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Carbon Fibre Reinforced Aluminium Mesh Composite Materials

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Abstract

This research aims at analysing two building materials with apparently distinct physical and chemical properties: the carbon fibre and aluminium; by mixing these two materials with epoxy resins we then intend to produce a novel composite building material whose physical and chemical properties differ from those of the initial materials and with mechanical strengths much improved as compared to other materials used at present in structural rehabilitation. In this respect, we consider this material to be extremely useful in the future for the rehabilitation of concrete and masonry structures. The product will exhibit significant mechanical strength values, a very good specific weight, elasticity in favour of the domain of use and an increased thermal and electrical conductivity. The material will also show to be an optimal solution for providing building durability and extending the serviceability period of masonry structures, which are commonly more vulnerable to the damaging factors of the external environment. Another quality is represented by the easiness with which it is produced, by a mixture of manual and mechanical technologies. The conclusions of our project are promising and lead to the possibility of including the material in question in the field of masonry and concrete structure rehabilitation as a new material that will bring about new and simplified technologies to be used in structural rehabilitation.

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Keywords: composite materials; aluminium net; carbon fiber; epoxy resin materials; structural rehabilitation

1. Introduction

Together with modern and high performance materials and technologies in various sectors of activity, there also occurs the need to introduce new building materials specially dedicated to structural strengthening and

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rehabilitation. With conventional rehabilitation methods, it can be noticed that during rehabilitation works, the building appearance suffers and the quality of the works is not always the desired one.

It is well known that masonry structures are among the oldest constructions made by people and that the majority of the historical monuments are erected with various forms of masonry. However, people were constrained to remain at the experiences and methods of construction that were found at that respective moment.

Moreover, the damaging factors originating in the aggressive external environment, such as the climate type or the seismic activity change from the moment in which the building was erected until the present moment, so that masonry structures suffer damages. All the aspects mentioned until now are in favour of a composite material that we now put forward: a carbon fibre reinforced with aluminium mesh with the help of epoxy resins.

Different from classical materials used to rehabilitate masonry structures, the new product will be durable, conferring a higher strength to structures made with various forms of masonry. The consolidation technology using the new material is much simplified because it can be applied directly on the modules forming the masonry. The appearance is also improved as the work can be masked with an external finishing specific to the building in question and simulating the original architectural aspect. The aluminium mesh in the new composite material (made of carbon fibre, Al mesh, epoxy resins) will play a double role in the strength of the new material used to strengthen or rehabilitate the masonry and will also contribute to setting and reinforcing the further on applied layers for finishing in this way replacing the classical reinforcement with various forms of fibres of finishing materials. Thus, both structural and architectural problems are successfully and simultaneously satisfied.

The production of the carbon fibre reinforced aluminium mesh can contain both manual and mechanised procedures, the composite material obtained benefitting from special physical and chemical properties that are quite promising in the present-day context of rehabilitation-based civil engineering.

2. Theoretical study

The fast and revolutionary technological evolution of the last decades also lead to the production of new and attractive materials for the field of constructions, such as the carbon fibre and the development of novel methods of combining materials that apparently are very different, even incompatible, to reach a new product with improved physical and chemical properties. Due to its attractive properties and considerable mechanical strengths, such as: high compressive strength, tensile strength~4300 [1]; increased Young's modulus of elasticity ~238 000 [1]; high thermal conductibility, excellent electrical conductibility; low own weight ~230 [1]; stiffness, carbon fibre has become a valuable material to be used to produce modern building materials. The aluminium mesh is also distinguished by its physical and chemical properties: tensile strength ~70 [2], good thermal conductibility: values oscillate between 0 and $239 Wcm^{-1}K^{-1}$ [2], at temperatures of 0-900K; axial tensile strength ~137 [2], compressive strength 280 [2], high electrical conductivity.

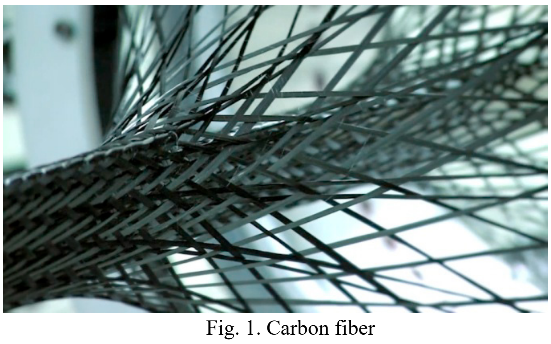


Fig. 1. Carbon fiber

Though the two materials develop notable individual characteristics, their blending together to produce a composite material with improved properties represents an engineering and technological challenge. A possible and accessible mechanical method to solve this difficulty is given by the special mill that allows for the interpenetration of carbon molecules in the aluminium mesh. After numerous tests, it was found out that the materials come into symbiosis after 48 ore, with the frequency of 200 rotations per minute.[4] When this time interval is over, the aluminium and carbon molecules form together a new material whose grains are rounded, whose molecular composition is homogeneous and which do not affect the properties of the original materials[7]. The previous process is fully mechanised, so that the technological flow can be continuous and the quantity of new material can increase. However, for the purpose of the present study we preferred the manual method, namely the lamination method, because of cost-related reasons: low cost in the production of the new material and a large variety of shapes; the shapes do not come out in a limited and finite number[5][6].

Manual lamination consists in gluing together the lamines of carbon and aluminium fibres impregnated with epoxy resins on several brick on which the tests will be carried. The dimensions of the lamines can vary, dependent on the foreseen result, with significant properties for the newly developed product.

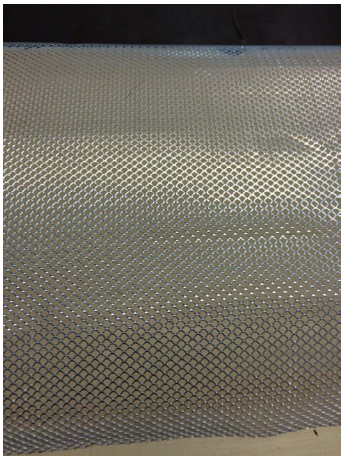
a)  b) 

Fig. 2. (a) aluminium mesh; (b) epoxy resins

Though masonry seems to be built from homogeneous materials, in fact the materials of origin can develop heterogeneous characteristics so that the carbon fibre reinforced with an aluminium mesh is an exception and it suits ideally for a successful rehabilitation. It is easy to fit on the bricks with resins, has a low own weight, improves the mechanical properties of the materials on which it is applied and maintains the masonry initial shape at the intervention place. Additionally, it does not alter other properties of the masonry elements, on the contrary it increases the masonry stability during exceptional actions, especially during earthquakes. Malleability is another distinctive feature of this composite, as it can be used on any kind of structure, even when it exhibits unique features.

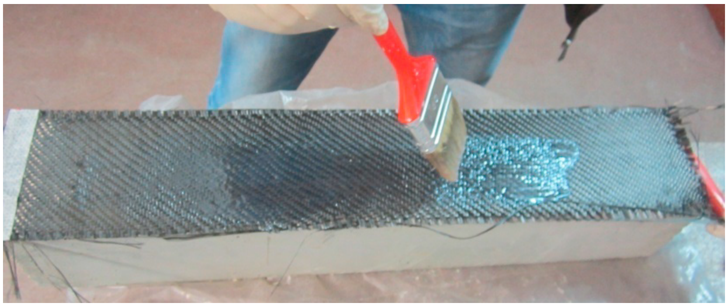


Fig. 3. Manual lamination

There are other physical and chemical properties worth mentioning for this new product: low density, good resistance to corrosive agents, slow oxidation which contributes to intervention duration and applicability as compared to conventional structure consolidation works with welded steel mesh, increased strength to disturbing external factors, reduced expansion thermal coefficient.

Fig.4. Epoxy resins on aluminium mesh

In spite of the fact that this new innovative material can be an optimal solution for the future of structural rehabilitations of masonry buildings, there are also several drawbacks to be discussed. First, the financial aspect is important, as the costs for production and placing it into work are higher than those of the currently used materials. To benefit from the numerous advantages of the fibre carbon reinforced aluminium mesh, customers need larger amounts of money than for traditional methods; however, the customer should be aware of the quality-cost ratio and should opt in for the new investment[8]. Moreover, the fibre carbon reinforced aluminium mesh, plays the role of a binder for the finishing elements applied onto the constructions, so that other materials with finishing properties need not be purchased as in other rehabilitation works, so that costs will finally come near to those in traditional methods[6][8].

Another drawback is represented by the behaviour to exceptional actions, such as fires and explosions. This material is more vulnerable to fire and explosion because of the epoxy resins used as binders which dilate at high temperatures and weaken the set. It is also an excellent thermal conductor so that both the carbon fibre and the aluminium mesh should remain intact and be able to further bear to the loads with no significant disturbance of the mechanical strengths. The special stiffness of the carbon fibre also plays a crucial role in this respect.

3. The experimental study

This part of our project will detail the tests performed in the Laboratory of Building Materials of the Faculty of Civil Engineering in Cluj-Napoca on masonry modules reinforced with carbon fibre and aluminium, through epoxy resins as well as the results after tests and the method used. At the end of the experiments we intend to highlight the physical and mechanical properties of the new product and to give reasons for which the material can be introduced for structural rehabilitations of various ty=pes of masonry constructions [4].

Tests were performed on 2 full core brick halves sandwiched with mortar M5, the final dimension being 12x12x17. The epoxy resins were produced by mixing together two adhesive components, in a metal cover inert to the substances mentioned earlier. The lamines of carbon fibre and aluminium joined together with the epoxy resins of trademark Sikadur-330 [9] were prepared to be applied onto the bricks. We laminated the brick module with a layer of epoxy resins, then we applied the carbon fibre mesh. Over the carbon fibre, another layer of resin was put and the aluminium mesh was added and the final external layer. The resin drying time and setting time depends upon the preparation of the binder. From the moment setting occurs, the material homogeneity and the cooperation between the carbon fibre and the aluminium mesh is evident.

In the side image, one can notice the easiness of the manual lamination and the uniform dispersion of the epoxy resin. It is also necessary to mention the homogeneity between the aluminium mesh reinforced with carbon fibre and the brick sandwich. AS one can see, this composite material fits in an excellent manner to any surface, irrespective of the particular features it presents.

a)

b)

Fig. 5. (a) Masonry module; (b) Masonry module with epoxy resins.

The advantage of the high homogeneity combined with the special stiffness of the carbon fibre provides evidently improved mechanical strengths as bricks are protected by the cover of the composite material. If masonry elements are crushed, the carbon fibre reinforced aluminium mesh remains intact, not allowing the crushed pieces to go out and maintaining an unchanged structure.

Fig. 6. Sandwich of bricks reinforced with carbon and aluminium

a)

b)

Fig. 7. (a) Determination of the resistance to compression; (b) Failure of the module

One of the mechanical properties which was significantly improved is resistance to compression. During the tests carried out, we used three samples: a simple brick sandwich (the standard sample), a sandwich of bricks reinforced with carbon fibres and a sandwich of bricks reinforced with carbon and aluminium. To determine the resistance to compression, we used the hydraulic press. In the case of the standard, brick failed at an average value of 15,7 N/mm^2 . The sample reinforced only with carbon fibre an increase was recorded, so that it failed only at an average of 17,9 N/mm^2(the experiment was deemed finished when the carbon fibre broke under the force exerted by the hydraulic press). However, the resistance to compression has the highest value when the brick sandwich is reinforced with both carbon fibre and aluminium, glued together with epoxy resins. This masonry module failed at the value of 20,83 N/mm^2.

AS it is visible from the image below, even if the aluminium mesh and the carbon fibre failed, it kept the brick together inside because of the epoxy resins that produced a strong homogeneous bond between the masonry element and the composite material and because of the very efficient cooperation between the carbon fibre and aluminium.

Fig. 8. Module after failure

The graph below highlights the compression strength of the product obtained compared to previous tests:

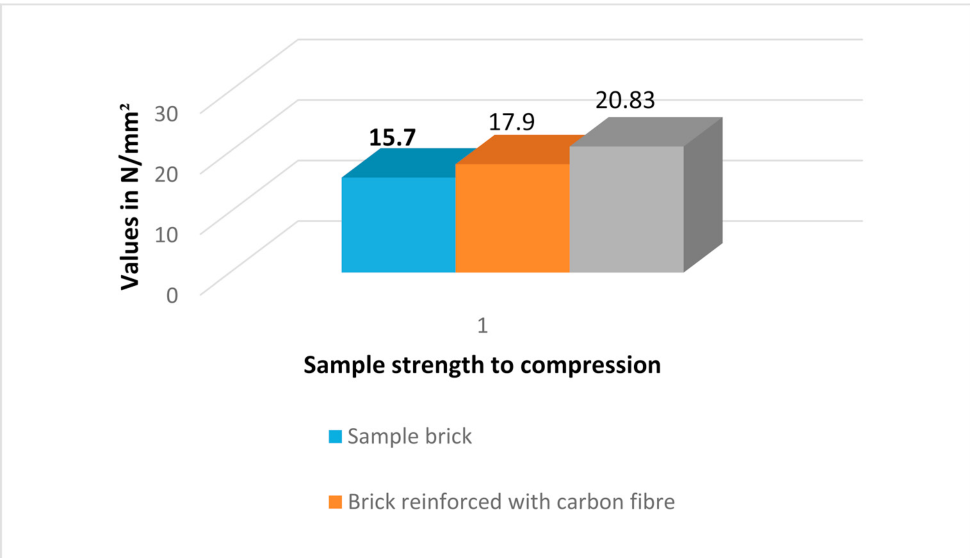


Fig. 9. Strenght to compression.

4. Conclusions

The research carried out helps draw the following conclusions:

- The strengths of the composite material with carbon fibres reinforced with aluminium meshes are higher than those of already existing materials and are promising for the domain of use of the structural rehabilitation of buildings with various types of masonry. An increase in the compression strength of 32,67% was recorded compares to the standard module.
- The work between the carbon fibre and aluminium mesh is excellent, the two materials reciprocally compensate so that it yields a product with favourable physical and chemical properties. The issue regarding epoxy resin at high temperatures and aluminium dilation are covered by the high carbon fibre stiffness. Aluminium flexibility significantly contributes to material malleability on any kind of surface. Lamination is performed easily and the two materials combine without difficulty.
- The material has a double role, that of masonry buildings strength structure consolidation and that of achieving setting of finishing elements later on applied. In this way, the capital and amounts of money required for rehabilitation are reduced.
- The new idea, not encountered until now in the building field, that of reinforcing the carbon fibre material with aluminium meshes by means of epoxy resins will bring about new solutions to consolidate masonry structures and to develop a novel composite material, with improved properties as compared to existing materials in use.
- To obtaine the new composite material made of carbon fiber reinforced with aluminum mesh using epoxy resins, there is no need for special technologies or extra workmanship which would increase the costs. The process of rehabilitation of masonry structures by this method can be done on site and does not require qualified personnel. The materials used can be obtained easily from specialized stores.
- This mode of structural rehabilitation is easy to use by anyone in all masonry structures and even in areas where it is difficult to access where classical methods of massive rehabilitation can not be achieved or would raise a lot of production costs
- The result of this experimental study is a new composite material, carbon fiber reinforced with aluminum mesh and epoxy resins, with improved properties. This new product has not been used so far in the masonry structure.
- The present paper can provide an opportunity for further research. Other case studies can be made with the carbon fibre and other kinds of meshes (of different shapes and size of mesh eyes, other lamination methods). The positive results of the present research make us further investigate other characteristics of this material, other lamination methods, other consolidation and rehabilitation technologies performed with this material whose properties can be subsequently improved in order to produce a higher level material as compared to the ones on the market at present.

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