Technical Sheet
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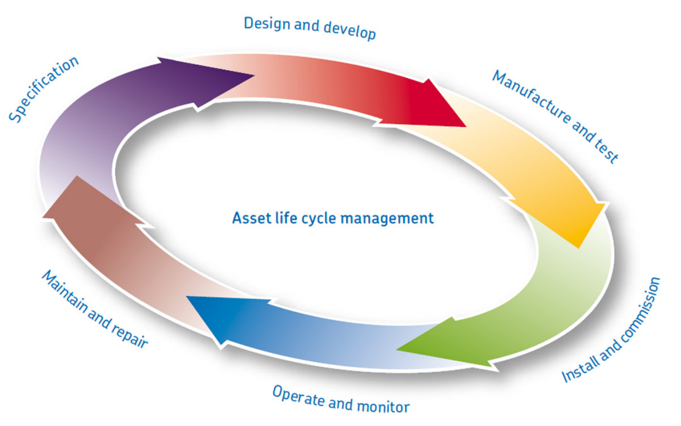
Composites UK
Trade Association

Life Cycle Cost of FRP Structures

Use of High Performance Materials

Since the introduction of high performance materials including composite reinforcements such as Fibre Reinforced Polymers (FRP) in 1980's (Burgoyne & Balafas, 2007), a steady increase in the utilisation has been observed, particularly over the last two decades (Ilg, et al., 2015). Its relatively high strength and stiffness, low density, and corrosion resistance make it a favourable alternative to more conventional materials such as steel and reinforced concrete (Hollaway, 2010). Due to the rise in global need for infrastructure investment, the feasibility of using FRP within the construction industry has become of increasing interest. In particular, repair and maintenance of numerous existing bridge structures has been identified as a priority within the industry (Richard, et al., 2007).



There is strong evidence to suggest that FRP materials are capable of outperforming more conventional bridge construction materials in terms of structural performance, maintenance and cost. However, high initial capital construction costs and poor Life Cycle Cost analyses have prohibited widespread use of composite reinforcement, largely attributed to a lack of knowledge and experience with the use of this material within the civil engineering industry (Ilg, et al., 2015).

Life Cycle Cost

Whole Life Cycle Cost is defined as an economic assessment that considers all of the relevant, projected costs and revenue associated with a particular asset, structure or project over its lifetime (Constructing Excellence, 2004). With regard to High performance materials, various methods for applying Life Cycle Costs have been proposed, for example by Ehlen (1999), Richard, et al. (2007) and Hastak & Haplin (2000), to enable comparison of FRP materials to more conventional construction materials. The choice of selection criteria included and method chosen lies ultimately with the assessor and, as demonstrated by Ilg, et al. (2015), the criteria chosen can have a significant impact on the outcome of the analysis. Monetary costings are more easily identified and considered, although non-monetised benefits are more subjective and difficult to assess, which often results in their omission in whole life cycle costings. Therefore, criteria should be carefully selected to represent the required stakeholders needs. Thus, life cycle cost analysis can provide a powerful tool for comparing alternative design structures and materials, supplying both designers and clients with more accurate and realistic cost comparisons of design options, enabling the most efficient and cost effective option to be selected.

Stages of Life Cycle Costs for FRP Structures

When assessing the feasibility of a project, there is often a significant focus on its initial costs, which is often a relatively small proportion of the total cost of a project over its duration (Richard, et al., 2007). Hence, there is a need for Life Cycle Costing. Four key stages of a structures life can be considered in the costing process (Ilg, et al., 2015): manufacturing (including developments and research), installation/construction, use (including maintenance and operation) and end of life (decommissioning or replacement). In the case of FRP, limited knowledge and case study data to support maintenance requirements and cost predictions have prohibited successful Life Cycle Cost analysis. Consequently, several attempts to provide alternative methods, including both quantitative and qualitative approaches, to Life Cycle Costing have been proposed, eliminating the need for extensive knowledge of the materials long term behaviour.

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Types of Life Cycle Analyses

Landfill tax now stands at £82.60/tonne (2015-2016 rate), Typical economic assessment of the various stages mentioned above can be calculated, as demonstrated by Nathan and Onyemelukwe (2000) through their three Life Cycle Costing methods, (Equivalent Uniform Annual Cost (EUAC), Maximising Benefits and Benefit Cost Ratio). Factors costed can vary considerably with method chosen. However, the clear knowledge gaps within the industry surrounding composite use have typically favoured conventional material use over FRP.

Purely physical cost assessments can be extended to include conventional, environmental and social/sustainability benefits associated with the structure, both during its construction and operation. Although, assigning a monetary value to such qualitative selection criteria can pose difficulty and controversy, and hence is often neglected in Life Cycle Costs of FRP structures. The impact of including the sustainability of materials was highlighted by the results presented by Ilg, et al. (2015).

Alternative methods that aim to capture the beneficial characteristic properties of FRP have been presented. One example proposed by Richard, et al. (2007) took into account the after construction costs associated with structures by means of a Life Cycle Performance assessment, which would facilitate a cost assessment. The method derives a comparative method based on material degradation characteristics of various composite materials. The level of deterioration can be refined by considering a group of structures together with their locality/environment, operational conditions and type, utilising Markov methods and statistical regression techniques. Similarly, Hastak & Haplin (2000) have produced a qualitative method which addresses the non-monetised benefits provided by FRP structures. A relative cost value is assigned based on a hierarchical system. Whilst measures have been taken to limit the impact of subjective decisions of the assessor, this cannot be completely eliminated. However, as with the economic assessment mentioned above, these methods all require validation against existing FRP structure data, which is limited and not widely available.

Economics of FRP from Existing Studies

Early Life Cycle Cost assessments, as completed by Ehlen (1999), Nystrom, et al. (2003) and Burgoyne & Balafas (2007), generally concluded that conventional materials were more economically feasible when compared to FRP, with the exception of very demanding environmental conditions. The cause has been attributed to the initial high cost of construction associated with FRP construction (Hastak & Haplin, 2000). However, these assessments were completed at a time where the introduction and application of FRP was relatively new, and thus attracted the very high costs associated with introduction of new technology. Prediction of cost decreases with gained experience were, at best, estimates of product development.

A more recent, comprehensive assessment completed by Ilg, et al. (2015) provides a more realistic insight into the feasibility of FRP today. Ilg, et al. identify that existing Life Cycle Costs have historically been under-researched, and often completed with a focus on mechanical properties of material, not on economics. Assessing a wide range of case studies with different structural applications of FRP (for example, bridge deck construction, full construct and repair), Ilg, et al. (2015) completed a focused cost comparison of FRP utilisation and concluded that it offered the most economical solution when subject to the inclusion of external costs, particularly associated with the gains in sustainability. While Life Cycle Costs for conventional materials were on average 10% better than FRP, mainly due to the relatively high initial costs still associate with FRP, inclusion of external costs in the Life Cycle Cost Calculation favoured FRP construction by 14%. Additional studies completed by Nathan and Onyemelukwe (2000) and Nishizaki, et al. (2006) also demonstrate that cost benefits can be achieved when projects involved environmental conditions that were particularly suited for FRP use.

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