Adhesives

According to DIN 16920, adhesives are “non-metal materials which bond assembly parts by means of surface adhesion and internal strength”. Before adhesives were standardized, nature herself made use of the technique: the carnivorous sundew produces an adhesive bond with its victim, wasps and bees glue their constructions; and anyone familiar with the sea has seen muscles and barnacles which are almost impossible to remove from a ship’s bow or a rock. We the people started using glue early on – the use of adhesives is older than welding, screwing or riveting. Around 3500 BC, the Sumerians boiled animal skins in order to make a glue; furniture with glued veneers has been attributed to the Egyptians in the 5th century BC.

Adhesion and Cohesion

Back to the DIN norm: the assembly parts are on the one hand bonded by means of the surface adhesion between the glue and the assembly part, i.e. the adhesion, and on the other hand bonded by means of the internal strength, i.e. the cohesion, of the adhesive material.

The bond between the glued piece and the glue itself takes place for different reasons. On the one hand, physically or chemically binding forces on the molecular level are responsible. This is, for example, the case with the bonding of metals and some plastics. On the other hand, very porous materials like, for example, wood mostly attach to the glue mechanically: the glue migrates (diffuses) into the microscopically fine surface pours and then hardens. The configuration of the adhesive and the combined attributes of the adhesive and the adherend determine the strength of the adhesion.

If the adhesive has bonded to the surface of the adherend, the tiny space between two assembly parts can be bridged. After hardening, the adhesive must have attained a sufficient amount of internal strength – the cohesion – for the bond to hold.

An exception to the adhesion-cohesion mechanism is found in the case of gluing thermoplastic plastics with pure solvents like, for example, dichloromethane or acetone. In this case, the solvent solvates (etches) the surface to such an extent that the long molecular chains that make up the solid plastic are loosened and then join with the chains from the assembly part to form a bond. If the solvent evaporates, none of the “glue” will remain behind and the interior strength of the joint will be solely determined by the plastic.

When working with adhesives it is advisable to take account of the temporal progress of the hardening process. Based on experience, the strength of an adhesive bond is very weak at the time of the joining, increases rapidly from there but then slows down. Even in the case of quick setting adhesives, the adhesive strength continues to increase for many hours and even days and only attains its maximum strength with the passage of time. This maximum strength, however, will, depending on environmental influences, then tend to drop off as weeks and months go by until a constant, though somewhat lesser strength is finally attained.

Attributes: Types of Adhesives

Gluing indeed becomes a science when trying to acquire an overview of the multiplicity of adhesive types. Adhesives can roughly be divided into solvent (drying) glues and reactive glues. In addition, there is a long list of adhesives that are very difficult to classify, for example, the broad field of adhesive tapes and transfer adhesives, hot melt adhesives or white glue and pastes.

Solvent (drying) adhesives bind by means of the evaporation of the solvent they contain, i.e. physically. There are two types:

- **Pure solvent or diffusion adhesives** – they are used for gluing thermoplastics that can be solvated. One example would be gluing polystyrene with dichloromethane. Gluing work with pure solvents demands that the adherends have good matching surfaces and that a small amount of pressure be applied. In addition, the solvent must be able to evaporate.
- **Solvent adhesives** are organic solvents with solid matter dissolved in them. Their spectrum begins with solvents with a very small amount of solid matter which, like the pure solvents, solvate the surface of pieces made out of thermoplastic plastic. An example of this is the gluing of polystyrene with a solution of polystyrene in DICHLOROMETHANE. Other solution adhesives contain a larger percentage of solid matter but nonetheless still solvate the plastic piece to be glued. They are often also suitable for binding non-soluble material. One example of this is RUDERER L530 with which very good bonds can be achieved even on non-plastic materials. Another important member of this group is the so-called all-purpose glue. For these, the purpose of the solvent is basically just to ensure that the glue retains its liquid state. Examples include UHU or TESA ALL-PURPOSE GLUE (Technicoll). The use of solution adhesives also requires that the surfaces of the adherends fit very well together. In addition, the solvent must be able to evaporate.

- **Contact adhesives** usually consist of very ductile synthetic or natural rubbers (polychloroprene is most common), which are dissolved in organic solvents. The solvent serves exclusively as a means to liquefy the adhesive. Contact adhesives must be allowed to dry for some period of time before the pieces to be joined are pressed together and, additionally, a fairly high amount of pressure is required in order to achieve a satisfactory bond. The excellent initial bond of the contact adhesive is produced by applying strong pressure for a short duration. Examples include Pattex or UHU por.

Dispersion adhesives consist of micro-fine plastic particles (often polyvinyl acetate), which are evenly dispersed in water – i.e. distributed evenly. The bond results from the evaporation of the water. In the process, the polymer particles join together to form a closed film. Examples of this type of adhesive are Ponal and Ponal express. Dispersion adhesives are only used when at least one of the adherends is made out of a porous, absorbent material because the solvent water takes a long time to evaporate. They are great for gluing materials like wood or cardboard.

Reactive adhesives make bonds through their components undergoing a chemical reaction which produces molecular chains (polymerization). On the one hand, these chains bond with the surface of the adherend (adhesion) and, on the other, construct a sturdy crosslinking with sufficient cohesion. The reactive adhesives are, then, plastics which polymerize in-situ to thermoplasts, duroplasts or elatomers.

Reactive adhesives come in the form of either one or two component glues.

The two component glues are more complicated to use because the components can only be mixed together shortly before using them. One component glues will bond with the addition of air moisture or UV light, to give two examples. The following types have distinguishing characteristics:

- **Polyaddition adhesive:** for these adhesives, both components consist of precursors of a plastic which upon mixing crosslink into duroplasts or elastomers. Examples include epoxy resin adhesives like metal epoxy or the 5-minute glue as well as polyurethane adhesives.

- **Polymerization adhesives** consist of monomers which, after the mixing together of the hardener and the binder, cure into thermoplasts or duroploasts. Polyester adhesives crosslink into duroplasts. Thermoplasts are produced when acrylic resin adhesives are used (e.g. Acrifix 192). Acrylic resin adhesives are one component adhesives that harden as a result of exposure to light; a simple formulation would be that they consist of liquid acrylic glass. Cyanoacrylate adhesives are fast hardening single component polymerization adhesives that are based on cyanoacrylate. The bond is formed as a result of contact with the moisture in the air. Strong bonds are the result and they can be used on practically any material. Examples include the well known superglues. The well known sealing compound silicone rubber also forms bonds as a result of exposure to air moisture. Cyanoacrylate adhesives are very good for bridging wide glue joints because they shrink very little.

Adhesives

Adhesive tapes and Transfer adhesives: Adhesive tapes basically consist of a carrier material that is coated on one or both sides with an adhesive. The carrier material can be a plastic film, a paper or a fabric.

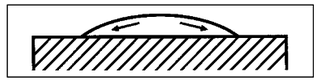
Transfer adhesives could be considered as adhesive tapes without a carrier material; they consist of an adhesive film on a protective cover which is removed before or during the gluing procedure.

Pressure sensitive adhesive is used for the coating of self-adhesive films and tapes or as the transfer adhesive. The self-adhesive attribute of pressure sensitive glues remain active for a relatively long time because, as a rule, they do not contain any solvent. The glues are available with an extensive range of adhesive attributes in order to satisfy the wide variety of uses for which this adhesive group is used. These attributes are determined by the selection and mixing of different raw materials as well as by the different mixing ratios used. Examples of the raw materials include natural and synthetic rubbers (e.g. polychloroprene) or totally synthetic resins (e.g. acrylate).

Pressure sensitive adhesives adhere to almost all smooth surfaces, tend to remain permanently elastic and cover a wide spectrum from removable adhesive bonds (“post-it” bonds) all the way to bonds of the highest resilience like, for example, those required in airplane building.

In the case of pressure sensitive adhesives on adhesive tape, there is a special phenomenon that always surprises: straight adhesive tapes for high load-bearing bonds do not feel sticky at all; they only develop their adhesive strength after they have been bound to the part that is to be glued for a certain amount of time. Here a distinction must be made between adhesives with high initial adhesive strength that have already achieved their maximum strength after a few minutes and those that require some number of hours before that point has been reached. Pressure sensitive adhesives with high initial adhesive strength usually have a relatively low maximum adhesive strength.

Hot melt adhesives: These adhesives consist of individual or multiple high polymer thermoplastic materials. They are liquefied by means of heat or a change in the chemical structure and form a bond as a result of the re-solidification.



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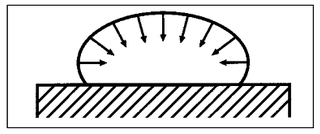

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What should be glued how?

Adhesive bonds can achieve a high degree of strength. The quality of an adhesive bond is, however, determined by numerous factors. Choosing the right combination of adhesive and material is certainly the first priority. In doing so, an important consideration is the so-called “surface energy” or “polarity”. A good adhesive strength can usually be achieved on a (polar) substrate with a high surface energy while bonds made on substrates with low surface energy (non-polar) are not so reliable. The surface energy criterion does not play much of a role in the case of gluing work on wood and paper, i.e. materials with finely textured surfaces. You can determine if a material has a high or low surface energy by placing a drop of water on it: if the drop becomes relatively flat, the material has high surface energy, if it takes on the shape of ball the surface energy is low.

high surface energy	low surface energy
Acrylic glass	Rubber
Rigid-PVC	Polyethylene (PE)
Epoxy resin	Polypropylene (PP)
Polyester resin	Polytetrafluorethylene (Teflon)
Polyurethane	Silicone
Polycarbonate	Silicone rubber
Aluminium	
Steel	
Copper	
Brass and other metals	

For bonding work on some of the more important material groups we have assembled the following information:

Plastic: when plastics are to be glued to one another, solvents (diffusion adhesives) can be used very successfully on many of the various types. Solvent adhesives, contact adhesives, pressure-sensitive adhesives, dispersion adhesives as well as most reactive adhesives are likewise suitable for use in gluing plastics. Plastics with low surface energy (e.g. PE, PP) and those containing plasticizers (e.g. SOFT-PVC) are problematical.

Rubber: good bonding of rubber with itself and with other materials can be achieved with vulcanizing liquids, cyanoacrylate-based reactive adhesives and polyurethane or contact adhesives.

Paper and Cardboard: wave-free bonding of paper and cardboard can be achieved with water-free all-purpose glues like TESA ALL-PURPOSE GLUE; paper, of course, can be glued with practically every type of adhesive. Water-based types of adhesives like, for example, WALLPAPER PASTE, are commonly used because they allow adjustments to be made after placement but they are not completely free of other types of problems. In model making, cardboard can be glued with dispersion adhesives like PONAL.

Metals: metals are best glued with reactive adhesives like epoxy resin, polyurethane or cyanoacrylate glues.

Wood: like paper and cardboard, wood can be bonded with most types of adhesives. Polyvinyl acetate dispersion adhesives like, for example PONAL, are particularly good for this work because they set very quickly and produce a strong bond. For exterior use or use in wet rooms there are special types or adhesive which are resistant to water. Large area gluing work with wood and wood-based materials can be efficiently done using contact glues like PATTEX.

Silicate materials: epoxy-based reactive adhesives, polyurethane adhesives or cyanoacrylate-based adhesives can be used to glue glass and ceramics. The epoxy resin adhesives are particularly good for bridging gaps. Cyanoacrylate adhesives are only conditionally suitable for gluing work on glass.

The table on page N 6/7 provides an overview of suitable material-adhesive combinations; it is divided by the different plastics and all other remaining materials. You can reduce your choice of possible adhesives by consulting the information at each individual adhesive type and the notes given for the individual materials.

Info: The charts on these pages are based on our own experiences. We cannot make any claim to completeness and cannot say with any certainty that our suggestions are in fact the best solutions to your gluing problems. You will notice that the charts do not make any assertions concerning whether an adhesive is rather more suitable for model making than for large area bonding work. We also do not mention the various one-sided adhesive tapes because their applications are basically so much different than those of liquid adhesives.

You will be able to reduce the possible choices for your adhesive needs by consulting the information given for each individual adhesive.

Legend

bold especially suitable adhesive

italics good for two-dimensional (flat) bonds

(1) Bonding PP and PE is problematic in general; smaller surfaces can be prepared with Contact-Primer 6e and good bonds subsequently achieved using super glue as well as other glues.

(2) Best results when bonding wood are usually achieved when the wood surface has been primed/varnished. Important exception: Bonds made with wood glue!

(3) Bonding of elastic material with nonelastically curing adhesives will be successful if the bonded seam is made up of individual dots of glue.

(4) In the case of PS foams: Attention! Numerous adhesives are corrosive to the foam In the case of Soft-PVC: Attention! Plasticizer corrodes the adhesive (for suitable adhesives, see „Plastic“ in the chart

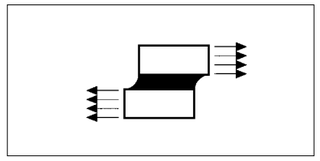
Plastics	**Acrylic** (PMMA)	**Polystyrene** (PS)	**Polystyrene foam** (Styrofoam, Styropor)	**Polycarbonate** (PC)	**Polyester** (PET)	**Polypropylene** (PP)	**Polyvinylchlorid** (Rigid-PVC)	**Polyvinylchlorid** (Soft-PVC)	**Polyurethane** (PUR)
Acrylic (PMMA)	5, 6, 7, **8, 9a, 9c,** 14, *16,* 18								
Polystyrene (PS)	5, 6, 7, **8, 9a,**14, *16,* 18	5, 6, 7, **8, 9a-b,** 14, *16,* 18							
Polystyrene foam (Styrofoam, Styropor)	1a, **9f,** 14, *16,* 18	1a, **9f,** 14, *16,* 18	**1a, 9f,** 14, *16,* **18d**						
Polycarbonate (PC)	5, 6, 7, **8, 9a,** 14, *16,* 18	5, 6, 7, **8, 9a,**14, *16,* 18	1a, **9f,** 14, *16,* 18	5, 6, 7, **8, 9a,** 14, *16,* 18					
thermoplastic Polyester (PET)	5, 6, 7, **8, 9a,** 14, *16,* 18	5, 6, 7, **8, 9a ,**14, *16,* 18	1a, **9f,** 14, *16,* 18	5, 6, 7, **8, 9a,** 14, *16,* 1	5, 6, 7, **8, 9a,** 14, *16,* 18				
Polypropylene (PP)	14, 16, **6+6e** (1)	14, 16 ,**6+6e** (1)	14, 16 (1)	14, 16, **6+6e** (1)	14, 16, **6+6e** (1)	14, 16, **6+6e** (1)			
Polyvinylchlorid rigid (Rigid-PVC)	5, 6, 7, **9a,** 9d, 14, *16,* 18	5, 6, 7, **9a,** 9d, 14, *16,* 18	1a, **9f,** 14, *16,* 18	5, 6, 7, **9a, 9d,** 14, *16,* 18	5, 6, 7, **9a, 9d,** 14, *16,* 18	14, 16, **6+6e** (1)	5, 6, 7, **9a, 9d,** 14, *16,* 18		
Polyvinylchlorid soft (Soft-PVC)	3b, **9e**	3b, **9e**	16	3b, **9e**	3b, **9e**	14, 16 (1)	3b, **9e,** 16	3b, **9e**	
Polyurethane (PUR)	**5, 6,** 7, 9a, 14, *16,* 18	**5, 6,** 7, 9a, 14, *16,* 18	1a, **9f,** 14, *16,* 18	**5, 6,** 7, 9a, 14, *16,* 18	**5, 6,** 7, 9a, 14, *16,* 18	14, 16, **6+6e** (1)	**5, 6,** 7, 9a, 9d, 14, *16,* 18	3b, 9e	**5, 6,** 7, 9a, 14, *16,* 18

		Plastics		**Rubber**		**Paper and Cardboard**		**Wood**	**Metal**
		high surface energy	low surface energy (e.g. PP, PE ...)	Solid Rubber, Latex	EVA-Foam (Foam Rubber)	Paper	Cardboard	Plywood, Balsa, MDF ...	Metal
Plastics	high surface energy	see table 1	see table 1						
	low surface energy (e.g. PP, PE ...)								
Rubber	Solid Rubber, Latex	***3,*** 5, **6,** 3c, 14, 16, 18 (3) (4)	14, 16, **6+6e** (1) (3)	***3,*** 5, 5f, **6,** 14, 16, 18, **19** (3)					
	EVA-Foam (Foam Rubber)	***3,*** 5, **6, 7,** 3c, 14, 16, 18 (3) (4)	14, 16, **6+6e** (1) (3)	3, **5,** 6, 14, 16, 18 (3)	1, *3,* 4, **5,** 6, 7, 14, 16, 18 (3)				
Paper and Cardboard	Paper	1a, *3,* 9a-b, 3c, ***13,*** 14, 16, ***16h*** (4)	14, 16 (1)	*3,* 6c, *13,* 14, 16	1, *3,* 6c, *13,* 14, 16, 18	**1a,** 1, 2, 10, 11,12, ***13,*** 14, 16, ***16h***			
	Cardboard	1a, *3,* 4, 9a-b, 3c , **10, *13,*** 14, 16, ***16h,*** 18 (4)	14, 16, 6c+6e (1)	***3,*** 6c, *13,* 14, 16, 18	1, *3,* 4, 6c, *13,* 14, 16, 18	**1a,** 1, 2, **10,** 11,12,***13,*** 14, 16, ***16h***	**1a-d,** 2, 4, **10,** 11, 12, ***13,*** 14, 16, 18		
Wood	Plywood, Balsa, MDF ...	1d, ***3,*** 4, 9a-b, 3c, **10,*13,***14, 16, ***16h,*** 18 (2) (4)	14, 16, 6c+6e (1)	***3,*** 6c, *13,* 14, 16, 18 (2)	1, *3,* 4, 5, 6c,*13,* 14, 16, 18 (2)	**1a,** 1, 2, 10, 11,***13,*** 14, 16 (2)	1a-c, **1d,** 2, 4, **10,** 11, ***13,*** 14, 16, 18 (2)	**1d, *3,*** 4, **10,** 16, 18 (2)	
Metal	Metall	***3,*** 4, **5, 6, 7, 9a,** 3c, 13, **14,** 16, 18	14, 16, 6+6e (1)	***3,*** 5, **6,** 14, 16, 18	1, *3,* 4, 5, 6c,*13,* 14, 16, 18 (2)	1a, 1d, 3, ***13,*** 14, 16, ***16h***	1a, **1d, *3,*** 4, 5, *13,* 14, 16, **16d,** *16h,* 18	**1d, *3,*** 4, **5, 5f,** *13,* 14, 16, 18 (2)	1d, **5, *5b,* 5f, 6,** 7, 14, 16, 18

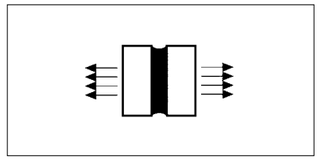
Adhesives

The Structuring of Adhesive Bonds

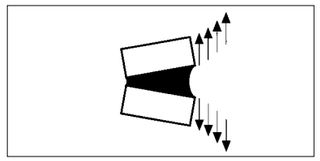
The strength of the adhesive bond is not only determined by the material-adhesive combination but rather depends just as much on the structuring of the adhesive bond. When parts that are to be bonded are used in a construction, care must be given to the type of load that the adhesive can handle and which are the ones that are problematic. There are four basic types of load:



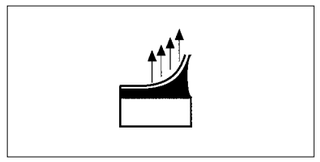
shear forces run parallel to the bond.



Tensile forces work vertically to the bond and are evenly distributed along the entire bonded area.



Cleavage forces are not uniformly distributed over the bonded area but are rather concentrated along a circumscribed section of the bond.



Peeling forces only work at the edges of the bonded surface meaning that these forces can be resisted by using only a small amount of adhesive.

Adhesive bonds should always be so constructed that the greatest surface area can receive the glue and so that exterior forces will only be able to work on the entire bonded area evenly. That is the case if the bond is only to be subjected to shear or tensile forces. Cleavage and peeling loads should be avoided in the construction itself because those forces only work on limited areas of the bonded area.

The areas to be glued should be as flat and coplanar as possible in order to assure a good fit. The bond space should be as narrow as possible especially when using solvent adhesives and contact adhesives so that the coat of glue can be as thin as possible. Reactive adhesives (with the exception of cyanoacrylate adhesives) or foam adhesive bands allow somewhat thicker adhesive coats.

In addition to the material-adhesive combination and the constructive formation of the bond, the properties of the surface to be glued also contribute to the quality of the adhesive bond.

The most important determinate is the cleanliness of the surface to be glued. Failure of an adhesive bond can almost always be traced to a incomplete cleaning of the glued area. So: the area to be glued must be clean and free of dust. Grease and other impurities can be removed with solvents like an isopropanol-water mixture or ACETONE; dust can be brushed away or blown away with compressed air. Do not use a detergent as a cleaning agent because many of these contain silicone which will tend to hinder the formation of the bond. Metal surfaces can be lightly roughened before applying the adhesive in order to attain greater adhesive strength.

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The substrate to be glued must itself be solid because a loose material surface will peel away together with the glue and nothing will hold. Example: adhesive tape does not stick well to a raw wood surface or a particle board or rusted metal or to a surface with peeling paint.

The following table supplies an overview of the different criteria for the use of various adhesive types::

	Hot melt adhesives	Contact adhesives	Dispersion adhesives	Two-component adhesives	Cyanoacrylate adhesives	Transfer adhesives
Fixing is required			••	••		
Resilient after a short time	••	••			••	••
Gap bridge > 2mm	••			••		
Both surfaces to be glued are absorbent			••			
Can be used for large areas	-	••	••	-		••

•• : yes
- : moderate