# Tensile and flexural properties of recycled glass fibre reinforced polyester composite

**B. Abdi, S. A. Hassan*, M. U. Wahit and U. A. Hanan**

Composite materials are used in a wide range of applications. Unfortunately, composite materials have not been properly recycled, especially in thermoset-based polymer composites. Recycled glass reinforced polyester–polyester composite material from waste material was identified for this study. In the recycling process, the glass fibres were not separated from the polyester matrix, but instead the material was grinded into finely chopped substance which is to be used as reinforcement material for fabricating other composite materials. Compression moulding process was used for fabricating recycled glass fibre reinforced polyester plate. Load–extension and stress–extension curves of fabricated composite materials subject to tensile and flexural loading were produced, and then the mechanical properties of this material were determined experimentally. The effect of loading rate on flexural properties of recycled glass reinforced polyester–polyester materials was studied, and it was found that by increasing the strain rate, the flexural stiffness was increased.

**Keywords:** Tensile, Flexural, Glass–polyester, Mechanical recycling, Mechanical properties, Loading rate

## Introduction

Recently, the applications of composite materials in several industries such as oil and petroleum, aerospace, automotive, marine and civil industry are increased dramatically. Unfortunately, because of the nature of composite materials that are heterogeneous, composite materials and especially thermoset composite materials have not been properly recycled. Several recycling methods such as mechanical recycling, thermal recycling and chemical recycling are used in industry to recycle the composite materials. The recycling method is chosen based on the type of reinforcement and matrix and the type of application.[1,2] Most of the previous studies in the field of recycling composite materials were focused on thermoplastic composite materials, and there is a limited study in recycling of thermoset composite materials. For example, Pickering[2] studied the current recycling technologies for thermoset composite materials and reviewed the recycling methods for composite materials. In this review, three techniques including mechanical recycling, thermal recycling and chemical recycling were discussed in details. In the mechanical recycling process, all of the constituents of the original composite materials are reduced in size and appear in the resulting materials which are mixtures of polymer, fibre and filler.[3–7] A range of application has been investigated for recycle materials such as fillers or partial reinforcement in new composite material. However, understanding the mechanical, physical and chemical properties of recycle material is the most important.

In this study, the flexural and tensile behaviour of recycled glass reinforced polyester–polyester (RGPRP–P) materials that produced by using mechanical recycling technique and compression moulding process were carried out at different loading rate of 1, 10 and 100 mm $min^{-1}$, and the obtained results were compared together. Load–extension and stress–extension curves for both tensile and three-point bending tests were produced, and the mechanical properties of this material were determined. The effect of loading rates on flexural properties of recycled glass fibre reinforced polymer (GFRP) was studied.

## Experimental procedure

Glass–polyester composite from the waste production such as composite water tanks and pipes was selected and used for this study. Mechanical recycling consists of cleaning and grinding process used to produce short fibre RGPRP for preparing sample. It should be mentioned that the recycled materials consist of glass fibre–polyester. The recycled materials were dried in the electrical oven at temperature of 50°C for 1 hour, and then the fibres were saturated with polyester resin mechanically and pressed into mould under pressure of 900 MPa and cured in room temperature (27°C). Totally, three plates with dimension of 250 mm × 200 mm and the thickness of 4 mm and total weight of 213 g with fibre mass fraction of 46·9% were prepared, and then the samples were cut by using computer numerical control (CNC) machine to

Centre for Composites, Universiti Teknologi Malaysia, 81310 Johor Baharu, Johor, Malaysia

*Corresponding author, email shukur@fkm.utm.my


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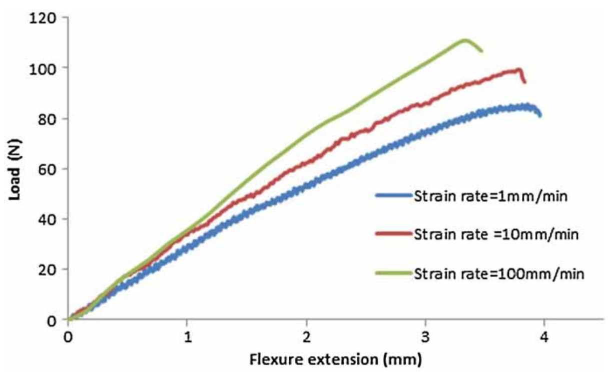
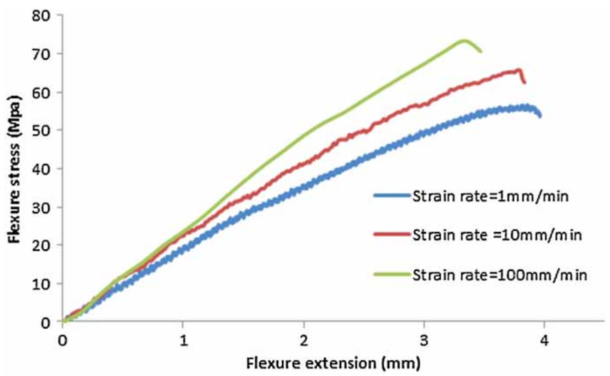
prepare dog bone specimens for tensile according to the ASTM tensile standard test method and rectangular specimen with dimension of 15 mm × 100 mm according to the ASTM flexural standard test method.

The specimens were tested experimentally by using Instron universal testing machine. Three-point bending tests were conducted at different loading rates including 1, 10 and 100 mm min$^{-1}$ with support span of 59·5 mm, and the tensile tests were conducted at only one loading rate of 1 mm min$^{-1}$. Each type of tests including tensile and flexural tests was repeated three times, and the average of obtained results was used for further analysis.




**1 The load–extension curve of three-point bending tests of RGPRP–P**




**2 The flexural stress–extension curve of three-point bending tests of RGPRP–P**

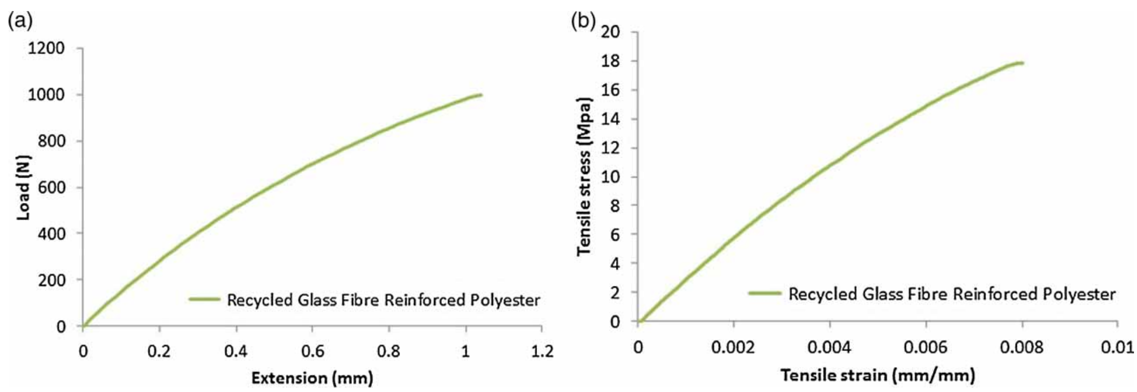
## Results and discussion

Several RGPRP–P specimens subject to three point bend loading were tested at different loading rates including 1, 10 and 100 mm min$^{-1}$ to determine flexural properties of materials. Figures 1 and 2 show the load–extension and flexural stress–extension curves of three-point bending tests of RGPRP–P.

It can be seen from Figs. 1 and 2 that loading rate have effect on flexural properties of materials and by increasing loading rate, the flexural properties of recycled glass fibre reinforced composite materials were increased. From Fig. 1, it can be seen that by increasing loading rate from 1 to 10 mm min$^{-1}$, the maximum applied load was increased 16% while the extension was reduced 2%. By increasing loading rate from 10 to 100 mm min$^{-1}$, the maximum applied load was increased 11·56% while the extension was reduced 13·5%. In other words, by increasing the loading rate from 1 to 100 mm min$^{-1}$, the maximum applied load was increased 29·4%. Therefore, it can be discussed that by increasing the loading rate, the failure load is increased while the failure extension is reduced, and there is a relationship between the loading rate and flexural failure load and failure extension. This relationship can be determined.

Owing to the relationship between the load and stress, the same behaviour was determined for flexural stress behaviour of recycled glass fibre reinforced composite materials (Fig. 2). It can be seen from Fig. 2 that by increasing the loading rate from 1 to 10 and 100 mm min$^{-1}$, the flexural stress was increased to 16 and 29·4%, respectively, that exactly the same as the behaviour of load–extension. From Figs. 1 and 2 and by considering the constituent materials of recycled glass fibre reinforced composite materials that consist of recycled glass–polyester and polyester resin, it can be discussed that the dependence of flexural behaviour of these materials on loading rates comes from polyester resin. By comparing the flexural properties of these materials obtained from the experimental tests with the flexural properties of chopped strand mat glass–polyester with the same fibre volume fraction and thickness that obtained from the analytical calculation (role of mixture),[8] it can be discussed that the flexural properties of this materials are lower than that of chopped strand mat glass–polyester materials.

Figure 3 shows the load–extension and stress–strain behaviour of recycled glass fibre reinforced composite materials subjected to tensile loading. It can be seen




**3 *a* The load–extension and *b* the stress–strain behaviour of RGPRP–P**

from Fig. 3*a* that the specimens were failed at extension of 1·04 mm and maximum load of 997·19 N. According to Fig. 3 and considering the Hooke's law, the modulus elasticity of recycled glass fibre reinforced composite materials was calculated 2889·48 MPa. By comparing these results with the tensile properties of chopped strand mat glass–epoxy with the same fibre volume fraction and thickness that obtained from the analytical calculation (role of mixture),[8] it can be discussed that the tensile properties of these materials are lower than that of chopped strand mat glass–polyester materials.

## Conclusion

The tensile and flexural behaviour of recycled glass fibre reinforced polyester composite materials were determined experimentally. It was found that the loading rate has an effect on flexural behaviour of these materials, and by increasing the loading rate, the flexural property was increased while the flexural extension at failure load is reduced. In tensile tests, only one loading rate was used, and it was found that the modulus elasticity of recycled glass fibre reinforced with polyester resin is around 2·9 GPa. By comparing the obtained results for these materials with the mechanical properties of chopped strand mat glass–polyester with the same fibre volume fraction and thickness, it was found that the mechanical properties of this materials are lower and the polyester inside the recycled glass–polyester materials have an effect on the mechanical properties which reduce the mechanical properties.

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