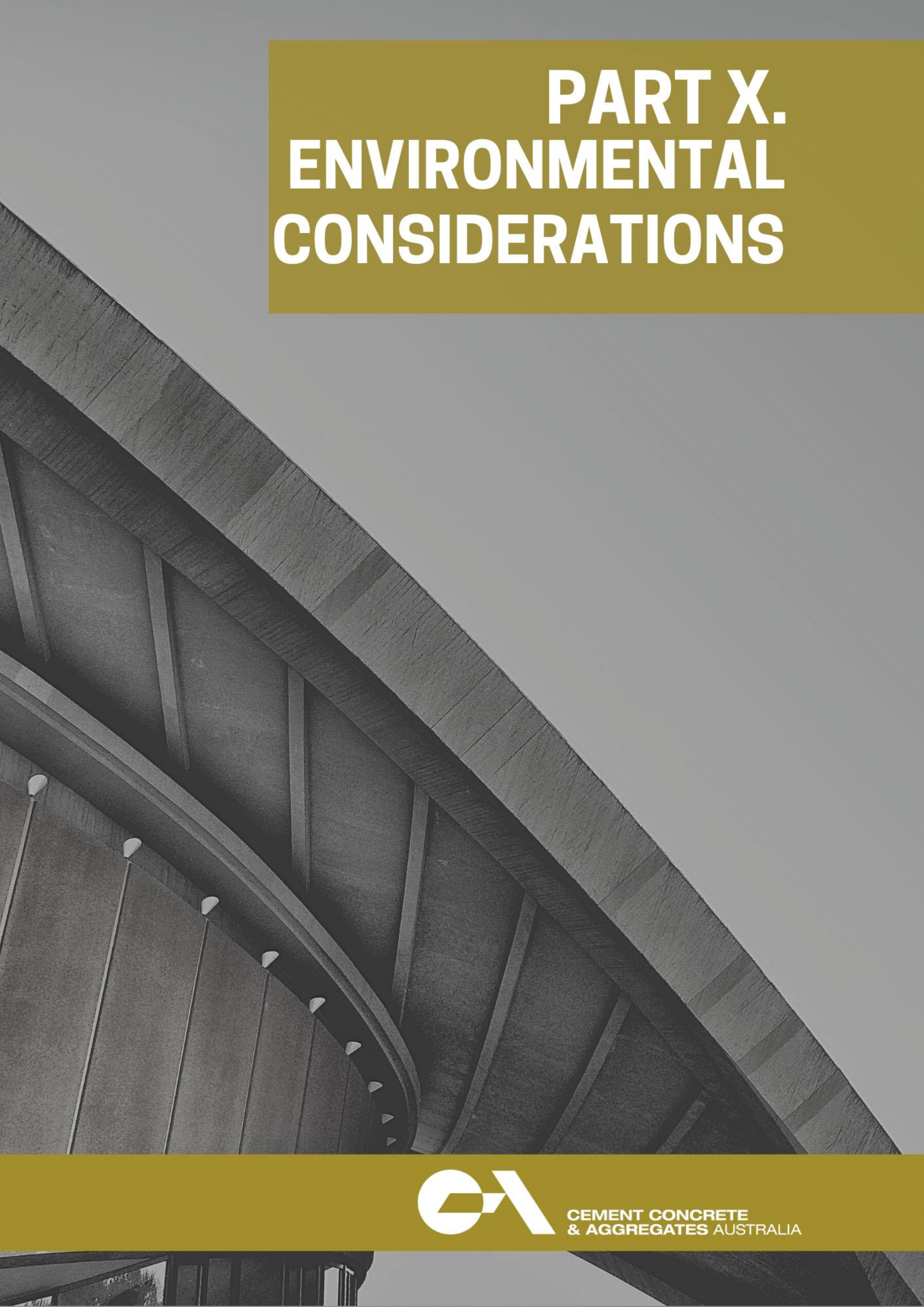

PART X. ENVIRONMENTAL CONSIDERATIONS

CEMENT CONCRETE
& AGGREGATES AUSTRALIA

This section aims to discuss a range of matters related to 'environment' that affect, or are affected by, the cement and concrete industries. Whether it is from a technical perspective or a community perspective, matters related to 'environment' are topical in both politics and society in general. Since concrete is the most widely used manufactured material in the world, and the second most consumed product next to water, it has the potential to have a major impact on society and on the environment. This section will attempt to consider the wide range of issues that are involved.

CONTENTS

1. INTRODUCTION

Given the global scale of cement and concrete manufacture and use, environmental factors relating to these materials need to be considered at several levels. With about 33 billion tonnes of concrete being produced per annum across the globe, supported by more than 4 billion tonnes of cement manufacture, the potential for global environmental impacts exists. However, concrete is also produced and used on a very local scale – with concrete plants in most towns and certainly in most cities – so consideration of concrete's presence at a local level also needs to be considered.

Whereas once the potential impacts of industrial materials were solely the concern of various levels of Government, through their granting of approvals and licences to build and operate plants, this is no longer the case. 'Environment' is a 'hot issue' in the community, with community concerns extending from local effects related to noise and dust and traffic movement to awareness of and concern about global issues like climate change and pollution of land and sea. To further complicate matters, all levels of Government seem to be increasingly influenced by these community concerns, whether solidly based or not. This means that 'industry' now has to have a strong awareness of the environmental issues that may result from their activities and be seen to be reacting to them in practical and demonstrable ways.

This section will examine both global and local 'environmental' issues affecting cement and concrete production and use; as well as provide some information about the responses that are being taken to understand and minimise environmental impacts.

2. GLOBAL ISSUES

2.1 CONCRETE USE

Concrete use globally has risen to a level of about 33 billion tonnes per annum. The recent rise in concrete use has been dramatic – having doubled since about 2000. Concrete as we know it came into being in the mid-1800's and has become increasingly popular since then. The re-building of cities after World War Two was made faster and more economically effective through the use of concrete, and presently, population growth in countries like China and India is fuelling further rapid growth.

Concrete has many advantages over alternative building materials like steel and timber. Concrete is produced locally, using local materials (except for cement), and employs local labour (both skilled and unskilled) in the task of concrete construction. Relatively speaking, concrete is also 'cheap'.

NOTE*: Poor quality concrete construction is also a problem in unsupervised construction situations and can lead to serious structural failures when its use is abused, particularly in earthquake regions or areas that suffer serious weather events.*

While the performance of concrete structures has many advantages, some environmental concerns arise. The large volumes of concrete consume large volumes of raw materials and water. In some parts of the world, for example, sand has become a scarce resource and its recovery and sale have led to illegal mining and 'sand smuggling' operations with consequent environmental degradation. The requirement for large amounts of aggregate materials can lead to poor operation of quarries in some regions. While quarrying activities are very well managed in Australia, this is not always the case globally.

Overall, concrete has assisted countries to grow and house their populations in much more habitable structures, reducing disease and poverty. The simply huge volumes of concrete use make it a target for environmental concerns despite the positive benefits it brings.

2.2 CEMENT MANUFACTURE

The huge rise in concrete production and use has been made possible by the parallel development of cement production capability worldwide. Cement manufacturing capacity has risen from about 1.5 billion tonnes per annum in 2000 to over 4 billion tonnes per annum now. Cement manufacture is a capital and energy-intensive activity that creates considerable concern over the emission levels of CO_2 – a Greenhouse Gas (GHG) – which is believed to be responsible for global climate warming.

In a modern cement plant, the CO_2 emission intensity is about 0.82 tonnes of CO_2 per tonne of cement produced. About 60% of the CO_2 comes from the calcination of limestone, while the remaining 40% comes from the burning of fossil fuels to heat cement kilns and for electricity production used to power the cement plants, including cement milling. The about-60% proportion is an inescapable component due to the chemistry involved. Improved plant efficiencies can reduce the 40%, though the level of improvement has reached close to its limits in recent decades.

From a global perspective, the cement industry is considered to produce about 7-8% of anthropogenic CO_2. If the global cement industry was a country, it would be about the third-largest emitter of CO_2. While at 7-8% the cement industry is well behind industry sectors like transport and energy production in terms of CO_2 emissions, it still comes under considerable scrutiny.

Recognition of the concerns about CO_2 has led the industry to improve its processes over the last few decades, including its expanded use of supplementary cementitious materials like fly ash and slag to partially substitute for cement in concrete production. In Australia, this has led to CO_2 levels in overall cementitious materials used in concrete to be reduced by about 30-35% relative to the use of cement only (i.e. from about 0.82 tonnes of CO_2 per tonne of cement to <0.6 tonnes of CO_2 per tonne of cementitious material).

The concerns about GHG emissions have also led to a huge amount of research work being carried out on alternative cements (or alternative binders), and some limited commercialisation of these 'new' concretes. This work and the nature of these materials are discussed in Section 23 of this Guide. In addition, the cement industry is involved in research to determine if 'carbon capture' is a viable process with which to capture and store the CO_2 produced during cement manufacture.

3. LOCAL ISSUES

3.1 CONCRETE PLANTS

From a community perspective, concrete plants provide some insight into the presence of concrete which otherwise, relative to the widespread use of the material, tends to be taken for granted. Plastic concrete is a 'perishable' product, with only a finite time available to move it from the batch plant to the job site. Since much of the concrete construction is located in community areas, it follows that concrete plants need to be located within these areas, or close to them. As urban sprawl continues (in most places) it is only a matter of time before the community and concrete production overlap. Given the 'time imperative', there is no real option to move concrete production further away from development areas, so it has meant that the concrete industry has had to 'lift its game' to win the confidence of the community. Generally, this has been achieved, and the industry has a strong awareness of community needs and expectations, and the need to abide by local Government requirements, particularly related to environmental issues.

NOTE*: There is one area that does create tension and that is truck movement. It is inescapable that transporting concrete to job sites requires truck movements, and this is often at peak hours. Even this aspect of industry/community interaction is being addressed where it can be. Truck movements are also associated with the delivery of raw materials to concrete plants – aggregates and cementitious materials particularly – and in some cases these are carried out at night to minimise truck movements in otherwise busy periods.*

Modern concrete plants are generally well screened from the community, and past concerns like high levels of noise and dust have been addressed quite successfully. Some basic environmental concerns like water run-off and water re-use are also being properly addressed. This work is being done both at plant and industry levels, and the range of Guideline documents prepared for use by concrete producers is testament to the seriousness of the industry in addressing these issues. These guidance documents include:

- CCAA, *'Environmental Management Guideline for Concrete Batch Plants'* (October 2019);
- CCAA, *'First Flush and Water Management Systems: Guide and Principles'* (August 2013);
- CCAA, *'Use of Re-Cycled Water in Concrete Production'* (August 2007);
- CCAA, *'Best Practice Guidelines for Concrete By-Product Re-Use at Concrete Batch Plants – Queensland'* (June 2012);
- CCAA, *'Guidelines for Delivery of Bulk Cementitious Materials to Premixed Concrete Plants' (*March 2018);
- CCAA, *'Guideline for Pedestrian and Traffic Management at Concrete Batch Plants'* (November 2018).

There are many examples of concrete producers ensuring that their operations 'fit' within their community and plant siting and operation are often undertaken to ensure that the concrete industry is seen as a good citizen.

3.2 RESOURCE USE

From an economic perspective, it is essential that the large volumes of raw materials, particularly aggregates, are sourced from as close to the concrete plant as possible. This also has environmental benefits through requiring less travel distances for trucks carrying out these deliveries. The concrete industry is supported by large quarrying activities, and these are also a source of community concern. Generally, quarry operations do not gain the attention of the community as these operations are typically well screened, and dust and noise issues (from blasting) are very well managed. From a quarry operation perspective, the main area of contention is when quarries seek to expand their resource and the community becomes aware of this through consultation processes. Often protracted battles are waged to prevent or limit quarry expansion. This has the effect of forcing quarries further away from the areas where their products are used and hence increasing truck movements and costs.

It is truck movements that, once again, make the quarry industry visible. The reality is that in Australia, quarry products are used at the rate of about 8 tonnes per person per year, so large quantities are being moved on our roads. Development of housing, industry and infrastructure as we know it cannot occur without these quarry products.

The various concerns about quarry activities has again resulted in a strong industry response to ensure quarry operators understand the issues and have tools to address them. Some of the guidance documents available to industry include:

- CCAA, *'CCAA Guideline – Assessment and Control of Environmental Noise Emissions from Quarries – Qld.'* (May 2105);
- CCAA, *'Extractive Industry Model Codes Version 1.0 and Guideline for the Extractive Industry Model Codes Version 1.0'* (August 2012);
- CCAA, *'Safety Data Sheets for Products Containing Respirable Crystalline Silica'* (December 2018);
- CCAA, *'Workplace Health and Safety Guideline – Management of Crystalline Silica in Quarries'* (January 2020).

The availability of natural sands is also decreasing, forcing the industry to look further afield for suitable sources, and also to look at alternatives to the natural products. The use of manufactured sands is now a 'norm' in concrete production. Approvals from specifiers for the use of manufactured sand as a partial replacement for natural sands came after a large body of industry research had been carried out to (a) technically describe appropriate properties for manufactured sands, and (b) develop and assess appropriate test methods to assess them. This work is described in a CCAA Research Report *'Manufactured Sands – National test methods and specification values'* (January 2007). The use of manufactured sands not only reduces the pressure on natural sand sources but also increases the efficiency of use of quarry resources.

3.3 USE OF INDUSTRIAL WASTES

For several decades, the concrete industry has been a large recycler through its significant use of 'waste' materials in its products. Fly ash and slag, nominal 'wastes' from coal-fired electricity generation and iron blast furnaces respectively, have been used as partial cement substitutes in Australian concrete. Their use has seen about a 35% reduction in the embodied CO_2 levels in concrete – this CO_2 deriving from cement. As well as directly improving the environmental credential of concrete, the use of these supplementary cementitious materials also improves concrete quality – particularly durability performance and also reduces the volumes of waste materials that would otherwise be landfilled. Fly ash and slag also form the basis of much of the development work on alternative binders as discussed in Section 23 of this Guide.

Recycling of concrete demolition wastes is carried out in Australia, but probably not to the extent that it is in other countries. Market size and transport distances mitigate against the broader re-use of concrete demolition wastes, though the level of re-use is increasing.

Some other recycled materials are being used in concrete and trials are underway to expand that use where possible. Crushed, recycled glass is used to a small extent as a partial sand replacement in concrete. Further test work is required to validate this use. Recycled glass can also be used as a cementitious material if crushed to a high degree of fineness (similar to cement) but this is not economical at this time. Other materials that have been the subject of research and field trials include (a) crumbed rubber (from tyres) as a partial aggregate replacement, (b) recycled plastics converted into plastic fibres for use in reinforcing, (c) sintered fly ash and bio-chars as aggregate replacements and (d) rice husk ash (waste from combustion of rice husks or hulls) for use as a supplementary cementitious material.

4. CONCRETE AS A BUILDING MATERIAL

4.1 CONCRETE PROPERTIES

Concrete has a number of inherent properties that make it an ideal building material, and it compares very favourably with other materials in terms of being strong and resistant to fire and pests; it is durable; it is inert and non-toxic (with no volatile emissions); it has a high thermal mass and good (sound and thermal) insulation properties; it is versatile and has the distinct advantage of being able to be moulded to many shapes and then subsequently harden in that shape; it is re-cyclable; and it is of relatively low cost. These various properties have contributed to the huge and increasing growth in concrete construction worldwide.

While cement manufacturing is capital intensive, concrete production is a low capital cost, simple process that is carried out locally and supports local economies. Properly designed and constructed concrete structures are very strong and very durable and can provide good long-term value to users.

When properly designed, concrete buildings impart environmental benefits as a result of several important characteristics, namely:

1. Concrete can store heat which then later flows into the building as it cools down in the evening resulting in reduced air conditioning loads through creating a more consistent temperature environment;
2. Concrete can act as a thermal insulator;
3. Concrete reduces sound transmission in commercial and residential structures; and
4. If there are concerns about a 'heat island' effect in built-up areas then concrete roofs, roads and footpaths can be made reflective through using light coloured (or white) concrete.

More detailed reviews of concrete properties important for building and construction appear in the following:

- CCAA Briefing 10, *'Building in bushfire-prone areas'* (July 2007);
- CCAA Briefing 12, *'Thermal mass benefit for housing'* (July 2007);
- CCAA Briefing 16, *'Quiet and comfortable concrete homes'* (July 2007);
- CCAA Briefing, *'Handy hints in specifying concrete buildings'* (March 2018).

4.2 LIFE CYCLE ASSESSMENT

There is no doubt that the manufacture of cement is both energy intensive and results in significant CO_2 (GHG) emissions. However, stand-alone this does not imply that cement or concrete use is environmentally unsound. If a structure is required, then it needs to be constructed from one material or another, and in any assessment a comparison is required. Moreover, it is the structure as a whole that should be assessed, not simply one component of it, and for its whole life cycle.

A technique known as Life Cycle Assessment (LCA) can be carried out to assess the energy use and GHG emissions associated with the construction, operation and ultimate demolition of any structure. To make sense of this assessment it should be done on a comparative basis to assess the relative performance of various construction material options.

An independent study carried out to compare various construction material options used in the construction of a domestic dwelling, an office building and a warehouse was carried out. The results showed that:

- There was no significant difference between the material options studied in terms of energy intensity and GHG emissions for the three building types reviewed;
- The energy use associated with the construction and maintenance of the structures was only about 10% of the total energy used during its lifetime, with energy use associated with building operation being by far the greatest component;
- Consideration of any single structural or operational element did not give a

realistic assessment of materials or structure comparisons; and

- LCA gives a balanced assessment of the energy and emissions performance for the entirety of the structure and life cycle including materials, construction and operational activities.

A more comprehensive review of the material properties of concrete and their environmental significance, as well as details of the LCA study, has been reported in the following:

- CCAA, *'Concrete – The responsible choice'* (July 2012).

4.3 GREEN STAR

The Green Building Council of Australia has developed a sustainability rating system known as Green Star that allows a sustainability score to be ascribed to a building – though the system is currently limited to office buildings and apartment blocks. Star ratings can range from 1 Star = Minimum Practice to 4 Stars = Best Practice; 5 Stars = Australian Excellence and 6 Stars = World Leadership in sustainable practices in building design, construction and operation. Star ratings are earned through scores derived from a wide range of sustainability initiatives that are included in the building. The total score determines the Star-rating.

From a concrete perspective, there are up to 3 Green Star points available as follows:

- One point – where 'Portland' cement use is reduced by 30% in all concrete used across the project – relative to a reference mix;
- Two points – where 'Portland' cement use is reduced by 40% in all concrete used across the project – relative to a reference mix;
- One point – where at least 50% of the water used in concrete is captured or reclaimed water, plus **either** of at least 40% of coarse aggregate is crushed slag aggregate or other alternative materials (provided this does not increase the Portland cement content of the mix by more than 5 kg/m^3), **or** at least 25% of the fine sand is manufactured sand or other alternative material (provided this does not increase the Portland cement content of the mix by more than 5 kg/m^3).

NOTE*: A series of reference Portland cement contents are listed in the Green Star documentation for all concrete grades from 20-100 MPa and claimed Portland cement reductions are measured against the nominated cement content in these references mixes.*

More detail on the Green Star system and its application are provided in the following references:

- CCAA Industry Guide, *'Green Star – Life Cycle Impacts – Concrete Credit 19B1 User Guide'* (August 2017);
- CCAA Industry Guide, '*Green Star Mat-4 Concrete Credit User Guide'* (June 2015);
- CCAA Technical Note 70, *'Six-Star Concrete Housing'* (April 2013).

While the Green Star system is currently used for offices and apartments, there is a system under development called 'Future Homes' that intends to extend the Green Star system to domestic housing.

4.4 LEED RATING SYSTEM

The LEED system is an American sustainability rating system that has been in place for many years and which is sometimes referred to in Australian projects. The latest version, Version 4, has changed from a system that focussed on single attributes of materials (e.g. recycled content or regional materials) to one that takes a more holistic approach through the use of LCA and product disclosure and optimisation. Product disclosure means reporting environmental, social and health impacts associated with use of materials using third-party assessments, examples being Environmental Product Declarations (EPD) (see 4.5) and Health Product Declarations (HPD). Projects are required to use at least 20 products for which EPD's and/or HPD's exist, and concrete has an advantage here because if concrete is used in slabs, paths, walls etc., each constitutes a 'product'. Use of locally produced (within 100 miles/ 160 km) products is also encouraged, which again favours concrete. A Construction Waste Management credit that is included is also beneficial provided construction wastes are used for alternative purposes and not landfilled. The system also includes a Global Warming Potential (GWP) assessment which requires, much like the Green Star system, project concrete mix designs to incorporate binder and aggregate components that have a lower GWP than baseline mixes that might otherwise be used.

4.5 ENVIRONMENTAL PRODUCT DECLARATIONS (EPD's)

EPD's are independently verified and registered documents that communicate transparent and comparable information about the life-cycle environmental impacts of products. There is an ISO Standard (ISO 14025) that details the requirements for preparing EPD's. Certified EPD's need to be prepared in accordance with Product Category Rules which describes the scope of the LCA that needs to be carried out and identifies the types of potential impacts that need to be evaluated and reported. The LCA's must be carried out by a neutral third-party. There is no 'global' EPD for concrete and individual companies must develop an EPD for their product(s) as manufactured in their plants and using the suite of materials available to them.

EPD's are useful in achieving accreditation in systems like LEED (as noted above) and will likely become a fundamental part of bidding processes for projects funded, for the time being at least, by large corporations and Government bodies.

5. SUMMARY – CONCRETE AND THE ENVIRONMENT

In the last (almost) 200 years, concrete has become the most popular building and construction material used throughout the entire world. That this is the case is testament to its relative simplicity of manufacture and use, its design versatility, its strength and its durability. The use of concrete is common in both the developed and under-developed worlds and the recent strong growth in its use is associated largely with the growing wealth of previously poor countries. Concrete is, by volume, the most commonly consumed material in the world after water, with recent production estimates being about 33 billion tonnes per annum. Almost any material used to this extent will bring with it concerns about impacts on the environment. That concrete uses large volumes of natural resources (e.g. aggregates) and contains a proportion of an energy and GHG-intensive product like cement adds to the environmental concerns. It is estimated that the cement industry contributes about 7-8% of the world's man-made CO_2.

In response to concerns about environmental impacts, the cement and concrete industries have made concerted efforts to (a) understand the nature and performance of its products, and (b) to find ways to mitigate any environmental concerns. While much of this work has been very successful and the concrete industry generally works well within its local communities, the concerns about GHG emissions remain and are largely insurmountable with current technologies. Work is underway to develop new cement types that give lower GHG emissions (see Section 23 of this Guide).

The reality for the moment is that concrete use will continue to grow, as will cement manufacture. Despite concerns, concrete is an effective and efficient building material from both engineering and environmental perspectives and its ongoing use reflects this. It remains a challenge for the cement and concrete industries to find a way to ensure that concrete – as we know it or in a modified form – remains the first choice for most future building activities.

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