Appreciating Adhesives

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Definitions
An adhesive is a substance used to attach one material to another. There are mineral adhesives such as solder, concrete (cement) and waterglass; adhesives derived from animals, called glues, such as casein (milk) gelatine (skin and bones); and vegetable adhesives such as starch, gum, resin and rubber. Many synthetic adhesives have been developed to provide special properties that result in better adhesion or bonding. The earlier ones were cellulose based, and balsa cement is the prime example. This was followed by polyesters, polyvinyls, epoxies and acrylic resins, the best known being cyano-acrylate.

Some of these adhesives melt when they are heated so are called thermoplastic; e.g. wood glue, hotmelt glue and solder. Others are termed thermo-setting because heat speeds the hardening or setting process. The epoxy and acrylic resins are in this class. The most numerous class of adhesives is of a material dissolved in a liquid which evaporates leaving the solid to provide the bond . Cellulose cements and starches are the most common examples of this type, which includes the contact adhesives.

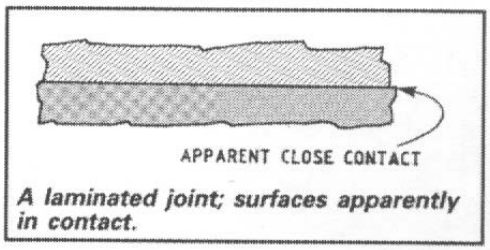
Modellers use mainly cellulose cements, vinyl resin (PVA), epoxy resin, cyano-acrylate and synthetic rubber contacts. Aliphatic resin glue is similar to PVA. All these adhesives are easy to use, stable in storage and give excellent bonding when used in the most appropriate way for each type. They are all suitable for wood joints although contact cement is best for large contact areas. PVA is also good for foam plastics, where epoxy resin may be used but is more expensive, and epoxy is also good for metal to wood bonding, while the cyanoacrylates seem to be good for every1hing, but are the most expensive of them all.

Poison: with care!
The toxicity of all modelling adhesives is very low. The worst feature is the risk of development of an allergy to epoxy resin; usually a slow process which is not reversible but is preventable. Much has been written about the toxicity of cyano-acrylates, but, apart from the fumes released during curing causing eyes to run and an occasional sneeze,after surgery. While not toxic, care is still necessary: they stick fingers to airframes very weill And don't forget that dope is a very good adhesive: it belongs to the balsa cement group, being a cellular derivative.

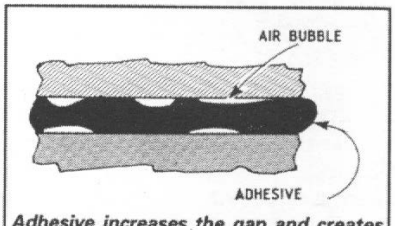
Of the adhesives mentioned above, two types, the polyesters and the epoxies, are two-part materials. Each consists of the glue and a hardener, which causes polymerisation when the two are mixed and the adhesive sets. Heating speeds up the process, but overheating may weaken the bonding due to the polymerisation being too rapid.

The action of adhesives

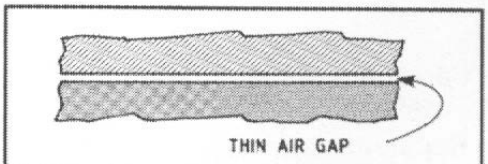
The means by which an adhesive bonds two surfaces together is twofold. It has been found that two very clean



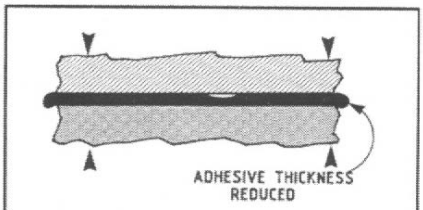
A laminated joint; surfaces apparently in contact.



Adhesive increases the gap and creates



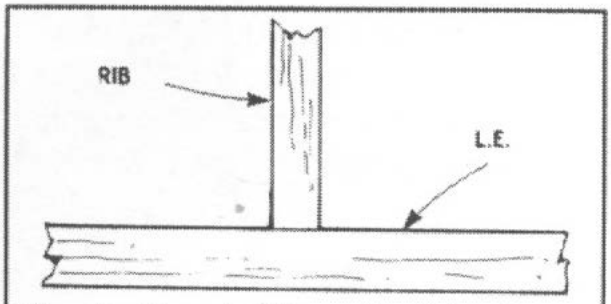
A thin air gap has to be filled with adhesive to bond the surfaces.



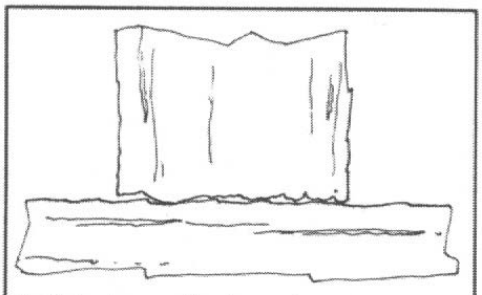
When the joint is clamped the contact between the surfaces is improved and the amount of adhesive reduced so that the strength of the joint depends less on the strength of the adhesive.

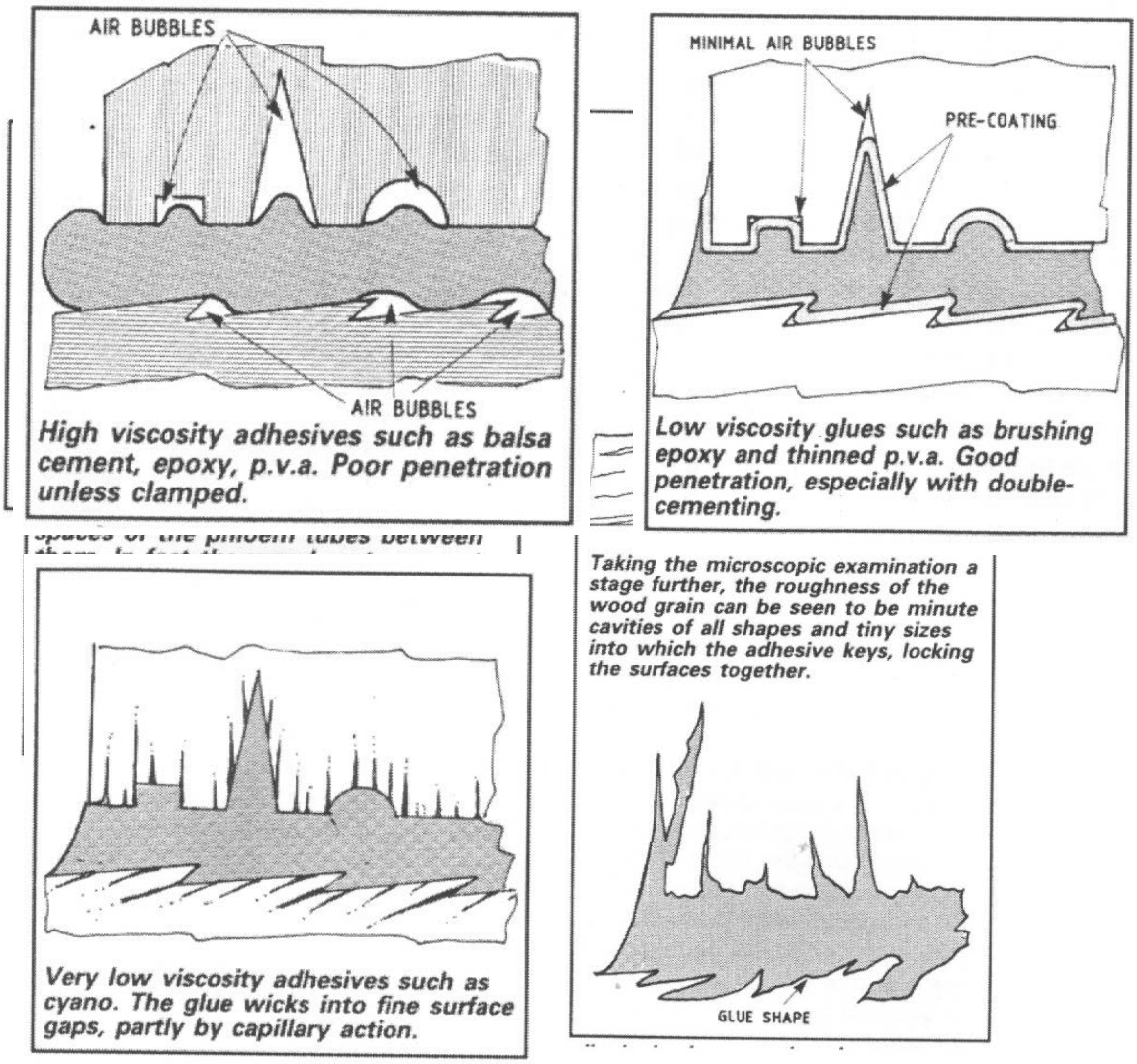
surfaces, particularly of the same material, such as bonded by pressure alone, although the join is not as strong as the material in each part. Plastics also exhibit this property, and bonding improves if heat is applied with the pressure. This can be taken as far as causing the surfaces to melt together giving a welded joint. However, it has been concluded from such bonding tests that if the surfaces were truly clean, with no adherent molecules of air or other substances, adhesion would be as strong as the material itself. This cannot be achieved in practice, and does not apply to porous surfaces such as wood, which is the material most used by modellers.

In the phenomenon of clean surface-bonding, it is thought that the surface molecules of the substances are brought so close together that the inter-molecular forces giving the substance its own strength are brought into play, and so the line of separation between the parts ceases to exist. Such molecular fames are very strong, and organic molecules can be synthesised to provide different bond strengths as shown by soft plastics and hard plastics.



Simple rib-to-leading edge joint does not provide much surface for adhesion; nevertheless, joint is quite strong, especially if precemented.


Satisfactory adhesion takes place because the mating surfaces are rough; rib end grain and cross grain of leading edge, when viewed magnified, offer plenty of opportunities for adhesive to be effective.

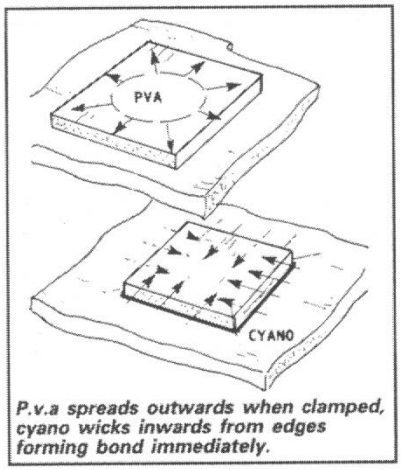


Since molecular bonding is not important with modelling materials, the strength of glued joints must be provided in a different way. The action of model adhesives is to provide a key that locks the two parts together. There is some molecular bonding between the adhesive and each part being joined, but the adhesive itself fills the space between them, and by penetrating the adhesive hardens or as the solvent evaporates.

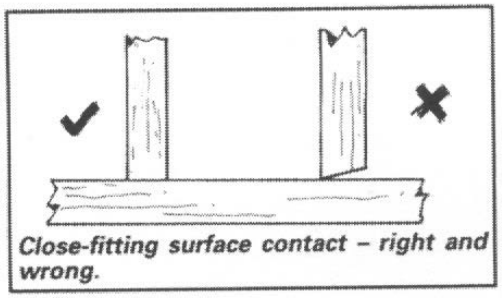
The bond strength is increased by ensuring that all the gaps are filled with adhesive. This is the purpose of pre-cementing a joint with balsa cement, PVA and aliphatic resin glues; and is also the reason for applying epoxy adhesives with a spatula or squeegee to force the various materials into the grain of the surface. Bond strength is then maximised by clamping the parts together until the adhesive has set.

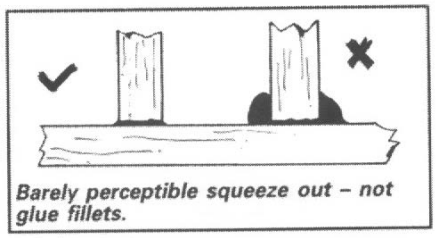
Factors affecting bond strength

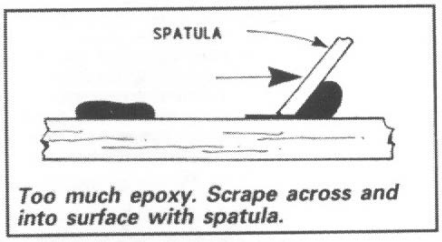
The ultimate strength of the bond depends upon the innate strength of the adhesive. For example, a balsa to balsa joint usually breaks by the balsa fibers separating, not by the adhesive fracturing. For balsa to hardwood the balsa is the weakest component. For hardwood to hardwood the joint will usually separate on the glue line unless it is firmly clamped till the glue has set properly. With plywood, the use of epoxy or thick cyano will usually result in fracture by the ply laminations peeling apart. This is because



P.v.a spreads outwards when clamped, cyano wicks inwards from edges forming bond immediately.


Close-fitting surface contact – right and wrong.


Barely perceptible squeeze out – not glue fillets.



Too much epoxy. Scrape across and into surface with spatula.

the adhesive used in the plywood is usually a thermoplastic phenolic which is not as strong as the epoxy or cyano glue.
Bond strength, on the other hand, is reduced by foreign matter in the joint, by a poor fit surface to surface, by the use of insufficient adhesive (usually not the case'), by incorrect choke of adhesive and by disturbing the joint before the adhesive has reached the strength needed to cope with the stresses of handling. Some epoxies gain strength for days after use. Dope may continue shrinking for a week or more after the final coat. Since wood, particularly balsa wood (see the Materials article in Aeromodelling digest 1990) is quite porous, the penetration of the adhesive into the wood is very important to the strength of the joint. Furthermore, joints in models often have end grain to cross grain, which means that one side is stronger than the other. To provide maximum penetration, the adhesive should be thinned so that it can soak into the wood. The best adhesives are PVA and aliphatic resin (mixed to combine some flexibility from the PVA with the rigidity of the aliphatic) thinned with water. This technique reduces the bulk of the glue in the joint, and to avoid cavities it is necessary to double coat the surfaces, otherwise known as pre-cementing the joint. This can be done before the first coat has dried.

The situation is taken care of fully by using cyano-acrylate, which wicks into the grain of the wood, strengthening the material for a short distance on both sides of the joint. When the parts are placed together before the cyano is applied, there is a risk that some areas of the joint are without adhesive, particularly when the joint area is too wide for the cyano to soak across. To overcome this problem, a slow setting adshesive

such as PVA is smeared on the inside area, the parts are assembled and the cyano is applied to the edge areas of the joint, surrounding the PVA which will harden slowly. The strength of the cyano bond enables the joint to be moved before the PVA has completed its adhesion.

A dual adhesive system can also be used to advantage by giving the joints of an airframe a coat of dope after the first adhesive, such as thinned PVA or cyano, has set. The dope soaks into the joint to seal and strengthen without adding significant weight. It dries quickly too.

The gluing technique

1. Choose the best adhesive

Models can be assembled using only one adhesive. Many years ago balsa cement was by far the best choice, since animal wood glue, casein and paper paste had been recognised as being quite inferior and more difficult to use. Balsa cement is still a good choice since the new ones have been improved considerably over the early one, which usually shrank, thus causing warps. However, some joints cannot be assembled in the short time that balsa cement remains sticky, since it has fast-evaporating solvents. The logical replacement is PVA or aliphatic types. Their only disadvantage is their long drying time. Some modellers use epoxy glues exclusively. They are the strongest adhesives, there are many types with different setting times and they are best for hardwoods. Low-stress joints between metal and wood and even metal to metal can be made with a suitable epoxy. But they are messy and they are allergenic. The current trend is to use cyano glues for all joints: a fast one for balsa and a slow one for hardwood and for large contact areas. They are easy to use, cure fast and give excellent bonding. The fumes bother some modellers: their cost bothers others, who use them sparingly. They are the best glue for on-field repair when a contest demand it

2. Make a close-fitting joint

The surfaces between which the adhesive has to be used should be clean (no oily substances or dust) and should be parallel. When they are not, the adhesive will be squeezed out at one side, and build up on the other. In neither place will the bond be at maximum strength. The parts should be a firm fit so that assembling tends to force the adhesive into the grain of the wood without forcing it all out of the joint. When the gluing surface becomes larger, say, greater than a square centimetre, some pressure should be applied to get the surfaces close together.

3. Use a clamping technique

a) Pin the parts to the building board. (Note that balsa cement does not cause the pins to stick to the balsa; a twist and pull will release a clean pin. On the other hand, PVA, epoxy and cyano attack the metal and cause adhesion of the pin to the wood, requiring a strong twist and a careful pull to get the pin out. (Hold the airframe down in either case.)

b) Weight the parts down onto the board, one on top of the other.

c) Use rubber bands or rubber strips.

d) Or use clothes pegs.

e) Or small G clamps.

f) Or a hobby vise.

g) Or large clamps or bricks.

4. Allow the adhesive to set properly The time required for this to happen under normal conditions (a cool, dry room) is usually given on the adhesive container or package.

When conditions are hotter or dryer, the time is shortened; that is why we put things out in the sun, or fan them with a hair dryer. When it is colder and damper, add 50% to the specifled time.

Store adhesives with consideration
A cool, dry place is adequate for all of them. Water-based glues dry out slowly and clog the spout of the container. Balsa cement also dries and thickens over a long period of time, such as months, on the shelf, once the tube has been opened. Epoxies last for years, particularly if kept cold, and some modellers keep their unopened cyano bottles in the door of the refrigerator.

Keep the soldering outfit away from other materials, particularly if using an acid flux, and also if metal cutting and filing or grinding is done in the same area.

Summary

Post-war chemistry has enabled the development of many special adhesives whose properties can be used to great advantage in modelling. While this complicates the issue of what is essentially a leisure time activity, it is good practice to have available a range of adhesives to take advantage of the means they provide to make better, stronger, longer-lasting and safer models. There is also no need to compromise the advantages due to cost: one of the best adhesives is also the least expensive.