Case Study

# Graphene delivers new generation of fibreglass swimming pools

first graphene
The world's leading graphene company

Fig.1 – Fibreglass swimming pool

## PureGRAPH® graphene additives in fibreglass laminate – increase strength, reduce weight and improve durability.

PureGRAPH® graphene additives significantly increase the flexural strength and water resistance of the fibreglass laminates used in swimming pool shells. These enhancements give a stronger, lighter product with improved resistance to water penetration and can simplify the manufacturing process.

## Background

The global market for swimming pool construction in 2017 was claimed to have reached USD38.2 billion, with annual in-ground pool installations expected to grow at a CAGR of 3.8% to 2028[1]. Traditionally, pools were constructed in concrete or with a vinyl liner. Improvements in glass-fibre materials technology, particularly gel coating systems have led to a growth in the popularity of fibreglass reinforced composite pools. Fibreglass pools have the advantage of short installation times, lower installation costs and typically lower maintenance costs than other systems.

For a successful installation, the flexural strength of the pool wall must be sufficient to retain shape and withstand the pressure of the external sand and gravel supporting aggregate and also support the weight of water, which is particularly critical during initial filling.

Fig.2 – Monoblock fibreglass in-ground swimming pool

The swimming pool structure must resist water penetration. The front face is well protected by a high-value gelcoat, but the reverse side must also resist ground-water penetration. In poorly performing systems, water diffusion into the composite matrix can lead to hydrolysis and result in osmotic blistering, ultimately leading to failure of the swimming pool structure. Various strategies have been adopted to reduce water penetration from the reverse side, such as the inclusion of a vinyl ester barrier layer within the laminate structure.

**Source:**

1 https://www.businesswire.com/news/home/20181130005119/en/Global-Swimming-Pool-Construction-Market-2018-2026

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## The project

First Graphene has enhanced the strength and water resistance of glass-reinforced polymer (GRP) laminates using PureGRAPH® graphene additives in the resin mix. These GRP laminates are typically used in boatbuilding, water storage systems and in the case of this study, fibreglass pools.

Studies were carried out by First Graphene using chopped glass fibre reinforcement and polyester styrene-based resin. Similar results are achievable using vinyl ester resins.

PureGRAPH® graphene powders are mixed at low concentrations into the polyester styrene resin using standard industrial mixing equipment. No pre-treatment of the graphene additive is required for the PureGRAPH® to disperse well into the resin system.

## How do fibre-reinforced plastic laminates fail?

GRP composites have many advantages including high mechanical strength, formability and low-cost and are therefore commonly used in marine and leisure applications.

However, GRP systems can be susceptible to moisture absorption. They contain reactive groups that will react with absorbed water via hydrolysis, leading to degradation of the matrix structure and osmotic blistering.

These failures can degrade the composite system, reducing interlaminate strength and ultimately resulting in mechanical failure.

The absorption of water into the matrix is measured by ASTM D570-98 which uses a Fickian-diffusion model to characterise the diffusion of water. The relationship between water absorption, immersion time and sample thickness is given by the equation:

$$\frac{M_t}{M_\infty} = \frac{4}{\pi^{1/2}} \left(\frac{Dt}{L^2}\right)^{1/2} \quad [2]$$

By plotting the ratio of mass of water absorbed at a given time ($M_t$) to the final mass absorbed ($M\infty$) **against** the square root of the time at which the mass was taken, the diffusion coefficient (D) can be calculated as the gradient, giving a measure of how easily water is absorbed. A “Sigmoid Curve” is typically observed, suggesting a two-stage process:

- **Stage 1:** Water absorption into the matrix - kinetic.
- **Stage 2:** Hydrolysis of the matrix by absorbed water – thermodynamic.

**Source:**

2 Ref: Crank & Park; Trans. Faraday Soc, 45, 1949

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## Results

Our study focused on improving the flexural strength and water resistance of GRP laminates. We found that PureGRAPH® graphene nanoplatelets enhanced the characteristics of the fibreglass laminate compared with standard laminates currently on the market.

**We demonstrated improvements in:**

- **Flexural strength – enabling lighter laminates**
- **Water-resistance – enabling increased laminate durability**
- **Thermal conductivity – enabling even cure in thick sections.**

Flexural strength results presented in **Fig. 3** demonstrate that a single layer laminate structure based on PureGRAPH® enhanced resin increases flexural strength by >30% and substantially exceeds the international pool standards.

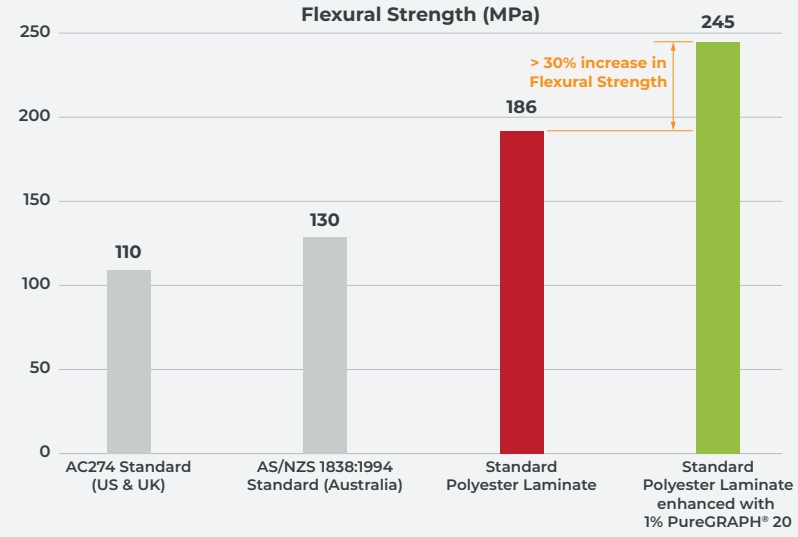


**Fig.3 – Flexural Strength Results of Graphene Enhanced Laminates Compared with Industry Standard Specifications – tested in accordance with AS 2132 & ASTM D 790 – 03**

**Fig. 4** details how the graphene-enhanced laminate outperforms typical laminates in terms of water absorption. The figure represents the reduced sorption curve of typical commercial pool laminates in the red-zone and reduced water sorption levels that can be achieved with graphene additives in the green zone. Tests were carried out in water at a temperature of 120˚C.

**Data shows that including small amounts of graphene into the system can reduce the diffusion coefficient by a factor of 10.**

Reduced water diffusion into the composite matrix reduces the likelihood of osmotic blistering and subsequent pool failure.

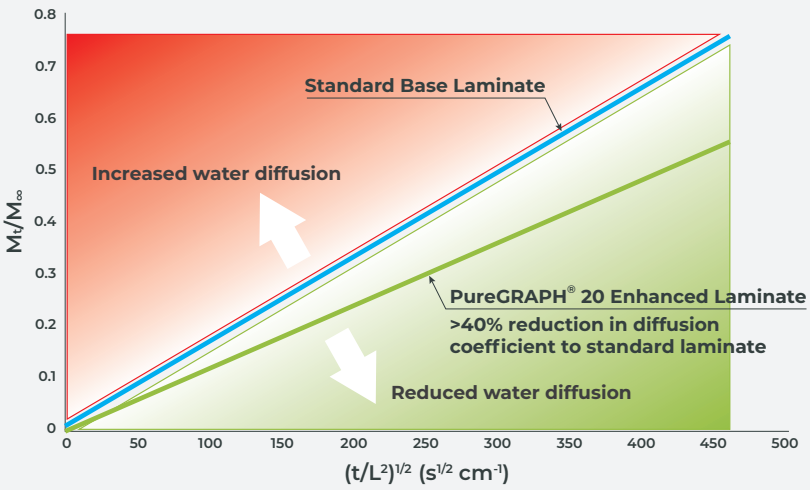


**Fig.4 – Reduced Sorption Curves from immersion tests, indicating the speed of water diffusion - tested in accordance with ASTM D 570-98 over a 72-hour period at elevated temperatures and pressures.**

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In conclusion, by adding low levels of PureGRAPH® to the polyester-styrene resin the flexural strength is improved allowing thinner and lighter laminate, for strength increases of > 30% the product may be light-weighted by a similar 30%. The increased strength may also lead to significant cost savings due to less material consumption and shorter lay-up times and the lighter weight can reduce transport and installation costs.

Enhanced water resistance provided by the PureGRAPH® means that additional layers containing barrier materials may not be required, enabling a much simpler and typically lower cost product construction, and a reduction in the number of layers leading to the reduced potential for interlaminar failure.

## Benefits

- **Increased strength and rigidity of pool structure >30%**
- **Light-weighting >30%**
- **Reduced potential for osmotic blistering**
- **Reduced unit costs**
- **Simplification of laminates and manufacturing process.**

For more information on PureGRAPH® products please contact us at **info@firstgraphene.net**


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