revolutionary re-use of polyester boats

What do you do with end-of-life recreational polyester boats? Turn them into retaining walls for Dutch canals of course!

BY DR. IR. ALBERT TEN BUSSCHEN

Associate Professor, Professorship for Polymer Engineering
Windesheim University of Applied Sciences, Zwolle, The Netherlands

There are currently an estimated 13,000 end of life boats in Holland, a figure that one prediction says is set to rise to an astonishing 75,000 by 2030. In France 500 boats were dismantled last year however there is still a backlog of at least ten to fifteen years. The International Council of Marine Industry Associations (ICOMIA) has estimated that there are more than 6 million recreational craft in Europe alone; so expect the problem to only worsen.

These are just some of the quantities affecting the industry the METSTRADE Sustainability in the Marine Industry conference was told in late 2016. But industry leaders also heard how some progress is now being made with end of life boats – albeit on a limited scale. Clearly this is a subject that has been exercising Albert ten Busschen for some time. A chance meeting at an IIMS event in Holland recently led to the commissioning of this special article on this important subject - the elephant in the room some would say. Albert has found a novel and practical use for end-of-life boats and writes passionately about the problem, his methodology and solution.

Growing number of obsolete polyester yachts

There is a growing number of obsolete boats coming from the recreational vessel fleet. This is a direct result of the number of boats that were acquired during the seventies and eighties of the last century when it became fashionable to own a yacht. On top of that, nowadays the demand for second-hand models is very low as boat ownership has gone out of fashion with the younger generation. Boat owners therefore dispose of their old boat either by taking it to a boat dismantling company or just abandon it. The disruptive potential is enormous as already some Dutch canals are blocked by orphaned boats.

Boat dismantling companies remove the useful parts from a boat like the mast, stainless steel parts, the motor, the propulsion system and authentic parts like hard-wood steering wheels and brass window frames. These parts can be sold. However, the remaining boat hull and cabin are worthless and end up as landfill for which additional costs have to be made. The majority of these hulls and cabins are built from glass fibre reinforced polyester composite, GRP, or popularly referred to as 'polyester'. In The Netherlands alone the volume of these End-of-Life (EoL) polyester boat parts came to 1,400 tonnes in 2015 and will grow to 4,000 tonnes per annum in 2030.

Primary recycling is not an option

For the past two decades the composite industry has been working on the recycling of composite products. Several efforts have been made to regain the raw materials: reinforcing fibres and plastic. A recent comprehensive overview has been given by the ACMA in 2016 [1]. This so-called primary recycling, meaning regaining the original components of which the material is composed, appeared not to be successful. Besides the low quality of the recycled components, these methods never became economically viable. At the moment the so-called 'cement-kiln route' is the accepted route by the European Union as a recycling method for composites, although only the caloric value (combustion energy) and the silicium dioxide present in the EoL thermoset composite are regained in a cement oven [2]. This 'cement-kiln route' is clearly also not a form of primary recycling but moreover, as with primary recycling it has not been economically successful.

The solution: structural re-use

The principle of the structural re-use of EoL composite products is based on the use of oblong elements gained from EoL composite parts embedded in virgin material. In this way, the good properties that are still present in the EoL composite products (high mechanical strength and resistance to water) are put to good use in the new composite. This methodology, which was financed by a government grant, was developed by the Professorship for Polymer Engineering of Windesheim University of Applied Sciences, The Netherlands. Contrary to primary recycling where raw material components are regained, this method leaves the composite structure as it is and falls in the category of secondary recycling.

To achieve a maximum strength contribution of the oblong elements of the old composite, a high fill rate is desired and, therefore, the amount of virgin embedment material (resin) needs to be limited, this also from an economical point of view. Because of their shape, the elements contribute to the reinforcement of the new products, as schematically illustrated in Figure 1. The material consists of re-used material in the form of strips (green, from here on indicated with subscript 'r' from 're-used') embedded in a polymer matrix (yellow, from here on indicated with subscript 'm'). Using classical micromechanical models [3], the stiffness (E-modulus) and the strength of the resulting new composite product (indicated with subscript 'c') can be predicted.

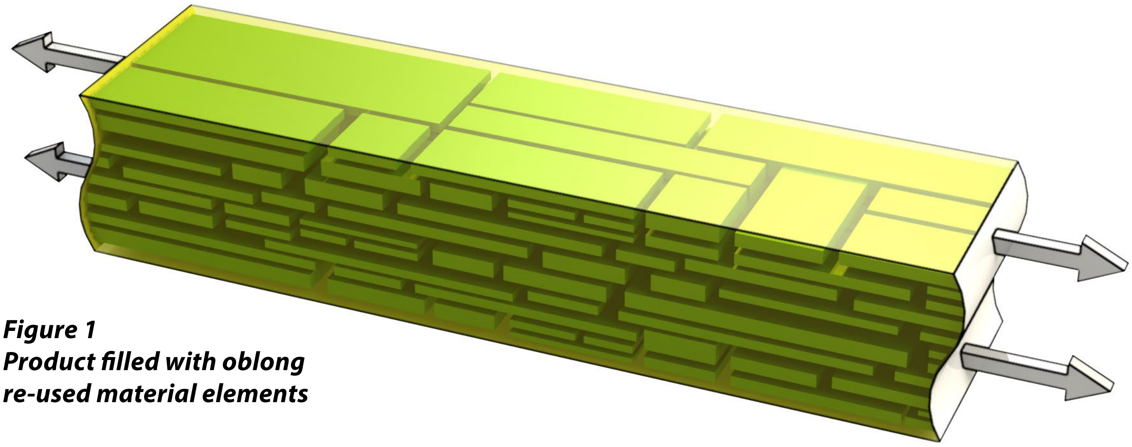
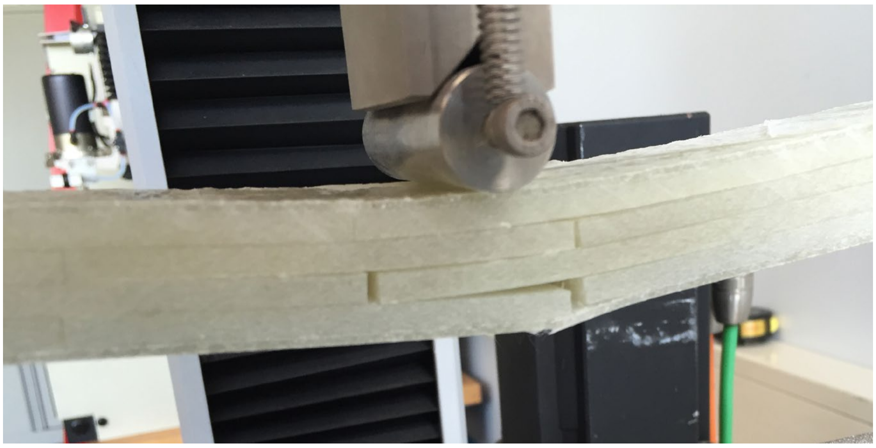


Figure 1
Product filled with oblong re-used material elements

Effective modulus of elasticity: (based on parallel model)	$\mathbf{E_c \approx v_r \cdot E_r + v_m \cdot E_m}$	**(1)**
Effective tensile strength:	$\boldsymbol{\sigma_c \approx v_r \cdot \sigma_r}$	**(2)**

In formulas 1 and 2 the volume fractions of the components are used, indicated with the symbol 'v'.

The performance of new products consisting of re-used composite elements depends on the length of the embedded oblong elements. An extensive study has been performed on the effect of length, positioning and pre-treatment of the elements by three-point bending tests [4].



It was found that the bending strength of a profile built from strips increases with the strip length as depicted in Figure 2.

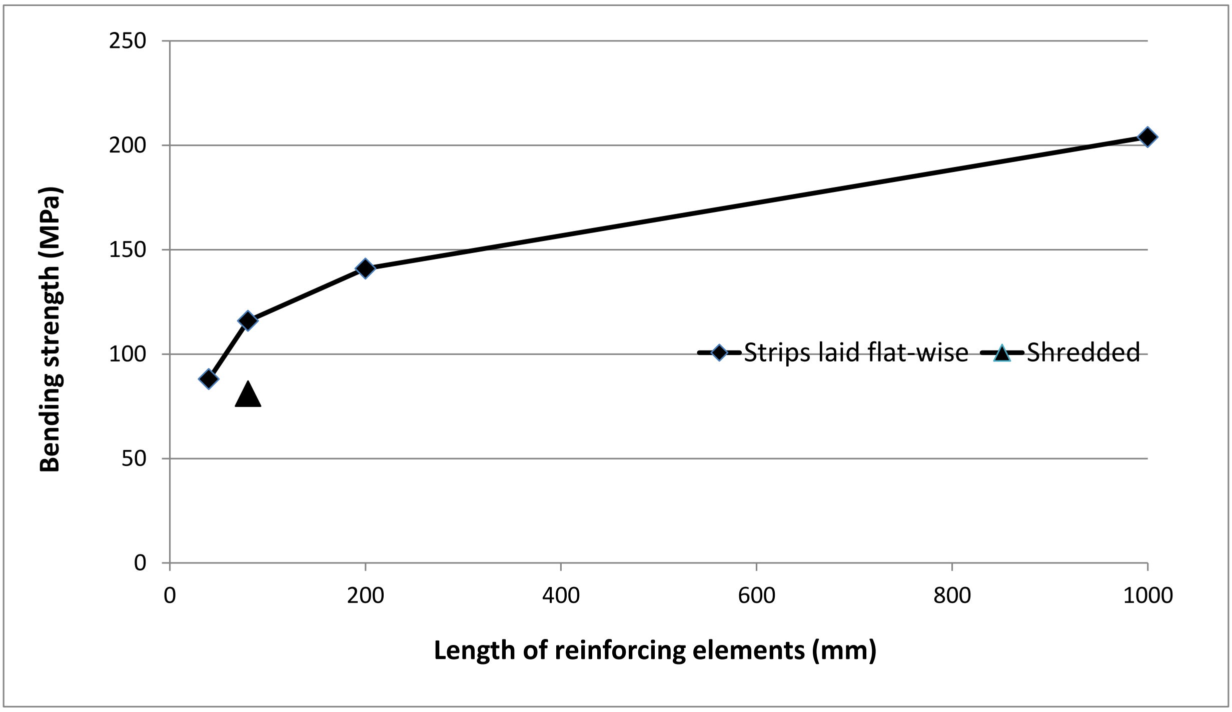


Figure 2 - Bending strength as function of strip length

As well as the use of re-used composite in the form of strips, the use of shredded material also was investigated. Shredded composites yields flakes that are also oblong in shape (see photo below) and can therefore act as a reinforcement in the same way as strips. The advantage of shredding is that it is a more economical process than sawing the old composite into strips. On the other hand, as can be seen from Figure 2, the strength that can be achieved in a new products is on a lower level than with the use of strips.

Re-use for retaining walls in canals

Photo by/courtesy of BiinC

There are a great number of canals in The Netherlands. The manifold canals originate from the fact that large parts of the land were reclaimed from the sea and canals were needed for transportation but also to remove drainage water. To maintain the integrity of the shore of a canal, generally a camp sheet is installed that acts as a retaining wall. Camp sheeting can be manufactured in different ways and using different materials, depending on the depth of the water at the shore side, the height of the soil-wall to be retained and the type of soil (sand, clay, peat). Camp sheeting is in permanent contact with water, both at the canal side and at the soil side. Therefore the materials must be long term water resistant. Both steel and tropical hard wood camp sheeting are degraded at the water surface within 20 years and have to be replaced. The photo right shows a degraded steel camp sheeting (Photo by/courtesy of BiinC).

Medium size camp sheeting is generally constructed as so-called sheet-piling: interlocking profiles of tropical hard wood which are vertically installed into the soil using a vibrating hammer block. Tropical hard wood profiles used for camp sheeting have a typical length of 3 to 6 metres of which the retaining height of the soil is typically one third of its length, the other part being forced into the ground. The profiles have a cross-section with a typical thickness of 40 to 60 mm and an effective width of 200 to 400 mm and are fitted with a tongue-and-groove detailing to interlock with the neighbouring profiles. Although tropical hard wood has a relatively high durability in wet conditions the life-time under these conditions is limited to 20 years maximum. Moreover, it is undesirable to use tropical hard wood because of the strain it puts on the rain forests. Therefore it was investigated whether these tropical hard wood profiles can be replaced by composite profiles made from re-used EoL thermoset composites.

It is the expectation that the new composite camp sheeting made with EoL thermoset composite will be extremely durable since the service life of composite products in wet conditions is reported to be 60 to 100 years [5]. Moreover, the new composite profiles can be engineered for a high mechanical strength, using the reinforcing elements of the EoL composite in combination with virgin material. Paradoxically, two drawbacks of the re-use of EoL composite principle work to the advantage in the design of these new camp sheeting. The first drawback is the relatively heavy weight of the new composite, the second is the limitation to flat designs like profiles and panels because of the relatively large and oblong elements.

Production and installation of profiles

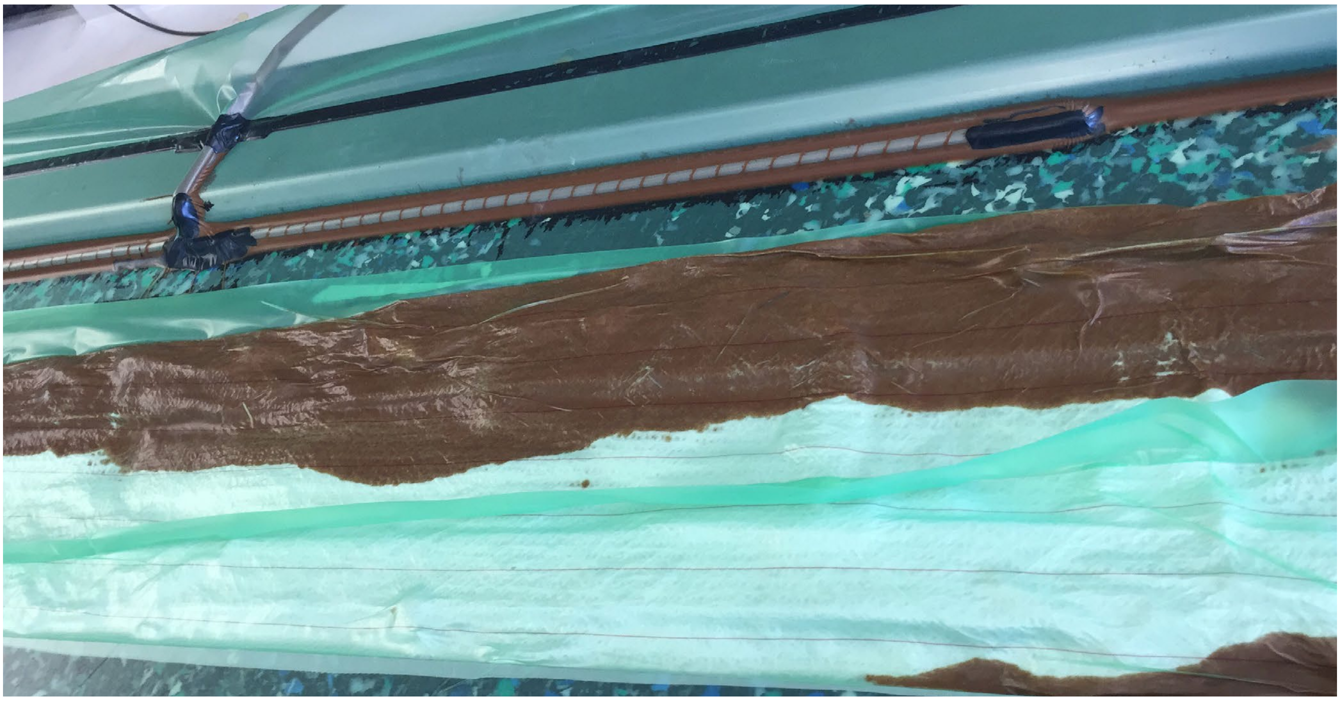

Photo by/courtesy of 't Harpje

A grant was obtained from the province of Flevoland for a demonstration project using the methodology of structural reuse of composites. In this project Windesheim partnered with the Dutch water authorities 'Zuiderzeeland' and the infra technical building company Reimert Bouw & Infra. The aim of the project was to produce 80 sheet piling profiles for the installation of a retaining wall near a lock-gate in Almere. Obsolete polyester boat hulls were supplied by the boat dismantling company 't Harpje - see photograph right (Photo by/ courtesy of 't Harpje).

In the first processing step, the hulls of the obsolete polyester boat hulls were torn into large panels.

In the second step, these panels are sawn into long strips. In addition to panels many irregular composite parts were obtained that could not be sawn into strips. These parts were shredded into flakes.

For the production of the camp sheeting profiles a combination of sawn strips and shredded flakes was used as reinforcing elements. In total 80 profiles of 3.5 meter length were made using vacuum-assisted infusion under foil using steel moulds.



As with the tropical hard wood profiles, the profiles made with EoL material were fitted with a tongue-and-groove system for mechanical interlocking with neighbouring profiles.

At the Beatrix lock-gate in Almere, The Netherlands the 80 profiles were used to install a camp sheeting. The placement process, vibrating the profiles into the soil with a hammer block was experienced by the crane operator to be as easy as with the traditional profiles made of tropical hard wood.

Future outlook

The production of profiles for camp sheeting using the principle of structural re-use of EoL composites proved the technical feasibility of the methodology. These profiles, however, were made with the relatively labour-intensive method of vacuum-assisted infusion under foil, which made the products too expensive to be of economical interest to the market. The market potential should therefore be explored by investigating a different set of products using a wide variety of production methods. In the next development phase, automated production methods will be investigated as well as products like supporting beams and building panels as these hold potential for the re-use of EoL thermoset composite principle as described in this article.

References

[1] Update on Recycling
ACMA Global Composite Recycling Workshop
Paris, March 7, 2016.

[2] Composites Recycling Made Easier.
EUCIA-Publication, 2012.

[3] I.M. Daniel, O. Ishai
Engineering Mechanics of Composite Materials
Oxford University Press, 2006
ISBN 0-19-515097-X

[4] A. ten Busschen
Structural Re-Use of End-of-Life
Thermoset Composites
Reinforced Plastics 61/3, 2017, pp 187-191

[5] S. Halliwell
Fibre Reinforced Polymers in Construction:
Durability
BRE Report IP10/03, September 2003
ISBN 1 86081 635 5

ABOUT THE AUTHOR

Biography of Dr. Ir. Albert ten Busschen
Dr. Ir. Albert ten Busschen (Zwolle, 1966) has a vast experience in the development and production of composite products and building products. After his study and promotion on composite mechanics at the Technical University in Delft he worked at PPG Fiber Glass Industries as manager of the application laboratory. After this, he directed the wood building product department at SHR Wood Research and worked as R&D manager on wood-polymer composites at Tech-Wood. Since 2005 he is Technical Director of Poly Products in Werkendam. In this company various composite products are developed, produced and installed for which Albert has the technical responsibility. One of the successes has been de CSC-certification of the Cargoshell composite container for which he has been the project leader. Moreover, Albert was chairman of the Dutch composites association CompositesNL for eight years. Since 2015 Albert has become associate professor on composites at the University of Applied Sciences Windesheim, The Netherlands.