Australian Government
Civil Aviation Safety Authority

Airworthiness Bulletin

AWB 02-011 Issue 2 - 19 March 2021

Timber, Plywood and Adhesives for Aircraft Use

An Airworthiness Bulletin is an advisory document that alerts, educates and makes recommendations about airworthiness matters. Recommendations in this bulletin are not mandatory.

1. Effectivity

Aircraft of wooden construction or which contain major components made from wood, such as wing spars.

2. Purpose

To provide basic guidance in summary form to assist properly authorised persons considering the substitution of structural wood, including plywood and adhesives specified in the approved data for an aircraft, and for the manufacture and maintenance of wooden aircraft structures.

Issue 2 has been published to clarify some aspects relating to timber, plywood and adhesives.

3. Background

CASA continues to receive enquiries related to the supply, use, maintenance and repair of wood and wood components for aircraft, and suitable adhesives for use with wood. Some enquiries relate to the use of indigenous timber and plywood as substitutes for the traditional or specified materials, including determining the structural integrity of the wood and the adhesives used in very old wooden aircraft.

Since aircraft wooden construction spans many years, a standard or specification previously used to construct an aircraft, while still relevant, may now be difficult to obtain or considered obsolete. References to a standard or specification in this Bulletin are provided to preserve the reference. CASA does not warrant availability.

3.1 Selection and Approval of wood (including indigenous timbers)

Those seeking to use a particular material should be able to demonstrate that it meets the applicable existing or an alternate approved specification. Further, an appropriately authorised person, such as a person authorised under CASA subpart 21M, should also be satisfied that that the material, when selected in accordance with such a specification, is satisfactory for the intended application and can therefore approve the use of such a material:

1) as a direct substitute for a traditional material

2) as a qualified substitution for a traditional material (e.g. to be used with extra thickness, or not to be used for particular applications).

3) using established design parameters to take advantage of any superior qualities.

4) using established design parameters to accommodate lesser strength materials.

The approved design and repair data for an aircraft will usually specify the type and characteristics of the wood, plywood and adhesives required for each application within the design.

Sometimes the wood type identified may be quite generic, e.g. “aircraft grade spruce”, “Grade A spruce”, “birch ply” etc. In the past, the Civil Aviation Safety Authority (CASA) previously issued some specifications for such timbers and plywood in the CAO 108 series, which have since been withdrawn.

CASA does not intend to issue particular specifications, as this could be unnecessarily restrictive. Neither does CASA normally approve materials or give an approval to an organisation to release timber under an Authorised Release Certificate. The onus, therefore, particularly with regard to amateur built aircraft, is on the end user to be satisfied that the timber meets the requirements of the approved design data.

The end user is entitled to use the material when satisfied that the documentation provided by the supplier states that the material meets the required specification and should perform his/her own inwards goods inspections and any tests required. Use of another timber and/or adhesive from that specified in the approved design data of a certificated aircraft requires approval by an appropriately authorised person to justify the change.

A number of emergency wartime specifications were issued in Australia during the Second World War to allow indigenous timbers such as:

- Hoop Pine,
- Bunya Pine,
- Queensland Maple,
- Bollywood, and
- Silver Quantong.

These examples can be used in aircraft structures, and these specifications are still relevant. Emergency wartime specification No. (E) 2D. 811-1944 listed various indigenous substitutes for Sitka spruce.

Much investigation was also done to define the properties of various woods and plywoods made from indigenous timbers for aircraft use. Examples include:

- Emergency wartime specification No. (E) D. 804-1934 for scented Satinwood (Coachwood) and Leatherwood,
- Emergency wartime specification No. (E) D. 812-1943 for Hoop Pine, and
- RAAF Engineering Hand Book; RAAF Publication No. 314. November 1944. (Section 2 WOOD).

3.2 Approved data for manufacture and repair

In addition to the data provided by aircraft manufacturers, there is considerable information now available in the public domain on wooden aircraft construction and maintenance, including:

- The Federal Aviation Agency (FAA) AC 43.13-1B "Acceptable Methods, Techniques and Practices", and
- CASA AWB 02-045 'Using FAA AC43.13-1B Change 1, and
- The United Sates Department of Defense (DoD) Bulletin ANC-18, AIR FORCE - NAVY - COMMERCE (ANC) BULLETIN: AIRCRAFT DESIGN CRITERIA - DESIGN OF WOOD STRUCTURES (JUN-1951).

These documents contain detailed information about the properties and use of various timbers, which can be used to develop approved data, and which may be downloaded from various websites.

3.3 Timber

When selecting and ordering wood, the end-user should reference the complete wood specification to ensure that is meets the design requirements for the intended application. All specifications involve visual grading of the timber for presence of defects, straightness of grain, tensile and compressive strength, and typically require that the density of the wood is within a specified range. Testing may be required to establish certain physical properties.

Timber is best for aircraft use when quarter sawn from the log. This is primarily because quarter sawn planks will be more stable, that is, less liable to develop defects such as warping, bowing or twisting. Due to the difficulty of finding good lengths of suitable timber stock today, shorter, high quality sections are frequently laminated to make the larger sections required for spars, or to obtain the length of wood required. Properly scarfed and/or laminated timber should be as good as a solid piece of the same the timber.

When ordering timber, it is usually best to specify the timber to be supplied at the finished dimensions, (refer para (3e) Dimensional & weight tolerances for replacement parts) because unacceptable internal defects are often discovered when re-sawing larger billets or flitches to the required finished dimensions.

Sawn timber, if not kiln dried, as received from the supplier, should be stored horizontally in the work area on racks with small wooden strips separating the pieces and with weights on the top plank (positioned over the separating strips) for a period of approximately two years, to allow air circulation and thereby moisture content (MC) to stabilise. Wood which exhibits warping or cupping, cracks or radial checks/cracks during or after this time should be rejected or, if possible, salvaged by further re-sawing.

Kiln dried sawn timber should be stored in the wood workshop area (in the same way as for non-kiln dried wood) for at least two weeks to allow the moisture content to stabilise before being used.

Stabilising the moisture content before use is particularly necessary when timber from the coastal regions (typically at 15% MC) is shipped inland (typically 8% MC). Refer wet/dry bulb and temperature tables for drying data. Often quality furniture manufactured in coastal regions, when shipped to inland Australia develops cracks after a while. Once the timber has stabilised at the local MC without cracking, it is less likely to crack when fabricated into the aircraft and protected with varnish.

Wooden aircraft of European origin were commonly constructed from Baltic Pine, which in most grades is slightly heavier and stronger than Spruce. Wooden aircraft of US origin are commonly constructed from Sitka Spruce or Douglas Fir. Spruce was traditionally selected to a specification such as the British 2V37 “Sitka Spruce as Finished Timber” and American MIL-S-6073.

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.

Density is a good indicator of strength, but if the wood intended to be used exceeds the required density by a significant margin, the aircraft or the component could end up being too heavy. The number of annual 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 rings per inch.

However, timber from temperate zones e.g. Queensland Hoop Pine often does not show a distinct ring growth pattern. It is also 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 important consideration is that the density and strength characteristics, including brittleness, are in accordance with the applicable specification.

Such 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 locating 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 those applications within the aircraft structure where impact loads are not anticipated, brittleness becomes less of 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 supplied (identified by batch number, type of wood, etc.) meets the required specification, and include the test results for the particular batch of wood supplied.

* *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.*

3.4 Plywood

Plywood should be carefully assessed with regard to the type of wood used and the thickness the face plies, the interior plies and the adhesive used to bond the plies to produce the composite, particularly in regard to structural strength and forming or bending. Be wary of inferior plywoods, which may have thin face plies and a much thicker, inferior core ply of a different species to the face plies to make up the specified thickness. Some inter-ply adhesives are not suited for bending.

Birch plywood has been commonly used where high strength and resistance to abrasion are required, and in applications where the plywood is to be bent. Plywood suitable for aircraft construction has typically been supplied to a specification such as:

- British Standards Institution (BSI) Specification BS 6V 3:1943 Specification for Aircraft Material,
- High Strength Plywood for Aircraft, or
- Germanische Lloyd (GL) GL3 which appears to have been superseded by Germanische Lloyd GL Rules II-2-2 Wooden Materials. Section 1 D refers to Plywood for Aircraft.
- Where a specification does not specify minimum allowable strength and elastic properties for plywoods (Typically at 15% MC), this data can be obtained from Table 2-13 of ANC-18, or other recognised sources.

Plywoods intended to be used in aircraft other than Birch use softer wood species and so are used for lesser strength applications, where resistance to buckling at minimum weight is desired. Plywoods such 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 plywood uses all quality plies of the same species.

Ensure that the specified thickness of the plywood has not been achieved using thin high-quality face plies bonded to a soft and thicker core ply to make up the thickness. Aggressive sanding of a face ply can have the same effect.

Also, aircraft plywoods should have plies which 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 plywood is often denser than aviation grade.

Hoop Pine plywood, for example, may be available in Australia, but users should be satisfied that it meets their requirements or is supplied against the emergency wartime specification for plywood. Where it is considered impractical to conduct impact tests on plywood logs, veneer or finished product, careful consideration should be given to brittleness, for example, if used in high impact areas such as landing gear attachments.

3.5 Dimensional & weight tolerances for 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’ and due to slight variations arising from being hand built by individuals. However, for new designs and for replacement parts, proper establishment of tolerances is essential. The following suggestions are given:

1) 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.
2) 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.
3) Many wooden parts must be fitted on the job, and to aircraft which did not have specified dimensional tolerances, so tolerances are not always relevant.
4) 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.
5) When dealing with laminated parts, the flatness and twist of the individual layers is critical, because glues are not intended to be gap fillers.
6) Considering how the density and weight of different woods may vary, a tolerance on weight might be expected.
7) 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.

3.6 Adhesives

As with other materials and processes, alternate adhesives to those specified by the manufacturer, designer or by other approved data for timber and plywood MUST be approved by a CASA 21M Authorised person or a CASA delegate. With regard to amateur aircraft construction the onus is on the end user i.e. the manufacturer or repairer to be satisfied that the adhesive is:

1) Suitable in the particular application, i.e. waterproof, non-elastic, not corrosive or destructive to the wood fibres, not subject to fungal attack etc.,
2) Specified by the aircraft or adhesive manufacturer as suitable for aircraft wood gluing,
3) Meets a suitably recognised standard,
4) Properly identified, including the specification provided in the documentation received with the adhesive,
5) Subjected to whatever goods inwards inspection and testing the user needs to be satisfied, and
6) Used in accordance with the adhesive manufacturer’s instructions with regard to shelf life, mixing instructions, spreading requirements, pot life, clamping requirements, temperature and humidity limitations, gap filling properties etc.

The following adhesives have been used for aircraft wood gluing:

- Resorcinol Formaldehyde Synthetic Resin Glue
- Urea Formaldehyde Synthetic Resin Glue (UF), and
- Epoxy resin Araldite AW 134 and Hardener HY 994.

> Note that with regard to the above, FAA AC 43.13-1B Chapter 1, states:
>
> "Federal Specification MMM-A- 181D and Military Specification MIL-A-22397 both describe a required series of tests that verify the chemical and mechanical properties of Resorcinol. Resorcinol is the only known adhesive recommended and approved for use in wooden aircraft structure and fully meets necessary strength and durability requirements. Resorcinol adhesive (resorcinol-formaldehyde resin) is a two-part synthetic resin adhesive consisting of resin and a hardener."
>
> "Plastic resin glue (urea-formaldehyde resin glue) has been used in wood aircraft for many years. Caution should be used due to possible rapid deterioration (more rapidly than wood) of plastic resin glue in hot, moist environments and under cyclic swell-shrink stress. For these reasons, urea-formaldehyde should be considered obsolete for all repairs."

CASA's predecessors prohibited acid catalysed phenolics (ACP) and urea formaldehyde (UF) adhesives in CAO 101.28 etc., and early Airworthiness Advisory Circular (AAC) articles stated that the acid in ACP glues is only a catalyst, which, after the glue cures, is free to be absorbed into and slowly attack the wood, and that ACP glues had been implicated in some accidents.

However, UF has been widely used in Australia for gliders and powered sailplanes, even though research had cast doubt on long term durability of UF glues, particularly under 'outdoor' conditions, as stated in AC 43-13 1B. While modern UF formulations may be considered to have, to some extent, overcome the problems of WWII UF's and some formulations may be more durable than others, all appear to suffer from exposure to weather.

Gliders and powered sailplanes previously constructed using UF should be stored in hangars or trailers, protected from the weather; severe climatic changes and subject to stringent structural inspections and rejected when loss of structural integrity is first detected.

Adhesive systems where the resin is put on one side of the joint and the hardener on the other side are not acceptable.

Resorcinol and epoxy glues cure to an inert compound and should not fail at the glue line under test. While Resorcinol is potentially stronger, it is very reliant upon good fit and clamp-up. Epoxy adhesives are generally more tolerant of assembly technique.

Casein glues have been widely used in the past but are now considered to be inferior when compared to the synthetic –resin adhesives which are currently available. Casein is made from milk proteins which are susceptible to temperature fluctuation and attack by micro-organisms when 'wet', including being exposed to the moisture in the air, and where the moisture content of the wood and adhesive is above 18% MC.

It should be noted that some modern adhesives are not compatible with casein glue. Where a casein glued joint is to be re-bonded with a different adhesive, all traces of the casein glue must first be removed before the new adhesive is applied, because residual casein or other adhesive may prevent the new adhesive from curing properly. Consideration should be given to the extent of penetration by casein glue into the fibres of the wood being re-glued. If there is any doubt about satisfactory removal of casein contamination, a repair scheme should be considered that allows for replacement of contaminated sections by scarf/insert etc.

More information on glues can be obtained at:

- British Civil Aircraft Airworthiness Information and Procedures CAP 562; Chapter 51 Standard Practices and Structures – General,
- Leaflet 51-10 Inspection of Wooden Structures and Leaflet 51-40 Synthetic Resin Adhesives, and
- Standard BS EN 301: 2006, entitled : 'Adhesives, Phenolic and Aminoplastic, for Load Bearing Timber Structures: Classification and Performance Requirements'

Users should understand and apply the correct techniques used in the applicable gluing process, including timber surface preparation for gluing, the need for 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. Good fit at all joints and proper clamping are essential to ensure the required thin glue line at joining surfaces.

It is crucial not to disturb the joint until the adhesive has cured or hardened. Full strength may not be developed until the temperature reaches the minimum cross-linking temperature. Ensure the joint is not 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.

The ‘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 glued structure, and to break the joints. There should be 100% wood fibre break. Fundamentally the glue should be lot stronger than the shear strength of the wood, so the glue should not break.

It is suggested that in addition to the test pieces made and destroyed during construction, that some glue joint samples made during the construction or repair of the aircraft are kept secure somewhere within the aircraft, in order to be later broken during destructive testing to determine the continuing integrity of the other glued joints in the aircraft structure which have been exposed to the same conditions, at say, 10, 15 and 20 years’ time in service - and even longer. While these samples can themselves be lightly glued into the aircraft, they should also be clearly identified in the aircraft’s maintenance records.

The only adhesives to be used for composite aircraft (including amateur built aircraft) for bonding foams, glass cloth, etc., are those specified on the drawing, or local alternatives endorsed by the designer.

3.7 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 recommended.

Adequate ventilation and drain holes must be provided in wooden aircraft structure to avoid fungal attack. Enclosed structures such as box spars are typically provided with some means of ventilation and/or drain holes for each bay to prevent moisture build-up and are to be kept clear. Rear fuselage frames and wing ribs should have functional drain passages to prevent water collecting. Metal parts can corrode, especially if they are in contact with wood with high moisture content.

Some designers specify fabric covering over the plywood to protect the plywood. Traditionally this was cotton based fabric (Madapolam) with dope squeezed through to the undelaying wood 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.

3.8 Ageing aircraft issues

In general, wood does not have a fatigue life limit, and if properly looked after, i.e. properly preserved and stored, not subjected to abuse, overload or contamination, will last indefinitely. The metal attaching parts and through bolts, however, may well have fatigue lives and could be subject to corrosion, particularly if in contact with moist or wet timber.

If an aircraft of wooden construction is left out in the rain, it is recommended to check for water ingress and retention, particularly in the trailing edges of wings, at the bottom of the fuselage behind frames, and to check for corroded metal parts.

Through bolts in wooden structure should be periodically removed and inspected. Any corrosion on the bolt is usually associated with the adjacent wood being stained and the likelihood of wood decay in the bolt hole, adjoining wood structure or the wood under a fitting. The need for adequate sealing around bolts and fittings, drainage and internal ventilation of the structure cannot be overemphasised, particularly with box spar structures.

Adhesives can deteriorate, and although modern adhesives are far superior to pre-1945 glues, nevertheless, the integrity of the adhesive should be checked during periodic maintenance and following unusual loads. Ways to achieve this include:

1) Overall critical inspection of the aircraft - e.g. flexing the wing or other structure, looking for detached ribs, tapping joints to determine if there is any movement or disbonding.
2) Using a thin feeler gauge to detect edge separation at patches packings, gussets, and reinforcing ply repairs and spliced joints.
3) A thin sharp knife inserted into a joint to see if the joint pops apart.
4) Breaking the samples left in the aircraft and/or stored with and identified in the aircraft maintenance records for 100% wood fibre break as discussed in Paragraph (3f).
5) Proof load tests.

Particular attention should be paid to the continuing integrity of old aircraft glued with casein because 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 closely monitored for continued adhesive integrity.

Although having been prohibited for a long time, it is possible that some Pre-1945 vintage aircraft have been glued with acid catalysed phenolics (ACPs). Many aircraft constructed using ACPs were condemned in the 1950s, but examples from that era still might be re-discovered and 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 dope and fabric deteriorated with time, especially for aircraft stored outside. When the fabric was removed to re-cover the aircraft at an interval sometimes as low as 5-10 years, it provided a good opportunity to thoroughly inspect the internal wood structure.

However, modern synthetic fabrics are lasting 20 or 25 years and even longer - before needing replacement. 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 repeated cutting and patching access holes.

4. Recommendations

1. Obtain the approval of an appropriately authorised person before using materials other than those identified in the approved data for a certificated aircraft.
2. Ensure all wood, including plywood, which is intended to be used, meets the applicable specification for the particular species of wood because batches of timber of the same accepted species can vary.

3. Observe the precautions associated with the selection and use of adhesives in accordance with the manufacturer's data for that product. Alternative Adhesives must be approved.
4. Identify the adhesive used in the construction of an aircraft to ensure appropriate maintenance actions and continuing airworthiness of the structure.
5. Store wooden aircraft out of the weather and limit exposure to temperature and moisture extremes and cycles.
6. Periodically inspect wooden structure in accordance with approved data and particularly following sudden impact/overload resulting from unusual flight attitudes or manoeuvres, turbulence or heavy landings

5. Reporting

Report defects in relation to wood, wooden structure, hardware and adhesives to CASA via the Defect Reporting Service.

6. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link email address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

Airworthiness and Engineering Branch
Aviation Group
Civil Aviation Safety Authority
GPO Box 2005, Canberra, ACT, 2601