Comparing GRC and UHPC

This techNOTE from The International Glassfibre Reinforced Concrete Association (GRCA) serves to provide comparative information between Glassfibre Reinforced Concrete (GRC or GFRC) and the more recent development of Ultra High Performance Concrete (UHPC)

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This is the eighteenth in a series of technical notes covering aspects of glassfibre reinforced concrete (GRC / GFRC) technology.

Glassfibre Reinforced Concrete (GRC or GFRC) has been in commercial production since the early 1970s. Including the time spent in research and development, the industry now has over 50 years' experience. GRC is used in more than 100 countries around the world, primarily in decorative applications (most commonly as cladding panels), but also in engineering. The development of Ultra High Performance Concrete (UHPC) is more recent. Over the last twenty years or so, various types of UHPC have been developed. These can also be used to produce impressive architecture.

UHPC uses dense particle packing, combined with fibre-reinforcement and an exceptionally low water/cement ratio to achieve very high strength and density. The exact classification of UHPC is not well defined across broad regional areas, but it is generally agreed that it should have a minimum compressive strength of 150MPa in structural applications (1), or 120MPa for decorative applications.

UHPC was initially developed for structural use and has been used extensively in the USA in road applications, such as road overlays and expansion joints, where its durability, due to its very low permeability, is an advantage, particularly in places with aggressive climates. In the USA and elsewhere, it has been used to make concrete girders for bridges (2), although it is primarily used as a surface overlay, as this reduces the amount of UHPC required and therefore lowers costs. More recently, UHPC has also been used in decorative applications.

Although the two materials have very different properties and manufacturing methods, there are similarities between UHPC and GRC, which can lead to confusion:

- both materials have a high cement content – GRC is typically made with a 1:1 sand-cement ratio; UHPC is generally similar
- both use fibres as reinforcement – GRC uses AR glass fibres, whereas UHPC can incorporate organic, metallic or glass fibres.

Properties of UHPC

A major drawback of the majority of UHPC mixes is that they are highly viscous and can only be used in poured applications, making certain shapes much more difficult to produce than by sprayed processes, normally requiring complex, closed moulds. This is because most UHPC mixes have non-Newtonian properties, meaning they stiffen under pressure, and are very difficult to pump, requiring specialized equipment. For this reason, it can also be difficult to apply sprayed 'face-coats' to UHPC panels. In addition, the nature of UHPC means that particle sizes, the admixtures used and mix procedures must be tightly controlled, which requires a high level of material control few concrete manufacturers are capable of. Because of this, most UHPC mixes must be supplied to the manufacturer as pre-blended formulations, which often add considerable cost.

Properties of GRC.

In comparison, GRC can also be produced by casting, but more importantly, can also be sprayed, removing the need for closed/double moulds, hence reducing costs and simplifying the production process. GRC also uses very few materials (sand, cement, water, AR glass-fibres and admixtures), which (apart from the glass-fibres) are generally available locally, and this makes accessibility, batching and mixing a simpler and more economical process.

Comparison of Properties

	Unit	GRC (Sprayed)	Decorative UHPC	Structural UHPC
Compressive Strength	MPa	50-80	130+	150+
Flexural Strength (MOR)	MPa	20-30	15-25	40-50
Elastic Modulus	GPa	10-20	45-55	50-60
Density	kg/m^3	1900-2100	2350-2400	2400-2550
Production Method		Sprayed or Cast	Generally, Cast Only	Cast Only
International Standards		EN 1169, EN 1170 1-8, EN 15191, GRCA & ASTM standards	ASTM standards, others under development	ASTM standards, others under development

Design Considerations

When considering the most relevant properties for architectural cladding, i.e. flexural strength and ductility, the major advantage of sprayed GRC (Grade 18, with a characteristic flexural strength of >18MPa) is its ductility, which ensures a non-brittle failure. This can only be matched by some structural UHPC formulations, reinforced with a high content of steel fibres. However, these fibres can be visible on the surface of the finished element, which is a major drawback in decorative applications. As a result, most architectural UHPC formulations incorporate glass or organic fibres to minimise their visibility on the surface. These tend to exhibit a more brittle failure, and are more comparable to a Premix GRC.

When considering which material to use, various questions should be asked, for example:

- What are the shapes of the pieces? Is it practical to cast them, or will there be efficiencies gained from spraying?
- How and where will fixings be placed? How many are needed? Will this be practical considering the production method?
- Is a brittle failure acceptable for the application?
- What are the mechanical properties (flexural and compressive strength) required to obtain the target dimensions of the element(s)?
- Are there any specific requirements that need to be met e.g. higher than normal resistance to freeze-thaw weathering, bomb-blast resistance etc.

In some cases, the performance of GRC may be further enhanced with the addition of special admixtures or pozzolans, or more careful selection of sand grades. Development of “high performance” GRC composites is ongoing – these have the potential to offer many of the benefits of UHPC, without some of the drawbacks.

Advantages and Disadvantages of GRC and UHPC

	GRC / GFRC	Decorative UHPC	Structural UHPC
Castable	✓	✓	✓
Sprayable	✓	✗	✗
Non-brittle Behaviour	✓	✗	✓
Non-Metallic Reinforcement	✓	✓	✗
Uses locally available raw materials	✓*	✗	✗
Used for structural applications	✗**	✗**	✓
International Standards	✓	✗	✗

*Except for Alkali Resistant Glass Fibre
**Both materials can have structural uses in limited applications, but in general are only used for decorative purposes

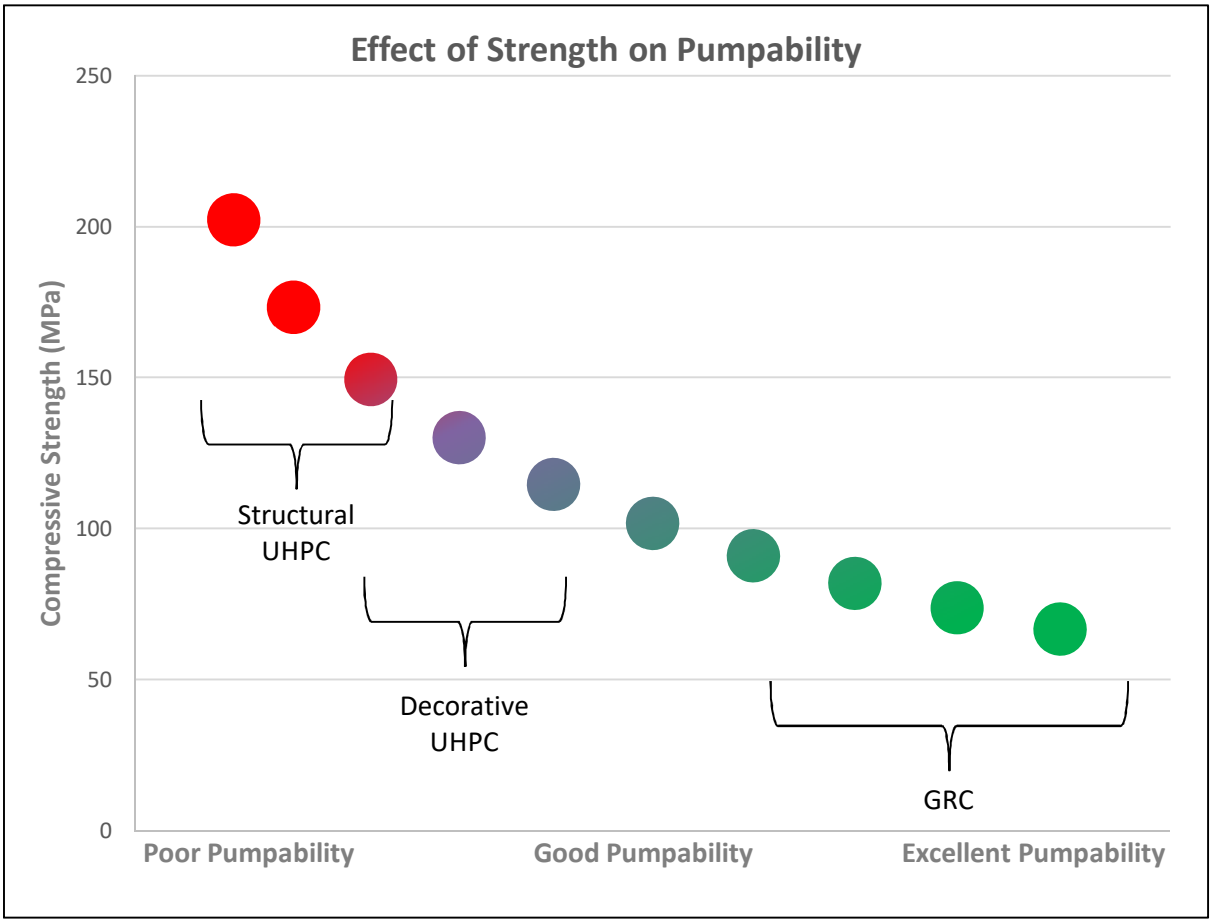

Figure 1. Effect of Strength on Pumpability

Figure 2. UHPC Overlay Installation (Source: Federal Highway Administration) (3)

Figure 3. Train Station in Kénitra, Morocco – Decorative UHPC (Source: Bearch) (4)

Figure 4. Sunscreen panels in Casablanca, Morocco – Decorative UHPC (Source: Bearch) (4)

Figure 5. Mumbai Airport (Terminal 2), India – Sprayed GRC

Figure 6. Elizabeth Line, London UK – Sprayed GRC.
The flowing profile is achieved by the spray process, without the need for a closed mould.

In conclusion, both materials have advantages and disadvantages. The higher strengths of UHPC's may offer the opportunity to design thinner sections but thickness may be dictated by practical considerations and hence the "advantage" may not be realisable. In other applications, a higher strength may not be necessary. In such cases, GRC may be preferable. Ultimately, provided the strength and other properties are known, reliable and are useable, engineers can design with almost any material and the main consideration then is cost. Finally, it should be noted that International Standards, Codes of Practice and industry guidance for UHPC and UHPFRC is quite limited. Whereas GRC, being a more recognised, established, and utilised material, is well documented in this respect. In addition, GRC's capabilities continue to satisfy additional project specific standards set by leading authoritative independent warranty and insurance providers.

Further Case Studies that demonstrate the creativity and confidence portrayed by Architects, Designers and Engineers in integrating GRC into the built environment, based on its known performance attributes, can be seen on the GRCA website https://www.grca.online/case-studies.

techNOTE 18 References:

(1) American Concrete Institute. *PRC-239-18: Ultra-High Performance Concrete: An Emerging Technology Report.*
(2) Federal Highway Administration. A State-Of-The-Art Report for The Bridge Community. [Online] https://www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/13060/index.cfm.
(3) Federal Highway Administration. Ultra-High Performance Concrete for Bridge Deck Overlays. [Online] https://www.fhwa.dot.gov/publications/research/infrastructure/bridge/17097/index.cfm.
(4) Bearch. [Online] https://www.bearch.ma/.

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