. 5 shows the property of the adhesive joint subjected to uniaxial tension at different temperatures. At T = -20°C and T = +23°C a typical an initial linear increase of the strain with the external stress is observed. Within this linear range the stiffness is mainly determined by an elastic reversible deformation.

With increasing load due to constriction a stress concentration is formed at the joint edges that finally leads to the formation of cracks. From there the slope of the stress-strain-curve is determined by the resistance of the adhesive joint to crack propagation. This load level can not be used for practical application. However, the high resistance to tearing inheres safety against excessive local stress. With increasing temperature softening of the adhesive in conjunction with a decrease of the tension strength and the elongation is observed.

The test program also contained the prove of the application. Further tests with conditioned samples aimed to determine the resistance of the adhesive itself and the adhesion to different environmental conditions. A survey to the test program gives Table 2.

The adhesion system showed a non-critical behaviour with respect to the application instructions and the resistance to different environmental influences. The failure was predominantly cohesive in the adhesive joint. Occasionally observed gas inclusions are caused by poor conditions during the adhesive curing. Some of the HPL-plates tested failed after long-time immersion in water, since the adhesion was stronger than the internal strength of the test samples. In some test partially adhesive failure was observed between the adhesive and the primer or the primer and substrates.

Table 2. *Testing of the application instructions and the resistance to different environmental conditions*

testing of the application instructions	exceeding the open time of the adhesive system about 20 minutes
	influence of the application temperature, application at T = +3°C and T = +45°C
	application on wet substrate surfaces
	application on dirty surfaces
resistance to different environmental conditions	immersion in water at T = +40°C, 500 h, 1000 h, 1500 h
	resistance to facade cleaning products at T = +40°C, 500 h
	resistance to humidity and NaCl – atmosphere according to DIN 50021 SS, 480 h
	resistance to humidity and SO_2 – atmosphere according to DIN 50018 – KFW 0,2 S, 20 cycles
	resistance to bacteria and fungi development according to ISO 846, method B and C

4. APPLICATION EXAMPLE

The first large building project with the new adhesion system carried out was an office block in Sindelfingen near Stuttgart (Fig. 6). As the facade was mounted during the winter season under worst climatic conditions hence it was necessary to cover and heat the facade to get suitable conditions for the application of the adhesive system.

Fig. 6. *Office block with bonded facade*

The building project has a facade area of about 1400 m². The height of the building is more than 20 m. The MEGACERAM facade panels used have 6,5 mm thickness and the dimensions length x width = 1,30 m x 0,50 m.

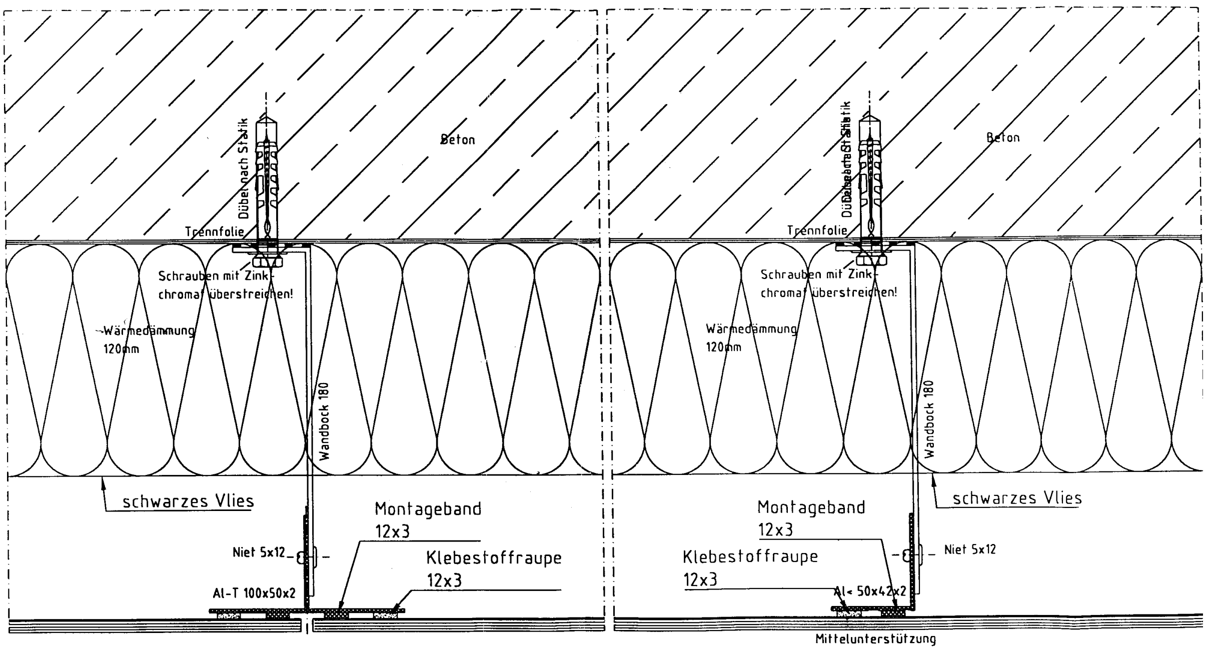


Fig.7 *Horizontal cut of the facade*

Fig. 7 shows a horizontal cut of the facade. The aluminium-support frame consists of T-shaped support frames. L-shaped support frames are located in the mid-span of the panels as well as at the corner and boundary lines. They are arranged vertically to provide for a good ventilation and to prevent water from collecting in the vicinity of the structural adhesive.

5. CONCLUSION AND OUTLOOK

The Sika-Tack-Panel adhesion system reached the first approval in Germany for structural bonding of facade panels without an additional mechanical safety device. An extensive test program was carried out to get the approval. The aim was to determine the mechanical properties of the structural adhesive under different load conditions, the resistance environmental influences and the safety due to the application of the adhesive system. The design values were determined on the basis of the test results.

The adhesive system is subjected to a quality control of the manufacturer and the supervision by the FMPA. Moreover, only qualified staff is allowed for the application. Already a couple of companies have been certified. This guarantees the quality of the product as well as the application of the system required.

The admission of further types of facade panels to the approval is in mind. In the future, engineers and architects can dispose of the whole range of facade plates, that can be mounted with the adhesion system. Some further building projects have been carried out or are in the planning stage and prove that the advantages of the adhesive system have been already recognised.