ENVIRONMENTAL EFFECTS ON TENSILE STRENGTH AND OTHER MECHANICAL PROPERTIES OF HAND LAY-UP GRP PANELS

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ABSTRACT
The use of fiber reinforced composites as structural mechanical components is on the increase. Glass reinforced plastics (GRP) are the least-priced and most commonly used on account of their several advantages over the more expensive composites. Production related defects in these composites frequently promote degradations in mechanical properties when exposed to hostile media. Coupon test specimens cut from a GRA automobile panel, produced by hand lay-up technique, were investigated for responses to specific environmental conditions. Results indicate up to about 30% reductions in tensile strengths and tensile moduli due to exposure to wetness or diurnal cycling of wetting, drying and temperature variations. These effects tend to be reversible upon thorough drying. However continuous soaking in mud appears to have more permanent effects on the tensile modulus, with a 20% reduction even after washing and drying. Exposure to wet conditions also resulted in less brittle failure, with about 23% increases in the maximum strains.

Keywords: *Resin Matrix Composites, Production Defects, Hostile Media*

1. INTRODUCTION

Fibre reinforced composites, especially GRP (glass reinforced plastics) are increasingly used as load bearing mechanical components in a range of industrial applications. GRP composites possess good dimensional stability and high strength to weight ratios; they are also non-combustible and relatively lower-priced. Those components for outdoor applications in warm humid tropical parts of the world are frequently subjected to some form of hostile environments.

Various techniques are employed in the production of these load-bearing materials so as to tailor-make and prepare them to withstand specific load conditions [1]. *The hand lay-up and related methods are simple and labour intensive, involving semi-skilled labour and are therefore very suitable for developing countries where such labour is abundant and low-priced. Moreover, tooling costs are quite low. The hand lay-up moulding technique, which is also known as "Contact Moulding", is equally suitable for economic short run productions of large components, as car bodies, aircraft parts and chemical plant containers. Related production methods include: spray-up moulding, vacuum bag moulding, cold press and hot press moulding methods, pressure bag moulding and autoclave moulding.

As in all organic matrix composites GRP

composites possess some defects, originating from manufacturing processes [2]. These include: voids in resin-rich regions, interlaminar delaminations, surface wrinkling, ungelled resin patches, fiber breakages or misaligments, trapped air bubbles, non- uniform distributions of fibres, and so forth. These defects result in general reductions in the strengths and other mechanical properties below their dry room temperature values. For example these defects may allow penetration of acid in GRP components to promote environmental stress corrosion to which glass fibres are susceptible [2]. Among other related problems in the industrial applications of these components is moisture migration associated with delaminations, which may result in reductions in ILSS (interlaminar shear strength) as in aerospace parts subjected to thermal spiking (rapid excursions to high temperatures) with subsequent high strain rates [3].

Appropriate quality control procedures and production details are employed to minimize the effects of production related defects which cannot be completely eliminated, as shown by the results of Mobuchon -et al [4,5] on high quality expensive graphite/ epoxy aircraft angle sections. Alix et al [6] have proposed a damage mechanics approach for a relatively low cost study of delaminations, using carbon/epoxy laminates. Post-curing residual thermal strains in resin matrix composites are additional sources of concern in these materials.

In general, tensile strength, flexural and interaminar shear strengths and other mechanical properties of resin matrix composites are subject to gradations in specific hostile media. These may consist of moisture, elevated temperatures, high-thermal gradients, acid or alkaline fluids, diurnal cycling of moisture and temperature, which may be acting separately or in combinations. Specific quality control and production details must be employed to protect susceptible resins and reinforcing fibres so as to minimize the consequences of these degradation tendencies. Recent analytical and experimental investigations on the effects of delaminations [7] and on damage tolerance [8] have been directed at reducing unnecessary rejects in quality control.

This paper presents the effects of some of these elements of hostile media on hand lay-up GRP automobile body panels.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

An automobile body panel (Fig. 1) was produced from commercial E-glass fibres in polyester resins, using detailed hand lay-up procedures [1]. Special production details included the provision of thin layers of protective gel coat on both surfaces of the panel for protection against hostile media. The reinforcing materials consisted of thin layers of continuous fiber surfacing mat randomly laid, next to the gel coat, and then chopped strand mat laid to the required thickness at the interior. Fibre volume fraction was about 30%. These layers were intermittently, carefully, consolidated using special rollers to minimize those production defects mentioned above. Mould production and lay-up details and other precautionary steps to reduce processing defects were strictly followed. The provision of anti-weathering gel coats and careful consolidation of each layer of mat were especially very important in the reduction of all possible defects so as to minimize acid and moisture migration that could irreversibly damage the reinforcing fibres.

2.2 Test Conditions

The following environmental conditions were simulated for the coupon test specimens.

A. Dry room temperature (about 20°C)

B. 0° to 10°C ice cold wet condition, specimens to be tested wet.

C. 30-day diurnal cycling of wetting, drying and temperature variations (20° to 87° C), specimens to be tested wet at room temperature.

D. 30-day diurnal cycling of wetting, drying and temperature variations (20° to 87° C), specimens to be tested dry at room temperature.

E. Specimens soaked in tropical road mud at room temperature for 30 days continuous, then washed and dried before test at room temperature.

In Conditions C and D, the specimens were soaked in hot water (87°C), which was allowed to cool slowly to about 20°C room temperature for several cycles during the day; they were subsequently allowed to dry overnight, These cycles were repeated over a 30-day period. The above conditions A through E reflected some possible operational conditions for the automobile body panel in the tropical outdoor environments.

2.3 Test Methods

The Hounsfield Monsanto Tensometer Materials Testing Machine and Equipment were used for all the tensile tests. The coupon test specimens, 3 to 4 mm thick, were cut to about 23 mm width and varying lengths up to 300 mm. Actual guage length was 50mm for all tensile tests. These specimens were cut directly from the panel so as to expose the cut edges to the environmental test conditions. Poorly processed laminates would therefore allow moisture and / or acid diffusion and subsequent degradation of the reinforcing fibres or the resin matrix. Actual observed defects consisted mainly of interlaminar delaminations in some coupon specimens along the cut edges.

Tensile loads were applied at an initial strain rate of about 0.00010 per second. Failures in specimens A and B were by brittle fractures, consisting of resin - matrix cracking, resin - fibre interface cracking and subsequent rupture of the fibres. Other specimens C, D and E exhibited less brittle failures in the same sequence. Several coupons were tested for each test condition.

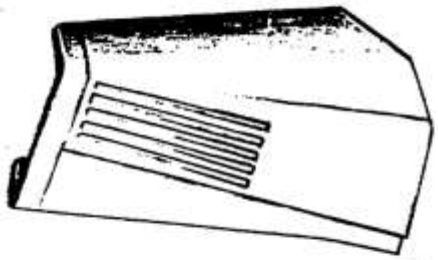

Fig. 1: Hand Lay=Up GRP Automobile Body Panel

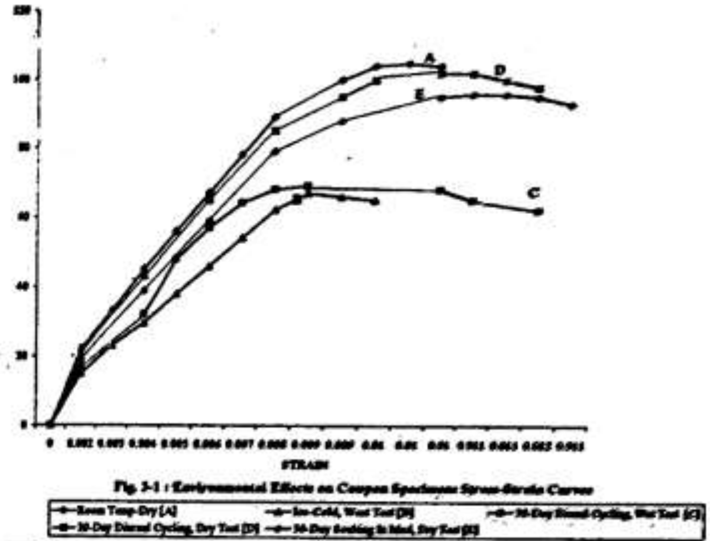

Fig 3-1 : Environmental Effects on Coupon Specimens Stress-Strain Curves

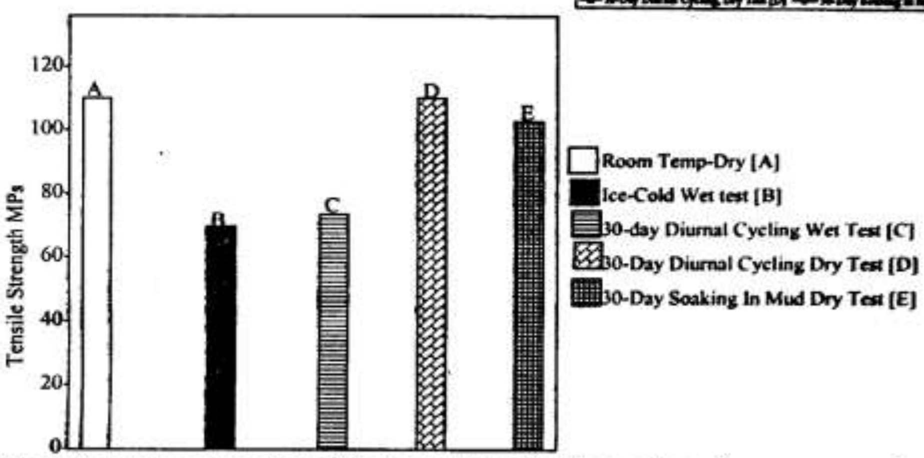

Fig. 3-2: Environmental effects on Tensile Strengths of coupon specimens

3. RESULTS AND DISCUSSION

Data were compiled and averaged for each condition. The stress strain diagrams for the five test conditions are shown in Fig. 2. The effects of these various environmental conditions on the tensile strengths and tensile moduli are shown in Fig. 3 and Fig. 4 respectively.

3.1 Environmental Effects on Tensile Strengths

Fig. 3 indicates reductions in tensile strengths in those specimens subjected to test conditions Band C by more than 30% below the dry room temperature values of the test specimens in condition A. In contrast, conditions o and E reduced the tensile strengths by only 4% and 8% respectively, below the dry room temperature tensile strength. Those specimens subjected to conditions Band C were tested in wet condition whereas the D and E specimens were dried before test. The drastic reductions in tensile strengths due to conditions B and C therefore suggest that tensile strengths of these composites are very sensitive to moisture effects, which may be reversible as indicated by the results of the D and E specimens. It would appear that ice-cold

condition alone would not reduce the tensile strength; the reduction in tensile strength of B specimens was due to the effects of moisture on these specimens which were tested wet. In general, tensile strengths of dry composites materials increase as the temperature is reduced.
The result on the specimens in conditions D and E also suggest that additional drying over a longer period might result in complete recovery of the tensile strengths of these specimens. The effects of the 30-day cycles of wetting, drying and temperature variations in conditions e and D, on tensile strengths would therefore appear to be completely reversible upon drying. In test condition E, the effects of soaking in road mud over the 30-day test period, on the tensile strength seem also reversible upon washing and drying for the mud materials in this part of the world. In sea-coast areas and those regions subject to the effects of salt water and other coastal effects, the road mud materials may have more drastic effects on the tensile strengths of resin matrix composites. On metal parts they promote corrosion.

3.2 Environmental Effects on Tensile Moduli And Maximum Strains

Fig.4 shows reductions in tensile moduli of 29%,28% and 20% under test conditions B, e and E respectively. Those specimens in conditions Band e were tested wet, again indicating the sensitivity of the tensile moduli of this composite to wetness. The effects of the cycles of wetting, drying and temperature variations over the 30-day period on the tensile modulus of the D specimens were almost completely reversed when the specimens were dried and tested at room temperature (about 20^0e). The 20% reduction in the tensile modulus of the E specimens which were dried test indicates a more drastic and possibly permanent effect of the road-mud materials, in this aspect, on this composite.
Fig.2 shows that specimens, D and E had approximately 23% increases in maximum strains in spite of having been dried before test. Thus exposure to moisture effects resulted in less brittle failures except for the ice-cold specimen.

3.3 Other Relevant Environmental Effects

Delamination defects are sources of shear strength (especially ILSS) reductions in resin matrix composites [9, 10]. Moisture diffusion and/or temperature variations tend to complicate the shear behaviour of such defective GRP composites. However, the test specimens cut from the panel in Fig 1 for this report were not suitable for shear tests.

4. CONCLUSION

Resin matrix composites have found increased applications in this part of the world. A number of defects are associated with the production of these composites and may subsequently affect the strength and other mechanical properties of the final products during service. This work has attempted to investigate possible degradation effects of specific environmental conditions on coupon test specimens cut from an automobile GRP panel produced by the hand lay-up technique. The only significant defects observed on the coupon specimens cut from the GRP panel were interlaminar delaminations along the cut edges of some of these specimens.
Those specimens subjected to the diurnal cycling of wetting, drying and temperature variations, or wet ice-cold condition, and tested in wet condition, indicated up to

about 30% reductions in tensile strengths and tensile moduli. However, those specimens which were subsequently dried before test showed only very small losses in both tensile strengths and tensile moduli following the diurnal cycling. This suggests that the effects of moisture and gradual temperature variations on the GRP panel tensile strengths and tensile moduli are reversible upon drying.

However, the effects of soaking in mud over the 30-day test period on the tensile modulus does not appear to be reversible, as a 20% reduction below the dry room temperature value was observed in spite of washing and drying the specimens thoroughly before test. In general, exposures to the various moist media resulted in less brittle failures even when dried before test, with about 23% increases in the maximum strains.

The influence of interlaminar delaminations on shear behaviour, especially interlaminar shear strengths of these band lay- up GRP automobile body components are being studied.

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