Low Carbon in Concrete Construction

CETANZ 2025

Holcim New Zealand

Why do we need Low Carbon?

Global and Local Drivers

Six GLOBAL MEGATRENDS Driving Construction
How do we respond to Construction trends?

POPULATION GROWTH

From ~8 billion today to ~10 billion by 2050

URBANISATION & MEGACITIES

Approx. 2.5 billion more people are expected to live in cities by 2050

Higher demand for **SUSTAINABLE CONSTRUCTION SOLUTIONS** due to resource scarcity & climate change

Increased demand for **BETTER LIVING STANDARDS** and more efficient infrastructure

BUILDING EFFICIENCY

Innovation driving light and modular construction solutions

More **REPURPOSING REUSING REPAIR & REFURBISHMENT** driving urban demand

NZ & Carbon

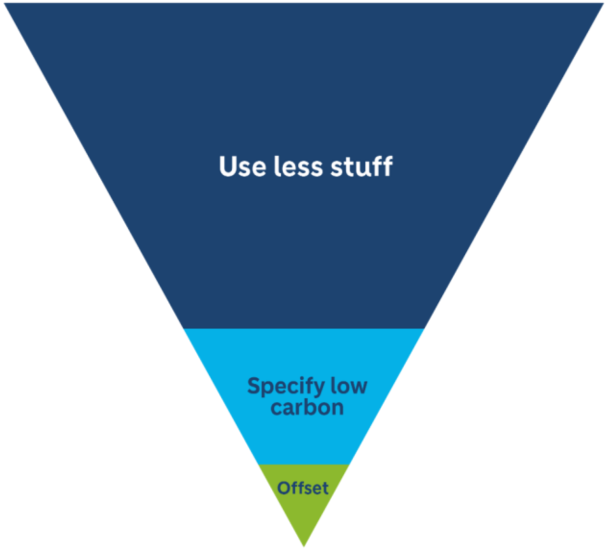
The NZ Government has outlined 5 key pillars for carbon reduction with Building and Infrastructure being pillar 1.

Building Research Association of New Zealand (BRANZ) estimates that buildings contribute directly and indirectly to up to 20% of the country's total greenhouse gas emissions (BRANZ, n.d.).

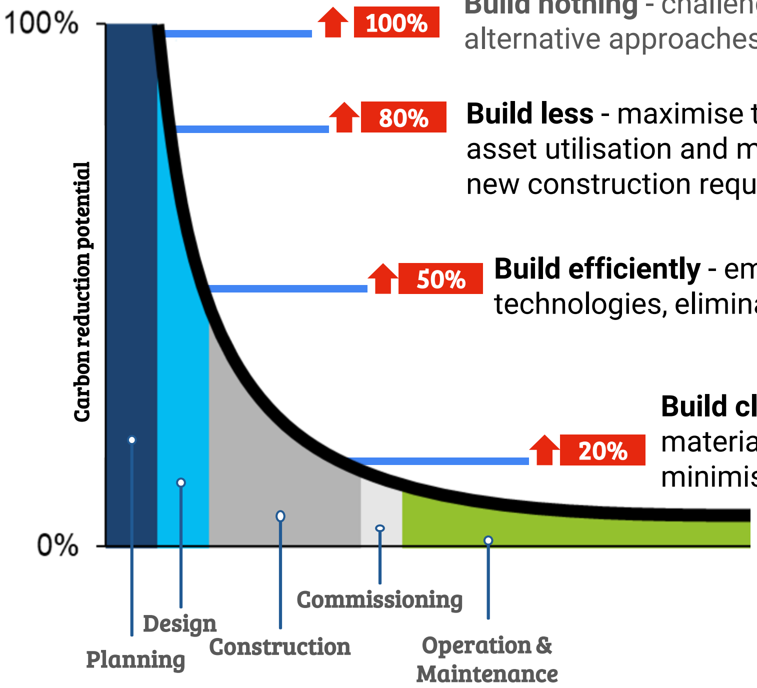
The Building for Climate Change (BfCC) programme aims to achieve "near zero carbon" buildings by 2050 (MBIE, n.d.), which is a way to enable "net zero carbon" buildings. Near zero (or net-zero ready) buildings have minimal embodied carbon and are highly energy efficient, with the remaining emissions easily offset.

DESIGNING FOR LOW EMBODIED CARBON

THE HIERARCHY FOR MATERIAL DESIGN DECISIONS



Hierarchy of material design decisions (© John Orr). Redrawn with permission.



Build nothing - challenge the root cause of the need; explore alternative approaches to achieve the desired outcome

Build less - maximise the use of existing assets, optimise asset utilisation and management to reduce the extent of new construction required

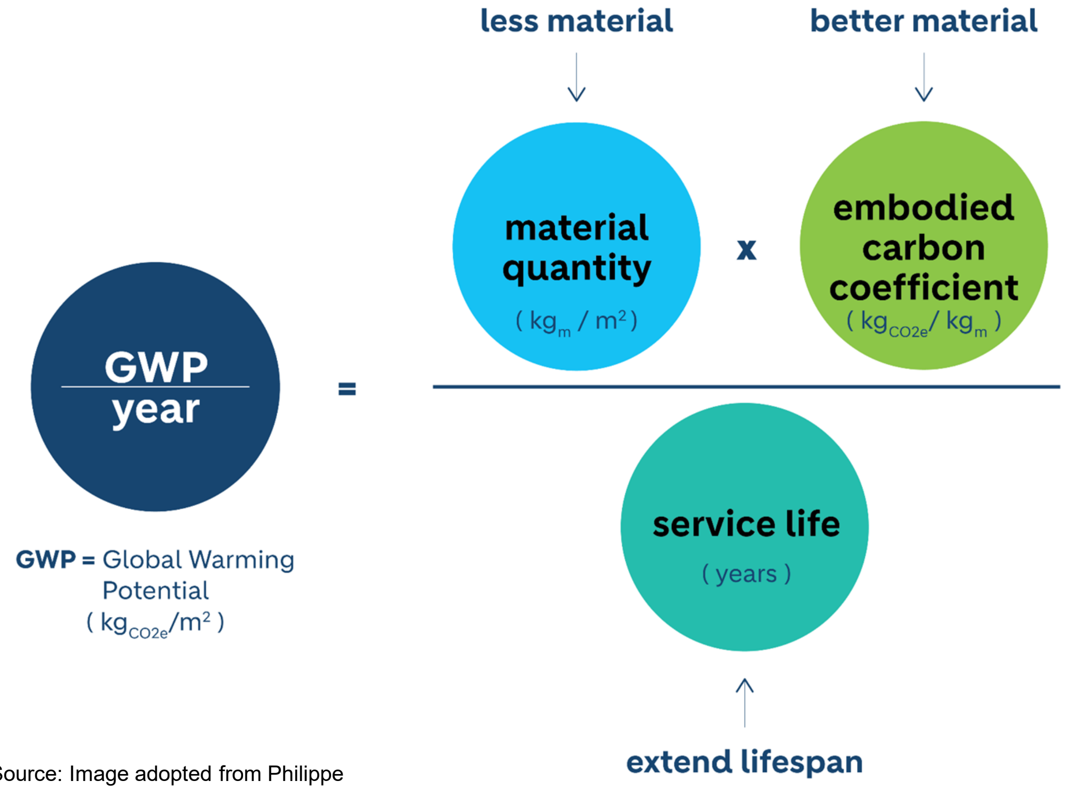
Build efficiently - embrace new construction technologies, eliminate waste

Build clever - design in the use of low carbon materials, streamline delivery process; minimise resource consumption

DESIGNING FOR LOW EMBODIED CARBON
THREE KEY COMPONENTS

DESIGNING FOR SUSTAINABLE CONSTRUCTION

can be broken down into 3 key components: using the **right materials**, at the **right place** and in the **right amount**, while **maximising the lifespan** of the building or infrastructure

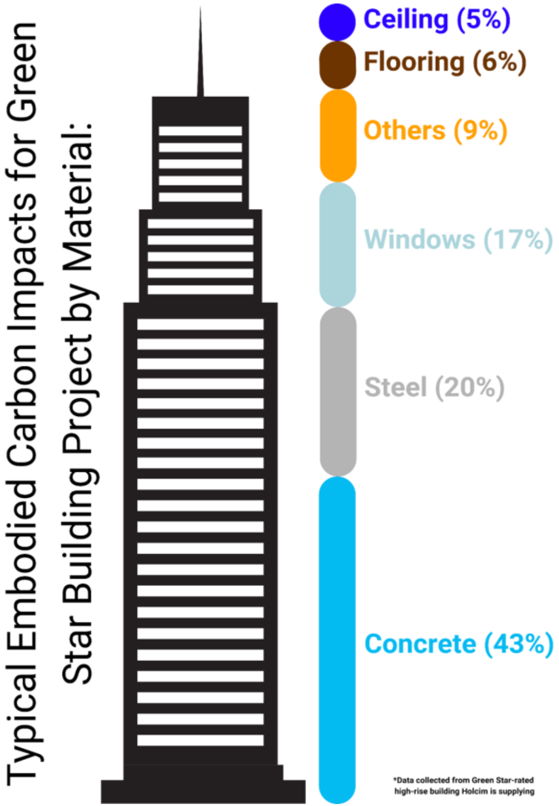


Source: Image adopted from Philippe Block

DESIGNING FOR LOW EMBODIED CARBON
THE HIERARCHY FOR MATERIAL DESIGN DECISIONS

OPTIMIZE THE SPECIFICATIONS

OPTIMIZE THE SOURCING COSTS



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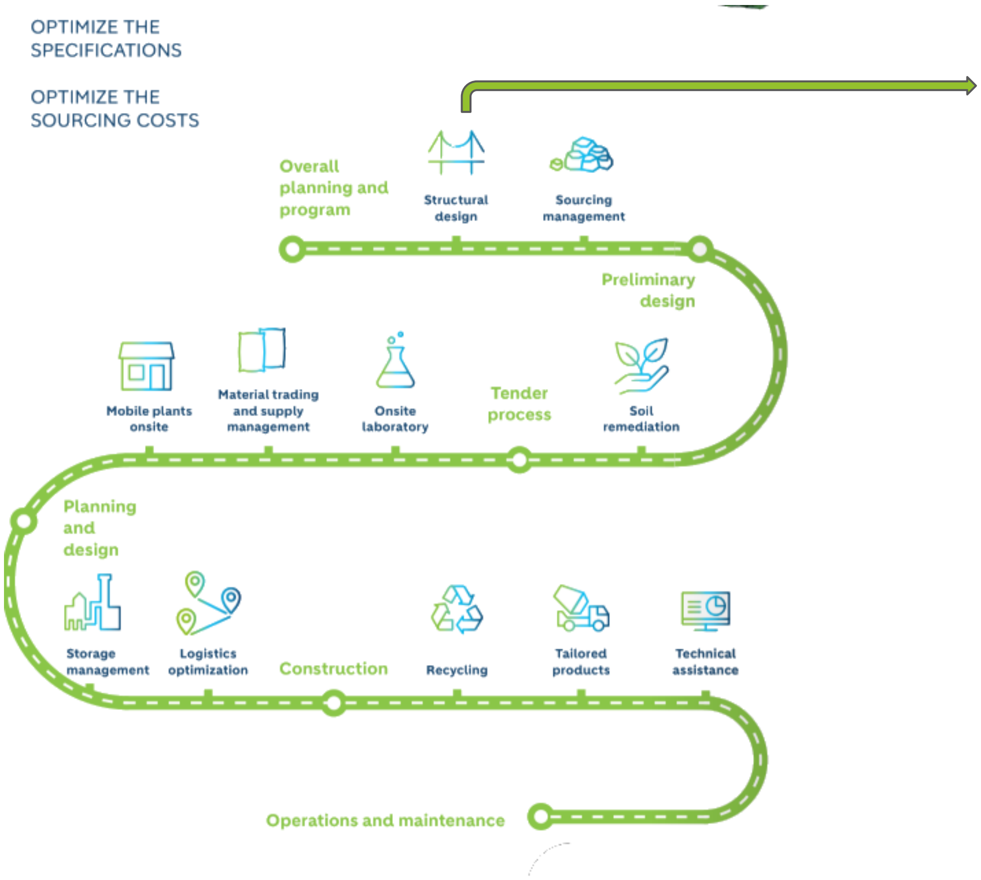
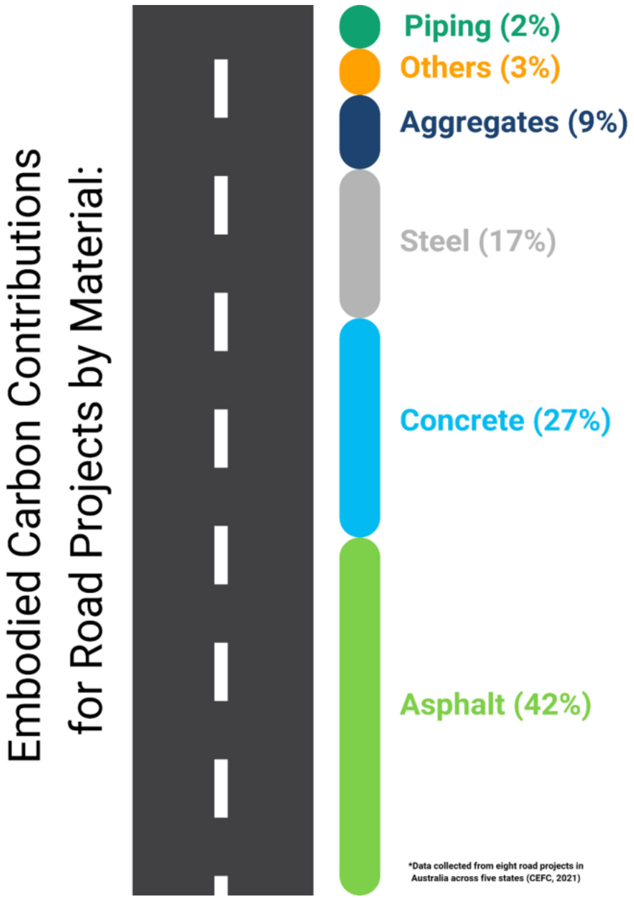
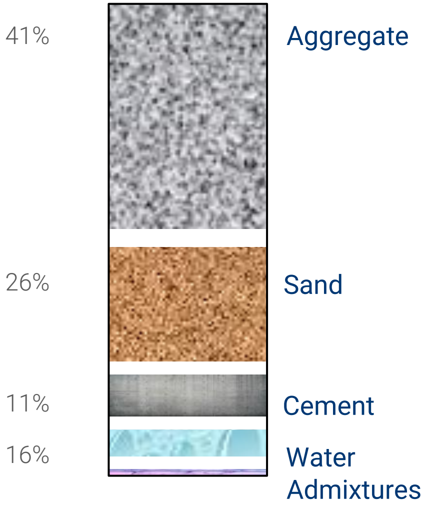




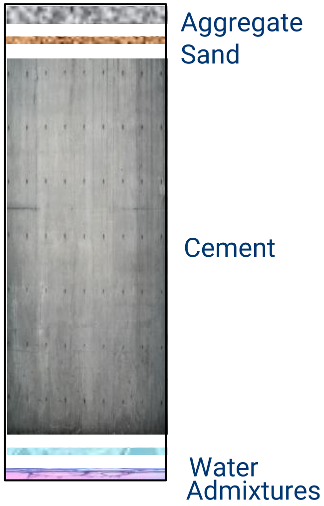
Cement is carbon-intensive

Cement is a small, but vital ingredient within concrete (11%) but a major contributor to the carbon footprint (80-90% in standard concrete).

Concrete Composition by Volume



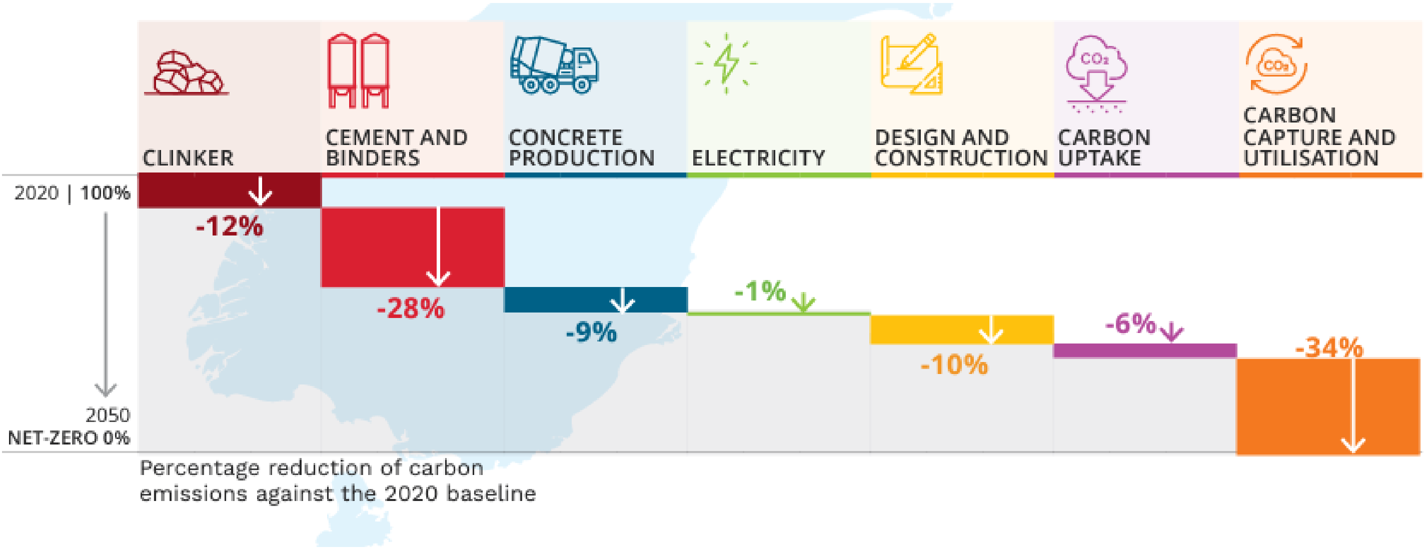
Concrete Composition by Carbon



New Zealand is using TOO MUCH traditional cement

ConcreteNZ Roadmap to net zero also supports this

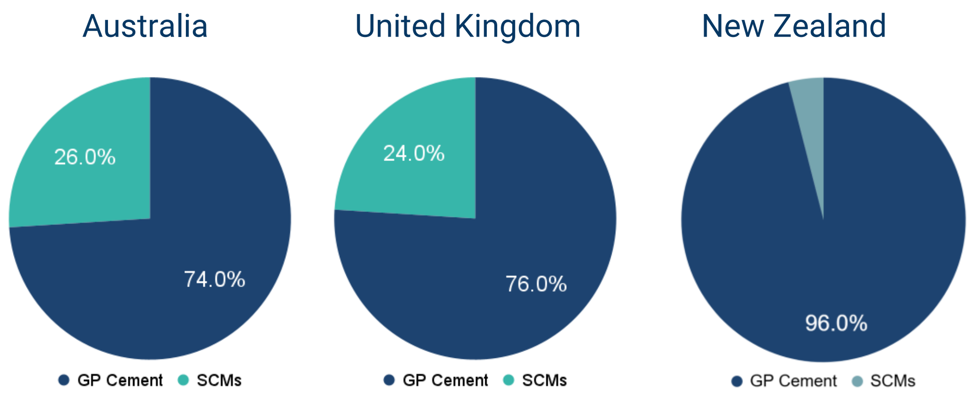
ConcreteNZ Roadmap to Net Zero supports this showing that reduction in carbon intensive binders is critical to achieve net zero emissions within concrete construction



1: ConcreteNZ Roadmap to Net Zero, August 2023

New Zealand is using TOO MUCH traditional cement

Global trend is to use low carbon cements & cement replacements

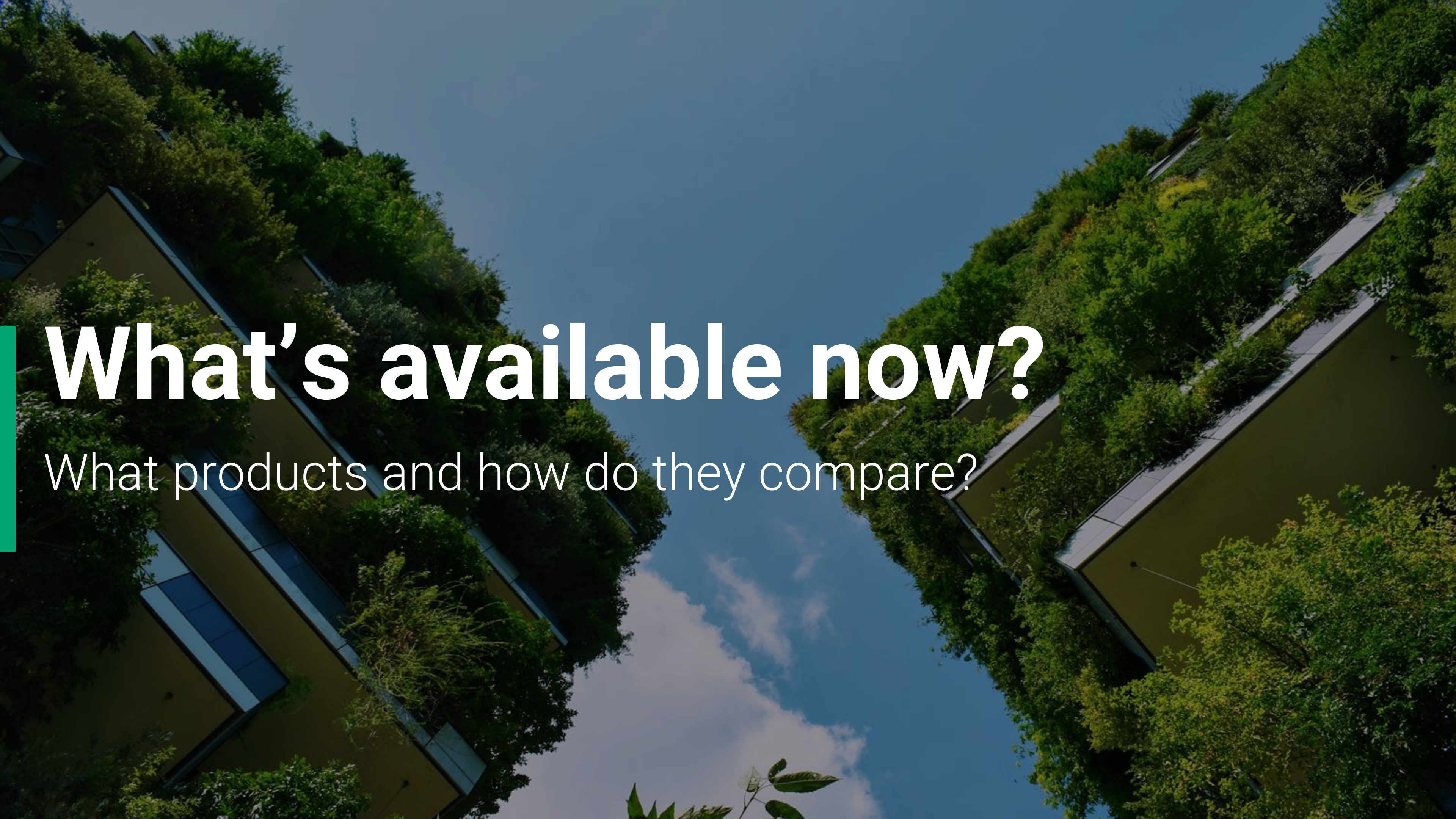


- Using less traditional cement to reduce the high embodied carbon content and realise improved performance
- Replaced by materials with similar cementitious properties but with a much lower embodied carbon
- Overseas the average use of cement replacements is around 25%. New Zealand averages less than 4% of total cement use

1: Australian Ash Development Association and Australasian Slag Association. **2**: https://cement.mineralproducts.org/downloads/industry_statistics.php

What’s available now?

What products and how do they compare?



What's required
SCMs in the NZ Standards

NZS 3122 is the cement standard, and outlines what can be used within the cement.

TYPE GP is OPC with upto 10% MIC

TYPE GB is Type GP blended with upto 75% SCMs

Note that limits ONLY apply to cement. Concrete companies can add higher ratios if they can prove that the material meets specifications as an engineered solution.

NZS 3122:2009

4 CEMENT TYPES AND COMPOSITION

4.1 General purpose cements

Requirements for general purpose cements are set out in table 1.

4.1.1 General purpose Portland cement (Type GP)

Ordinary Portland cement (OPC) is a hydraulic cement that is manufactured as a homogeneous product by grinding together Portland cement clinker, calcium sulfate, and processing additions. OPC does not contain mineral additions.

General purpose Portland cement is a hydraulic cement containing OPC and, at the discretion of the cement manufacturer, up to 10% of mineral additions but limiting the amorphous silica to <5%.

4.1.2 General purpose blended cement (Type GB)

Blended cement is a hydraulic cement containing general purpose Portland cement (Type GP) and, at the discretion of the cement manufacturer, one or more of the following:

(a) Greater than 10% and less than or equal to 35% of fly ash or pozzolan;

(b) Greater than 10% and less than or equal to 75% ground granulated iron blast-furnace slag;

(c) Up to 10% of amorphous silica.

NOTE – Blended cement is produced either by intergrinding Portland cement clinker with calcium sulfate, processing additions, mineral additions and one or more of the materials in 4.1.2 (a) (b) or (c) or by blending OPC or general purpose Portland cement with mineral additions and one or more of the materials in 4.1.2 (a) (b) or (c).

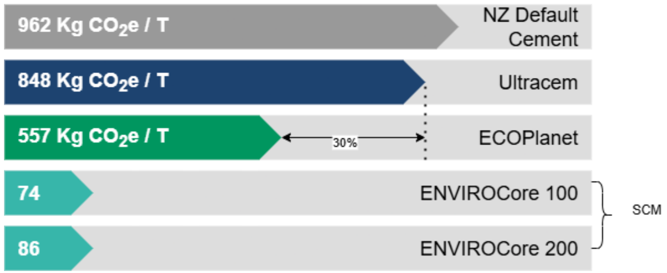
C 4.1.2

Blended cement requirements using limestone are covered by NZS 3125.

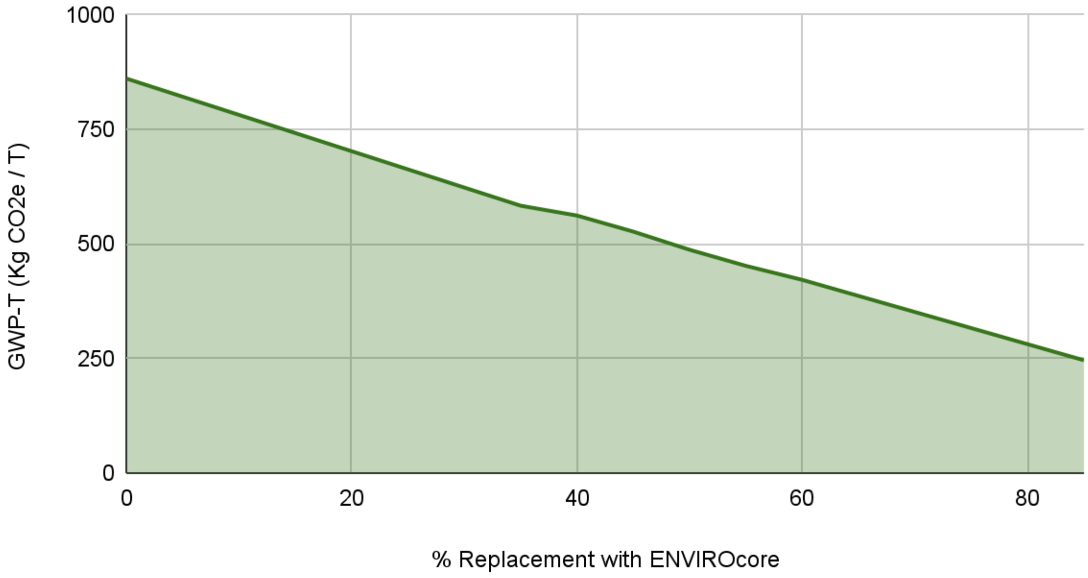
The embodied carbon **impact of cement**

Benchmarking Example:

GCCA Default NZ Cement



GWP-T Vs % replacement with ENVIROCore



Ground Granulated Blast Furnace Slag - GGBFS

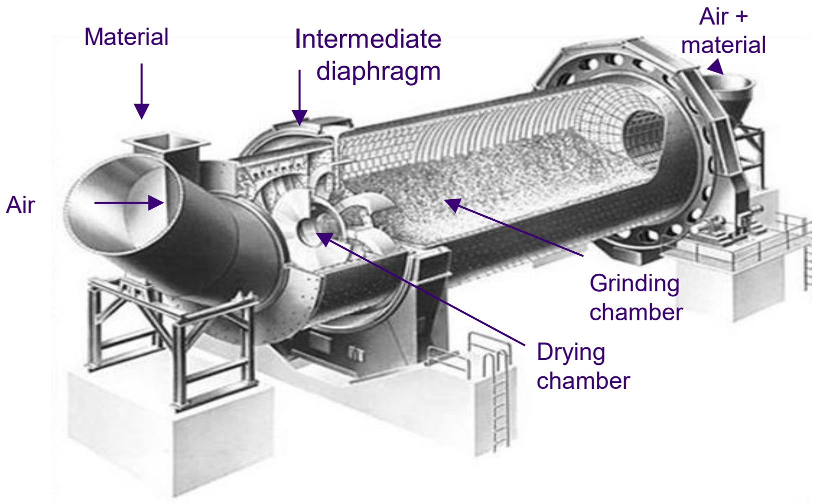
ENVIROCore 100

GGBFS

What is GGBFS

GGBFS or Ground Granulated blast furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

GGBFS is a latent hydraulic binder forming calcium silicate hydrates (C-S-H) after contact with water.



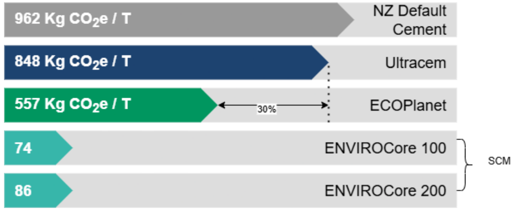
Processing

Holcim NZ turns the raw slag product from a coarse material into ground product with the use of a ball mill.

The granulated slag has a grain size of around 0.2 to 5mm

The GGBFS is ground to slightly finer than cement, with >90% smaller than 45µm

Impact



Benefits of GGBFS - Durability
Chloride Resistance

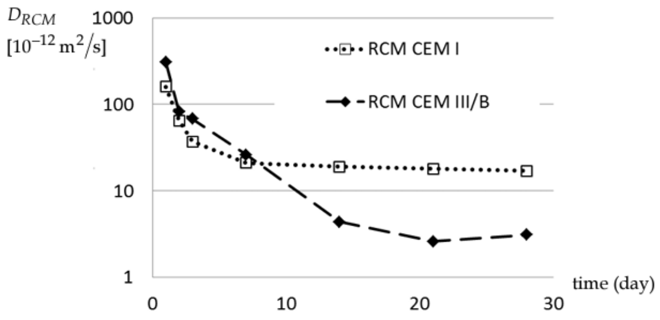
Concrete containing ENVIROCore 100 (GGBFS) is generally less permeable and chemically more stable than normal concrete.

This enhances its resistance to many forms of deleterious attack, in particular:
- Chloride-related corrosion of reinforcement
- Disintegration due to sulfate attack
- Cracking caused by alkali silica reaction

Chloride migration within concrete can cause chloride induced corrosion of steel reinforcement, leading to premature failure of key structure. This in enhanced within marine environments in which chloride salts are present.

The use of slag within concrete mixes reduces the migration potential of Chloride ions, and therefore reducing the risk of corrosion.

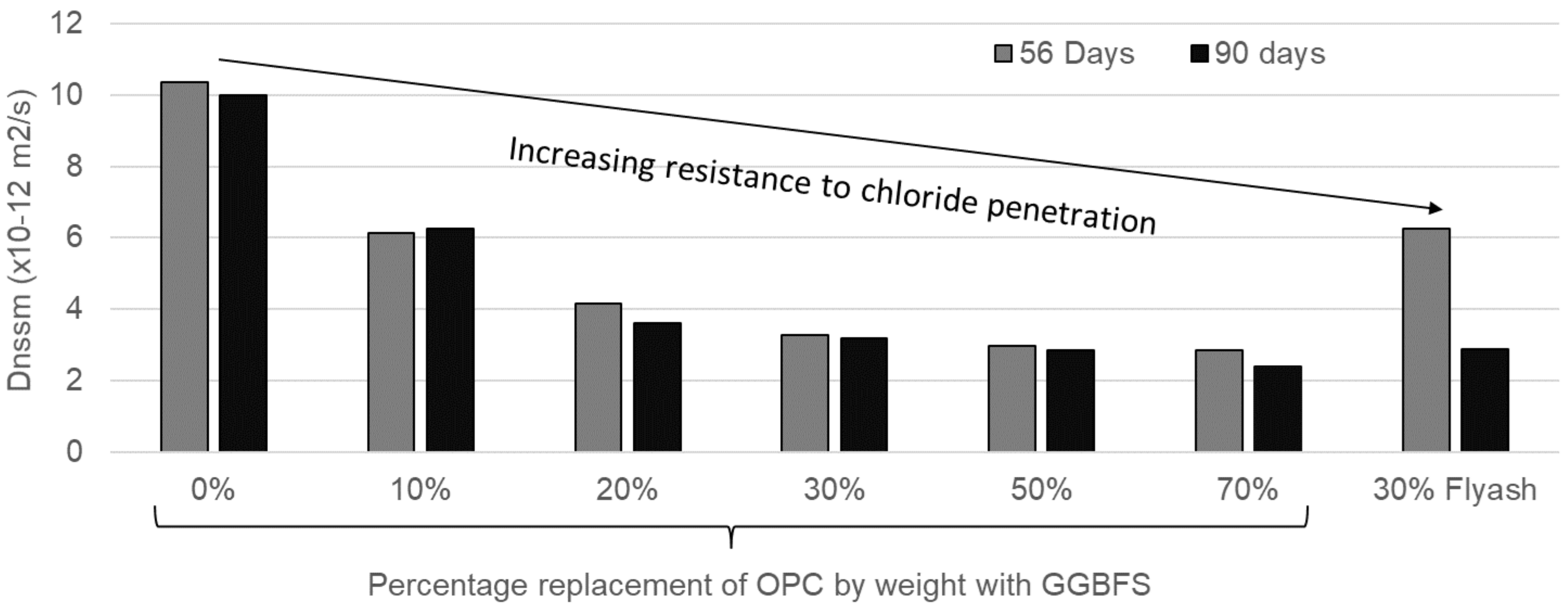
Within the NZS3101 standard, 65% GGBFS within a 45MPa (or greater) concrete is used with a minimum of 50mm cover for a 50 year lifetime within marine environments.



Chloride migration coefficient for Portland and slag cement mortar between one and 28 days age; Note: Y-axis log scale

Ref: Polder, R. B. (2012). Heron, 57(3), 197–210.

Chloride Resistance



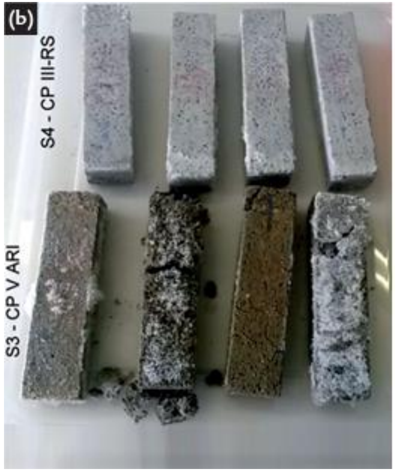
Benefits of GGBFS - Durability
Sulfate attack

Sulfate attack on concrete is when the cement matrix suffers from deterioration due to spalling, softening, and expansion in the sulfate environment

Sulfate attack is generally attributed to the reaction of sulfate ions with calcium hydroxide and calcium aluminate hydrate to form gypsum and ettringite. The formation of ettringite leads to an increase in solid volume, resulting in expansion, cracking, and mass loss, particularly when restrained

When ENVIROCore 100 is added, it

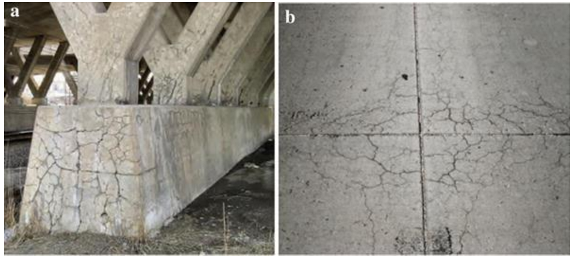
- Dilutes the C3A and C3S minerals within the clinker resulting in less aluminate species for the sulfates to react with.
- The Pozzolonic reaction further reduces the portlandite content as the hydrate. GGBFS may also consume calcium hydroxide,but to a lesser extent. As such, less portlandite is available to form gypsum or to provide calcium to form ettringite. Leading to less expansion
- GGBFS usually exhibit a finer pore structure, reducing permeability,and there by improving resistance to sulfate penetration.



S3 = General Purpose Cement (CEM I) after 91 days
S4 = 65% GGBFS after 105 days

Ref: Costa, L. C. B., Escoqui, J. M. R., Oliveira, T. M., da Fonseca, L. G., & Farage, M. C. R. (2018). https://doi.org/10.1590/0370-44672018710009

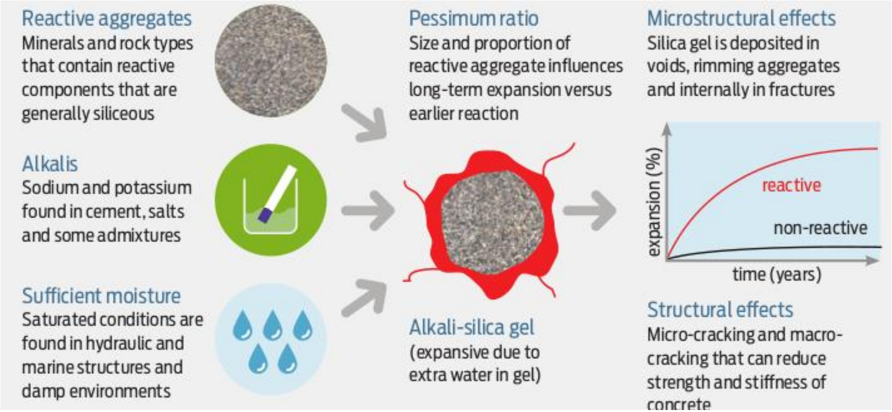
Benefits of SCMs - Durability
Alkali Silica Reactions



ASR or Alkali Silica Reactivity occurs when reactive silica within aggregates react with the alkalies (sodium and potassium oxides) in cement to form an alkali-silica gel which takes up water and swells. This can create cracking, which reduces both the concrete strength and the durability.

An example of this is within the Fairfield bridge, Hamilton, which took NZ$1.1 million to repair in 1991, after ASR issues were identified in the late 1980s (original construction finalised in 1934)

SCMs reduces the risk by control the pH of the paste causing the alkali to remain bound and not participate in the alkali-silica reaction.

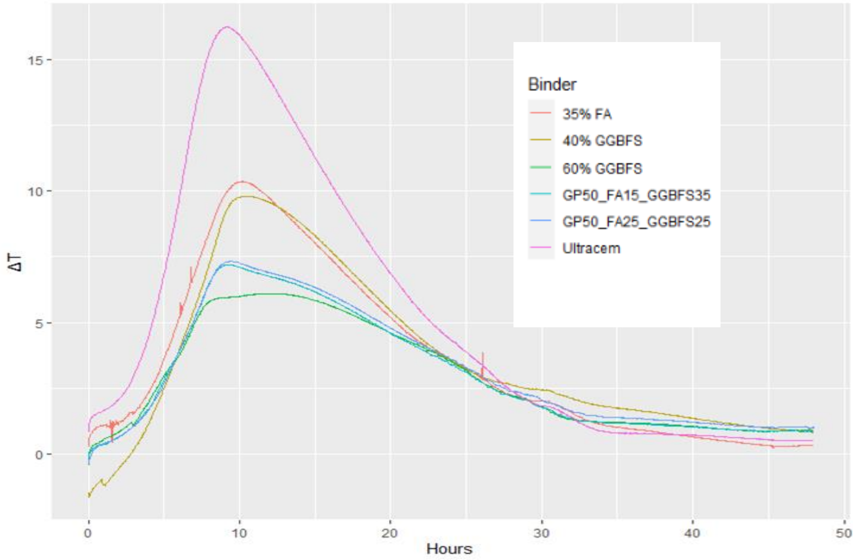


Infographic on ASR reactions (extract from J. Mackechnie, Keeping Concrete Affordable, Build. (2018))

Benefits of GGBFS - Low Heat Solutions

Lowering the heat generated during concrete mass pours offers several benefits, including:

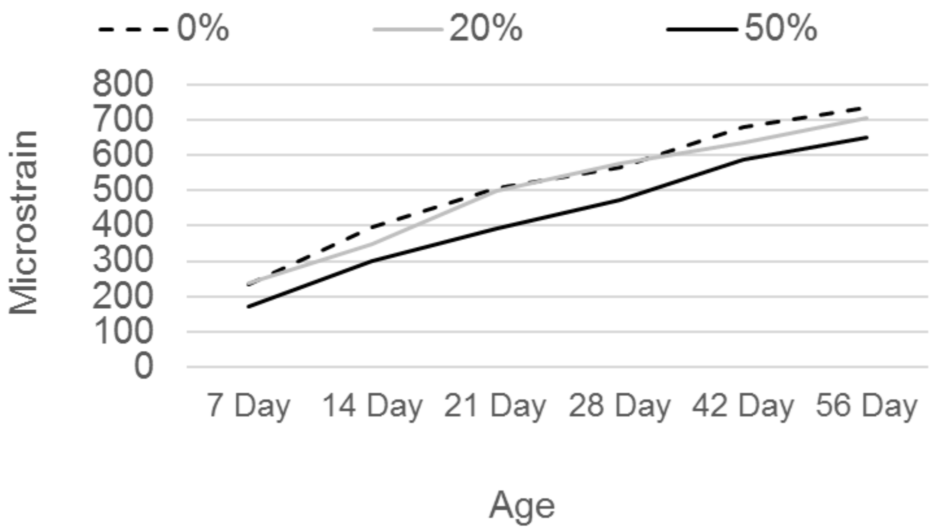
- **Reduced risk of thermal cracking:** Lower heat generation helps prevent the development of thermal gradients, which can lead to cracking in large concrete structures.
- **Enhanced long-term strength:** Excessive heat can accelerate the early-age strength gain of concrete but may compromise its long-term strength potential. By minimizing heat, the concrete can develop its strength more gradually and achieve higher ultimate strengths, ensuring a robust and durable structure over time.
- **Mitigation of drying shrinkage:** Excessive heat can increase the rate of moisture loss from concrete, leading to drying shrinkage and potential cracking. By controlling the heat of hydration, the concrete can retain moisture for a longer period, reducing drying shrinkage and minimizing the risk of associated problems.
- **Cost savings and improved construction schedule:** By reducing the risk of thermal cracking and associated repair work, construction delays and additional expenses can be avoided. Moreover, the extended working time provided by lower heat allows for more efficient construction sequencing, enabling faster project completion and potential cost savings.



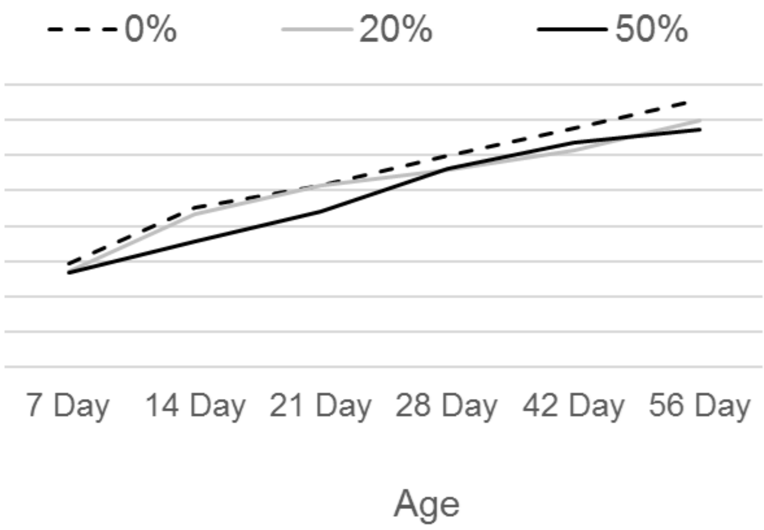
Low Heat mixes can contain GGBFS, Pozzolans, Fly Ash or a combination of all of these.

Drying Shrinkage Within Slag Concrete Mixes

20 MPa series



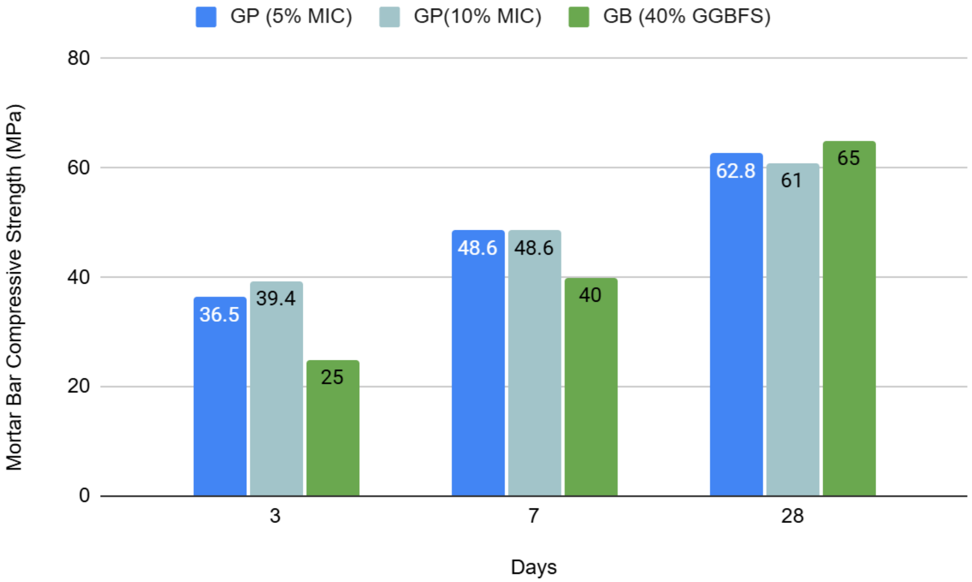
40 MPa series



The Strength impact
Type GB cement

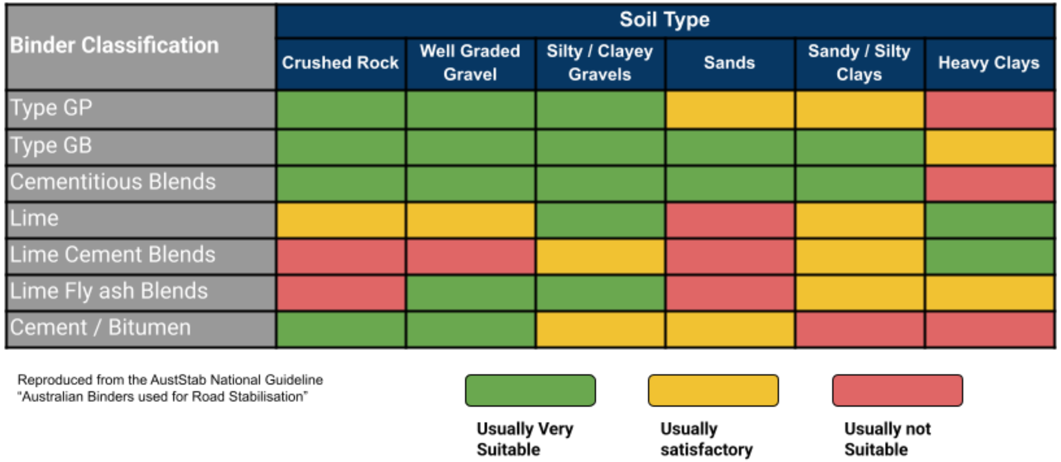
Increasing MIC contents on Type GP helps lower embodied carbon with very minor impacts to Cement Mortar performance.

Type GB cements can achieve significant carbon reductions compared to Type GP with improved final strengths, although tend to have slightly lower early age strength



Binder types for soil stabilization
Why are we not using Type GB cements?

As Cement suppliers are moving to higher MIC within Type GP, as a means to decarbonise, Type GPs can fall outside of NZTA specifications due to LOI.



Reproduced from the AustStab National Guideline "Australian Binders used for Road Stabilisation"

TNZ B/5:2008

- General purpose Portland cement – Type GP;
- General purpose blended cement – Type GB; or
- Special purpose low heat cement – Type LH.

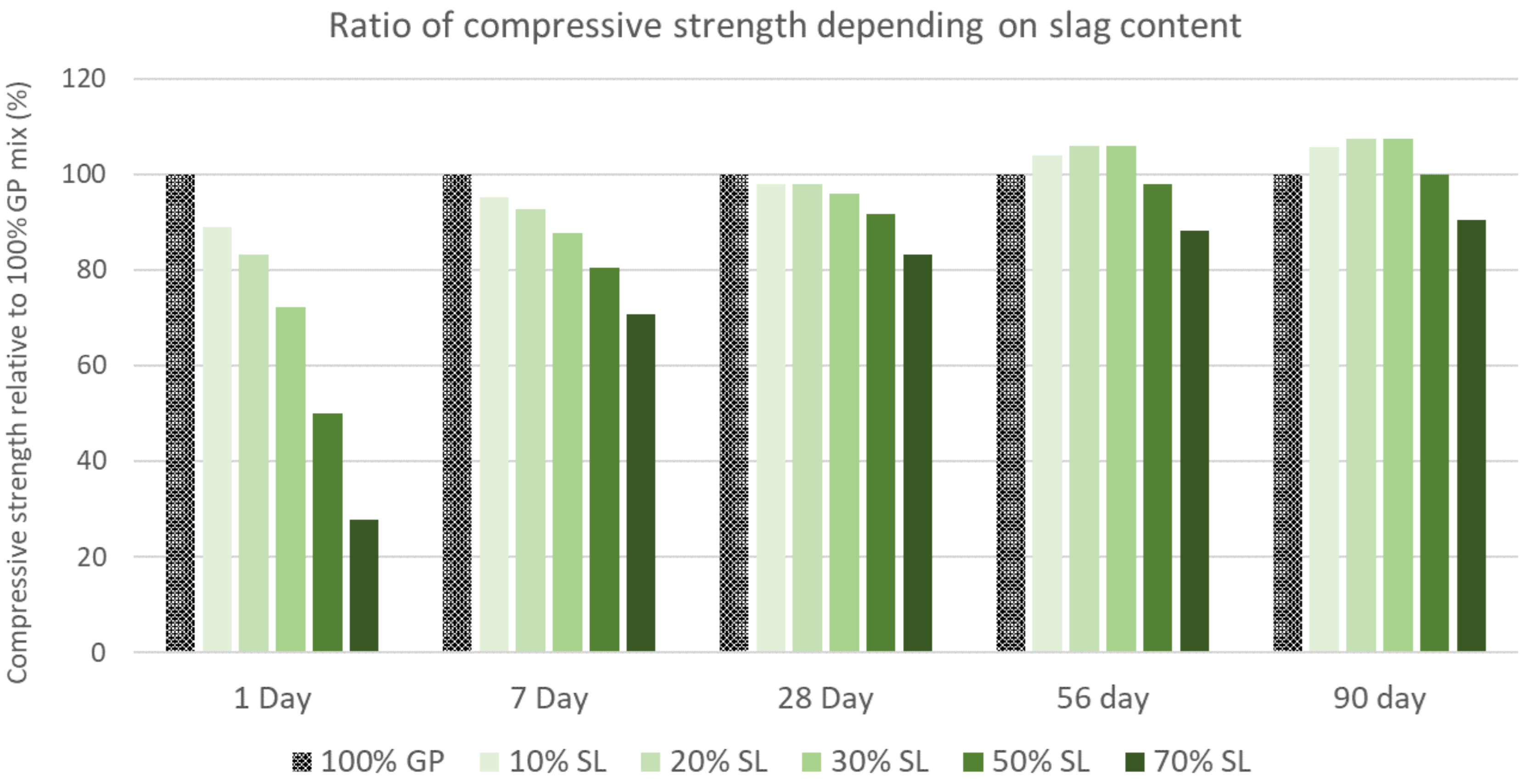
General purpose Portland cement, type GP, shall be used unless otherwise specified in the Contract documents. Note that high-early strength cement, type HE, shall not be used as a stabilising agent.

Cement shall be stored and handled to provide protection against deterioration or contamination. Cement that is more than 3 months old, or is suspected of not being stored in a way that protects it from deterioration, shall be tested for loss of ignition in accordance with AS 2350.2 or Appendix B of NZS 3122.

Type GP cement with a loss of ignition test result greater than 3.0% shall not be used.

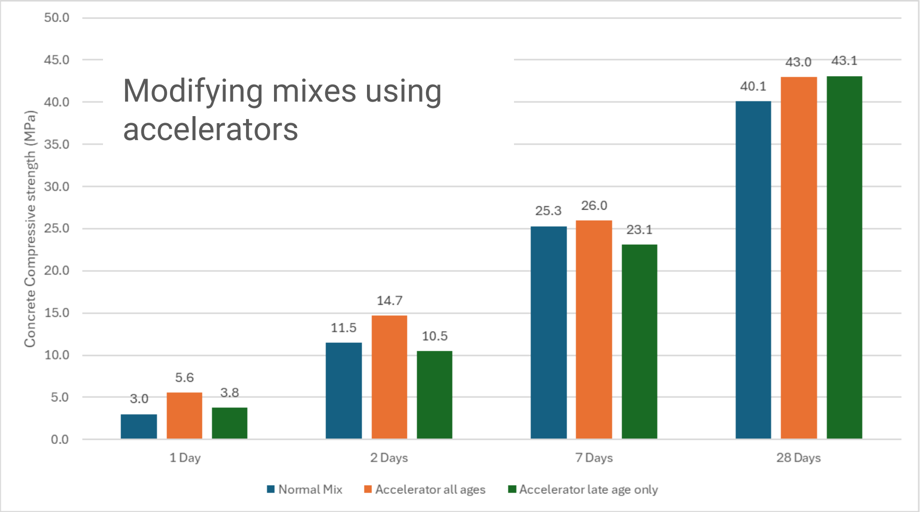
Types GB and LH cement with a loss of ignition test result greater than that determined by the cement manufacturer shall not be used.

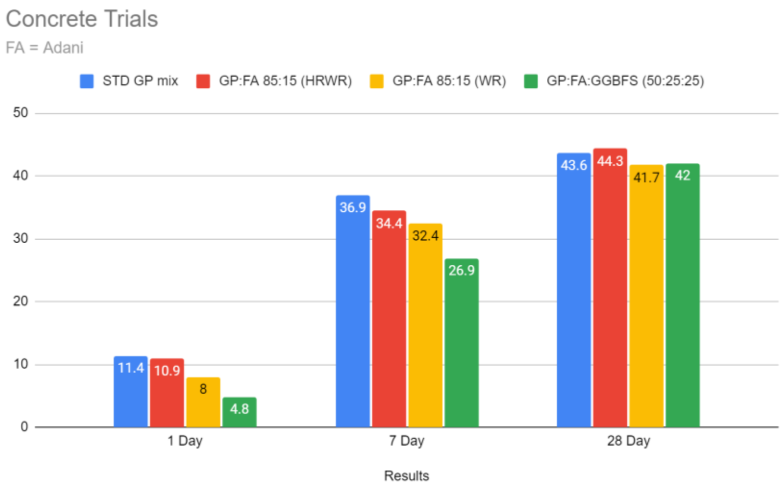
Strength Profile Within Slag Concrete Mixes



Effect of SCMs on Concrete Strength Profile

Admixture Selection can be used to modify performance





HRWR - High range Water Reducer
WR - Mid Range Water Reducer
GP - General Purpose Cement
FA - Flyash
GGBFS - Ground Granulated Blast furnace Slag

Typical Concrete Applications

Use	Typical Performance	Cementitious solutions
Slabs & footings	Slightly slower early strength development than Type GP, economical, environmental	Type GP with either 35% GGBFS or 10-15% FA replacement
Pilings & D.Walls	35-40MPa Mixes with high slump and improved workability.	Type GP with 15-30% FA replacement or 65% GGBFS Replacement
Mass Pour Slabs	Low Heat. Decreased permeability Early strengths are lower than GP. Use of GGBFS can increase shrinkage.	GP with 20-35%FA or 65% slag replacement. 8% SF is sometimes used to improve early strength
Chemical Resistance	Slower early strength development than Type GP, lower heat profile, durability & chemical resistance, sulphate resistance	Type GP with either 8% SF, 30-35% FA or >65% GGBFS replacement
Sulfate Resistance	Sulphate resistance, generally strength profile similar to Type GP	Type GP with 40% GGBFS replacement
General Construction	Slightly slower early strength development than Type GP, economical, environmental	Type GP with 10-15% FA or 35% GGBFS replacement, or Ternary blends 50:25:25 GP:FA:GGBFS
Marine or XA3 environments	Chloride and sulfate resistance	Type GP with >65% GGBFS
Bedding Concrete	Fence Posts, Clotheslines etc	Type GP Cement Upto 35% FA or 50% GGBFS replacement
General residential Concrete	General Concrete requirements (17-25 MPa)	35% GGBFS or 10-20% FA replacement of GP or Ternary Blend 50:25:25 GP:FA:GGBFS

Specifying Low Carbon?

How to start

PROCUREMENT PROCUREMENT PROCUREMENT
How Procurement Drive Demand for Sustainable Solutions?

INVESTORS / SHAREHOLDERS / COMMUNITIES

- Seek return on investment
- Monitor and rate ESG performance

CLIENT

- **Provides concept design and specifications**
- **Mandates sustainability rating**
- **Prescribes sustainability performance (eg: embodied carbon)**

Eastern Busway

Infrastructure Sustainability Council

DESIGNER

- Locks the design and take on the risk
- Specifies materials

MAIN CONTRACTOR

- Best value proposition to win the work
- Maintains tight budget and procurement management

SUBCONTRACTOR

- Best price to win the work (and/or value proposition)
- Maintains tight budget and procurement management
- Separate procurement process for materials

MATERIALS SUPPLIER (Concrete, Pipes, Aggregates …)

- Best value proposition to win the work
- Offers sustainable solutions

Influencing Specification **Low-carbon Concrete**

Ask for...

"Low carbon concrete"

Look for...

- EPDs produced and verified in accordance with EN15804

AUSTRALASIA EPD®
ENVIRONMENTAL PRODUCT DECLARATION

How to specify...

- The % reduction in GWP of the specified mix or within the group of mixes
- A reference base case that the reduction is based against
    - ISC reference mixes
    - Reference building mixes
- The Supporting documentation that should accompany this
    - Preference should be EPDs

Current examples

GWP in Specifications

Element	Concrete Grade	GWP Kg CO2 eq./m3
Pre-cast Walls	40MPa	309 kgCO2e/m3
Warehouse Slab	40MPa	309 kgCO2e/m3
Office Slab	25MPa	219 kgCO2e/m3
Kerbs	20MPa	199 kgCO2e/m3
Foundations	25MPa	219 kgCO2e/m3

Current examples

GWP in Specifications

Concrete Compressive Strength (MPa)	Baseline GWP Limit (kg CO2 / m2) A1-A3	Aspirational GWP Target (15% reduction) (kg CO2 / m2) A1-A3
20	269	229
25	293	249
30	340	289
35	365	313
40	390	354
45	425	375

Example of what to do

Concrete

Concrete product in order of preference is;

- Holcim ECOPact mixes achieving a minimum of 15% carbon reduction (Verified by an EPD in accordance with ISO 14025 and EN15804+A2.) against the baseline as shown below..
- Alternatives which achieve the same performance with a minimum 15% carbon reduction, verified by an EPD in accordance with ISO 14025 and EN15804+A2.
- Concrete mixes which provide an overall weighted carbon reduction of 15% against the baseline, verified by an EPD in accordance with ISO 14025 & EN15804+A2

Concrete Compressive Strength (MPa)	Baseline GWP Limit (kg CO2 / m2) A1-A3	Aspirational GWP Target (15% reduction) (kg CO2 / m2) A1-A3
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HOLCIM