APPLICATIONS OF GLASS REINFORCED PLASTIC (GRP) WASTE IN CONCRETE COMPOSITES

INTRODUCTION

In the United Kingdom, most GRP waste is currently sent to landfill due to its intrinsic thermoset composite nature, lack of information relating to its characteristics and insufficient knowledge of potential recycling options. As a part of the government and industry funded "Built Environment Action on Waste Awareness and Resource Efficiency" (BEAWARE) project, GRP waste was selected for new recycling applications in concrete composites. Two different types of waste samples (GRP waste powder and GRP waste fibre) were obtained from Hambleside Danelaw Rooflights and Cladding Limited, Inverness, Scotland. Findings of the testing programme showed that GRP waste can be used as a partial replacement for fine aggregate as well as an admixture in cement concrete. Additionally, the presence of polymer and short glass fibre content in GRP waste can significantly contribute to improve the quality of various concrete products and has ample scope for use in several applications in the construction sector.

METHODOLOGY

Concrete specimens were prepared in accordance with BS EN12390-2:2000 and BRE 1988 mix design for normal concrete using different proportions of cement, aggregate and processed GRP waste powder. More than 190 concrete specimens were produced using GRP waste powder content varying from 5% to 50% by weight, as replacement for fine aggregates. The overall methodology for making and testing the concrete specimens with GRP waste is summarised in Figure 1.

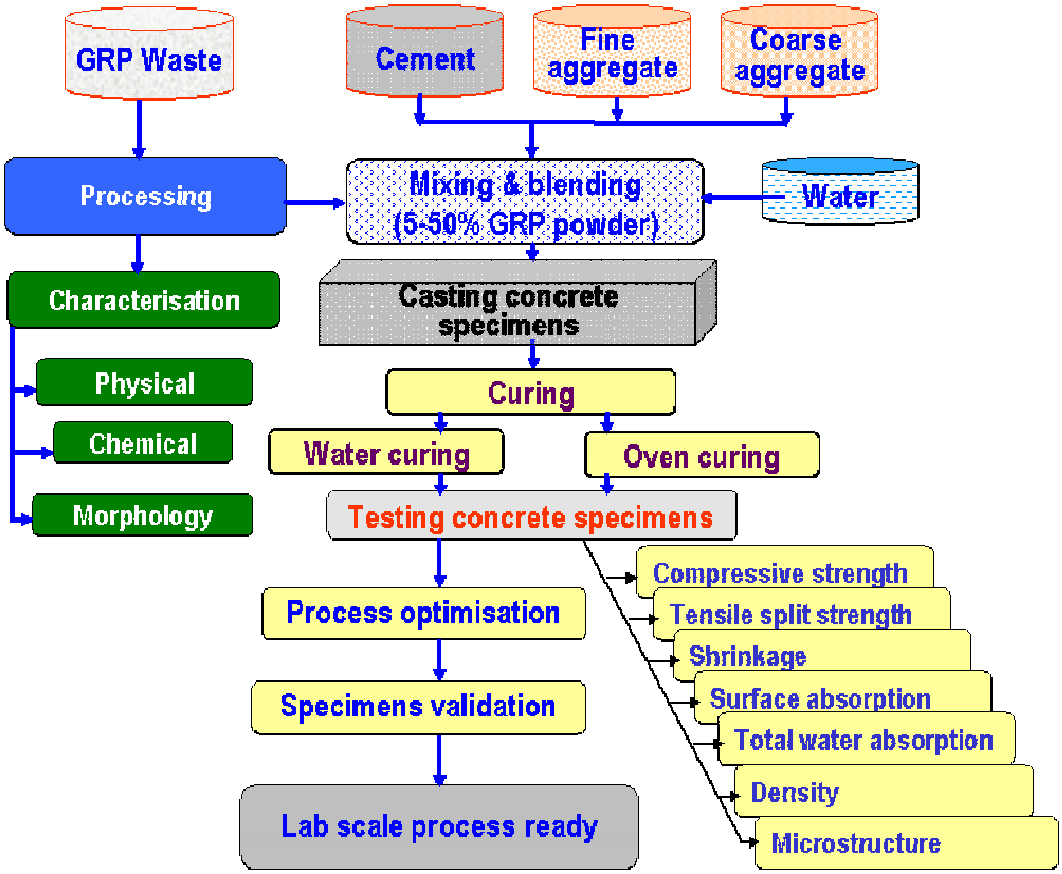

Figure 1: GRP waste in concrete composites testing process

Two types of curing processes of the concrete specimens were undertaken: water at 20 ± 2ºC and oven at 50 ± 2ºC. Cured concrete specimens were tested in accordance to BS EN 12390-1:2000. Laboratory experiments were conducted in two different stages:

(i) without additives; and
(ii) with additives (2% superplasticiser).

Attempts were also made to explore the potential of using GRP waste fibre within architectural cladding panels. Two different panel sizes: 300mm x 300mm x 8mm and 300mm x 300mm x 12mm were prepared in accordance with the product specification and test method BS EN 12467:2004.

FINDINGS

GRP waste in concrete without additives

Figure 2 illustrates the received GRP waste powder, and Figure 3 shows the developed concrete specimens using different proportions of GRP waste without additives (5 to 50%).

Figure 2: Received GRP waste powder **Figure 3: GRP waste concrete specimens**

The key findings of the GRP waste in concrete testing programme are:

- The 28 days mean compressive strength of concrete using 5% and 15% GRP waste powder without additives under water curing attained 37N/mm^2 and 34N/mm^2 respectively.
- The 28 days mean compressive strength of concrete using 30% and 50% GRP waste powder in concrete attained 29.5N/mm^2 and 19N/mm^2 compressive strength respectively.
- Increased proportions of GRP waste in concrete decreased the density (12%) and minimum density was 2140 kg/m^3 with 50% GRP waste powder.
- Increase in curing duration: there is an increase in compressive strength of concrete with GRP application and optimum compressive strength (180 days) was 45.75N/mm^2.

Although the 28 days compressive strength was not higher than the recommended values i.e. 45 N/mm^2, the products could be used for a variety of applications including concrete paving blocks and pre-cast concrete wall elements.

GRP waste in concrete with additives

The potential of using GRP waste in concrete to enhance compressive strength was also explored with the addition of 2% superplasticiser (2% of cement content)along with GRP waste (Figure 4).

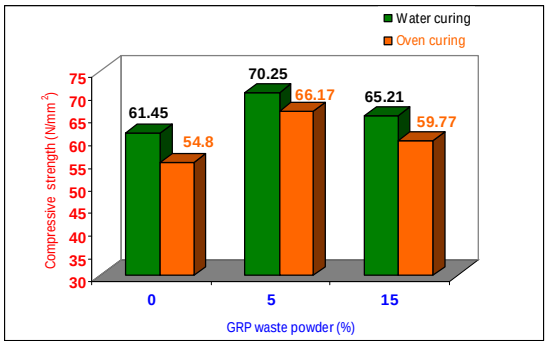

Figure 4: Effect of GRP waste powder on the compressive strength of concrete

The results can be summarised as follow:

- The 28 day mean compressive strength of the concrete specimens using 5% and 15% GRP waste with 2% superplasticiser were 70N/mm^2 and 65N/mm^2 respectively.
- The tensile splitting strength of concrete developed using 15% GRP waste powder with additives was 4.2N/mm^2, which is higher than the normal concrete tensile splitting strength.
- The initial surface absorption was reduced (by 16%) with GRP waste addition.
- The mean total water absorption of concrete specimen with 15% GRP waste was 0.42%, which is considerably lower than the 6% for normal concrete.

The results show that using GRP waste with the addition of 2% superplasticiser in concrete composites meets the desirable industry quality and comply with British Standards for the use in concrete products for construction purposes.

GRP waste fibre in architectural cladding panels

GRP waste fibre sample and the developed prototypes of architectural cladding panel products are shown respectively in Figures 5 and 6. The bending strength in terms of modules of rupture (MOR) of the 300mm by 300mm by 2mm architectural cladding prototypes using 5% GRP waste fibre was 16.5N/mm^2, whereas the bending strength of cladding panels usually varies from 17N/mm^2 to 24N/mm^2. Better quality panel products could be produced using standard manufacturing facilities if consistent quantities and quality of GRP waste fibre could be achieved.

Figure 5: GRP waste fibre

Figure 6: Architectural cladding panels from GRP waste fibre

Potential applications of GRP waste in concrete products

The results have been very encouraging and it appears that GRP waste in concrete has considerable application scope in construction, subject to further tests such as durability and end of life tests. Potential applications of GRP waste in concrete include: pre-cast paving slabs; roof tiles; pre-cast concrete wall elements; light weight concrete; concrete paving blocks; and architectural cladding materials.

Technical benefits

- 15% GRP waste (substitute to fine aggregates) with additives improved compressive strength, tensile splitting strength, shrinkage, initial surface absorption and water absorption of concrete.

- The presence of CaO, Al_2O_3 and SiO_2 and other polymeric compounds in GRP waste has the potential as additives to improve the binding and adhesion of concrete. The glass fibre content improved the reinforcement in the concrete composites.

Economic and environmental benefits

- The increased costs of using 2% superplasticiser is about £50 per cubic meter of concrete. Additionally, the use of GRP waste in concrete contributes to cost savings associated with waste handling, transport and landfill tax payment in addition to the cost of 15% of fine aggregates.
- The present investigation has set a foundation for further recycling opportunities of GRP waste ground powder and fibre in concrete and cement composites.

Dissemination of results and feedback: The British Precast Concrete Federation workshop

A workshop was organised by the British Precast Concrete Federation on 15th April 2008 at Leicester to discuss the findings of the use of GRP waste in concrete. Control concrete strength with superplasticiser, short terms compressive strength (12hrs), inclusion of GRP waste in cement stage, cost of GRP waste and its availability were discussed. The emerging outcomes are as follows:

- GRP waste is an inert material and will not react during the concrete making process.
- The mean compressive strength of control concrete (without GRP waste) with 2% superplasticiser was 61N/mm^2. GRP waste application alongwith 2% superplasticiser increased the 28 days compressive strength about 10% when compared with the control sample.
- The 12 hrs compressive strength of concrete specimens showed an increase of about 9% using GRP waste with additives over control. However, without additives, the 12 hrs strength was increased about 51%.
- Though there is a scope for possible inclusion of GRP powder at the cement stage rather than the mixing stage, the suitability for cement substitution can be confirmed by conducting appropriate laboratory experiments, which is not under the remit of this project.

Based on the information obtained from Hambleside Danelaw Ltd, the cost, production and availability of GRP waste in the UK are as follows:

- GRP waste cost: around £ 17 per tonne excluding transport.
- GRP waste production in the UK: about 55,000 tonnes per year and expected to increase around 10% per year.
- GRP waste availability: about 200 tonnes per year ground GRP waste in the form of fibre and powder is provided by Hambleside Danelaw GRP products manufacturing processes. Currently, Hambleside Danelaw Rooflights and Cladding Limited, Inverness, Scotland is the only company in the UK which has facility for grinding GRP waste. However, depending on the demand, there is a scope for supply of 5000 tonnes per year.

SUMMARY

The study results suggest that the use of GRP waste in concrete products and architectural cladding panels has technical, economic and environmental benefits. The use of GRP waste with superplasticiser improved the quality of concrete if compared to the control specimen (without GRP waste). However, the quality of panel products does depend upon the consistency and quality of GRP waste fibre, and the access to specialised architectural cladding manufacturing facilities. Furthermore, full compliance tests including durability studies and requirements, which may depend upon specific applications, are recommended. The findings of this study showed a viable technological option to help with GRP waste management, leading to cross-sector waste recycling applications within construction industry.

Further information and contact

The full GRP waste in concrete report is available at the BeAware website: www.beaware.org.uk.

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