VICTORIAN INFRASTRUCTURE DELIVERY AUTHORITY

Transport Infrastructure Decarbonisation Strategy

Lower Carbon Materials Visual Guide 2024

VICTORIA'S BIG BUILD

VICTORIA State Government

How to use this guide

This guide is intended to be used to raise awareness of the opportunities to use lower carbon materials to reduce upfront carbon emissions associated with transport infrastructure projects. The guide should be used together with advice from suppliers and in consultation with returned asset owners.

Legend

- Approved and common
- Approved but less common
- Innovation
- Considerations for use

The opportunity

Large infrastructure projects, such as those resulting from Victoria's Big Build present a unique opportunity to influence decarbonisation of the construction sector. By leveraging this unprecedented investment it is possible to optimise existing lower carbon technologies and identify and remove barriers to innovation.

Disclaimer

This Visual Guide is intended to support the uptake of lower carbon materials in alignment with the VIDA Transport Infrastructure Decarbonisation Strategy.

The information provided in this document is general guidance only.

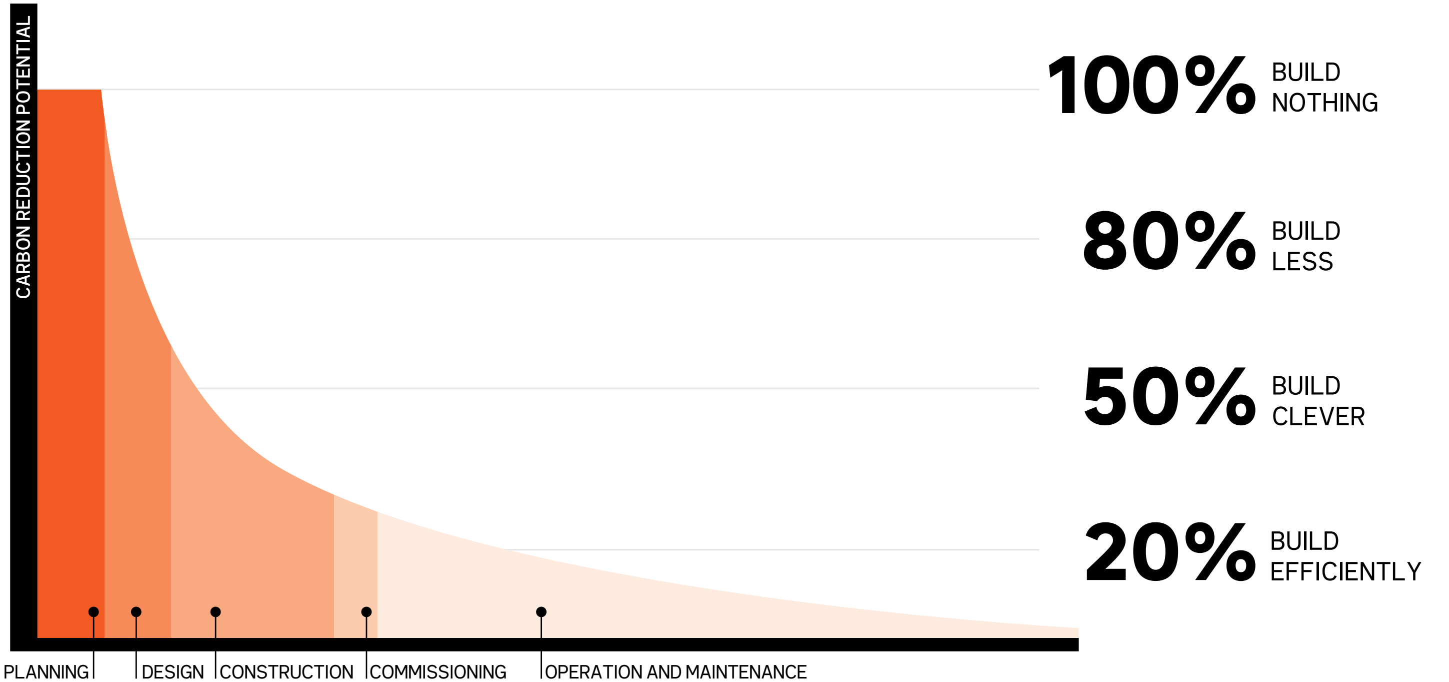
Personnel responsible for the delivery of projects shall undertake their own due diligence as to the adherence of materials and products listed against relevant asset owner standards and

Carbon reduction potential and project lifecycle

Opportunities to influence carbon emissions decrease through the project lifecycle.

Selection of lower carbon materials should only be considered once decisions have been made regarding the need to build and building less. When selecting lower carbon materials, give consideration to whole-of-life emissions.

Is the material durable? Does it have a suitable design life? Is the material value for money? Once these factors have been determined, building smarter and using lower carbon materials should be pursued.



Considerations for use

Can scope be removed entirely, or can the design be achieved in a different way? Are we building what is absolutely necessary?

Can we use less to achieve the same design/functional outcome?

Can we substitute with a lower carbon alternative e.g. a different material that achieves the same outcome. Can a recycled material be used?

Can we prefabricate to reduce waste & decrease install time and fuel burn or use modular design?

Concrete and carbon emissions

Throughout this guide, cement replacement and supplementary cementitious material (SCM) content are used as a proxies for lower carbon concrete and the terms are used interchangeably. When adopting mixes with SCM content, also consider the carbon intensity of the cement used and ultimately the concrete mix as a whole.

Third party verified product certification schemes such as Environmental Product Declerations (EPDs) or Life Cycle Assessments should be considered as they are valuable tools to quantify the actual emissions associated with a product. They also provide an opportunity to understand the emissions intensity and further decarbonise material manufacturing.

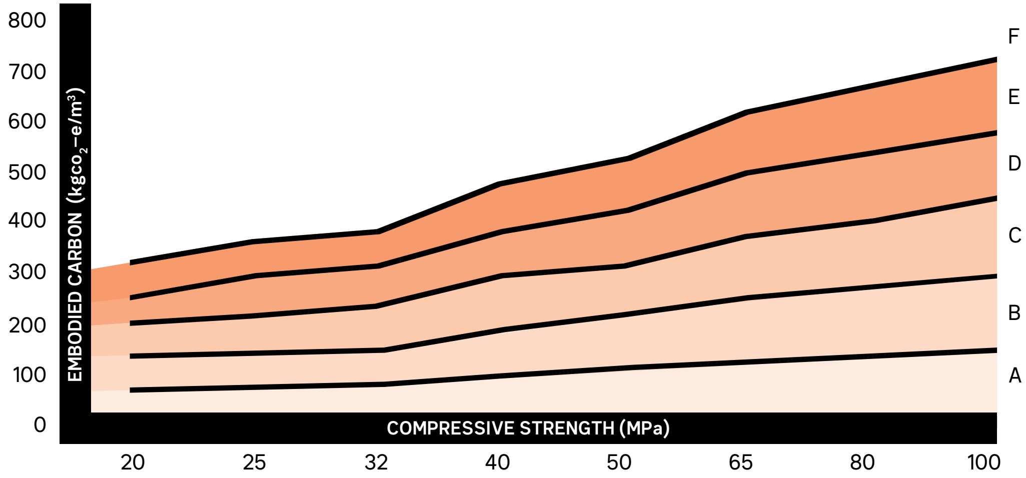
Note that SCM content may not always result in lower embodied carbon. The concrete strength, application, cement content and cement carbon intensity should be considered.

The Materials and Embodied Carbon Leaders Alliance (MECLA) have published guidance to support adoption of lower carbon concrete in Australia, classifying concrete based on embodied carbon from A (zero) to F (very high) for different concrete grades (reproduced below). Use of this guide is encouraged – When procuring concrete ask for the embodied carbon and compare to the MECLA classifications.

Statistics for Australian EPDs – All regions and types of concrete

	EMBODIED CARBON ($kgCO_2$-e/m^3)							
CONCRETE STRENGTH (MPa)	**20**	**25**	**32**	**40**	**50**	**65**	**80**	**100**
Maximum	313	350	374	467	516	608	529	575
75% Percentile	211	244	270	329	410	471	472	528
50% Percentile	199	218	246	302	349	379	429	465
25% percentile	177	198	224	264	320	357	422	441
Minimum	136	149	155	193	168	251	381	383

Data source: MECLA



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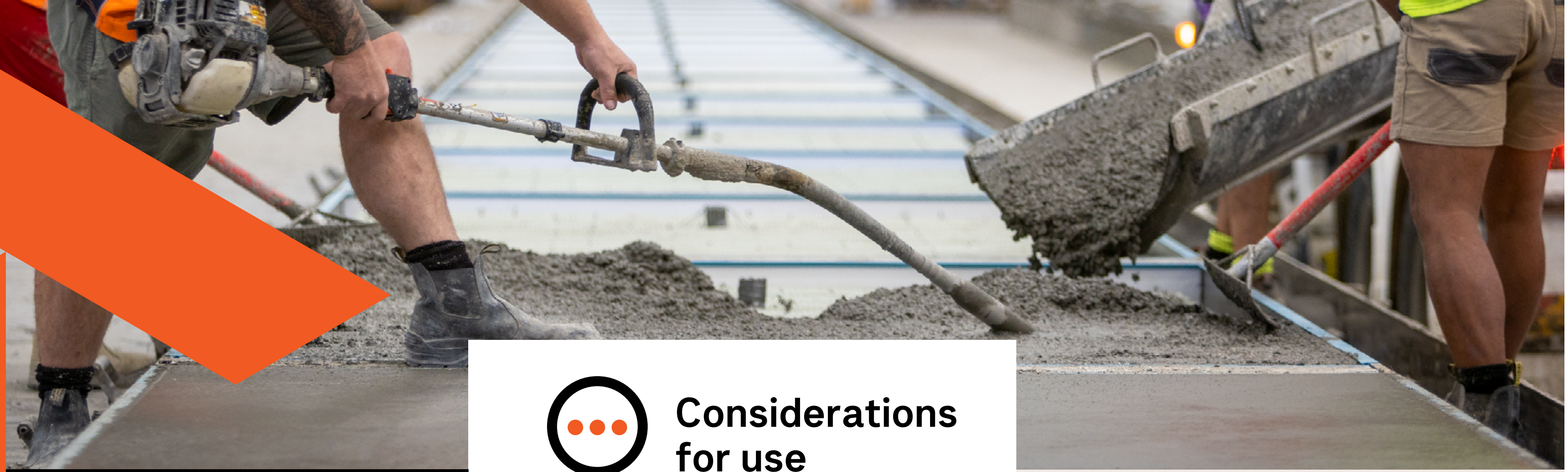


We need to build clever and build efficiently, utilising lower carbon materials, optimising the use of recycled material, through the Recycled First Policy.

Considerations for use

General considerations when using new and innovative concrete mixes

Consider **weather conditions** during concrete placing and curing, to mitigate hot and cold weather impacts on concrete setting and finishing. Follow practice provided in transportation agency specifications and industry guidelines.

Workability of mixes with high cement as mixes with high cement replacement can have reduced slump retention and increased viscosity. Pumpability should also be considered where necessary. Note that these barriers can be overcome through the use of additives such as plasticisers. Concrete suppliers are constantly improving these aspects so always contact your supplier.

Consider where lower carbon materials are being sourced from. Long **transport distances**, where these are using fossil fuel based vehicles, can negate the embodied emissions savings.

Consider **technical supervision** from the concrete supplier for 'innovation' and 'approved but less common mixes'. This will assist with resolving any issues if they are encountered on site.

Innovative applications and mixes with high cement replacement need to consider **constructability** (e.g., timing for formwork removal and proper curing procedures). Ensure the concreter is aware of how to work with the concrete to avoid poor outcomes. For example, when working with macro synthetic fibres ensure finish does not result in exposed fibres and waste.

Consider constructability when using high cement replacement for **bridge decks and piers**, ensuring proper curing techniques to prevent drying shrinkage and cracking. Adjust formwork removal timing according to weather conditions to maintain structural integrity. Also, account for the potential impact of occupation and working conditions on the construction schedule, especially when using high cement replacement mixes.

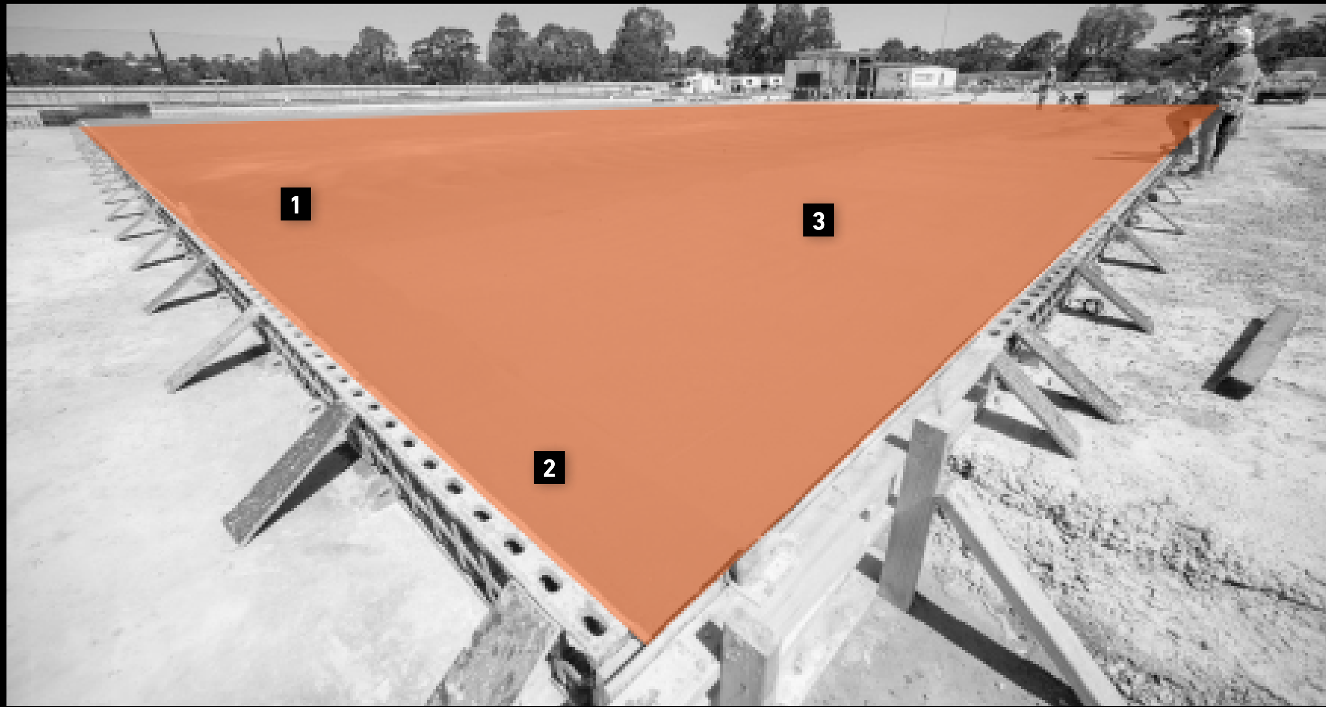
Concrete slabs

1 **Recycled concrete aggregate** can be used in low-risk structural elements, subject to the returned asset owner's approval.

- (Innovation) >20% recycled concrete aggregate (by weight).
- (Approved but less common) 10-20% recycled concrete aggregate (by weight), conditional approval.
- (Approved and common) 0-10% recycled concrete aggregate (by weight).

2 **High levels of cement replacement** can be used, up to 70% for low-risk structural elements.

- (Innovation) Mixes with >70% cement replacement, emerging supplementary cementitious material (SCMs) such as calcined clay, High Volume Fly Ash (HVFA) and geopolymer concretes.
- (Approved but less common) Mixes with 50-70% cement replacement.
- (Approved and common) Mixes with 30-50% cement replacement.



3 (Considerations for use) **Recycled concrete aggregate** levels are determined by performance. Without treatment, very high levels will start to impact compressive strengths but testing has proven lower levels to be effective.

(Considerations for use) **Recycled plastic aggregate** can be used but note emissions intensity may not result in lower embodied carbon.

(Approved but less common) Recycled plastic void formers can be used in slabs to reduce overall concrete volumes by up to 40%.

Approved and common | Approved but less common | Innovation | Considerations for use

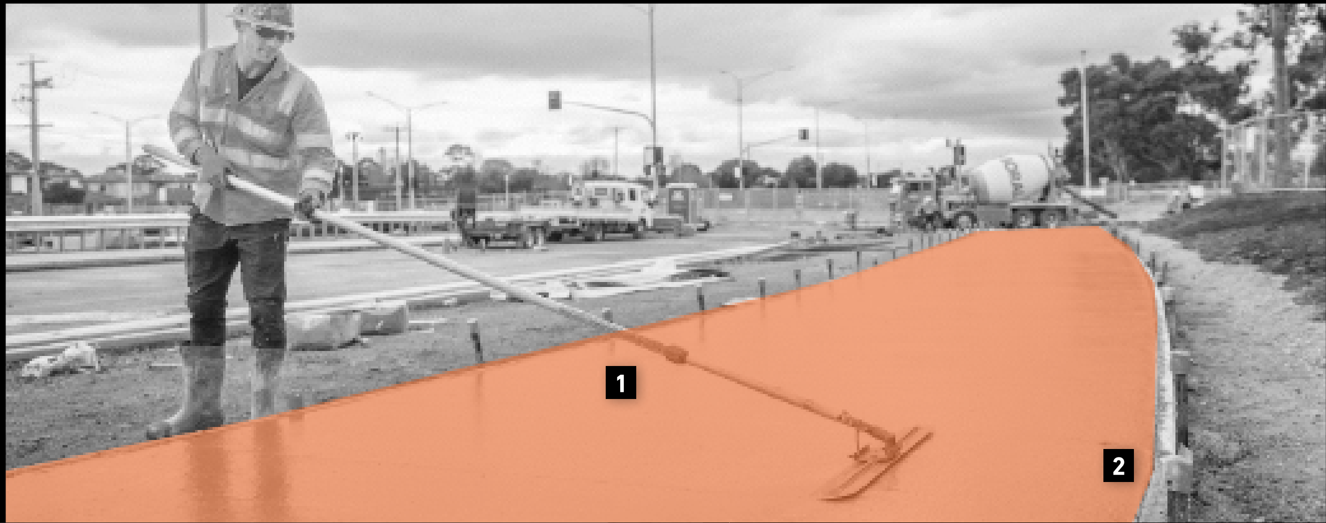
Shared user paths and other concrete applications

1 Concrete mixes with **high cement replacement** using (SCM).

- (Innovation) Mixes with >70% cement replacement, emerging SCMs such as calcined clay, HVFA and geopolymer concretes.
- (Approved but less common) Mixes with 50-75% cement replacement.
- (Approved and common) Mixes with 30-50% cement replacement.
- (Considerations for use) Mixes with at least 50% cement reduction are recommended for shared user paths.

2

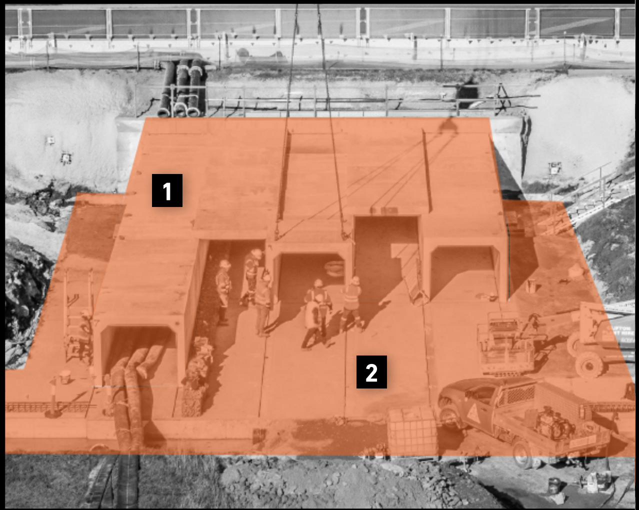
- (Approved and common) **Steel reinforcement** can be replaced with macro synthetic fibres made from recycled plastic.
- (Approved but less common) Steel reinforcement replaced by Glass Fibre Reinforced Polymer (GFRP) bars.



3 (Considerations for use) Shared user paths and similar applications such as infill concrete offer opportunities to test new mix designs as the assets can be easily accessed, repaired and are non-critical.

Approved and common | Approved but less common | Innovation | Considerations for use

Drainage

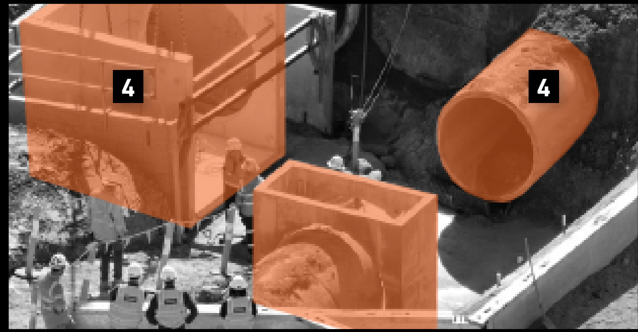


1 **Pre-cast culverts** can contain high levels of cement replacement.

- >50% cement replacement.
- 25-50% cement replacement.

2 **Blinding** is typically lower strength and can accommodate high cement replacement and recycled materials such as recycled concrete aggregate.

3 **Recycled plastic pipe** can be used in place of concrete, especially in roads behind kerb.

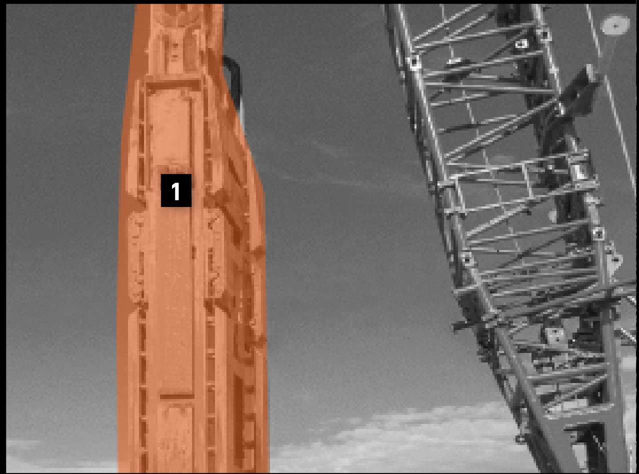


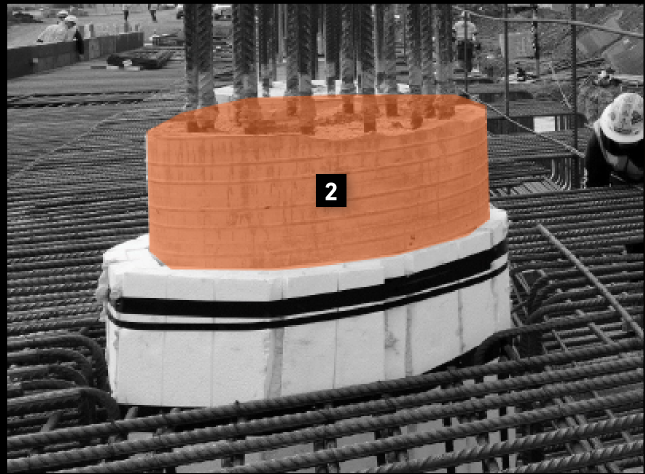
4 **Concrete pipe** and **pre-cast pits** can be manufactured with cement replacement.

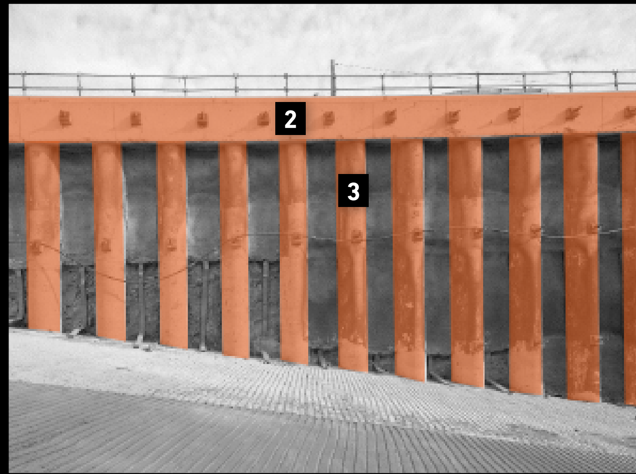
- >50% cement replacement.
- 25-50% cement replacement.
- **Early strength development** is often important for pre-cast concrete applications as this dictates production schedules. Therefore, very high SCM may not always be possible. Engagement with suppliers to assess their capabilities depending on project requirements and additives may be required to address this limitation. There are examples of geopolymer pre-cast products although these are not widely available.

Approved and common | Approved but less common | Innovation | Considerations for use

Piles and D-walls







When using high SCM mixes in CFA piles, consider pumpability as these mixes can be more challenging to work with in these applications.

1 **Diaphragm walls** can have high cement replacement, however as there have been some placement quality issues the consensus is ~40-50% is currently the optimum.

>70% cement replacement

50-70% cement replacement

Early strength development must be considered and mixes with high cement replacement may not be suitable where excavation of surrounding earth is required. Concrete suppliers are constantly improving these aspects so always consult your supplier.

2 Concrete mixes with high cement replacement (30-50%) can be used in **pile capping beams and pile caps.**

>50% cement replacement

3 Consideration to pumpability should be given where using in CFA pile applications – lower cement replacement may be more suitable in these circumstances.

Concrete mixes with high cement replacement can be used in **bored piles.**

>70% cement replacement

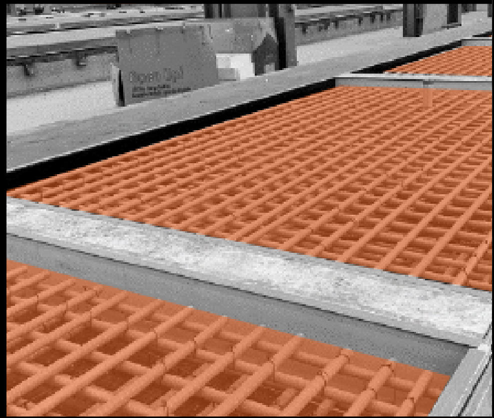
50-70% cement replacement

30% cement replacement

Approved and common | Approved but less common | Innovation | Considerations for use

Retaining walls and structures

Cement replacement and the use of general purpose limestone cement in shotcrete will depend on the application. **Shotcrete** used in mined tunnels and shafts has been demonstrated with replacements of 35-40% (where silica fume and fly ash are used together). In other applications high cement replacement may be constrained by pumpability requirements.



Glass Fibre Reinforced Polymer (GFRP) bars can be used in place of steel. This often results in lower cost and reduced emissions. GFRP bars are also suitable for corrosive and aggressive environments such as acidic soils, marine and coastal works and industrial areas.

Using **High strength steel reinforcement** (e.g. 600MPa), in place of traditional steel can result in reduced quantities and, when combined with recycled content and lower carbon manufacturing, can result in emissions savings of up to 40%.

Pre-cast concrete panels

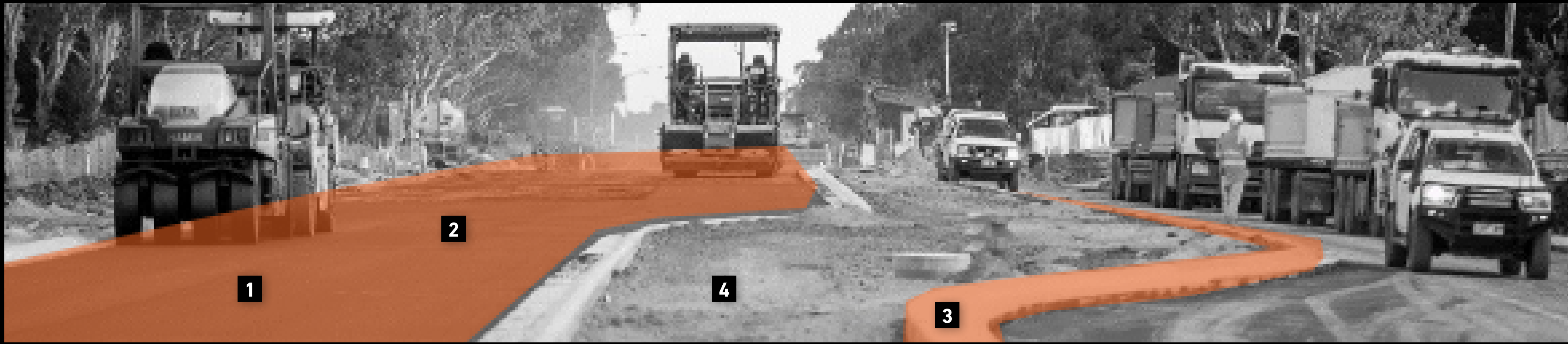
- >50% cement replacement
- 25-50% cement replacement
- Geopolymer
- GFRP bars
- High strength recycled steel

Pre-cast concrete panels (non-structural) can have high cement replacement (e.g. >50%). Geopolymer concrete and GFRP are also viable in these applications.

Geopolymer concrete is made without cement, using traditional SCMs together with an alkali activator. This can achieve emissions reductions of up to 80%.

Approved and common | Approved but less common | Innovation | Considerations for use

Roads and asphalt



Warm mix asphalt is heated to lower temperatures (~150°C vs 175°C) resulting in reduced emissions (~4%). Together with high RAP content results in lower carbon pavements. Consider also, 'ultra low' warm mix asphalts which are produced at even lower temperatures (~110°C) and could potentially be heated using fossil fuel free energy sources.

1

- Innovation: ultra low' warm mix
- Approved but less common: warm mix

Use of **reclaimed asphalt pavement** (RAP) reduces virgin bitumen use and associated emissions.

- Innovation: >40% RAP
- Approved and common: Up to 40% RAP depending on pavement layer.

2

Biogenic bitumen is made from waste organic sources and does not rely on crude oil for production. Biogenic bitumen can be net zero emissions and in some cases carbon negative (sequestration).

- Approved but less common: A15E binder approved for spray seals.
- Innovation: Biogenic bitumen in dense or open graded asphalt.

3

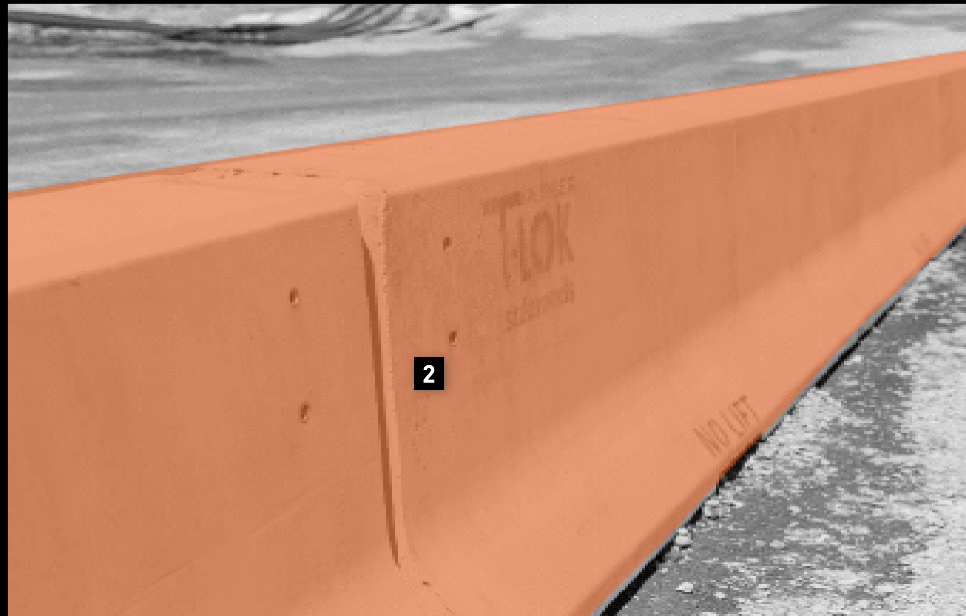
- Approved but less common: **Kerb and channel concrete** is typically of lower strength grade and can incorporate higher SCM content and recycled materials.

4

- Approved and common: **Road base** can comprise high levels of recycled content, such as recycled concrete, recycled ballast and other construction and demolition waste.

Approved and common | Approved but less common | Innovation | Considerations for use

Roads and asphalt



Crumb rubber derived from post consumer vehicle tyres can be used in asphalt to improve performance and reduce emissions. Together with warm mix technology emissions savings of around 10% can be achieved.

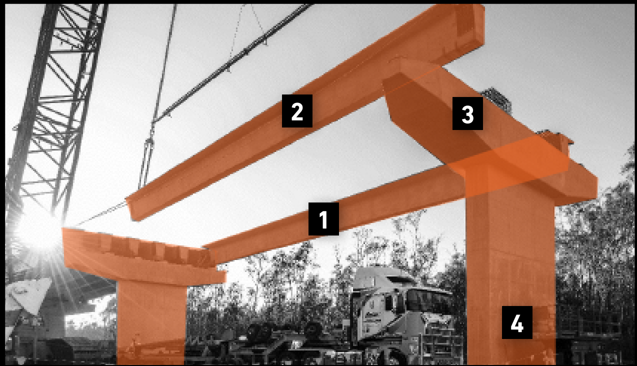
1 **Foam bitumen stabilisation** is a technology that utilises existing pavement, recycling together with injected foamed bitumen to create a new road surface. Emissions reductions are associated with reduced material use, transport movements and waste.

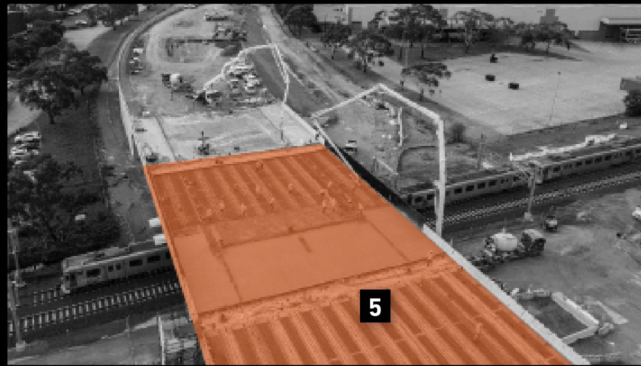
2 **Concrete barriers** can contain high levels of cement replacement (up to 50%). Geopolymer concrete products are also available as well as products with recycled materials such as crumb rubber which can have improved performance.

Lime stabilisation can be used to reduce import of material and off site disposal. However, consider the amount of lime required. High amounts of lime will result in increased embodied carbon.

Approved and common | Approved but less common | Innovation | Considerations for use

Bridges





1 **Ultra High Performance Concrete (UHPC)** is typically defined as a concrete with a compressive strength above 150 MPa. It has extremely high strength, ductility and durability. The very high cement content results in high embodied carbon by volume, however the high strength allows for less concrete and supporting structures to be used. Together with extended design life, this can result in reduced whole-of-life carbon. It is crucial that where it is used a correct design approach is taken to design out other materials, structures and thickness of the concrete.

2 For **pre-stressed precast elements**, ensure the required release strength is met for prestressed elements with high SCM mixes to allow for safe stress transfer without compromising the element's integrity.

Pre-stressed t-beams are available with 30% cement replacement.

3 Encourage the use of more than 50% SCM content for crossheads to reduce the risk of **Alkali-Silica Reaction (ASR)** and **Delayed Ettringite Formation (DEF)**, which can result from steam curing in large elements.

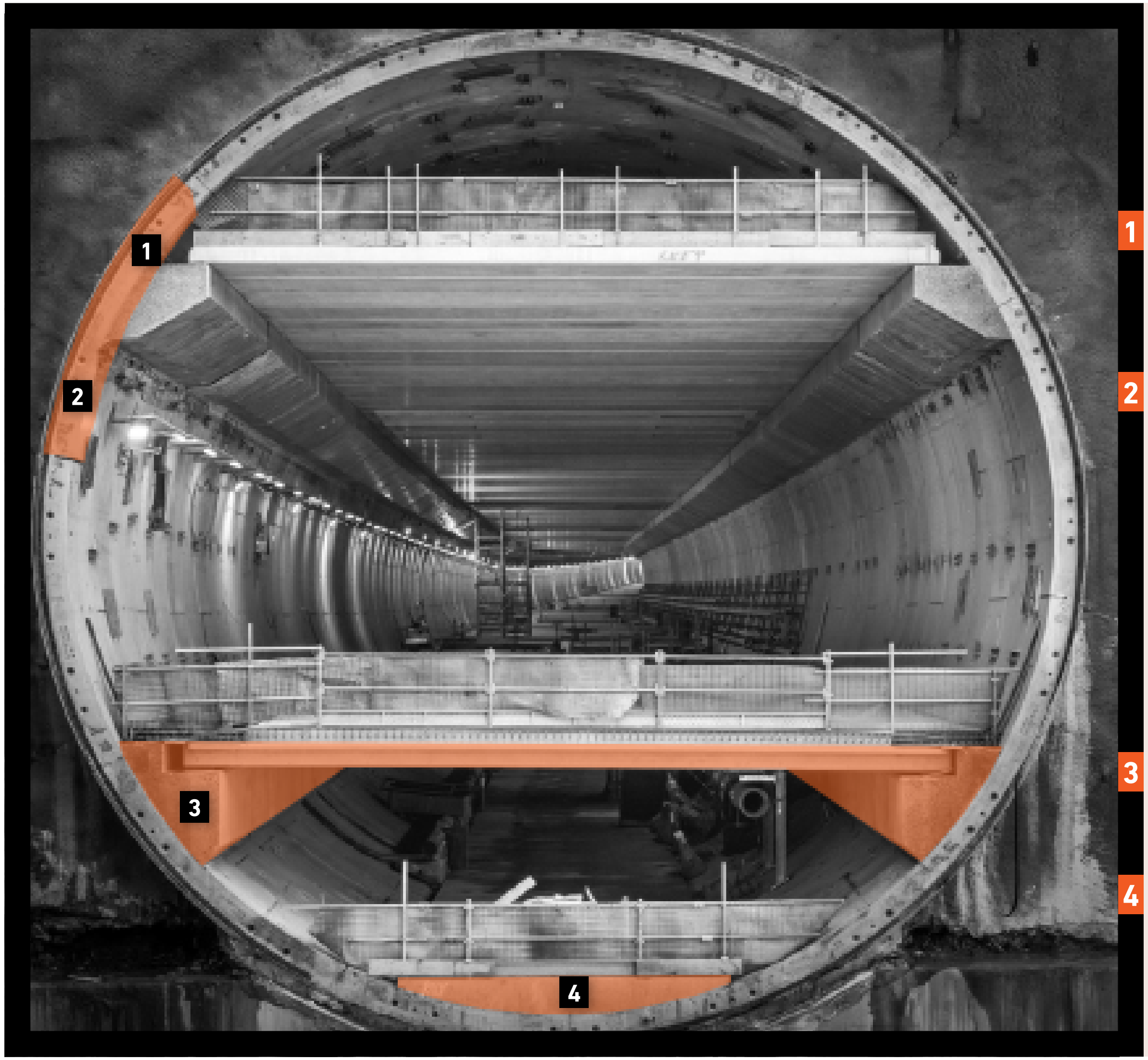
4 Consider **early-age strength gain** for precast elements with high SCM content as this may affect production and construction program schedules.

5 **High strength steel (e.g. 600MPa)** can be used, particularly in bridge decks and beams. Higher strength steel can reduce overall volumes. 100% recycled high strength steel bars are available manufactured in electric arc furnaces which have significantly reduced emissions compared to traditional steel.

6 **Glass Fibre Reinforced Polymer (GFRP)** structures such as pedestrian bridges, cycleways etc can be used in place of steel or concrete structures. This can result in lower cost and reduced emissions.

Approved and common | Approved but less common | Innovation | Considerations for use

Tunnels



1 High levels of cement replacement can be achieved for **cut-and-cover tunnels, tunnel shafts and caverns**. High levels of cement replacement with SCMs is also advised to mitigate the risks associated with aggressive soil conditions for underground stations.

TBM tunnel segments are produced in pre-cast facilities, in some cases on site allowing the team to adjust the mix and greater flexibility with setting times which can limit SCM content in precast.

2 Consideration should be given to **admixture dosing** – while these can help to improve production they also can have significant impacts on embodied carbon.

Production and program are key drivers. However, relatively high levels of **cement replacement** can be achieved in segments (e.g. up to 60%) and geopolymer concrete can also be used.

Use of **steel fibre reinforcement** in place of steel bar can significantly reduce embodied carbon. Check with your design team to determine the most efficient reinforcement applicable to tunnel segments.

3 **Road barriers** and other concrete elements in tunnels can incorporate recycled materials such as crumb rubber as well as high cement replacement.

4 Recycled materials and high cement replacement can be used in **concrete infill.**

Macro synthetic fibres can be used to enhance **fire resistance** requirements.

Approved and common | Approved but less common | Innovation | Considerations for use

Temporary works

Some projects involve substantial temporary works, allowing medium term trials and investigations to be undertaken with lower risk. This presents a great opportunity to establish monitoring programs based on the project's timeframe, building confidence in lower carbon concrete materials rather than testing them on permanent assets.

1 **Temporary concrete** works offer opportunities to test new materials, mix designs with low risk, workability, concrete finishes and saw cutting joints. This can include innovations such as biochar, recycled materials, geopolymer concrete, general purpose limestone cement, calcined clay and other emerging supplementary cementitious materials or concrete technologies where further testing or proof of concept is required.

2 **Temporary asphalt** pavements offer opportunities to test very high RAP content and other innovations such as ultra low warm mix asphalt, replacement of high embodied constituents such as lime with lower carbon alternatives.

Ultra-low warm mix asphalt together with 50% RAP content can result in up to 30% reductions in embodied carbon.

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