Adhesives

Adhesives are not a recent development but have been in use throughout history. From the Romans that caulked their ships with beeswax and wood tar to the Egyptians that used gum from the acacia tree and egg glue. The type of different adhesives did not change much for many centuries, and did not change much until later on this century.

Since the Second World War there has been a steady development in synthetic adhesives. This growth has been steady because of their superior advantages over traditional fastening techniques. Their superior strength to weight ratio , dimensional stability, better distributed loading has ensured new adhesives being introduced on a regular basis.

The choice of adhesive for the job in hand will depend on many factors, among them the substrates, the available equipment/environment and required performance from the bonded area.

Requirements of Adhesives

When any two materials are bonded together the resulting composite must be stronger than its independent components. The adhesive can be stressed in several different ways. The standard way is by shear which is the plane of the bonded surface, the other is peel strength (normal to the bonded surface) and lastly when the composite is placed under compressive loading (an example is foam sandwich laminate under load).

Tensile	Shear
Cleavage	Peel

The way the adhesive is stressed will determine the type of adhesive and the technique of application. As adhesives need to maximise the surface contact between the substrates and no surface is truly smooth , they must be sufficiently viscous to fill the cavities. Therefore all adhesives are applied as liquids. We can classify adhesives as being permanently liquid, solidifying by physical process or solidifying by chemical process.

Tar and sealing wax are examples of adhesives that solidify by cooling after being applied as hot liquids. Some animal and thermoplastic resins are applied in a similar manner (hot melt gun). Many glues such as contact adhesive, PVA white wood glues solidify on contact to the surface as a liquid by the loss of solvent or diluent. Evaporation or diffusion into a porous substrate may be involved.

The stronger adhesives generally are those that are thermosetting. They are applied as liquids but form a network of polymers by chemical reaction. A common system involves mixing two ingredients that will react after an induction period. The pot life of such a system is the time between mixing and conversion to a high viscosity unsuitable for spreading.

Shrinkage is an important factor in determining the correct adhesive. Any shrinkage caused by hydration , loss of solvent or chemical shrinkage, causes strains within the bond, that pull the adhesive away from the substrates (an example of this is bonding metals or wood with a polyester resin).

The adhesive must be able to withstand a first class bond over a long period of time even when exposed to moisture, temperature extremes, biological attack and movement. In order to achieve this there are a number of standards set up by the SABS, DIN (Germany), BS (British), ASTM (American) and ISO (International). To be sure always study the specifications of the adhesive to see if it fits the minimum regulations (an example is

that of marine plywood that must conform to the BS1204). Always check on the detailed experience of the adhesive and if any case studies have been performed.

Adhesive Types

The glues based on diluents and by melting will not be discussed in this article as they are seldom used in boat and composite construction.

The chemical type, especially the thermoset types will be discussed in more detail below.

It must be noted however that there is a growing trend toward using tape adhesives that already have a type of thermoset on a sheet of 'waxed' paper, (e.g. VHB tapes from 3M).

In the particular field of wood substrates the following three have been used for many decades:-

i) Urea-Formaldehyde

Urea resin adhesives are products of condensation between urea and formaldehyde. These are often used in the production of particle board and hardwood. This is not a 'user friendly' as it shrinks on curing and thus needs a high pressure and temperature to give an effective bond (4 - 10 Bar), it is also sensitive to the moisture content in the wood. They are also not very moisture resistant.

ii) Phenol-Formaldehyde

Phenol resins are the oldest type of synthetic resin adhesives. Originally used for hot pressing of softwood ply for the Second World War. They are highly toxic and require accurate mixing to ensure maximum strength.

Although phenolics have recently had a resurgence because of their flame/fire resistance, their processing constraints have not made it a popular adhesive and have been replaced by other chemical adhesives.

iii) Resornical-Formaldehyde

Resorcinal adhesives are best known as the black adhesive used in marine plywood. This adhesive has been used to construct plywood aircraft, minesweepers and patrol boats during and after the second world war.

Although the adhesive is a very tough and resilient, it is not easy to work with, without the correct equipment. It is also like the other two above prone to accurate processing conditions and have therefore been replaced by other adhesives.

ACRYLIC

This adhesive gives extremely tough bonds, but has a number of disadvantages such as rapid cure times, resistance to solvent and chemical attack. They are also expensive.

CYANOCRYLATE

This glue although considered as a recent introduction (with such names as Superglue, etc) was first introduced in the late 1950s. The reaction of the monomer occurs in a very short period of time (10 seconds) by ionic polymerisation with small traces of moisture. Although not a structural adhesive for boat building it is a useful adhesive for bonding Aluminium, metal, glass and ceramics to each other or to themselves if the surfaces are relatively matched.

The last two adhesives are the most 'user friendly ' and are the most popular adhesives used in composite and boat building today.

EPOXIES

Epoxy resin has probably been modified and supplied in more forms and more applications, than any other system

Their many advantages are that they can be modified to suit any application, are stable in the cured form, resistant to a large range of chemicals. They also only require slight pressure to ensure contact between surfaces. Epoxies can handle temperatures anything between -40 to 250 deg C. Epoxies can come in anything from a thin, liquid resin (eg DP101) to a thixotropic paste (eg DP55).

Epoxies in the boatbuilding industry range from wood adhesives that exhibit gap filling properties (eg DP55) to flexible epoxies for bonding wood onto the decks of yachts (eg DP85). Also available are highly compressive epoxies for bonding keels, adhesives for aluminium. Cure rates vary from a few minutes to several hours.

Epoxies can be used to fillet bulkheads into boats, bond hull and deck etc. They can also be used in a liquid form to prevent osmosis, and wood rot in the form as sheathing (see article Amateur boat builders 1990). Another popular use is as a filler or fairing compound (eg Easyfair) such as that that was recently used in the construction of Broomstick.

When using epoxies ensure that you follow the manufacturer's specifications. Make sure you do a test sample and check on the cure time before mixing. Make sure the cure time is long enough for you to do the job.

POLYURETHANES

A relatively newcomer to the adhesive market, polyurethanes have made inroads into the more established adhesives.

Polyurethane adhesives have the advantage that they remain flexible after curing. They often cure with moisture.

Examples of uses of polyurethane adhesives are for the bonding of windows into yachts, as a glue adhesive, as a caulking compound for teak decks and hull fittings (eg Sikaflex).

Disadvantages of polyurethane adhesives are that they have a limited shelf life as they can react with moisture in the air once opened. They also are susceptable to UV fro the sun and must thus be protected with a coating.

APPLICTION OF ADHESIVES

When a builder is faced with a adhesive problem he often goes for an adhesive that is readily available or is cheap. This can lead to critical failure of the structure. The importance of an adhesive is create an integral system, thus a careful decision must be taken.

The environment that the adhesive must be taken into account . If you are to use it close to wax , grease or any oily surface you are looking for problems before they occur. Likewise if there is a lot of moisture about if you are working with epoxies or acrylics.

When using wood, ensure that the moisture content is between 12 - 18% .

Preparation of the surface of the substrates is probably the second most important decision after choosing the correct adhesive. Although there are a number of different techniques of preparation, a brief overview of the most popular are listed below, together with the types of materials these are normally applied to :-

Degreasing - This is considered a standard procedure in cleaning substrates before applying the adhesive. It is used to remove all traces of oil and grease. Normally a hydro carbon such as Acetone , MEK or Methylene Chloride is used. Halocarbons can also be used (eg trichloroethylene), however these are not recommended without correct safety precautions. Always ensure that you cleaned the surface with a lint free, clean rag.

Abrading - Lightly abraded surfaces of the substrate give a better key to the adhesive than polished surfaces. Always clean/dust the surface of the sanded surface afterward.

Always remember the statement DAD, which if applied will almost guarantee a good bond. DAD stands for Degrease Abrade and Degrease. The last degrease is to clean off any settled particles after the sanding process.

It is interesting to note that the product Peelply/tear ply (looks like a nylon fabric with a special release agent impregnated in it) is becoming popular as an easy way of preparing a surface of fibreglass. All that is done is to apply the peelply as the last layer of a laminate. Once the laminate has cured, peel the last layer off just before you want to apply the adhesive or coating. I suggest that a Degrease is still applied to this technique to make absolutely sure of a clean surface.

In metals the abraded surface comes in the way of shot blasting. Always make sure that the blasted surface is coated immediately afterward. A similar process is also true for glass.

Special treatments. Many materials are prepared in a specific way in industry before bonding. We will only look at those that are used in the boat building industry.

Aluminium should be acid washed using a chromic or sulphuric acid. There are also proprietary products that etc the surface (eg Alumiprep). Stainless steel should be acid washed with Oxalic acid or HCl. Metal should be treated with shot blasting. It should be noted that all the above must follow standard acid wash procedures of washing off the treatment, dry and coat with a primer.

Plastics are a mixed bag and no standard technique can be applied, it is advisable to test a sample before applying it to the finished item. Some forms of techniques for plastics are abrade, acid wash, coroma discharge, plasma treatment and solvent clean.

CONCLUSION

As the above article has pointed out, adhesives are not a simple subject. Before you set about using the material, do the following check.

- Select the correct adhesive
- Ensure your substrate is correctly prepared
- Ensure your environment is conducive to bonding (ie not extremely cold , wet, oily etc.)
- Apply DAD (Degrease Abrade Degrease)
- Follow manufacturer's specifications - if you are not sure do a test piece first
- Mix only sufficient that you can use before it cures
- Apply pressure in accordance to manufacturer
- Clean up area before it cures , it's far more difficult afterwards
- Do not disturb until fully cured

All products listed in this article are available through Duroplastics. In the event that anyone requires more specific information, please contact the author.

Finally it should be remembered that one is dealing with chemicals and the correct safety and handling procedures should always be followed.