MEMOIRS OF THE FACULTY OF ENGINEERING
FUKUI UNIVERSITY
VOL. 25 No. 1 1977

A Study on the Thin Plate with Carbon Fiber Reinforced Hybrid Composite

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(Received Dec. 8 , 1976)

In this paper we describe an experimental study, this article is to report fundamental data of constructions attained by carbon fiber reinforced hybrid composite of 0.9mm in thickness whose resin base was reinforced. As a result of this series of test and experiments, it was found that; it is possible to attain reinforced resin base of hybrid composite of C.F.R.P. 16 times as much in rigidity against bending load as compared with that of single construction was observed with composite of 0.9mm lamina. It was found that sandwich construction of C.F.R.P. is superior, while, in the case of canapé construction, it was found necessary to have C.F.R.P. on the tension side. G.F.R.P. has possibility to be reinforced composite material, although it is considerably less superior to C.F.R.P.

1. INTRODUCTION

Attempts have been made to laminate and mold further the F.R.P. and to hybrid the same.[1)~5)] It is necessary to attain hybrid composite constructions which correspond to stress distribution. This article is to report fundamental data of constructions attained by carbon fiber reinforced hybrid composite of 0.9mm in thickness whose resin base was reinforced. Namely, sandwich construction and canapé construction were made to seek for bending character required for resin base, and possibility of reinforced resin base of hybrid composite of C.F.R.P. was sought for by means of static bending test.

2. EXPERIMENTAL MATERIALS

Experimental materials were made of carbon fiber (T300), or carbonized acrylic fiber (more than 250kg/mm^2 in strength and more than 22ton/mm^2

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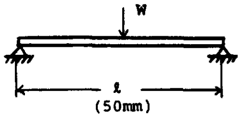
Table 1 General properties of carbon fiber reinforced prepreg.

Tensile strength (kg/mm^2), fiber direction	140
Tensile elastic modulus (ton/mm^2), fiber direction	13
Bending strength (kg/mm^2), fiber direction	140
Bending elastic modulus (ton/mm^2), fiber direction	13
Compressive strength (kg/mm^2), fiber direction	100
Compressive elastic modulus (ton/mm^2), fiber direction	13
Poisson's ratio	0.3
Interlaminar shearing strength (kg/mm^2)	8
Izod impact value (kg·cm/cm·notch)	110
Bending creep (80% load of average strength), fiber direction	below 10% of static strain for 500 hr
Bending creep fracture strength (for 500 hr), fiber direction	above 80% of static strength
Tensile fatigue strength (10^7cycles)	above 60 kg/mm^2
Rockwell hardness (E scale)	90
Barcol hardness	70
Coefficient of friction (parallel to fiber)	0.25
PV value ($kg/cm^2 \cdot m/min$)	1000
Steady abrasion modulus (PV=500) ($mg/hr \cdot cm^2$)	2
Heat conductivity (Kcal/m/h/°c), fiber direction	4
Heat conductivity (Kcal/m/h/°c), normal to fiber	0.40
Coefficient of linear expansion (/°c), fiber direction	-1×10^{-7}
Coefficient of linear expansion (/°c), normal to fiber	35×10^{-6}
Specific heat (cal/g/°c)	0.16
Specific resistance of volume (Ω·cm), fiber direction	0.005
Specific resistance of volume (Ω·cm), normal to fiber	5.7

Carbon fiber content ratio: 60%vol (after hardening)
Condition of hardening : 170 °c 1 hr, post cure
170 °c 2 hr

in elastic modulus) (3,000 filaments) as a base (57 wt.%), Prepreg P301 (epoxy resin 828, Shell Chemical Co., hardener BF_3-MEA) as reinforced layer, and P.M.M.A. as matrix. Reinforced layer and matrix were adhesionbonded each other. Table 1[6] shows general properties of carbon fiber reinforced prepreg used for the experiments, while Fig.1 and Table 2 shows base material construction of hybrid laminated sheet. Incidentally, epoxy resin prepreg with glass fiber (E-type, 200 filaments) as a base was also used together with carbon fiber reinforced prepreg. P.M.M.A. was denture acrylic (SHOFU) "Bio" resin.



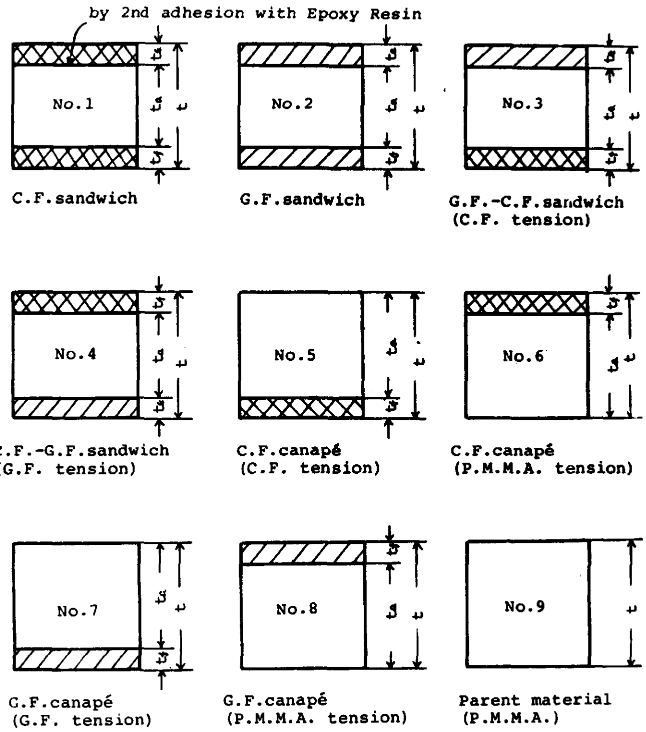


Fig.1 Constitution and dimension of hybrid composite construction.

Table 2 Dimension of specimen.

specimen	t_c (mm)	t_a (mm)	t_f (mm)	t (mm)	width,b (mm)
No.1:C.F.sandwich	0.25	0.38	0.25	0.95	10.35
No.2:G.F.sandwich	0.17	0.45	0.17	0.86	10.30
No.3:G.F.-C.F.sandwich (C.F. tension)	0.17	0.37	0.25	0.88	10.00
No.4:C.F.-G.F.sandwich (G.F. tension)	〃	〃	〃	〃	〃
No.5:C.F.canapé (C.F. tension)		0.63	0.25	0.91	10.15
No.6:C.F.canapé (P.M.M.A. tension)		〃	〃	〃	〃
No.7:G.F.canapé (G.F. tension)		0.75	0.17	0.94	10.60
No.8:G.F.canapé (P.M.M.A. tension)		〃	〃	〃	〃
No.9:P.M.M.A.				0.91	10.00

3. EXPERIMENTAL RESULTS AND CONSIDERATION

Fig.2 shows results of experiments made with each specimen with a view to find relationship between bending stress and deflection. There are very distinct difference among sandwich, canapé and single constructions, and the fact that rigidity of composite is big is found in lamina of denture base. Sandwich, canapé and single construction are in the order of rigidity superiority. If the carbon fiber layer is on the tension side, the material is most rigid, and even if the carbon fiber layer is on the compression side, the material is second rigid. Sandwich construction of carbon fiber layers can withstand stress with deflection of only about 1/16 as compared with single construction. In contrast with P.M.M.A. construction which shows deflection of 4.0mm against bending stress of 2.5 kg/mm^2, sandwich construction of carbon fiber layers shows deflection of as small as 0.25mm, while canapé construction of carbon fiber layer shows deflection of 1.25mm, which is approximately 1/3.2 of that of P.M.M.A. construction. Results of experiments made with each specimen with regard to relationship between maximum stress on the tension side and deflection are shown in Fig.3, from which it is known that the material having carbon fiber layers on the tension side is superior to the material without any reinforcement layers on the tension side. In other words, characteristics of materials can be clearly dis-

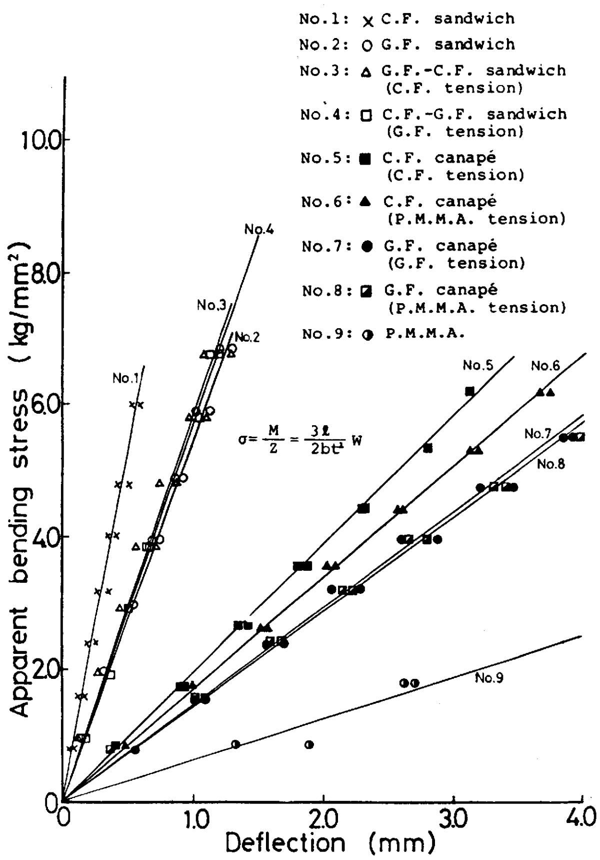


Fig.2 Relation between apparent bending stress and deflection.

tinguished by having or not having reinforcement layers on the tension side. Table 3 shows elastic moduli of each specimen under bending load, obtained by beam theory applied to flat bar and through experiments. From the calculation and experiment, it was known that lamina composite with denture base has elastic modulus of 16 times in experimental value and 38 times in calculated value as much of elastic modulus of single construction. Discrepancy between experimental and calculated values seems to be due to effect of secondary adhesion.

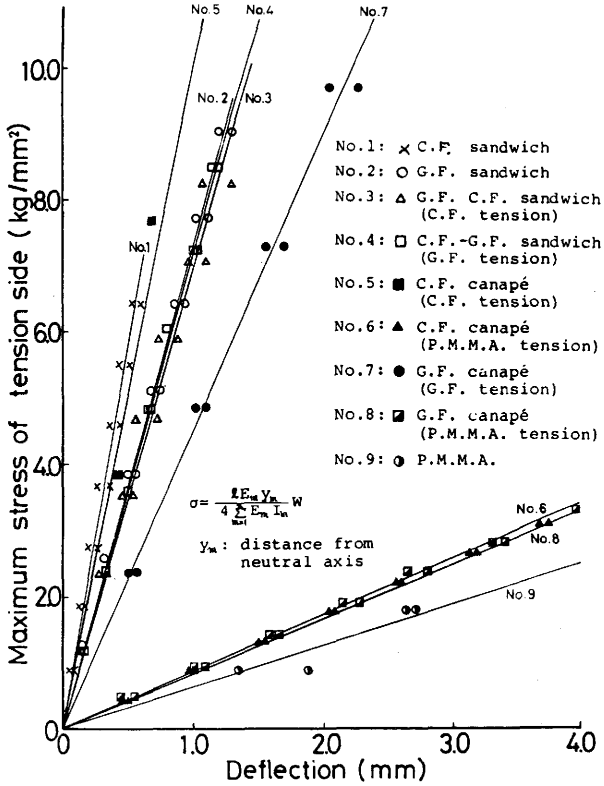


Fig.3 Relation between maximum stress of tension side and deflection.

Table 3 Calculated and experimental apparent bending elastic modulus.

Specimen	Calculated bending elastic modulus (kg/mm²)	Experimental bending elastic modulus (kg/mm²)
No.1:C.F.sandwich	11360	4474
No.2:G.F.sandwich	6115	2713
No.3:G.F.-C.F.sandwich (C.F. tension)	8C'5	2760
No.4:C.F.-G.F.sandwich (G.F. tension)	8045	2865
No.5:C.F.canapé (C.F. tension)	996	916
No.6:C.F.canapé (P.M.M.A. tension)	996	778
No.7:G.F.canapé (G.F. tension)	845	625
No.8:G.F.canapé (P.M.M.A. tension)	845	638
No.9:P.M.M.A.	300	289

4. CONCLUSION

The following summary can be made from the results of the present experiments. As a result of this series of tests and experiments, it was found that.

It is possible to attain reinforced resin base of hybrid composite of C.F.R.P. 16 times as much in rigidity against bending load as compared with that of single construction was observed with composite of 0.9mm lamina. It was found that sandwich construction of C.F.R.P. is superior, while, in the case of canapé construction, it was found necessary to have C.F.R.P. on the tension side. G.F.R.P. has possibility to be reinforced composite material, although it is considerably less superior to C.F.R.P.

ACKNOWLEDGMENTS

The authors wish to express his sincere thanks to Prof. Dr. Y.Kawamura, Prof. Dr. S.Kawai, Dr. Y.Okuno and Dr. H.Matsushiro of Osaka University for their encouragements and valuable discussions.

The authors would like to express sincere thanks to Mr. Osamu Takigawa of Tōre Co. Ltd. for preparing to experimental materials.

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