AD-A161 921 FLEXURAL PROPERTIES OF CARBON FIBRE CLOTH/WOOD VENEER LAMINATES(U) ROYAL AIRCRAFT ESTABLISHMENT FARNBOROUGH (ENGLAND) J H SEWELL APR 85 RAE-TM-MAT-STR-1055 1/1

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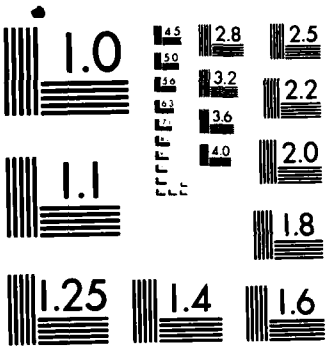

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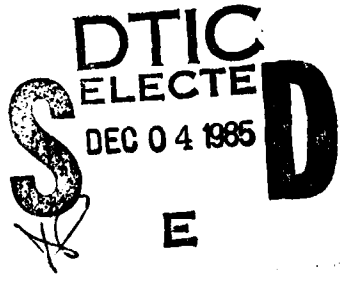

Procurement Executive, Ministry of Defence
Farnborough, Hants

ROYAL AIRCRAFT ESTABLISHMENT

Technical Memorandum Mat/Str 1055

Received for printing 17 April 1985

FLEXURAL PROPERTIES OF CARBON FIBRE CLOTH/WOOD VENEER LAMINATES

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SUMMARY

Flexural tests have been made on epoxy or phenolic resin bonded hybrid laminates comprising carbon fibre cloth outer layers on wood veneer cores. Breaking loads and stiffnesses of many of the hybrids exceed those of all carbon fibre cloth laminates of the same weight per unit area of panel. This improvement in flexural properties can be accompanied by a significant decrease in materials costs owing to the replacement of expensive carbon fibre cloth by cheap wood veneers. Significant weight savings may be achieved if carbon fibre laminates are replaced by hybrid laminates having the same flexural breaking strengths or stiffnesses.

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1 INTRODUCTION

During studies of emergency repairs to metal aircraft skins, thin wood veneers were considered for bridging holes to act as supporting layers during subsequent application of wet laminated carbon fibre cloth reinforcements over the damaged areas. As the carbon fibre reinforced patch was bonded to the wood veneer substrate after resin cure, it was decided to examine the properties of composite materials consisting of carbon fibre cloth layers on one or both sides of wood veneer cores. Flexural moduli and breaking strengths were measured because of the simplicity of test specimen preparation and because these are important mechanical properties of flat panels. Initial experiments showed that, with carbon fibre cloth on both sides of the wood veneer layers, promising specific breaking strengths and stiffnesses in flexure were achieved. Further experiments on a range of laminates were therefore made. Results are reported for laminates manufactured with carbon fibre cloth, epoxy or phenolic resins and various wood veneers.

2 MATERIALS

Wood veneers, used as received, were 0.6 ± 0.03mm thick crown mahogany, striped mahogany, plain walnut, plain oak and 1 ± 0.04mm thick veneers of Honduras mahogany and beech. The carbon fibre cloth used mostly was five-shaft satin weave (1/7) 0.3 mm thick but a few specimens were made using 0.32mm thick 2/2 twill weave cloth.

Four different thermosetting resin schemes were used for making laminates; these were:

(a) Shell Epikote 828 epoxy resin with Ancamine AC hardener mixed in proportions of two parts of resin to one of hardener by weight. The pot life at 22°C was about 10 min.

(b) Ciba-Geigy Araldite LY 1927 GB epoxy resin (100 parts by weight) with hardener HY 1927 GB (36 parts by weight). The pot life at 22°C was about 40 min.

(c) Synthetic Resins Ltd, Uravar 1519 phenolic resin. This resin is less toxic on burning than the epoxy resins.

(d) Micanite and Insulators Co Ltd, Tego glue film. This is a 0.1mm thick phenolic resin film adhesive.

Tygaflor sheet was used as a release material during moulding of laminates.

3 PREPARATION OF SPECIMENS

Wood veneers were cut into pieces measuring 100 mm × 75 mm with the grain parallel to either the long or short side. Carbon fibre cloth was cut into somewhat larger pieces for ease of manipulation and was impregnated with Epikote 828 or Araldite 1927 resin schemes by stippling with a stiff brush. A brush coat of resin was applied to each wood veneer surface and the various layers laid up in sequences detailed in Tables 1 to 3. The carbon fibre cloth was arranged so that the warp satin side was visible with the warp direction parallel to the long side of the wood veneer. Each lay-up was placed on a vacuum table for ½ h at atmospheric pressure; specimens made with Epikote 828 resin were then cured by heating at 60°C for 2 h under a light load (approximately 7 kPa) to

prevent buckling. Araldite 1927 laminated specimens were allowed to continue to gel for 16 h and were then lightly loaded (as for Epikote 828) and heated at 60°C for 2 h immediately followed by 80°C for a further 2 h.

Carbon fibre cloth brushed with Uravar phenolic resin solution was placed in an oven at 120°C for 5 min to evaporate solvents. Wood veneer surfaces were brushed with Uravar solution and placed on a vacuum table under atmospheric pressure for 2 min to remove solvents. This process was repeated and the wood and/or carbon fibre cloth layers stacked in a press in sequences shown in Table 4 and heated at 150°C and compressed at 6.895×10^3 kN m^{-2} (1000 lb in^{-2}) for 30 min. The specimens were cooled under pressure to prevent deformation.

Wood veneer and/or carbon fibre cloth layers were stacked in the press in sequences given in Table 4 with one layer of Tego phenolic film adhesive between each reinforcing layer and, when carbon fibre cloth was used, with one film layer on each outer laminate surface. The layers were compressed at 5.171×10^3 kN m^{-2} (750 lb in^{-2}) at 150°C for 10 min and cooled under pressure.

4 METHODS OF TESTING

Densities of laminates were calculated from their weights and dimensions after trimming; the immersion method was not used because of the need to keep the specimens free from any contamination and in a standard physical state. The laminates were then cut into strips 100 mm long and approximately 18 mm wide; in Tables 1 to 4, vertical arrows denote that the wood grain in the test specimen is parallel to the long edge of the strip. The specimens were tested in three-point bending (77 mm span) on an Instron machine at a cross-head speed of 5 mm/min until failure occurred. Span/depth ratios were between 25:1 and 60:1 and failure times were between 60 and 150 s; a span/depth ratio of 40:1 has been recommended[1] for flexural strength measurements on carbon fibre reinforced plastics with times to failure between 30 and 180 s.

5 RESULTS

Densities, flexural moduli and flexural breaking strengths of laminates are given in Tables 1 to 4. In general, the results quoted are average values for four specimens cut from each laminate. However, for laminate types 1 and 3, five different panels were made on different days and a total of 25 specimens tested, while for laminate types 2 and 4, four different panels were made and 20 specimens tested.

The flexural modulus, M , was calculated from the linear part of the load/deflection curve:

$$M = \frac{s^3 b}{4at^3 d} \quad . \tag{1}$$

The breaking strength, F , was calculated from the maximum load at failure:

$$F = \frac{3ws}{2at^2} \quad . \tag{2}$$

In both formulae, s = span (77 mm), b = load to give deflection, d , w = load at failure, a = width, t = thickness.

A method of calculating percentage weight savings gained by substituting hybrid laminates for carbon fibre laminates of equivalent flexural breaking strengths or beam deflections under the same load was derived from equations (1) and (2) and is given in Appendix A. The weight savings, calculated from results in Tables 1 to 3, are given in Table 5. Relative stiffnesses and breaking loads of laminates having the same weight per unit surface area were calculated as shown in Appendix B and are given in Table 6. These methods of comparison assume that the flexural strengths and moduli of the carbon fibre laminates are independent of thickness.

5 DISCUSSION

Tables 1 to 4 show that, in most cases, the values of flexural strength and modulus were greater for the carbon fibre laminates than for the wood veneer or hybrid carbon fibre/wood veneer laminates. However, significant weight savings could be achieved by replacing carbon fibre laminates with hybrid laminates having the same flexural breaking strengths or stiffnesses (Table 5). When carbon fibre and hybrid laminates of the same weight were compared, relatively high values of flexural breaking strength and stiffness were generally obtained for the hybrid laminates (Table 6). In a number of comparisons where this effect was observed, *eg*, specimens 1 and 3, 25 and 29, 31 and 35, the hybrid laminate was almost exactly the same weight as the carbon fibre laminate with which it was compared. For laminates 1-4, the use of Bartlett's test[2] showed that the breaking strength data obtained for different panels of the same laminate type, made on different days, could be regarded as coming from a single population. Student's t values[2] showed that the differences between the flexural strengths of carbon fibre and hybrid laminates of the same weight per unit area were significant (99.9% probability for laminates 1 and 3 and 90% probability for laminates 2 and 4). The hybrid laminates are thicker than the carbon fibre laminates of the same weight, so the relatively good flexural stiffness and strength of the former are to be expected.

When laminated with epoxy resins, the flexural breaking strengths of hybrid laminates generally decreased with increase in the number of wood veneer layers (Tables 1 and 3). This observation does not apply to laminates made with phenolic resins (Table 4). Laminate stiffness tended to decrease with increase in the number of wood veneer layers for both epoxy and phenolic resins. Further work is required to establish the reasons for these variations in properties.

Nearly all the carbon fibre specimens failed catastrophically on the tension surface, either snapping completely or partially breaking with some delamination. However, almost all of the hybrid specimens failed when the carbon fibre layer on the compressive surface buckled in the immediate vicinity of the application of the load and the specimen remained intact with significant residual strength. This effect does not appear to be a strong function of the specimen span/depth ratio; whilst carbon cloth laminates, *eg*, specimen 2, failed catastrophically on the tension surface hybrids thinner than specimen 2, *eg*, specimens 5, 8, 11 and 14, failed in the same way as hybrids thicker than

specimen 2, *ie*, in compression. Of the epoxy resins used, Araldite 1927 gave slightly stiffer and stronger carbon fibre laminates than Epikote 828. Nevertheless, the data obtained for laminates 15 and 31 (see Tables 1 and 3) show that the properties of hybrid laminates made with Epikote 828 could compare favourably with those of carbon fibre laminates made with Araldite 1927. Carbon fibre laminates made with Uravar 1519 were very stiff but not as strong as those made with the epoxy resins and carbon fibre laminates made with Tego glue film were much weaker.

Table 4 shows that carbon fibre cloth wet laminated on the faces of beech wood veneer with phenolic resin (Uravar 1519) stiffened the wood on a comparative weight basis but had little effect on the relative breaking strengths, *eg*, compare laminates 40 and 43, 42 and 45. These samples failed during bending when the carbon fibre layer under compression parted from the wood; poor interlaminar strength was also the cause of failure of the phenolic resin carbon fibre cloth laminates. However, a hybrid laminate bonded with a combination of Uravar 1519 and Tego glue film (laminate 48) had superior strength and stiffness for the same weight per unit area compared with laminate 40 (Uravar 1519 only) mainly because of the low density of the wood inner layers when bonded only with Tego glue film. Hybrids bonded with Tego glue film only (laminates 49 and 50) were much stiffer and stronger for the same weight than the corresponding carbon fibre laminate 46; the corresponding wood laminates 51 and 52, because of their relatively low densities, were also superior to the carbon fibre laminate 46 when the properties of specimens of identical weight were compared (Table 6). Striped mahogany, which has an interlocked grain, and walnut veneers gave, in general, the best relative strength and stiffness in hybrid wood veneer/carbon fibre laminates compared with the other wood veneers tested. Resins penetrated the wood veneers, to varying degrees; striped mahogany veneers were readily impregnated, *eg*, the epoxy resins completely penetrated a 0.5mm thick veneer within 1 min on the vacuum table.

The degree of resin impregnation will obviously influence water diffusion into the wood and this needs to be studied further.

The principle of using thin high strength skins and low density core materials to produce light structures of relatively high stiffness is well known; various forms of honeycomb sandwich constructions have been used for aircraft application for many years. Balsa wood and various foams have also been used successfully as lightweight core materials. The present work has shown that wood veneers can be used as core materials to readily manufacture thin (1.5 to 4mm) carbon fibre/wood veneer laminates having relatively high flexural properties. Ease of penetration of wood veneers by laminating resins can result in good resistance to interlaminar failure. A further attraction of wood veneers is their low cost. However, further work is required to establish whether other properties of the hybrid laminates are satisfactory, *eg*, information regarding water absorption and long term properties must be obtained.

7 CONCLUSIONS

Various hybrid carbon cloth/wood veneer laminates have been manufactured using epoxy or phenolic resins. Weight savings could be achieved by replacing carbon fibre

laminates with hybrid laminates having the same flexural breaking strengths or stiffnesses. Many of the hybrid laminates exhibited flexural stiffness and strength properties which were significantly better than those obtained for equivalent carbon fibre laminates of the same weight per unit area of panel. The flexural properties depended on the wood veneer, laminating resin and detailed lay-up. Materials costs of hybrid panels are substantially less than those of carbon fibre laminates of the same weight. Further work is required to assess long term properties, particularly the effects of exposure to humid atmospheres; other mechanical properties also need to be studied.

Acknowledgment

The author wishes to thank Delcy Moore for making many of the specimens described in this Memorandum and for assisting in their evaluation. Thanks are also due to Mr J.B.Cameron of Permali Ltd, for the supply of beechwood veneers and phenolic resin and Tego glue film samples.

Appendix A

COMPARISON OF WEIGHTS OF PANELS HAVING SAME FLEXURAL PROPERTIES

A.1 Relative panel weights for same flexural breaking load

$$F = \frac{3ws}{2at^2} ,$$

where F = flexural breaking strength,
w = load at failure,
s = span of beam,
a = width of beam
and t = beam thickness.

Let reference panel (normally carbon fibre) be denoted by suffix 1.

Let panel for comparison be denoted by suffix 2.

Under identical conditions,

$$F_1 = K\frac{w_1}{t_1^2} , \qquad F_2 = K\frac{w_2}{t_2^2} ,$$

where K is constant $\left(\frac{3s}{2a}\right)$

therefore $w_1 = \frac{F_1 t_1^2}{K}$ and $w_2 = \frac{F_2 t_2^2}{K}$,

when

$$w_1 = w_2 , \qquad F_1 t_1^2 = F_2 t_2^2 .$$

For unit area of panel,

$$\rho_1 = \frac{m_1}{t_1} ,$$

where ρ = density
and m = panel weight,

therefore $t_1 = \frac{m_1}{\rho_1}$ and $t_2 = \frac{m_2}{\rho_2}$,

therefore $$F_1\left(\frac{m_1}{\rho_1}\right)^2 = F_2\left(\frac{m_2}{\rho_2}\right)^2 ,$$

therefore $$\frac{m_2}{m_1} = \frac{\rho_2}{\rho_1}\left(\frac{F_1}{F_2}\right)^{\frac{1}{2}} .$$

A.2 Relative panel weights for same deflection under same load

$$M = \frac{s^3 b}{4at^3 d} ,$$

where M = flexural modulus,
s = span of beam,
b = load,
a = width of beam,
t = beam thickness
and d = deflection of beam under load b .

For the same load, b , and under identical testing conditions,

$$M_1 = \frac{K}{t_1^3 d_1} \quad \text{and} \quad M_2 = \frac{K}{t_2^3 d_2} ,$$

where K is constant $\left(\frac{s^3 b}{4a}\right)$

therefore $$d_1 = \frac{K}{t_1^3 M_1} \quad \text{and} \quad d_2 = \frac{K}{t_2^3 M_2} ,$$

when

$$d_1 = d_2 , \qquad M_1 t_1^3 = M_2 t_2^3 ,$$

therefore $$M_1\left(\frac{m_1}{\rho_1}\right)^3 = M_2\left(\frac{m_2}{\rho_2}\right)^3 ,$$

therefore $$\frac{m_2}{m_1} = \frac{\rho_2}{\rho_1}\left(\frac{M_1}{M_2}\right)^{1/3} .$$

Table 1

FLEXURAL PROPERTIES OF SATIN WEAVE CARBON FIBRE CLOTH, CARBON FIBRE CLOTH WOOD VENEER AND WOOD VENEER LAMINATES

F = 1/4 satin weave carbon fibre cloth layer
M = Honduras mahogany layer
C = Crown mahogany layer
W = Walnut layer
O = Plain oak layer
S = Striped mahogany layer

Arrows indicate grain direction.

Laminated with Shell Epikote 828 resin/Ancamine AC hardener, 2:1

Laminate number	Lay-up	Average thickness (mm)	Density ($g\ cm^{-3}$)	Flexural modulus ($kN\ cm^{-2}$)	Flexural breaking strength ($kN\ cm^{-2}$)
1	F/F/F	1.24	1.324	4300	54 (5.9)
2	F/F/F/F	1.70	1.315	4400	61 (5.7)
3	F/M/F ↑	1.89	0.946	3400	35 (4.6)
4	F/M/M/F ↑→	2.84	0.830	2600	27 (3.7)
5	F/W/F ↑	1.46	1.040	3800	53
6	F/W/W/F ↑→	2.26	0.940	3300	35
7	F/W/W/W/F ↑→↑	2.79	0.930	2900	32
8	F/O/F ↑	1.50	1.080	3500	49
9	F/O/O/F ↑→	1.98	1.00	4000	42
10	F/O/O/O/F ↑→↑	2.71	0.97	3100	37
11	F/C/F ↑	1.40	1.080	3800	52
12	F/C/C/F ↑→	2.77	0.880	2800	26
13	F/C/C/C/F ↑→↑	2.81	0.940	2700	34
14	F/S/F ↑	1.40	1.140	4500	58
15	F/S/S/F ↑→	1.86	0.960	4200	46

Table 1 (concluded)

FLEXURAL PROPERTIES OF SATIN WEAVE CARBON FIBRE CLOTH, CARBON FIBRE CLOTH WOOD VENEER AND WOOD VENEER LAMINATES

Laminate number	Lay-up	Average thickness (mm)	Density ($g\ cm^{-3}$)	Flexural modulus ($kN\ cm^{-2}$)	Flexural breaking strength ($kN\ cm^{-2}$)
16	F/S/S/S/F ↑→↑	2.28	1.050	3500	39
17	S/S/S ↑↑↑	1.66	0.840	1200	14
18	S/S/S ↑→↑	1.70	0.841	1200	11
19	S/S/S (wood dried) ↑→↑	1.66	0.850	1300	15
20	S/S/S/S ↑↑↑↑	2.16	0.860	1300	15
21	S/S/S/S ↑→→↑	2.29	0.815	1100	10
22	S/S/S/S ↑→↑→	2.20	0.828	700	9
23	S/S/S/S/S ↑→↑→↑	2.80	0.838	1000	11

Note: For laminates 1-4, values of standard deviations for flexural breaking strengths are given in brackets.

Table 2

FLEXURAL PROPERTIES OF TWILL WEAVE CARBON FIBRE CLOTH AND CARBON FIBRE CLOTH/WOOD VENEER LAMINATES

F = 2/2 twill weave carbon fibre cloth layer
C = Crown mahogany layer
S = Striped mahogany layer
W = Walnut layer
O = Plain oak layer

Arrows indicate grain direction

Laminated with Shell Epikote 828 resin/Ancamine AC hardener, 2:1

Laminate number	Lay-up	Average thickness (mm)	Density ($g\ cm^{-3}$)	Flexural modulus ($kN\ cm^{-2}$)	Flexural breaking strength ($kN\ cm^{-2}$)
24	F/F/F	1.20	1.29	4200	54
25	F/F/F/F	1.67	1.32	3900	54
26	F/W/W/F ↑→	2.06	0.97	3400	37
27	F/O/O/F ↑→	1.91	0.98	3500	33
28	F/C/C/F ↑→	1.78	1.01	3800	24
29	F/S/S/F ↑→	2.02	1.01	3400	39

Table 3

FLEXURAL PROPERTIES OF SATIN WEAVE CARBON FIBRE CLOTH AND CARBON FIBRE CLOTH/WOOD VENEER LAMINATES

F = 1/4 satin weave carbon fibre cloth layer W = Walnut layer

S = Striped mahogany layer O = Plain oak layer

Arrows indicate grain direction

Laminated with Ciba Geigy Araldite LY1927GB resin/HY1927GB hardener 100:36

Laminate number	Lay-up	Average thickness (mm)	Density ($g\ cm^{-3}$)	Flexural modulus ($kN\ cm^{-2}$)	Flexural breaking strength ($kN\ cm^{-2}$)
30	F/F/F	1.02	1.328	5700	75
31	F/F/F/F	1.48	1.336	4800	67
32	F/W/W/W/F ↑→↑	2.71	0.928	3100	32
33	F/O/O/F ↑→	1.96	1.040	3700	42
34	F/O/O/O/F ↑→↑	2.68	0.981	3100	31
35	F/S/S/F ↑→	1.76	1.130	4200	48
36	F/S/S/S/F ↑→↑	2.38	0.998	3400	27

Table 4

FLEXURAL PROPERTIES OF SATIN WEAVE CARBON FIBRE CLOTH, CARBON FIBRE CLOTH/BEECH WOOD VENEER AND BEECH WOOD VENEER LAMINATES

F = 1/4 satin weave carbon fibre cloth layer B = Beech wood veneer layer

Laminated with Uravar 1519 phenolic resin and/or Tego glue film

Laminate number	Lay-up	Laminating resin	Average thickness (mm)	Density ($g\ cm^{-3}$)	Flexural modulus ($kN\ cm^{-2}$)	Flexural breaking strength ($kN\ cm^{-2}$)
37	F/F/F/F	Uravar 1519	0.83	1.509	9000	57
38	F/F/F/F/F	"	1.01	1.529	8200	37
39	$[F/]_{10}$	"	1.86	1.511	7400	42
40	F/B/B/B/F ↑ → ↑	"	2.51	1.219	4100	29
41	F/B/B/B/B/F ↑ → ↑ →	"	2.84	1.246	3400	26
42	F/B/B/B/B/B/F ↑ → ↑ → ↑	"	3.34	1.250	3500	28
43	B/B/B ↑ → ↑	"	2.06	1.160	2200	24
44	B/B/B/B ↑ → ↑ →	"	2.44	1.140	1200	18
45	B/B/B/B/B ↑ → ↑ → ↑	"	3.26	1.136	1800	22
46	$[F/]_{7}$	Tego glue film	1.80	1.464	4500	18
47	F/B/B/F ↑ →	B layers Tego-bonded F layers Uravar-bonded	1.69	1.315	5000	20
48	F/B/B/B/F ↑ → ↑	"	2.76	1.032	4100	32
49	F/B/B/B/F ↑ → ↑	Tego glue film	3.15	0.944	2000	21

Table 4 (concluded)

FLEXURAL PROPERTIES OF SATIN WEAVE CARBON FIBRE CLOTH, CARBON FIBRE CLOTH/BEECH WOOD VENEER AND BEECH WOOD VENEER LAMINATES

F = 1/4 satin weave carbon fibre cloth layer B = Beech wood veneer layer

Laminated with Uravar 1519 phenolic resin and/or Tego glue film

Laminate number	Lay-up	Laminating resin	Average thickness (mm)	Density ($g\ cm^{-3}$)	Flexural modulus ($kN\ cm^{-2}$)	Flexural breaking strength ($kN\ cm^{-2}$)
50	F/B/B/B/B/B/F ↑ →↑ →↑	Tego glue film	4.86	0.861	1400	21
51	B/B/B ↑ →↑	"	2.62	0.863	1400	13
52	B/B/B/B/B ↑ →↑ →↑	"	4.40	0.828	1300	13

Table 5

WEIGHT SAVINGS OBTAINED BY REPLACING CARBON FIBRE LAMINATES WITH HYBRID LAMINATES HAVING THE SAME FLEXURAL PROPERTIES

Table number	Laminate number	Weight saving for same flexural breaking load (per cent)	Weight saving for same deflection of specimen beam under same load (per cent)
1	1	Reference carbon fibre laminate	
	3	11	23
	5	21	18
	8	14	13
	11	17	15
	14	17	15
1	2	Reference carbon fibre laminate	
	4	5	25
	6	6	21
	7	2	19
	9	8	22
	10	5	17
	12	-3	22
	13	4	16
	15	16	26
	16	0	14
2	25	Reference carbon fibre laminate	
	26	11	23
	27	5	23
	28	-15	23
	29	10	20
3	31	Reference carbon fibre laminate	
	32	0	20
	33	2	15
	34	-7	15
	35	0	12
	36	-18	16

Table 6

COMPARISON OF FLEXURAL PROPERTIES OF LAMINATES HAVING IDENTICAL WEIGHTS

Table number	Laminate number	Relative flexural breaking load	Relative deflection of specimen beam under same load
1	1	1	1
	3	1.28	0.47
	5	1.61	0.55
	8	1.35	0.67
	11	1.43	0.62
	14	1.45	0.61
1	2	1	1
	4	1.11	0.43
	6	1.12	0.49
	7	1.04	0.55
	9	1.19	0.49
	10	1.10	0.58
	12	0.95	0.48
	13	1.10	0.61
	15	1.42	0.41
	16	1.00	0.64
2	25	1	1
	26	1.27	0.45
	27	1.10	0.45
	28	0.77	0.47
	29	1.24	0.51
3	31	1	1
	32	0.99	0.51
	33	1.01	0.62
	34	0.85	0.60
	35	1.00	0.70
	36	0.72	0.59
4	38	1	1
	40	1.22	1.01
	41	1.06	1.30
	42	1.11	1.29
	43	1.11	1.61
	44	0.88	2.76
	45	1.06	1.89
	47	0.74	1.04
	48	1.86	0.60

Table 6 (concluded)

COMPARISON OF FLEXURAL PROPERTIES OF LAMINATES HAVING IDENTICAL WEIGHTS

Table number	Laminate number	Relative flexural breaking load	Relative deflection of specimen beam under same load
4	46	1	1
	49	2.87	0.60
	50	3.32	0.64
	51	2.00	0.69
	52	2.32	0.67
1&3	31	1	1
	2	0.94	1.02
	4	1.05	0.44
	6	1.04	0.51
	9	1.02	0.50
	15	1.33	0.42

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No.	Author	Title, etc
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5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
7673000W	Royal Aircraft Establishment, Farnborough, Hants, UK
5a. Sponsoring Agency's Code	6a. Sponsoring Agency (Contract Authority) Name and Location
N/A	N/A

7. Title Flexural properties of carbon fibre cloth/wood veneer laminates

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Sewell, J.H.			April 1985	20	2

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.

15. Distribution statement

(a) Controlled by – Head of Materials & Structures Department, RAE

(b) Special limitations (if any) –

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16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Carbon fibre* Wood veneers* Flexural properties

17. Abstract

Flexural tests have been made on epoxy or phenolic resin bonded hybrid laminates comprising carbon fibre cloth outer layers on wood veneer cores. Breaking loads and stiffnesses of many of the hybrids exceed those of all carbon fibre cloth laminates of the same weight per unit area of panel. This improvement in flexural properties can be accompanied by a significant decrease in materials costs owing to the replacement of expensive carbon fibre cloth by cheap wood veneers. Significant weight savings may be achieved if carbon fibre laminates are replaced by hybrid laminates having the same flexural breaking strengths or stiffnesses.

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