3 Is GRC a "Green" Building Material?

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Abstract: Given the environmental and energy concerns, there has been a considerable interest in recent years with regard to the use of sustainable building materials in construction. Questions like 'Is GRC a green material?' or 'How green is GRC' have been frequently asked by clients, architects, engineers etc. This paper looks at this subject from different perspectives and discusses some of the important issues. The use of Calcium Sulphoaluminate Cement (CSA) and pozzolanic materials as portland cement replacement and the use of recycled materials as fillers or aggregates are considered. The environmental impacts of GRC and precast concrete in similar applications are compared. The 'greenness' of GRC as evaluated by the BRE Environmental Assessment Method (BREEAM) and the Leadership in Energy and Environmental Design (LEED) rating system is also investigated.

Key words: GRC, sustainability, green material, environmental, BREEAM, LEED

Introduction

A growing demand for green building materials has been noted in modern construction industries. Many countries have introduced sustainable construction strategies which naturally include using "green" building materials. This not only helps provide human beings with greener and more comfortable living environments but also creates new challenging markets for the construction industry. The global market for green building materials is estimated to reach $406 billion by 2015 according to a report by Global Industry Analysts, Inc (2010).

As a specific section of precast industry, GRC products make a non-negligible contribution to the built environment. They are widely used in public and private sector projects of many sizes, from housing and landscaping through commercial buildings to highways and infrastructure. Given that GRC products are generally thin sectioned and hence use less material than their traditional precast equivalents, there are immediate and obvious advantages when such subjects as "carbon footprint" are raised. But how does GRC compare with other materials such as metals, glass and other composites? Can we do more to increase the benefits already inherent in GRC? Above all, what are we, as an industry, doing to research and promote the "green credentials" of GRC?

The purpose of this paper is to stimulate discussion and to get the industry thinking. In recent years, the authors have noted that questions from specifiers regarding GRC products and the environment are becoming more frequent. Given the continuing need for the human race to reduce carbon emissions the questions are bound to increase and become more difficult to answer. Whilst this will require investment in research and development it could also present a significant opportunity for GRC to increase its share of the world market for sustainable building materials.

Is GRC a Green Material?

First, what is a green material? The United States Green Building Councils (USGBC) definition of Green construction materials are those materials composed of renewable, recyclable or reusable resources that can be used indefinitely without negatively impacting on the environment. If we strictly keep to this wording, GRC may not be that green. The main problem is the high content of cement. Unfortunately, it has never been easy to profile cement as a green material as it is energy intensive and has high carbon dioxide emissions, and cement kilns are a source of mercury emissions. *Cement production accounts for over 5% of the world's carbon emissions although a proportion is ultimately reabsorbed by the cement over time (i.e. by the process of carbonation which is beneficial to GRC).*

The reality is that most building materials consume lots of natural resources and we cannot simply stop using them as they are part of our lives. However, we can improve the greenness of GRC by careful selection of raw materials, proper design and more advanced production technologies etc. Furthermore, to justify whether a building material is green we need to compare it with its counterparts since none of them can claim to be 100% green.

Sourcing raw materials

Pozzolans

Pozzolans like microsilica, pulverised fly ash (PFA), ground granulated blast furnace slag (GGBS), metakaolin and the latest development, a finely ground pozzolanic material made from recycled E-glass fibre called VCAS, can be used as a cement replacement in GRC. They are often used to replace about 10% to 30% of the ordinary Portland cement (OPC). These pozzolans react with the calcium hydroxide by-products produced during cement hydration. Benefits include reducing cement content, reducing efflorescence, boosting strength and increasing durability etc. (Singh et al. 1984; Shah et al. 1988; Thiery et al. 1991; Marikunte et al. 1997; Zhu and Bartos 1997; Peled et al. 2005; Jones et al. 2008). A super classified PFA under the trade name Super-Pozz was also found to be particularly effective in increasing the workability of premix GRC (Che, 2010), which can help develop self compacting GRC.

Amongst these pozzolans, microsilica, PFA, GGBS, VCAS are derived from industrial waste and can certainly add green points to GRC. Metakaolin is a manufactured pozzolanic material, the green benefit is substantially compromised by the consumption of natural clay mineral kaolinite and energy during the calcination process.

Despite having the above benefits, pozzolans in general are not attractive to GRC manufactures due to their availability and cost concerns. Another drawback is that the initial strength gain is delayed, consequently prolonging the mould stripping time.

Calcium Sulphoaluminate Cement (CSA)

CSA cements were essentially developed in China in the 1970s for shrinkage compensation. They soon gained particular popularity in the Chinese GRC industry thanks to their rapid hardening and low alkalinity properties. The rapid hardening property enables a fast turnover of moulds. This can mean that less moulds are needed although moulds generally have a finite life defined in the number of products cast rather than "time" so this is not always a "real" advantage and hence the overall production cost should always be considered. The low alkaline environment of the matrix also helps to increase the long term durability of the GRC.

Another key advantage is that CSA cements are significantly greener. Portland cement is fired in kilns at temperatures of around 1500°C, whereas CSA cements only need to be fired at temperatures of around 1250°C. The resulting CSA clinker is softer than OPC clinker, requiring less energy to grind.

On average, 900 kg of CO_2 are emitted for the production of every tonne of ordinary Portland cement. In contrast, only 216 kg of CO_2 is emitted to produce CSA cement, a reduction of 76%. This reduction is far greater than that achieved by using pozzolans as OPC replacements. Concrete made with 100% CSA is 2 to 6 times greener than OPC that has had a significant quantity of cement replaced with pozzolans, and that includes 'green' pozzolans like PFA and GGBS.

TiOCem

Developed by Heidelberg Cement, TiOCem is a cement containing nano-crystalline titanium dioxide (TiO_2) which acts as a photocatalyst when exposed to sunlight to convert the harmful nitrogen oxides (NOx) air pollutants to harmless nitrates (NO_3^-). NOx is a major pollutant from exhaust gases and can cause respiratory problems. NOx pollution is exacerbated in car-choked big cities. Large surface areas of concrete made with TioCem (e.g. cladding panels, sidewalks etc.) are claimed to reduce the NOx dramatically. According to results from controlled tests, between 40 to 80 % of NOx emitted onto a TioCem concrete sidewalk by internal combustion engines was removed from surrounding air. However, this can also be a costly and inefficient system if the TiOCem cement is used throughout the thickness of the product since only the surface layer is exposed and hence active. This is an area where the Sprayed GRC production system provides a distinct advantage. By incorporating TioCem in the surface "face coat" layer of a GRC product (e.g. a cladding panel), the TioCem material is not only used in the right place, it is also used efficiently. The GRC backing layer can be sprayed with a normal OPC mix.

Projects in Germany and China where TioCem has been used on GRC panels are already in service and the positive publicity from these will help to further expand the market for this material.

Recycled glass

The traditional market for recycled glass sees the glass cullet being returned to glass manufacturers where it is combined with virgin raw materials in the furnace to produce new glass. In the last decade the concrete industry also started using recycled glass as an alternative raw material.

When it comes to GRC, finely ground recycled glass can be used as a sand replacement or as a pozzolan like VCAS to replace a proportion of the cement. However, although being a recycled material, the CO_2 reduction benefit is limited since energy is needed to grind and sort the glass into the required grading.

Currently the high cost of these materials is enough to deter GRC manufacturers. For example, the price of a 40 pack pallet (1 tonne) of silica sand and ground recycled glass with similar grading including delivery in the UK is £110 and £286 (http://www.specialistaggregates.com), respectively. Availability of bulk supply is another problem. The authors tried to contact a handful of processors when preparing this paper. In the UK, almost all of them are presently operating on a relatively small scale.

One more concern is the alkali-silica reaction (ASR). Research indicates that it is almost certain that ASR will happen when glass is used as aggregate (Byars et al. 2004). However, the severity varies and no definitive conclusion has been drawn.

Another consideration must also be given to the fact that glass is made from silica sand and that silica sand is generally widely available. If a GRC manufacturer's sand supply is nearby and the nearest glass recycling/processing plant is not, then it probably makes no sense, either economically or environmentally, to use recycled glass as a sand replacement. The words “recycled” and “glass” often receive a positive reaction when used in the context of sustainable building materials. However, the use of recycled glass in GRC is not as obviously beneficial as it may first appear. Simply using it to gain green points would currently just be a gimmick.

Production Methods

Traditionally, the production of GRC is relatively labour intensive and can incur high levels of material wastage. Unfortunately, when producing claddings or intricate architectural elements for “one-off” contracts there is almost no alternative. Attempts to introduce robotics into the production of sprayed GRC elements have generally proved to be too expensive, inefficient and limited in terms of the range of shapes and sizes possible.

Nevertheless, opportunities exist to improve the efficiency of GRC production and hence its greenness. For example, whilst the attention grabbing architectural panel market for GRC is not insignificant, the market for more mundane standard products, both architectural and industrial, is growing well and in many areas has already surpassed the “one-off” cladding project market in terms of material usage. It is these areas where investment in the development of more efficient production methods and mix designs can be better justified

For example, whilst many look upon Premix GRC as a poor relation to sprayed GRC, in terms of industrialised production Premix GRC offers many advantages. These not only include better control of mix design, materials usage and wastage but also more consistent material properties and less labour. Too much emphasis is placed on the higher strength of sprayed GRC when often the strength of a good quality Premix is adequate for the application concerned.

Self compacting GRC developed by Fibre Technologies International and the bottom-up pumping technology developed by the author (Che, 2010) and Power-Sprays can significantly increase the efficiency of production and eliminate the need for vibration. The elimination of vibration also helps provide a greener working environment.

Of course, there are exceptions and it should not be thought that GRC production methods are limited to manual spray and cast premix. When developing a production system for a standard product the process must always start with the product and the required properties. Often this may result in a compromise in terms of the materials used and the GRC mix design. Whilst some manufacturers have adapted traditional production methods others have developed their own unique processes. For example, there are manufacturers who have adapted automated spray systems to make cable troughs, permanent formwork and other simple 3 dimensional forms. There are also others who have successfully developed self compacting Premix GRC mixes with lower than normal fibre contents yet adequate mechanical properties to produce roof tiles, drainage channels, utility enclosures and many other mass produced products.

Some companies have also developed their own hybrid production systems to suit their range of products. Rieder in Germany employs a special extrusion process to make cladding panels (Fibre C). Successful projects include the Soccer City Stadium in South Africa for the 2010 FIFA World Cup football competition among many less prominent applications. Winsun in China also uses an extrusion system to make cladding panels (SRC) and so far has completed 500,000 m^2 of cladding projects since 2009. Other examples of specially developed production systems include the use of woven AR glassfibre textiles (Pachow and Neunzig, 2011) and FRP reinforcing bars combined with Premix GRC (Che and Peter, 2011). These systems attempt to concentrate the reinforcement where it can provide the maximum benefit to the tensile strength of the matrix.

Recyclability

The main ingredients of GRC are based on the plentiful and naturally occurring minerals used in the manufacture of cement, aggregates and glass fibres. These natural materials are not normally regarded as pollutants. Hence GRC can be regarded as a stable mineral based material and can be simply crushed and land filled. It uses less energy and takes less time to crush GRC than reinforced concrete since the former has no coarse aggregate and the time to recycle steel rebars is saved. To take one step further, it has even been reported that ground GRC can be used as filler or fine aggregate to make new GRC (Takeuchi et al. 1998).

GRC vs. Precast concrete

It is not easy to compare the greenness of GRC and precast concrete. The argument lies in the high usage of cement in GRC and use of polymer, which makes the cleaning water less recyclable. Also steel reinforcement is greener than glass fibre since steel is the most recycled material. However the reduced thickness, consequently the reduced weight, of GRC does provide several environmental benefits. A study carried out by UK's Concrete Industry Alliance with the support of the government's Department of the Environment, Transport and the Regions (DETR) compared GRC and precast concrete products that perform the same function. The results show that GRC has a much lower environmental impact by a factor of as high as 60%, when compared to traditional precast concrete (Ferry and Parrott, 1999).

When used as cladding panels or internal partition walls, the reduced thickness of GRC results in an increased usable floor area. In terms of a stud frame cladding panel, the cavity behind the GRC panel can be used to install insulation materials. GRC composite partition wall is widely used in China. According to an assessment conducted by the Chinese GRCA on a concrete-frame structured three-bedroom flat with a floor area of 150 m^2, the use of insulated GRC cladding panel and GRC partition wall could increase the usable floor area up to 6 m^2 compared with aerated concrete block wall.

The reduced weight of GRC also means ease of handling, reduced site-work and transport cost including transporting the raw materials to the factory and finished products to sites. GRC is also relatively light in weight compared to traditional stone or terra cotta ornaments. If the use of GRC is studied in the early stages of design, it can lead to significant saving in superstructure and foundations.

GRC and BREEAM & LEED

As the leading and most widely used accredited environmental rating scheme for buildings, BREEAM sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance. The Building Research Establishment (BRE) Green Guide to Specification is part of BREEAM. It provides designers and specifiers with easy-to-use guidance on how to make the best environmental choices when selecting construction materials and components (Anderson et al. 2009).

According to the BRE Green Guide 2008 rating, the relative environmental impacts of a GRC cladding panel constructed with stainless steel support, insulation, EPDM rubber layer, light steel frame, plasterboard and paint are rated A+ while a similarly constructed glass reinforced plastic (GRP) cladding rated A and a sandstone faced non-load bearing precast concrete sandwich panel with structural steel frame, light steel studwork, plasterboard and paint rated E (BRE, 2011). It should be noted that other types of GRC products need to be assessed separately to get their own rating.

The LEED Green Building Rating System, developed by the USGBC, provides a suite of standards for environmentally sustainable construction. It provides third-party verification that a building or community is built according to several measures aimed at promoting sustainability: Energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, stewardship of resources and sensitivity to their impacts (USGBC, 2011).

GRC has been frequently specified and used on LEED Certified Projects. Albeit products alone do not provide LEED points, they help contribute toward the performance of the building in the Energy and Atmosphere, Materials and Resources, Indoor Air Quality, and Innovation and Design Process categories. When properly used, GRC may contribute up to 27 points toward LEED certification, which is enough for the building to get a certified level of certification.

Conclusion

It is not easy to draw a conclusion as to whether or not GRC is truly a green building material. Compared with precast concrete and many other building materials, it is certainly “greener” and makes a non-negligible contribution to a sustainable built environment. Furthermore, the greenness of GRC can be improved by proper design, careful selection of raw materials and production technologies. However, simply using recycled material to make GRC is impractical although it is tempting as many clients and specifiers have the false impression that using any recycled materials must be “good”. Nevertheless, GRC is in a strong position and the industry should invest to capitalise on its existing advantages and to explore new ones.

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