AIRWORTHINESS BULLETIN

Australian Government
Civil Aviation Safety Authority

Timber, Plywood and Adhesives for Aircraft Use | **AWB** 02-011 **Issue :** 1
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1. INTRODUCTION

There are many aircraft on the Register that are made of wood or contain major components made from wood eg wing spars. Also wood is widely used in the sports aircraft field.

CASA continues to receive a steady stream of enquiries related to the supply, use, maintenance and repair of wood and wood components for aircraft, and suitable adhesives for use with wood.

Many enquiries relate to the use of indigenous timber and plywood as substitutes for the traditional materials.

Some enquiries are related to the structural integrity of the wood and the adhesives in very old wooden aircraft.

This Airworthiness Bulletin summarises the available information, and provides guidance related to the manufacture and maintenance of wooden aircraft structures.

Additionally, CASA has published an Airworthiness Bulletin AWB 51-1 *Aircraft Fabric Coverings* on the CASA website www.casa.gov.au, which should be read in conjunction with this Airworthiness Bulletin.

2. SELECTION AND APPROVAL FOR USE (including indigenous timbers)

The build and repair data for an aircraft will usually specify the timber and plywood required and to what specification. Often it is generic eg “aircraft grade spruce”, “Grade A spruce”, “birch ply” etc.

In the past, the predecessors of CASA issued some specifications for timbers and plywood in the CAO 108 series. These are currently being withdrawn. CASA does not intend to issue particular specifications, as this would be unnecessarily restrictive. Instead, this AWB provides guidance to enable properly authorised substitution of materials as called up in the build and repair data for an aircraft, and for the establishment of allowable properties for new design using these materials.

CASA does not normally approve materials or give an approval to an organisation to release timber under an Authorised Release Certificate. The onus is on the end user to be satisfied that the timber meets the user’s requirement and the requirements of the approved design data. In other words, the end user is entitled to use the material if satisfied with the documentation provided by the supplier stating that the material meets the specification the end user requires. The end user must perform his/her own inwards goods inspections and any tests he/she requires.

Use of another timber from that specified in the approved design data of a certificated aircraft requires modification approval to justify the change of timber.

3. SOURCE OF INFORMATION ON MANUFACTURE AND REPAIR

There is considerable information available in the public domain on wooden aircraft construction and maintenance. There are text books available and the various standards are available. AC 43.13-1B “Acceptable Methods, Techniques and Practices” contains a large section on the repair of wooden aircraft. ANC-18 Bulletin “Design of Wood Aircraft Structures” is a document that contains much information about the properties and use of various timbers. This can be purchased from the USA Government Printing Office. Another source is at www.rareaviation.com.

There are a number of emergency wartime specifications issued in Australia during the Second World War for indigenous timbers such as Hoop Pine, Bunya Pine, Queensland Maple, Bollywood, Silver Quandong etc, and these specifications are still relevant. The emergency wartime specification No. (E)2D.811-1944 lists various indigenous substitutes for Sitka spruce. These standards are available through Standards Australia at www.standards.com.au.

4. TIMBER

Timber is best for aircraft use when quartersawn. This is primarily because of the stability and less likelihood of warping, bowing or twisting. With the difficulty of finding good timber stock today, often the best result is to laminate smaller quality pieces to make the larger sections required for spars, or to obtain the lengths required. When ordering timber, it is usually best to specify the timber to be supplied at the finished dimensions, as often one discovers unacceptable internal defects when re-sawing larger billets or flitches. Properly scarfed and/or laminated timber is as good as the timber it is made from.

Timber, once received from the supplier should be stored in the work area with sticks separating the pieces and with weights on top for a period of at least two weeks to allow the moisture content (MC) to stabilise without warping or cupping and to observe if any cracks or radial checks occur. This is particularly necessary when timber from the coastal regions (typically at 15% MC) is shipped inland (typically 8% MC). Often quality furniture shipped inland cracks after a while. Once the timber has stabilised at the local MC without cracking, it probably won’t crack when fabricated into the aircraft and protected with paint or varnish.

Wooden aircraft of European origin are commonly constructed from Baltic Pine, which in most grades is slightly heavier and stronger than Spruce.
Wooden aircraft of US origin commonly are constructed from Sitka Spruce or Douglas Fir.

Spruce was traditionally selected to a specification such as 2V37 “Sitka Spruce as Finished Timber”. This specification, whilst specifying a minimum density of 24 lb/cubic foot (384 kg/cubic metre), does not specify minimum allowable strength and elastic properties. Such properties can be obtained from Table 2-6 of ANC-18 or other recognised sources.

All specifications involve visual grading of the timber for presence of defects, straightness of grain and for some tests to establish physical properties, and determination of density to be in a specified range.

Density is a good indicator of strength, but too dense and the aircraft could end up too heavy. The number of rings per inch has been a traditional indication of density in trees from cold climates, and 15 or more rings per inch was considered good, whilst 10 was acceptable. Some specimens have up to 50. However, timber from temperate zones e.g. Queensland Hoop Pine often does not show a distinct ring growth pattern. What is important is that the density and strength are in accordance with the specification. Also it is more difficult to establish the straightness of the grain without a distinct growth ring pattern. Density and strength properties are normally measured at 15% MC.

The specifications typically call for tests for mechanical properties such as short length compression, modulus of rupture in bending and Izod impact testing. Timber suppliers are finding increasing difficulty in finding laboratories equipped and willing to do repetitive commercial testing. Traditionally, an Izod test for brittleness was specified. Freedom from brittleness is a very desirable property, but considering most aircraft applications where there is no impact load, brittleness is not an issue. Indigenous timbers can be brittle, so discretion is required if used in high impact areas such as landing gear attachments.

The simple three-point bending test* is considered a good test, as it checks the compressive and tensile behaviour of the sample in one test. If the timber supplier is satisfied that the timber continues to give good results in this bending modulus of rupture test, then this test alone may well be sufficient. It is up to the supplier to develop and calibrate any in-house test apparatus.

The supplier should provide documentation as requested by the end user stating that the timber meets the required specification.

** There is an abundance of information on the three point bending test available on the internet. A detailed description of the three point bending test is beyond the scope of this bulletin.*

5. PLYWOOD

Birch plywood has been commonly used where high strength and resistance to abrasion are required, and for bent applications. It is usually supplied to a specification such as 6V3 “High Strength Plywood for Aircraft”. This specification does not specify minimum allowable strength and elastic properties. Such properties can be obtained from ANC-18 or other recognised sources. Germanische Lloyd GL3 is another commonly used specification. Table 2-13 of ANC-18 gives the strength and elastic properties of plywoods at 15% MC.

Other aircraft plywoods using softer species are used for lesser strength application where resistance to buckling at minimum weight is desired. Such plywoods as Mahogany, Gaboon and Spruce have been commonly used.

The use of marine grade plywood should be approached with caution. The Australian standards may permit the interior layers to be of lesser quality or indeed of other species to the face plies. Aircraft grade uses all quality plies of the same species. Also aircraft plies are “balanced” that is with an odd number of plies with the same amount of fibres in the crossed direction to minimise warping. Marine grade is often denser than aviation grade.

Hoop pine plywood is available in Australia, but users should be satisfied that it meets their requirements or is supplied against the emergency wartime specification for plywood.

It is considered impractical to conduct impact tests on plywood logs, veneer or finished product. However, if used in high impact areas such as landing gear attachments, consideration should be given to brittleness.

6. TOLERANCES APPLIED TO REPLACEMENT PARTS

Tolerances were often not specified on old drawings for wooden aircraft, probably relying on in-house standards and practices, and a fair degree of fit on the job in the individual hand building. However, for new designs and for replacement parts, proper establishment of tolerances is essential. The following suggestions are given.

a) Timber, by its very nature, has wide variability in its mechanical properties and density, so the designer should be considering the worst case, and allow some dimensional margin built into wooden parts.
b) Timber shrinks and swells with changes in MC, mostly in the tangential direction along the annual rings, less in the radial direction across the rings and almost nil in the length direction. The recommendation is for spars to be supplied finished to the top of the tolerance and less critical parts to be supplied finished to not less than the nominal dimension.
c) Many wooden parts must be fitted on the job, so tolerances are not always relevant.

d) Tolerances should always relate to the next highest assembly, as the parts all have to fit together (i.e. ribs may have to slide over the spar, etc)
e) When dealing with laminated parts, the flatness and twist of the individual layers is critical, because glues are not intended to be gap fillers.
f) With many wooden parts, a tolerance on weight might be expected
g) Tolerances might be better expressed as a percentage of the dimension, rather than plus or minus on the nominal dimension, as obviously a small rib cap section could not absorb the tolerance acceptable on a large plank.

7. ADHESIVES

In line with other materials and processes, adhesives for timber and plywood are not approved by CASA. The onus is on the end user i.e. the manufacturer or repairer of the aircraft or product to be satisfied that the adhesive is suitable in the particular application.

a) Be satisfied that the adhesive is suitable for the application, i.e. waterproof, non-elastic, not corrosive to the wood fibres, not subject to fungal attack etc;
b) Is recommended by the adhesive manufacturer as suitable for wood gluing, and preferably (but not usually available) as recommended by the adhesive manufacturer as suitable for aircraft wood gluing;
c) Is manufactured in accordance with a suitable recognised standard;
d) Is used in accordance with the adhesive manufacturer's instructions as to shelf life, mixing instructions, spreading requirements, pot life, clamping requirements, temperature and humidity limitations, gap filling properties etc;
e) Be satisfied with the documentation received with the adhesive;
f) Do whatever goods inwards inspection and testing the user needs to be satisfied.

The following adhesives are commonly used for aircraft wood gluing:

a) Resorcinol Formaldehyde Synthetic Resin Glue
b) Urea Formaldehyde Synthetic Resin Glue, and
c) Epoxy resin Araldite AW 134 and Hardener HY 994.

Any worthwhile adhesive could be used, especially if supported by history of aeronautical use. New adhesives are still being developed.

The use of a different adhesive to that specified in the approved design data of a certificated aircraft requires modification approval.

CASA's predecessors prohibited acid catalysed phenolics and urea formaldehyde (UF) adhesives in CAO 101.22 etc and early AAC articles. However, urea formaldehyde has been widely used in Australia for gliders and some light aircraft, as modern UF formulations have to some extent overcome the problems of WWII UFs. Adhesive systems where the resin is put on one side of the joint and the hardener on the other side are not acceptable.

Casein has been widely used in the past. However, casein is made from milk proteins susceptible to attack by micro-organisms if the moisture content of the wood and adhesive is above 18%. The joints do not degrade instantaneously when wet but the amount of degradation is proportional to the time the joint is allowed to remain moist. Casein has many advantages as an adhesive, such as long pot life and setting at a low temperature. Modern casein formulations containing fungicide may be an acceptable aircraft adhesive.

Users should understand the techniques used in the gluing process, of timber surface preparation for gluing, cleanliness, and avoiding sanding of gluing surfaces (planed surfaces and light scraping are recommended). Contamination of the surface by oil from hands, sander dust etc can inhibit adhesive penetration into the fibres.

Some adhesives are not suitable for gluing at low temperatures. It is crucial not to disturb the joint until the adhesive has hardened. Full strength may not be developed until the temperature reaches the minimum cross-linking temperature. This is usually acceptable provided the joint has not been loaded prior to the final cure.

The moisture content of the wood should be considered, as too low a moisture content can wick the glue away from the surface and too high a MC can inhibit glue penetration.

Glass transition temperature is the temperature at which synthetic resin adhesives soften. Some epoxies in common use have low glass transition temperatures. Ensure the glass transition temperature is well above the expected temperature that the structure will be exposed to when the aircraft is sitting in the sun on a hot day.

The best way to have confidence in the result of any gluing procedure is to make up test specimens or coupons from the same batch of glue, or offcuts from the actual gluing and to break the joints. There should be 100% wood fibre break. Fundamentally the glue is a lot stronger than the shear strength of the wood, so the glue should not break.

An excellent idea is to put some glued samples into the bottom of an aircraft for later breaking to get an idea of the continuing integrity of the joints at say 10, 15 and 20 years and even longer. These samples can themselves be lightly glued into the aircraft.

8. PRESERVATION

Timber will achieve a moisture content equilibrium if left long enough in an environment. In general, wood will not rot if the MC is kept at 15% or lower. Allowing timber to fluctuate in MC can lead to rot – observe harbour wharf piles where they are eroded away at the limits of the tide rise and fall.

In general, wood will not crack or rot once dried to a suitable MC provided it is protected by paint externally and good quality spar varnish or epoxy varnish applied to internal structure surfaces to slow down the rate of change of MC. High humidity and high temperatures are the most dangerous combination as fungal attacks can start. Storing an aircraft in a covered trailer on hot humid days is not a good idea.

Adequate ventilation and drain holes must be provided to avoid fungal attack. Box spars in particular need to be provided with ventilation and drain holes in each bay. Rear fuselage frames and wing ribs should have drain passages to prevent water collecting. Metal parts can corrode, especially if they are in contact with wood with a high moisture content.

Some designers specify fabric covering over the plywood to protect the plywood. Traditionally this was cotton based fabric with dope squeezed through to attach the fabric. If modern polyester or fibreglass covering materials are used, be sure to follow the fabric manufacturer's process for attaching the fabric, as the dope squeeze method will not allow the dope to penetrate the fibres or "wet" the synthetic fibres.

Refer to AWB 51-1 for further guidance on fabric maintenance.

9. AGEING AIRCRAFT ISSUES

In general, wood does not have a fatigue life limit, and if properly looked after, i.e. properly preserved and stored, will last indefinitely. The metal attaching parts may well have fatigue lives and could be subject to corrosion. If a wooden aircraft is left out in the rain, it is very wise to check for water ingress, particularly in the bottom of the fuselage behind frames, and to check for corroded metal parts.

Adhesives can deteriorate, although modern adhesives are far superior to pre-1945 glues. Nevertheless, the integrity of the adhesive should be checked as part of the maintenance. Ways to achieve this include:

a) Overall observance of the aircraft e.g. flexing the wing looking for detached ribs, tapping joints to determine if there is any movement or disbonding.
b) Using a sharp knife inserted into a joint to see if the joint pops apart.
c) Breaking samples left in the aircraft for 100% wood fibre break as discussed in Section 5.
d) Proof load tests.

Particular attention should be paid to the continuing integrity of old aircraft glued with casein that did not contain fungicide, as the adhesive can deteriorate steadily over time due to fungal attack.

Also the strength of urea formaldehyde (UF) is known to degrade with time. Aircraft glued with UF, especially older aircraft, should be monitored for continued adhesive integrity.

Although prohibited for a long time, it is possible that some Pre-1945 vintage aircraft have been glued with acid catalysed phenolics (ACPs). Many were condemned in the 1950s, but examples may have surfaced, and these would be cause for concern. The problem with ACPs is that uncured acid left over in the curing process can destroy the wood fibre integrity in the joint.

When aircraft were covered with natural fibre cloths such as cotton, the fabric deteriorated with time, especially for aircraft stored outside. When the fabric was removed to re-cover the aircraft at interval sometimes as low as 5-10 years, this gave good opportunity to thoroughly inspect the internal wood structure.

However, modern synthetic fabrics are lasting much longer before needing replacement, perhaps 20 or 25 years. Thus the opportunity for a thorough inspection of the internal wood structure has been compromised. When covering with these synthetic materials, consideration should be given to providing sufficient access panels or removable patches to enable a proper inspection of internal structure without removing the covering, or damaging the covering by cutting access holes.

Refer to AWB 51-1 for further guidance on fabric maintenance.

10. FURTHER INFORMATION

Very good articles on timber, plywood, adhesives and wooden aircraft construction can be found on the following websites for:

Recreational Aviation Australia at address www.raa.asn.au and
Sports Aircraft Association of Australia at address www.saaa.com.

11. Enquiries regarding this AWB

Enquiries about the content of Airworthiness Bulletins should be made via the direct link e-mail address included on the Airworthiness Bulletin web site, AirworthinessBulletin@casa.gov.au or in writing to:

Manufacturing, Certification and New Technologies Office.
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