Acta Materialia Transylvanica 2/2. (2019) 105–109.
https://doi.org/10.33924/amt-2019-02-07
Hungarian: https://doi.org/10.33923/amt-2019-02-07
https://eda.eme.ro/handle/10598/31512

Development of a Composite Material for Impact Load

Tünde Anna KOVÁCS,[1] Zoltán NYIKES,[2] Lucia FIGULI[3]

[1] *Óbuda University, Donát Bánki Mechanical and Safety Engineering, Department of Materials Technology, Budapest, Hungary, kovacs.tunde@bgk.uni-obuda.hu*

[2] *Óbuda University, Doctoral School on Safety and Security Sciences, Budapest, Hungary, nyikes.zoltan@phd.uni-obuda.hu*

[3] *University of Zilina, Faculty of Security Engineering, Department of Technical Sciences and Informatics, Zilina, Slovak Republic, lucia.figuli@fbi.uniza.sk*

Abstract

The goal of this work was to invent a high energy absorbing composite material. This composite needs to be able to attach on the building's surfaces and increase blast-resistance. In this innovation, the test samples were reinforced with aramidfiber, glass fiber and carbon fiber and tested by Charpy pendulum impact testing machine. During the tests, the aramid and glass fiber reinforced composites showed good resistance and high energy absorption against impact load.

Keywords: *composite, impact load, blast-resistant material.*

1. Introduction

In every century, we can find guns and fencing, in the countries affected by war or terrorism. With the development of materials science and technology, weapons and defence methods have developed too. In our modern times, we are threatened not only by more traditional conflict but also by terrorism.

Terror attacks are unexpected and unpredictable. The techniques and explosive materials used can cause catastrophic damage. To limit this damage (to human life, buildings, vehicles, etc.) we need to use shielding to defend potential targets or employ strong blast-resistant materials in the design of such targets [1–4].

Under dynamic loads, materials show brittle behaviour. The ceramic bricks used for building construction are hazardous during fracture as the pieces fall, causing more damage where they land. The materials of old buildings are not replaceable, but additional retro-fitting can increase resistance [5–9]. In this way, while our cityscape does not change, the structural security of buildings can be increased. The retro-fitting of walls requires suitable selection of materials.

The construction materials currently in use are suitable for thermal insulation but do not provide protection or reinforcement of masonry under excessive dynamic loads. Additionally, most of the applied insulation materials are flammable.

The most important part of composite design is the determination of loads and, therefore, the determination of stresses [10–14]. On the basis of the determined loads, we can select the matrix and reinforcing materials and we can analysis their adequacy. Currently, there is a large number of matrix and reinforcing materials to choose from. These materials can be used to build a composite that is suitable for the specified loads. Several design systems can be used to design composites, which have a wide materials database and simplify both material selection and design.

2. Composite test samples manufacturing process

During our design tasks, we used three different kinds of fibers (carbon fiber, glass fiber, aramid fiber). The mechanical properties of these woven materials depends on the weave type, meaning the structure of the fibers, the properties also depend on the fibers direction. The materials used are shown in **Figures 1–3.**

The covering layer of the composite was made by the resin matrix (Araldite LY 1564) lamination

Table 1. *Mechanical properties of the epoxy resin impregnated composites* **[2]**

	Glass fiber weave	Carbon fiber	Aramid fiber weave
Impact strength (kJ/m^2)	weave	Aramid fiber	76
Density (kg/m^3)	weave	1500	1400

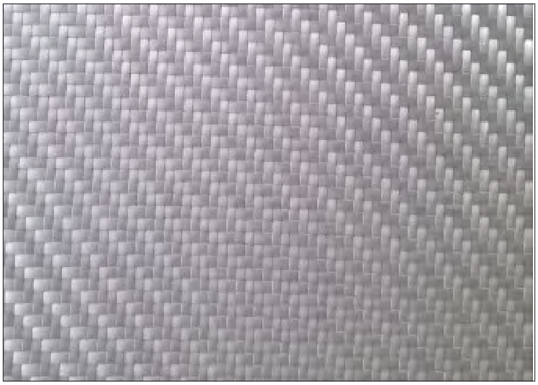

Figure 1. *Glass fiber weave*

Figure 2. *Carbon fiber weave*

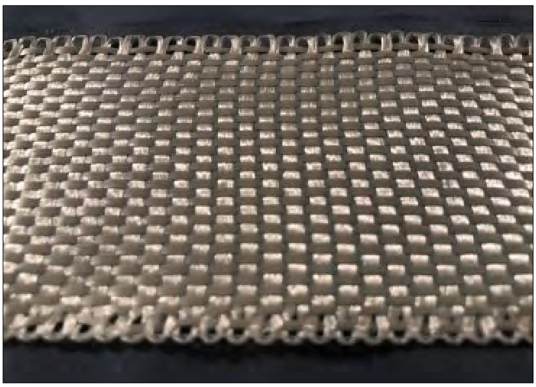

Figure 3. *Aramid fiber wave*

process. **Table 1.** summarizes the mechanical properties of the materials used.

For the manufacturing of the composite lamination, single direction fiber structure materials were used. The test samples were made without a notch. The results of the Charpy impact tests are shown in **Table 1. [2]**.

On the base of the literature data **[2]** we used 6 resin impregnated layers from the low strength aramid fiber and used 4 layers from the higher strength resin impregnated carbon and glass fiber to cover the samples.

The goal was to increase impact load resistance against impact loads of the traditional buildings walls by reinforced ceramic bricks. For the model tests we prepared an epoxy resin laminated fiber hybrid ceramic brick material, the layers are shown in **Figure 4.**

The mechanical properties of the used fiber reinforced materials as a function of the fiber direction, and layer numbers is shown in the **Table 2.**

The sandwich structured test sample was made with a vacuum infusion system. Cutting of the samples was performed after the solidification of the epoxy resin. On the basis of the samples anisotropy, the Charpy test impact load was positioned for the laminated surface (**Figure 5.**).

We simulated the dynamic load by Charpy impact test, the used test sample was without notch (**Figures 6–8.**).

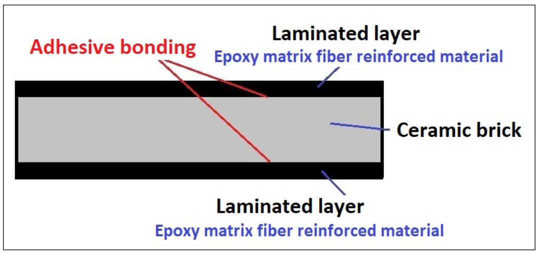

Figure 4. *The sandwich panel layers*

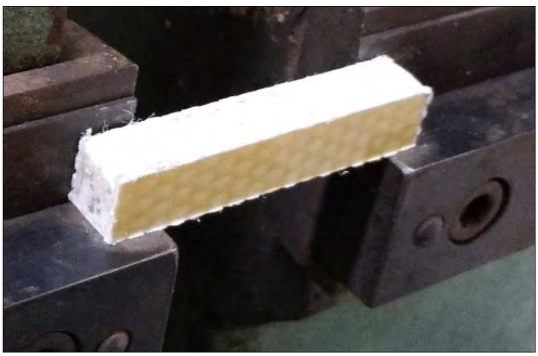

Figure 5. *Test sample position during test*

Table 2. *The mechanical properties of the used com-po-site materials mechanical properties*

	Glass fiber	Carbon fiber	Aramid fiber
Weave (g/m²)	390	480	220
Weaving type	2/2 Twill weave	2/2 Twill weave	1/1 Plain weave
Number of layers	4	4	6
Layer struc-ture	$(0_{sz})_4$	$(45_{sz})_4$	$(0_{sz})_6$

Figure 6. *Glass fiber weave and epoxy resin lam-inat-ed test sample*

Figure 7. *Carbon fiber weave and epoxy resin lami-nated test sample*

Figure 8. *Aramid fiber weave and epoxy resin lami-nated test sample*

3. Experiments

The test samples were tested by the Charpy impact instrument on the basis of MSZ EN ISO 179-1:2010 standard [4]. 1 kg load hammer and 10×10×55 mm size test samples were used for the first test.

The glass fiber weaved samples under 1 kg impact load showed high resistance, without breaking, the hammer rebounded, on the test sample surface, caused only small penetration (shown in Figure 9.).

One side of the coating of the aramid fiber weave and epoxy resin laminated test sample flaked, and the ceramic brick split.

Carbon fiber weave and epoxy resin laminated test samples were broken (Figure 10.), the composite is rigid.

In the case of the repeated test using a 30 kg load hammer, the result was unmeasurable. Even though visual assessment was possible.

Table 3. *The results of the experiments*

	Glass fiber weave	Carbon fiber weave	Aramid fiber weave
Impact energy (J)	7,3	5	6,9
Impact strength (kJ/m²)	73	50	69

Figure 9. *Glass fiber weave and epoxy resin laminated test sample after test, on the surface. Notice the impact formed notch*

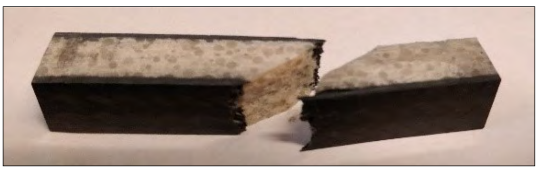

Figure 10. *Carbon fiber weave and epoxy resin laminated test sample after test*

4. Conclusions

The glass and carbon fiber weave laminated test samples under a 30 kg impact load showed rigid behaviour, and they didn't shown toughness (Figure 12–13.). In the case of the aramid fiber weave and epoxy resin laminated test samples, the ceramic inner layer cracked but did not break, (Figure 14.). .). One side of the composite the aramid layer became delaminated from the ceramic surface showing that the adhesive bonding was not enough strong.

The aramid fiber weave laminated test samples under 1 kg and 30 kg resisted the impact load without breaking. The glass fiber weave reinforced samples under 1 kg impact load, without modification but under 30 kg impact load, showed rigidity and breakage.

Our future aim is to test these test samples by impact load between 1 kg and 30 kg, to determine the load limit of the glass fiber weave reinforced samples.

It can be concluded that the aramid fiber weave lamination is suitable for dynamic load, but in the case of the sandwich structure used, the adhesive bonding was not strong enough between the aramid coating and the ceramic with the used epoxy resin.

Acknowledgement

The authors are grateful for the technical support during the test samples preparation to the associates of KANDSI Kft. (AKOBEZ)

References

[1] Ashby M. F., Jones D. R. H.: *Engineering Materials 1. An Introduction to Properties, Applications and Design*. Third Edition, Elsevier Butterworth-Heineman, Cambridge, UK P.K., 2005.

[2] Szakali M., Szűcs E.: *The defence planning model formation and development / Védelmi tervezési-modellek kialakulása és fejlődése*. Hadmérnök, 12/1. (2017) 24–40. ISSN 1788-1919

[3] Malick P. K.: *Fiber-reinforces composites*. Third edition. Taylor and Francis, Boca Raton, USA, 2008.

[4] Ráthy I., Pinke P., Huszák Cs.: *PP mátrixú fröccsöntött kompozitok mechanikai vizsgálatai.* Acta Materialia Transylvanica, 1. (2018) 105–109. https://doi.org/10.2478/amt-2018-0039

[5] Lange D.: *A review of blast loading and explosions in the context of multifunctional buildings*. Fire technology SP Technical Research Institut of Sweden 2013. ISSN 0284-5172

[6] Gay E., Berthe L., Boustie M., Arrigoni M., Buzaud E.: *Effects of the shock duration on*

Figure 11. *Aramid fiber weave and epoxy resin laminated test sample after test*

Figure 12. *Glass fiber weave and epoxy resin laminated test sample after test*

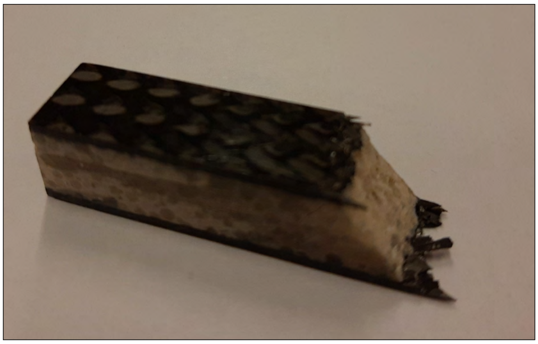

Figure 13. *Carbon fiber weave and epoxy resin laminated test sample after test*

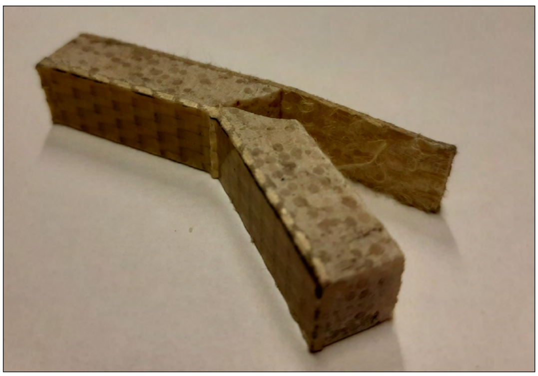

Figure 14. *Aramid fiber weave and epoxy resin laminated test sample after test*

the response of CFRP composite laminates. Journal of Physics D: Applied Physics, 2014 https://doi.org/10.1088/0022-3727/47/45/455303
[7] Zvaková Z., Figuli L., Guttenová D.: *Analysis of blast load steel beam.* Juniorstav 2014, VUT Brno, ISBN 978-80-214-4851-3.
[8] Figuli L., Jangl Š., Papán D.: *Modelling and Testing of Blast Effect On the Structures*. IOP Conference Series: Earth and Environmental Science, 44. (5), 052051 https://doi.org/10.1088/1755-1315/44/5/052051
[9] Lu G., Yu T.: *Energy absorption of structures and materials.* Woodhead Publishing Limited, Cambridge, England 2000.
[10] Qiao P., Yang M., Bobaru F.: *Impact Mechanics and High-Energy Absorbing Materials: Review.* Journal of Aerospace Engineering, 21/4. (2008) 235–248. https://doi.org/10.1061/(ASCE) 0893-1321 (2008) 21:4(235)
[11] Zhou H., Wang X., Ma G.,. Liu Z.: *On the effectiveness of blast mitigation with lightweight claddings.* Procedia Engineering, 210. (2017) 148–153. https://doi.org/10.1016/j.proeng.2017.11.060
[12] Figuli L., Štaffenová D.: *Practical Aspect of Methods Used for Blast Protection*. Key Engineering Materials, 755. (2017) 139–146. https://doi.org/10.4028/www.scientific.net/KEM.755.139
[13] Daruka N., Kugyela L.: *Ipari robbanóanyagok megjelenésének lehetőségei az improvizált robbanószerkezetek kialakításának tekintetében.* Robbantástechnika, 35. (2018) 155–174.
[14] Galusca D. G., Galusca L., Tóth L.: *Analyses of Deformation of Fibre Reinforced Composits.* In: microCAD'98, M Section: International Computer Science Conference. Miskolci Egyetem, 1998.