SWA INNOVATION HUB

SWA

Greener, Low Carbon & Geopolymer Concrete Products

Market Sounding Report

Office of Major
Transport Infrastructure
Delivery (OMTID)

Contents

1 Introduction

This report presents the results of market sounding in relation to existing solutions (as at the December 2022) for geopolymer, low-carbon or 'green' concretes, both commercially available and in development in Western Australia. Low-carbon concrete products present alternatives to business as usual (BAU) concrete manufactured with Ordinary Portland Cement (OPC). This report has been prepared by the Sustainability Waste Alliance (SWA) Innovation Hub.

A supplier outreach exercise was undertaken nationally to identify green, low-carbon and geopolymer concrete products with similar or equivalent performance to general purpose (GP) concrete using the following criteria:

- Reduction in embodied carbon dioxide (CO_2), through:
    - decreased consumption of OPC by substitution with alternative materials or processes, or
    - implementation of a manufacturing process that minimises carbon emissions.
- Increased use of recycled recovered and recycled materials as concrete constituents, and subsequent reductions in the use of raw quarried materials.

Alongside the product criteria, the following information was sourced from suppliers where available:

- Unique features
- Availability for deployment in WA
- Procurement details

The suppliers that were subject to this product research include the following:

- BGC
- Boral
- Hanson
- Holcim
- Murdoch University (Collicrete)

Note: Any information about the individual performance characteristics of products in this report has been provided directly by the product supplier or gleaned from supplier marketing and promotional material.

Information about embodied carbon dioxide for each product has been sought from product EPDs or the suppliers where possible. However, it is important to note that every concrete mix design will result in a different level of embodied carbon depending on the concrete specification. Estimated embodied carbon emissions of concrete mix designs should be discussed with suppliers during procurement.

The product information in this report has not been independently verified or endorsed by SWA.

2 Background

2.1 Ordinary and General Purpose Cement and Concrete.

Ordinary Portland Cement (OPC) is the fundamental binding constituent in business-as-usual (BAU) concrete. Manufacturing OPC involves heating limestone and clay at temperatures of about 1450°C. This manufacturing process is responsible for about 7% of global anthropogenic CO_2 emissions[1]. Worldwide, about 4.5 billion tonnes of OPC is manufactured annually. To reduce the carbon footprint of such a critical construction material, industry innovation has led to the development of products that can perform similarly to OPC concrete with reduced embodied CO_2 emissions.

General Purpose (GP) cement is considered to be the BAU cement used widely in Australia. GP cement consists of OPC and supplementary cementitious materials (SCMs) such as fly ash, slag and silica fume.

For the purposes of this report BAU concrete will be referred to as general purpose (GP) concrete. GP Concrete consists of GP cement, aggregates (fine and coarse) and water. To produce 'greener' concretes, solutions have been explored to replace as many of these constituents as possible with recovered and recycled materials.

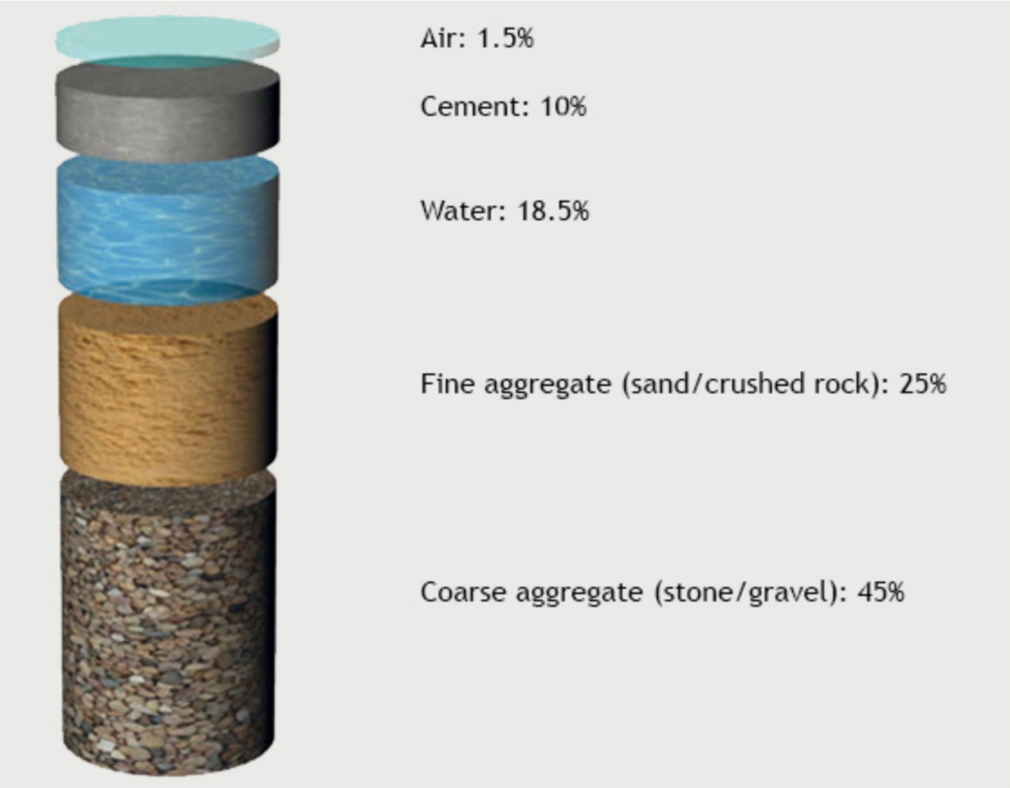

Image: The Concrete Centre, UK[2]

In Australia, fly ash, ground granulated blast furnace slag (GGBFS), manufactured sand and non-potable water have been widely used (in varying proportions) as fundamental ingredients in GP cement for well over 50 years. These are not new materials. However,

---

[1] InternationalEnergy Agency (IEA), 2018. Technology Roadmap – Low carbon transition in the cement industry. Available online at: https://iea.blob.core.windows.net/assets/cbaa3da1-fd61-4c2a-8719-31538f59b54f/TechnologyRoadmapLowCarbonTransitionintheCementIndustry.pdf

[2] https://www.concretecentre.com/Publications-Software/Concrete-Compass/Low-Carbon-Concrete.aspx

market demand for greener and low-embodied carbon products has led to innovation and higher rates of SCM use in some parts of the market, and greenwashing in others.

The embodied carbon of GP cement in Western Australia ranges between 992 and 1098 kg CO_2-e per tonne[3] but the embodied emissions of standard GP concrete in Australia (making use of standard rates of fly ash and slag) is less than 600 kg CO_2-e per tonne. It is important to note that much of the material in GP cement (including cement clinker and recycled materials such as GGBFS) is imported. This increases the embodied emissions of the final concrete product.

The practice of using recovered or recycled materials (even imported recycled material) in concrete has multiple, cascading benefits. Using recycled material reduces the need to extract raw materials, relieving stress on natural reserves, reduces CO_2 emissions and diverts construction and demolition (C&D) waste from landfills.

The greener concretes explored in this report are compared to GP concrete as the industry benchmark using a standard compressive strength of 40 MPa.

Alternative concretes have been developed to make use of different constituents and mix ratios. This report considers two categories of substitutes for GP concrete as follows:

2.2 Green Concrete

Green concrete makes use of recycled materials to replace one or more of the traditional constituents in concrete, such as fine aggregate, coarse aggregate, or the binding agent(s). Recycled material may partially or fully replace BAU constituents. Examples of recovered and recycled materials that can be used in concrete are provided below.

- Binding Agents:
    - Fly-ash
    - Ground granulated blast furnace slag (GGBFS), from iron and steel furnaces
    - Lithium processing by-product
    - Other reactive natural or engineered pozzolanic materials.
- Fine Aggregates:
    - Macro-synthetic fibres
    - Manufactured sand (from C&D waste and quarry dust)
    - Crushed glass
- Coarse Aggregates:
    - C&D concrete, recycled brick and tile
    - Recycled railway ballast
    - Recycled road base

Some concrete constituents are easier to replace with recycled constituents than others. Construction and demolition waste or recycled materials from civil infrastructure may be processed and used as aggregate for green concrete. Manufactured sand produced by crushing quarried rock is frequently used as a replacement for natural sand, and railway ballast may be crushed, ground or screened to a suitable size distribution for use as coarse aggregate.

A popular practice in green concrete manufacturing is to increase the substitution of OPC in the cement binder with supplementary cementitious materials (SCMs). SCMs are engineered

[3] Adbri cement product EPD (2022). Figures per tonne of GP cements manufactured in Munster (992 kgCO2-e) and Kwinana (1098 kg CO2-e), WA.

or industrial by-products used to enhance the binding strength of GP concrete to achieve higher compressive strengths and other durability benefits. The use of SCMs as an alternative to OPC is increasing, although the availability of traditional SCMs (fly ash and slag) is decreasing. Substitution of OPC with SCMs results in significantly lower embodied CO_2.

Concretes can also be manufactured using super sulfate cement. This is a sulfate-activated cement binder using GGBFS, gypsum and cement clinker[4] to produce a cement that is particularly resistant to sulfate attack. Of the concretes described in this report, only the Boral Envisia product makes use of super sulfate cement.

In WA most SCMs are imported from interstate or internationally. In Australia the majority of GGBFS is imported. There is only one domestic supplier of GGBFS in Australia at Port Kembla, NSW. All GGBFS used in Queensland, Victoria, South Australia and Western Australia is imported from overseas.

There are consequences to using SCMs at high substitution rates such as elongated concrete setting times, reduced early-age strength and the need for increased water and therefore binder content. In Western Australian summertime conditions, slower setting times can be an advantage but to manage this during cooler periods accelerants and additives can be used. Concrete additives are often proprietary formulas and typically add costs to the manufacture of green concretes.

Concrete suppliers may choose to provide a range of green concretes with varying constituent proportions. They may also modify the product mixture to suit the project need. This flexibility allows the client to have their concrete mixtures optimised for cost and performance while minimising embodied CO_2.

2.3 Geopolymer Concrete

Geopolymer concretes are made with aluminosilicates (from natural or recycled sources) combined with a strong alkali activator(s). The primary environmental benefit of geopolymer concrete is the ability to bind the component materials without using the emissions-intensive OPC. Geopolymer concretes can achieve a substantial reduction in embodied CO_2 emissions compared to GP concrete. The use of recycled materials provides an additional CO_2 benefit.

Geopolymer concretes can exhibit advantageous performance characteristics when compared to GP concrete, including increased chemical resistance, lower curing temperatures and rapid curing time[5].

Geopolymer concrete is not widely available in WA. Barriers to the uptake of geopolymer concretes include a lack of certainty regarding concrete properties, performance and compliance with AS 3600 and related standards.

---

[4] Qingyong Wu, Qingzong Xue, Zhuqing Yu (2021). Research status of super sulfate cement. Journal of Cleanre Production. Volume 294. Available online at: https://www.sciencedirect.com/science/article/abs/pii/S0959652621004480

[5] Amer Hassan, Mohammed Arif, M. Shariq. 2020. A review of properties and behaviour of reinforced geopolymer concrete structural elements- A clean technology option for sustainable development. Journal of Cleaner Production, Volume 245. Available online at: https://www.sciencedirect.com/science/article/abs/pii/S0959652619336327

Geopolymer concretes have been used successfully in Australia by Wagners in Queensland[6] Rocla have also made geopolymer concrete products in (mainly in NSW) for many years[7].

While geopolymer concretes can be manufactured in conventional concrete batching plants and do not require significant capital cost outlays, they do typically cost more than GP concretes.

[6] Geopolymer concretes, Wagners: https://www.wagner.com.au/media/1519/efc-factsheet.pdf
[7] Srividya T., Kannan Rajkumar P.R., Sivasakthi M., Sujitha A., Jeyalakshmi R. 2022. A state-of-the-art on development of geopolymer concrete and its field applications. Case Studies in Construction Materials, Volume 16. Available online at: https://www.sciencedirect.com/science/article/pii/S2214509521003272

3 BGC Low-Carbon Concrete (Pending Re-release)

3.1 Product Background

BGC Concrete operates concrete batch plants in the Perth metropolitan area. BGC Concrete is in the process of finalising a re-release of its low-carbon concrete product, formerly branded as 'GreenStar'. The intention is to rename the product and publish their first environmental product declaration (EPD) in December 2022.

For the purposes of this document the BGC B-Green Concrete product will be referred to as BGC low-carbon concrete.

BGC low-carbon concrete achieves reduced embodied CO_2 by replacing a portion of OPC with SCMs, including GGBFS and silica fume. Manufactured sand and aggregates from returned concrete material are incorporated to partially replace raw quarried material.

3.1.1 Links

- https://www.bgc.com.au

3.2 Product Material

3.2.1 Composition

BGC low-carbon concrete replaces up to 65% of the OPC binding agent with GGBFS and silica fume. Total cementitious material content includes a range from 10-65% SCMs and 35-90% OPC. BGC low carbon concrete can include a slag activator to enhance the performance of the product. The inclusion of the slag activator results in improved setting times and increased early-age strength.

BGC low-carbon concrete incorporates 25% recovered and recycled material, including manufactured sand and reclaimed concrete aggregate. Reclaimed aggregate is sourced from C&D recyclers in the Perth metropolitan region.

BGC is hesitant to incorporate higher rates of recycled material into the product due to (a). a perceived lack of industry confidence in this practice, and (b). the potential effects on concrete performance. However, they are more confident to incorporate a wider variety of recycled materials into pre-made concrete blocks.

3.2.2 Strength & Durability

According to BGC, their low-carbon concrete exhibits equal compressive performance to GP concrete ranging from 20 to 40 MPa. Shrinkage is reportedly equal to or surpasses GP concrete, achieving between 550 and 650 microstrain, and is stated as being suitable for deployment in marine environments.

BGC advises that their low-carbon concrete product demonstrates higher chemical durability compared to GP concrete, exhibiting higher resistance to sulfate attack and chloride ingress, and aiding the protection of steel tendons used in post tensioned applications.

3.2.3 Environmental Impact

Embodied CO_2 information for the product is not available at the time of writing. BGC have confirmed that embodied CO_2 information will be included in the product EPD. However, sustainability benefits are likely to centre on the replacement of OPC with alternative SCMs and the replacement of raw quarried aggregates with recycled materials.

3.3 Applications

The following applications are listed by BGC in marketing material:

3.3.1 Structural

- Slabs
- Suspended slabs
- Columns
- CFA piling
- AFS walls
- Cavity fill
- Footings

3.3.2 Non-structural

- Footpaths
- Stairs

3.4 Installation Examples

Civil projects: MRWA (Thomas Road), PTA (Byford Over Rail Project), CFA Piliing throughout the Perth Metropolitan area.

Industrial: Kwinana Waste to Energy Plant, East Rockingham Waste to Energy facility, Covalent Lithium Refinery

Commercial: Lot 54 Archimedes Drive Forrestdale; Marley Spoon, Centurian Place, Jandakot; BevChain, Maddington.

3.5 Occupational Health & Safety Concerns

BGC's low-carbon concrete purportedly exhibits similar OHS risks to GP concrete. It is rated as a Category 2 skin corrosive and Category 2A eye irritant with a risk of causing serious eye damage. Standard PPE and handling procedures are recommended.

The product is non-flammable but may produce toxic gasses when exposed to extreme heat. The concrete has low mobility in soil and poses a low risk to the environment.

4 Boral Envirocrete & Envirocrete Plus

4.1 Product Background

Boral has factories in Maddington and Mandurah WA.

Envirocrete is a proprietary product engineered to reduce embodied CO_2 and incorporates SCM materials for use as both cementitious and aggregate constituents. There are two variations of Envirocrete in WA: Envirocrete and Envirocrete Plus. The difference between the two products centres on the proportion of SCM binder in their mixtures.

Both Envirocrete products are recommended for applications where early age strength is not a priority. Setting time for both products is increased due to the high SCM content.

4.1.1 EPD Link

- https://epd-australasia.com/wp-content/uploads/2021/08/Boral_EPD_2021_Perth_v1.2_SP02338.pdf

4.2 Product Material

4.2.1 Composition

Envirocrete replaces up to 40% of the standard OPC content with GGBFS. Envirocrete Plus increases the OPC substitution rate to a minimum of 45% with higher substitution percentages available on demand. However, the SCMs in Envirocrete are non-reactive without the OPC content.

The inherent constraints on the ability of SCMs to replace OPC becomes apparent at higher substitution rates. The higher the ratio of SCM to OPC, the slower the concrete setting time. Boral recommends increasing the percentage of OPC in projects where fast setting time is necessary.

In both varieties of Envirocrete, raw quarried sand is replaced with manufactured sand.

Non-potable water (onsite rainwater and reclaimed water from the aggregate washing process) is used to hydrate both mixtures.

4.2.2 Strength & Durability

Envirocrete is marketed as a flexible and low-maintenance concrete with compressive strength between 25 MPa to 40 MPa depending on the mixture ordered.

Envirocrete Plus is quoted as exhibiting improved chloride, sulfate and acid resistance. It reportedly demonstrates equal strength performance to Envirocrete but takes longer to set, achieving approximately 25 MPa five days after placing.

Both products are represented as having high resistance to alkali-silica reactive (ASR) properties. Dry shrinkage also shows an improvement over standard GP concrete: 550 microstrains at 56 days.

Boral's product representatives have stressed that low-carbon concretes rely on binder substitutes. This can negatively affect early-age strength. However, it is possible to provide an appropriate balance of early-stage strength and low embodied carbon depending on the need of individual projects.

4.2.3 Environmental Impact

Boral provide an EPD document for their Envirocrete products. At 40 MPa the embodied CO_2 emissions of Envirocrete and Envirocrete Plus are 273 kg and 260 kg CO_2-e/m^3 respectively. This represents a 50-55 % reduction on the embodied emissions of standard GP concrete.

4.3 Applications

The following applications have been listed as appropriate in Boral marketing material:

4.3.1 Structural

Envirocrete:

- Home & industrial slabs
- Commercial buildings (conditional)
- Precast and tilt-up panels (conditional)

Conditional applications depend on limitations related to pumpability and early strength gain.

Envirocrete Plus:

- Home, industrial & post-tensioned slabs
- Commercial & high-rise buildings
- Precast and tilt-up panels
- Infrastructure projects
- Marine environments

4.3.2 Non-structural

Both variations of Envirocrete are marketed as being appropriate for the construction of:

- Driveways
- Pavements
- Polished concrete

4.4 Installation Examples

4.4.1 The Vines, Ellenbrook, WA

A section of footpath in The Vines at Ellenbrook was restored using Envirocrete[8].

[8] Image:https://www.boral.com.au/products/concrete/advanced/envirocrete

4.4.2 Darling Walk Project, Sydney, NSW

Envirocrete Plus was used at the Darling Harbour foreshore because of its marine durability. The concrete was implemented in all strength grades, as well as in some post-tensioned application[9].

4.5 Occupational Health & Safety Concerns

Similar to GP concrete, Envirocrete is classified as a Category 1 eye irritant that may cause serious damage on physical contact, and a Category 2 skin corrosive. Standard PPE and treatment procedures are recommended by the Envirocrete Safety Data Sheet.

Envirocrete has no environmental hazard rating. The product is not flammable, but toxic gasses may be released on significant heat exposure.

[9] Image:https://www.boral.com.au/sites/default/files/media_library/documents/Envirocrete_brochure.pdf

5 Boral Envisia

5.1 Product Background

Envisia is a low-carbon concrete developed by Boral with enhanced sustainability credentials when compared to Envirocrete and Envirocrete Plus. Envisia incorporates higher percentages of recycled material and ZEP, a proprietary binding activator developed with a mixture of SCM materials to enhance compressive strength.

5.1.1 EPD Link

- https://epd-australasia.com/wp-content/uploads/2021/08/Boral_EPD_2021_Perth_v1.2_SP02338.pdf

5.2 Product Material

5.2.1 Composition

Aggregate content in Envisia is a combination of raw quarried and recycled materials. Fine aggregate consists of raw quarried and manufactured sand, while coarse aggregate consists of raw quarried material. The amount of recycled material that can be incorporated largely depends on local supply. A higher ratio of raw material is used when suitable recycled material is not available. The final mixture is hydrated with non-potable rainwater and water reclaimed from the aggregate washing process.

Boral's ZEP binder is marketed as a highly developed mixture of processed GGBFS and fly-ash blended with OPC. Use of the ZEP binder in the Envisia mix enables the product to achieve a compressive strength of 70 MPa. The use of ZEP in Envisia allows for a 60% reduction in total OPC content.

5.2.2 Strength & Durability

Mixtures of Envisia designed for high-strength applications can achieve compressive strengths up to 70 MPa. Boral states that Envisia exhibits significantly lower dry shrinkage compared to GP concrete (about 43% to 50% less) and enhanced chemical resistance including reduced chloride diffusion and water permeability.

5.2.3 Environmental Impact

The product EPD states that embodied CO_2 emissions in Envisia concrete are 243 kg CO_2-e/m^3, representing a 60% decrease compared to GP concrete. Reduction in embodied CO_2 emissions has been achieved using material and manufacturing efficiencies.

5.3 Applications

Envisia is marketed as best suited to projects where fast setting and early-stage strength are essential. Explicitly, Boral markets Envisia's applicability for high-rise and suspended slabs but also states that the product is suitable for a variety of civil and commercial applications, as follows:

5.3.1 Structural

- Home and industrial slabs
- Commercial buildings
- Infrastructure
- High-rise buildings
- Post-tensioned slabs
- Precast and tilt-up panels
- Marine environments

5.3.2 Non-structural

- Driveways
- Pavements
- Polished concrete
- Other civil projects

5.4 Installation Examples

5.4.1 Kendrick Park Cycleway, Sydney, NSW

Low-lying cycleway in Kendrick Park, Sydney. The area is subject to frequent flooding and the project required a concrete product that could demonstrate resistance to water exposure and potential submersion[10].

5.4.2 Forrestfield to Perth Airport Link, Perth, WA

Envisia concrete was used to construct the track base for the Forrestfield-Airport link. Envisia was chosen for its engineered fire resistance and superior pumpability and included a micro-synthetic fibre additive. The additive ensured the concrete could be pumped up to a 2 km distance[11].

5.5 Occupational Health & Safety Concerns

Envisia's ZEP product introduces health risks compared to GP concrete. Envisia is a Category 2 skin corrosive and Category 1 eye irritant. The ZEP component is a Category 1 carcinogen and Category 3 respiratory irritant. The product's safety data sheet recommends the use of PPE, installation in a well-ventilated area, and standard treatment procedures for cases of exposure. No immediate physical risk or risk of fire is associated with ZEP or Envisia, and both components have low soil mobility posing a limited environmental risk.

10 Image: https://www.boral.com.au/projects/kendrick-park-cycleway
11 Image: https://www.boral.com.au/projects/forrestfield-airport-link

6 Hanson Sustainable

6.1 Product Background

Hanson has distribution hubs across the Perth metropolitan area.

Sustainable is one of two low-carbon concrete products available from Hanson. The concrete achieves reduced embodied CO_2 by substituting OPC with SCM binders. Similar to other low-carbon concretes, *Sustainable* achieves equivalent compressive strength to GP concrete but with longer setting times as a result of the SCM incorporation. It is therefore recommended for use in projects that do not require high early strength performance.

6.1.1 Links

- https://www.hanson.com.au

6.2 Product Material

6.2.1 Composition

Hanson's *Sustainable* concrete partially replaces OPC with SCMs to reduce embodied CO_2. The SCMs used in *Sustainable* include fly-ash, GGBFS and silica fume, with variations depending on the availability of materials in the region of manufacture. Hanson seek to reduce transportation costs by sourcing locally available materials where possible.

In Perth, Hanson manufacture *Sustainable* using fly-ash sourced from Collie in the South West of WA. Aggregates are sourced from the greater Perth region. *Sustainable* is available in three varieties with different OPC substitution rates. The varieties use a rating system: Bronze (30% SCMs), Silver (40%), and Gold (50%).

Hanson operate a screening and recovery program for returned concrete for reuse as coarse aggregates. Business as usual gravel aggregate is quarried locally in Red Hill and Ellenbrook. Fine aggregate includes a combination of raw quarried and manufactured sand.

The content of recycled aggregate in the *Sustainable* mix varies between 20% and 60% depending on availability. Raw quarried aggregate content increases when recycled materials are not available or do not meet quality criteria.

Sustainable is hydrated with non-potable rainwater collected on site and recovered water from aggregate washing.

6.2.2 Strength & Durability

According to Hanson, *Sustainable* compressive strength and durability is comparable with GP concrete at 32 MPa. Representatives from Hanson have indicated the early-age strength decreases with the inclusion of SCMs. *Sustainable* is recommended for use in projects that do not require early setting times.

6.2.3 Environmental Impact

The inclusion of SCMs in place of OPC is the primarily emission reduction mechanism for the *Sustainable* product. At 300 kg of CO_2-e/m3, *Sustainable* contains around 40% less embodied emissions than GP concrete.

6.3 Applications

The following applications have been listed as appropriate in Hanson marketing material:

6.3.1 Structural

- Slabs
- Blinding
- Block-fill
- Piling
- Shotcrete

6.3.2 Non-structural

- Kerbs
- Pavement

6.4 Occupational Health & Safety Concerns

Sustainable concrete exhibits similar OH&S risks to GP concrete, including classification as a Category 1 skin corrosive and a Category 1 eye irritant. Normal PPE, handling and first aid procedures are recommended. *Sustainable* also exhibits no risk of combustion on exposure to an open flame or extreme heat.

7 Hanson Ecotera

7.1 Product Background

Hanson has distribution hubs across the Perth metropolitan area.

Similar to the Hanson *Sustainable* product, Ecotera achieves a lower carbon footprint through a reduction in OPC. Ecotera incorporates a higher percentage of SCMs and additives to improve shrinkage and compressive strength with accelerated setting times.

7.1.1 Links

- https://www.hanson.com.au

7.2 Product Material

7.2.1 Composition

In Perth, Hanson manufacture Ecotera using fly-ash sourced from Collie in the South West of WA. Aggregates are sourced from the greater Perth region.

Ecotera includes an increased proportion of SCMs, replacing between 50% and 70% of the OPC content, depending on the mix requested.

Hanson proprietary or other activation additives can be included to compensate for the loss in early-age strength as result of the high proportion of SCMs. The inclusion of accelerants in Ecotera is intended to improve setting times, shrinkage, and overall compressive strength.

Similar to the *Sustainable* product, Hanson make use of recycled aggregates at rates between 20% and 60% depending on availability. Non-potable rainwater and recovered water are used wherever possible.

7.2.2 Strength & Durability

Ecotera can achieve a compressive strength up to 40 MPa, depending on the project requirement.

Hanson product marketing indicates shrinkage of 250 to 450 microstrain, improved early-age strength and reduced curing time relative to other green concretes. The 40% reduction in chloride diffusion rate may protect steel reinforcement from corrosion and extends the life of the project.

Hanson advertises Ecotera as a green concrete fit for use in projects where low shrinkage and high strength are essential, such as in high-rise applications.

7.2.3 Environmental Impact

Embodied CO_2 emissions vary depending on the rate of displaced OPC. Fifty, sixty and seventy percent SCM binder substitutions can achieve embodied CO_2 emissions as low as 152 kg CO_2-e/m^3. This can represent as much as a 70% reduction in embodied emissions compared to GP concrete.

In addition to the lower embodied emissions of Ecotera, Hanson also provides the option of purchasing carbon offsets to achieve a lower net carbon emission product.

7.3 Applications

The following applications have been listed as appropriate in Hanson marketing material:

7.3.1 Structural

- Building slabs
- Post-tension slabs
- Columns
- Other high-rise projects

7.3.2 Non-structural

- Kerbs
- Pavement
- Civil projects

7.4 Occupational Health & Safety Concerns

Ecotera exhibits additional OH&S risks compared to GP concrete due to the inclusion of additives. Ecotera is classified as a Category 1 skin corrosive and a Category 1 eye irritant, as well as a Category 1 carcinogen and a Category 3 respiratory irritant.

Normal PPE, handling and first aid procedures are recommended. Ecotera exhibits no risk of combustion on exposure to an open flame or extreme heat.

8 Holcim – ECOPact and ECOPact+

8.1 Product Background

Holcim's main factory in Western Australia is based in Welshpool. Their ECOPact product achieves reduced embodied carbon through a combination of recycled materials in the concrete mixture and carbon offsets. In ECOPact concrete, OPC is partly replaced with SCMs and additives.

Four varieties of ECOPact are provided by Holcim. The baseline varieties of ECOPact include ECOPact (with a 30% reduction in embodied carbon compared to GP concrete), ECOPact Prime (50% reduction in CO_2), ECOPact Max (70% reduction in CO_2), and ECOPact Zero (a net zero concrete were any remaining embodied carbon is offset by the purchase of carbon credits).

The ECOPact+ range includes the use of recycled and/or recycled aggregates in addition to the standard ECOPact product. This product is only available in Western Australia.

8.1.1 EPD Link

- https://epd-australasia.com/wp-content/uploads/2021/12/2021-Holcim-ViroDecs%E2%84%A2-Special-WA-Metro-ECOPact.pdf

8.2 Product Material

8.2.1 Composition

The ECOPact range includes SCMs (fly-ash, GGBFS and silica fume) as low-carbon binders to reduce the proportion of OPC.

Recycled C&D concrete and recycled railway ballast are used as coarse aggregates in the ECOPact+ range, replacing raw quarried material by up to 30%. A combination of natural and manufactured sand is used for fine aggregate, and the concrete mixture is hydrated with recycled and reclaimed water.

8.2.2 Strength & Durability

Holcim marketing indicates that ECOPact exhibits similar durability to GP concrete. It is advertised as be fire-resistant, fit to last more than 100 years, with a variety of strength options available up to 50 MPa.

8.2.3 Environmental Impact

Without offsets, ECOPact concrete can achieve between 30 to 70 % reduction in embodied CO_2 emissions when compared to standard GP concrete.

The ECOPact range includes a combination of actual carbon reductions and purchased carbon offsets to achieve the following:

- ECOPact – 30% reduction in CO_2-e/m^3
- ECOPact Prime – 50% reduction in CO_2-e/m^3
- ECOPact Max – 70% reduction in CO_2-e/m^3
- ECOPact Zero – 0 kg CO_2-e/m^3[12]

ECOPact and EcoPact+ is available in a range of strengths to 50 MPa.

[12] 100% reduction with the remainder achieved through carbon offsets

8.3 Applications

The following applications have been listed as appropriate in Holcim marketing material:

8.3.1 Structural

- Foundations/slabs
- Columns
- Beams
- Internal and external walls,

8.3.2 Non-structural

- Driveways
- Walkways
- Infill islands
- Blinding layers
- Other non-structural applications

8.4 Installation Examples

8.4.1 Mindyarra Rail Maintenance Centre, NSW

9,000 cubic metres of ECOPact concrete was used in the construction of the Mindyarra Maintenance Centre in Dubbo, NSW.

Image: *https://www.holcim.com.au/projects/civil-infrastructure*

8.4.2 Inland Rail Project, NSW

ECOPact concrete was used to manufacture culverts for the Inland Rail Project between Narrabri and North Star, NSW.

Image: https://www.holcim.com.au/projects/civil-infrastructure

8.5 Occupational Health & Safety Concerns

ECOPact exhibits health and safety issues typical of OPC and other green concretes. It is rated as a Category 2 skin corrosive and Category 1 eye irritant. Normal PPE and handling procedures are recommended.

The ECOPact SDS document lists heat and fire-resistant properties, with no risk of combusting or releasing toxic fumes on exposure to open flame or extreme temperatures.

9 Colliecrete (In Development)

9.1 Product Background

Colliecrete is a research project led by Murdoch University and funded by the Government of Western Australia to test the feasibility of producing a geopolymer concrete from Collie flyash that is made from 90% recycled material.

The geopolymer concrete comprises of fly-ash sourced from coal fired power generation in Collie and other industrial by-products, including screened C&D waste and mineral processing by-products. According to project leaders, Colliecrete has been tested to perform equally to GP concrete. Development of the product has been promoted as being near to completion. Full-scale production and commercialisation are underway.

9.1.1 Links

- www.colliecrete.com.au
- https://www.abc.net.au/perth/programs/wa-afternoons/colliecrete/13466300

9.2 Product Material

9.2.1 Composition, Strength & Durability

Fly-ash sourced from Collie is activated with chemicals to produce a geopolymer binder which is then mixed with aggregates. This includes traditional concrete aggregates such as sand and gravel, recycled materials such as C&D waste, or industrial by-products such as bauxite or lithium refining residues. This then forms a range of geopolymer concrete products suitable for various applications.

The Colliecrete mixture contains 90% recycled material. The remaining 10 % includes the activation chemicals and natural sand as a fine aggregate.

Colliecrete is exploring opportunities to replace natural sand with crushed recycled glass and make use of chemical by-products for activation. Colliecrete advise that they have tested the use of crushed recycled glass and alternative activating chemicals successfully. The Colliecrete product could contain100% recycled material by the time of its commercial launch.

In an ABC radio interview in June 2021, Colliecrete Research Director, Dr Martin Anda stated Colliecrete could achieve a compressive strength of 54 MPa. The Colliecrete project is exploring different mix designs and the combination of fly-ash and by-products from different sources to improve strength even further. The Colliecrete mix exhibits reduced dry shrinkage, leading to predictions of longer service life when compared to GP concrete.

There are no Australian Standards for geopolymer concrete. The Colliecrete project team use GP concrete standards to ensure the Colliecrete product is ready for commercialisation.

9.2.2 Environmental Impact

Embodied CO_2 information for Colliecrete is not available at the time of writing. Scientific literature on the emissions benefits of Geopolymers cites benefits anywhere between 10 % and 80 % reduction in CO_2 emissions compared to GP concrete, mostly as a result of feedstock transportation logistics (which is similar when compared to normal concrete applications); thus an average 80% reduction in geopolymer binder materials is typically assumed. Sustainability benefits flow chiefly from the ability to remove OPC entirely from the product, the ability to use locally sourced materials and the replacement of raw quarried aggregates with recycled materials.

Published research data on geopolymer concretes shows that any heavy metals or naturally occurring radioactive materials that may be present in fly ash and other industrial by-products are effectively bound during the geopolymerisation reaction. Comprehensive testing has shown these contaminants are not leached out on exposure of the geopolymer concrete to weather or to water. The Colliecrete team advise that independent leach testing of any mix design can be arranged as required.

9.3 Applications

Colliecrete can be used in civil and industrial applications and has been tested over a compressive strength range of 20 to 50 MPa.

9.4 Occupational Health & Safety Concerns

The Colliecrete project have not published a safety data sheet for the Colliecrete product. It is anticipated that the (pre-mixture) dry ingredients of Colliecrete will pose similar OH&S risks to normal concretes containing SCMs. Increased OHS concerns are likely to centre on the use of liquid alkali activation chemicals. These chemicals are corrosive and will require special handling procedures in addition to the usual requirements for standard concretes.

10 Procurement

Green, low-carbon and geopolymer concretes are variations on GP cement. They are formulated according to project requirements and are difficult to quote on an off-the shelf basis. Green, low-carbon and geopolymer concretes tend to be more expensive than OPC cements due to the smaller scale of production of these products.

As demand for greener products with lower embodied carbon and higher rates of locally sourced recycled materials grows, costs will become more competitive with BAU products.

Not all suppliers contacted were prepared to provide standard quotes for their products. The quotes that were provided ranged from \$190/m^3 to \$260/m^3 within the Perth metropolitan area. The project costs of concrete products are likely to vary according to the size of the order, the location of the project and the concrete strength specifications.

Supplier contact details for product enquires (current in December 2022) can be found below:

Supplier	Representative	Email	Phone
BGC	Janine McKinnon	jmckinnon@bgc.com.au	0490861112
Boral	Gino Auriemma	Gino.auriemma@boral.com.au	-
Hanson	Grey Wells	Grey.wells@hanson.com.au	0400468568
Holcim	Dylan Viviers	Dylan.viviers@holcim.com	0429790600
Colliecrete	Kathy Miller	colliecrete@gmail.com	0409378742

11 Tables for Comparative Product Specifications

11.1 Constituents, Performance & Emissions

COMPANY & PRODUCT	PRODUCT VARIATIONS	CONSTITUENTS (kg/m³, where 1 Cubic Metre of concrete ≈ 2,200 kg) Key; BAU, Partial Improvement, Greener option.				PERFORMANCE (For 40 MPa mixtures)		EMISSIONS (For 40 MPa mixtures)
		Fine Aggregate	Coarse Aggregate	Binding Agent	Hydrator	Dry-Shrinkage (Microstrain)	Compressive Strength (MPa)	Embodied CO_2 (kg/m3)
ORDINARY PORTLAND CEMENT EQUIVALENT	-	*CONSTRUCTION SAND* *730 kg*	*GRAVEL* *1,100 kg*	*PORTLAND CEMENT* *370 kg*	*POTABLE WATER* *120 L*	*650 MS*	*40 MPa*	*445-490 kg*
BGC Low carbon concrete (unreleased)	-	Construction Sand *639 kg (87.5%)* Manufactured Sand *91 kg (12.5%)*	Gravel *963 kg (87.5%)* Crushed Recycled Concrete *137 kg (12.5%)*	Portland Cement *222 kg (60%)* Steel GGBFS *148 kg (40%)*	Potable Water *60 L (50%)* Reclaimed Water *60 L (50%)*	550 to 650 MS *(<15% Reduction)*	20 to 50 MPa	PENDING (EPD release TBC December 2022)
Boral **'Envirocrete'**	Envirocrete Envirocrete Plus	Construction Sand Manufactured Sand *(Varying Mixture)*	Gravel *825 kg (75%)* Steel GGBFS *275 kg (25%)*	Portland Cement *204 to 222 kg* *(55% to 60%)* SCMs *148 to 166 kg* *(40% to 45%)*	Potable Water *12 L (10%)* Reclaimed Water *108 L (90%)*	550 MS *(15% Reduction)*	25 to 40 MPa	274 kg (Baseline) 260 kg (Plus)
Boral **'Envisia'**	Construction Concrete Post-tensioned Concrete	Construction Sand Manufactured Sand *(Varying Mixture)*	Gravel *825 kg (75%)* Steel GGBFS *275 kg (25%)*	Portland Cement *185 kg (50%)* ZEP Additive *185 kg (50%)*	Potable Water *12 L (10%)* Reclaimed Water *108 L (90%)*	400 MS *(40% reduction)*	40 to 70 MPa	241 kg

COMPANY & PRODUCT	PRODUCT VARIATIONS	CONSTITUENTS (kg/m³, where 1 Cubic Metre of concrete ≈ 2,200 kg) Key: BAU, Partial Improvement, Greener option.				PERFORMANCE (For 40 MPa mixtures)		EMISSIONS (For 40 MPa mixtures)
		Fine Aggregate	Coarse Aggregate	Binding Agent	Hydrator	Dry-Shrinkage (Microstrain)	Compressive Strength (MPa)	Embodied CO_2 (kg/m3)
ORDINARY PORTLAND CEMENT EQUIVALENT	-	*CONSTRUCTION SAND 730 kg*	*GRAVEL 1,100 kg*	*PORTLAND CEMENT 370 kg*	*POTABLE WATER 120 L*	*650 MS*	*40 MPa*	*445-490 kg*
Hanson 'Sustainable'	Bronze Silver Gold	Construction Sand *292 to 584 kg* *(40% to 80%)* Manufactured Sand *146 to 438 kg* *(20% to 60%)*	Gravel *440 to 880 kg* *(40% to 80%)* C&D Waste *220 to 660 kg* *(20% to 60%)*	Portland Cement *259 to 303 kg* *(70% to 80%)* SCMs *67 to 111 kg* *(20% to 30%)*	Reclaimed Water *120 L* *(100%)*	650 MS	32 MPa	245 to 343 kg *(30% to 50% reduction)*
Hanson 'Ecotera'	-	Construction Sand *292 to 584 kg* *(40% to 80%)* Manufactured Sand *146 to 438 kg* *(20% to 60%)*	Gravel *440 to 880 kg* *(40% to 80%)* C&D Waste *220 to 660 kg* *(20% to 60%)*	Portland Cement *111 to 185 kg* *(30% to 50%)* SCMs *185 to 259kg* *(50% to 70%)*	Reclaimed Water *120 L* *(100%)*	250 to 450 MS *(30% to 60% Reduction)*	32 to 40 MPa	147 to 245 kg *(50% to 70% reduction)*
Holcim 'ECOPact'	-	Fly-ash / GGBFS / Silica Fume *730 kg (100%)*	Gravel *1,000 kg* *(100%)*	SCMs *370 kg* *(100%)*	Potable Water *60 L (50%)* Reclaimed Water *60 L (50%)*	NOT PROVIDED	20 to 50 MPa	211 kg *(60% reduction)*
Holcim 'ECOPact+' Range	ECOPact Prime ECOPact Max ECOPact Zero	Fly-ash / GGBFS / Silica Fume *730 kg (100%)*	Gravel *770 kg (70%)* C&D Waste *330 kg (30%)*	SCMs *370 kg* *(100%)*	Potable Water *60 L (50%)* Reclaimed Water *60 L (50%)*	NOT PROVIDED	20 to 40 MPa	0* to 200 kg *(60% to 100%* reduction)*
Murdoch University 'Colliecrete'	Range of product lines available-	Construction Sand or other by-product including crushed recycled glass	C&D Waste or mining by-products *1,100 kg* *(100%)*	Fly-ash and activator chemicals *370 kg* *(100%)*	Potable water *120 L (100%)*	NOT PROVIDED	Up to 54 MPa	~0 kg* to 98 kg *(Average 80% reduction)*

11.2 Hazard Ratings & Product Details

COMPANY & PRODUCT	Manufacture Location (Closest to Perth)	HAZARD RATINGS		
		Human Exposure	Environmental Exposure	Fire Risk
GP CONCRETE	Multiple locations in WA	*Cat.2 Skin Corrosive* *Cat.2A Eye Irritant*	*Standard recommendation for spillage containment*	*Possible toxic fume emission on extreme heat exposure*
BGC B-Green Unreleased	Midland, WA	Cat.2 Skin Corrosive Cat.2A Eye Irritant	Standard recommendation for spillage containment	Possible toxic fume emission on extreme heat exposure
Boral 'Envirocrete'	Maddington & Mandurah, WA	Cat.2 Skin Corrosive Cat.1 Eye Irritant	Standard recommendation for spillage containment	Possible toxic fume emission on extreme heat exposure
Boral 'Envirocrete Plus'	Maddington & Mandurah, WA	Cat.2 Skin Corrosive Cat.1 Eye Irritant	Standard recommendation for spillage containment	Possible toxic fume emission on extreme heat exposure
Boral 'Envisia'	Maddington & Mandurah, WA	Cat.2 Skin Corrosive Cat.1 Eye Irritant Cat.1 Carcinogenic Cat.3 Respiratory Irritant	Standard recommendation for spillage containment	Possible toxic fume emission on extreme heat exposure
Hanson 'Sustainable'	Multiple locations in Perth Metropolitan area	Cat.1 Skin Corrosive Cat.1 Eye Irritant	Standard recommendation for spillage containment	No fire risk
Hanson 'Ecotera'	Multiple locations in Perth Metropolitan area	Cat.1 Skin Corrosive Cat.1 Eye Irritant Cat.1 Carcinogenic Cat.3 Respiratory Irritant	Standard recommendation for spillage containment	No fire risk
Holcim 'ECOPact' & Varieties	Welshpool, WA	Cat.2 Skin Corrosive Cat.1 Eye Irritant	Standard recommendation for spillage containment	No fire risk
'Colliecrete'	Collie, WA & other locations as required.	TBC. Dry materials likely to be similar to GP concrete. Wet alkaline activators likely to be Cat.1 Skin Corrosive	Standard recommendation for spillage containment	TBC. Likely to be more fire resistant than OPC

SWA

Prepared by: SWA Innovation Hub