

Briefing

Sustainable Concrete Infrastructure

Concrete is the most economical, enduring and fit-for-purpose building material; delivering strong performance across the three pillars of sustainability – social, environmental and economic. Without concrete, efficient and affordable infrastructure to service large cities would not exist.

INTRODUCTION

Infrastructure must be based on a sensible balance of social, environmental and economic considerations, and is essential to the development of modern civilisation. Road, rail, airport, utilities and port facilities provide for the necessary transportation of people, goods and communications that is the life blood of modern society. Infrastructure provides the essential supply of potable water, the removal and treatment of waste and sewage; it enables the provision of health, education and law-and-order.

This Briefing provides asset owners, designers and specifiers with information on how concrete meets the performance demands of infrastructure.

Concrete is the most essential building material necessary to build the infrastructure to sustain our civilisation. It provides the raw material to economically build vital facilities like wharves, dams, bridges, buildings, warehouses, roads, airports, water and sewerage lines and processing plants. Concrete is the most economical, enduring and fit-for-purpose building material; delivering strong performance across the three pillars of sustainability – social, environmental and economic. Without concrete, efficient and affordable infrastructure to service large cities would not exist.

WHAT IS SUSTAINABILITY?

A basic definition of sustainability is the capacity to maintain a process or state of being into perpetuity. In the context of human activity, sustainability has been described as activity or development *that meets the needs of the present, without compromising the ability of future generations to meet their own needs*¹.

To assess the sustainability of any system, a balanced consideration of environmental, economic and social aspects is required. This is referred to as the three-pillar framework, and is further discussed in *Concrete – the responsible choice*².

For infrastructure to be sustainable, it must be designed and constructed with materials and processes that deliver an acceptable performance with respect to society, the environment and the cost of the project over its full life-cycle. Sustainable infrastructure needs to be fit for the intended purpose, affordable, made from available materials, and durable – concrete uniquely delivers these objectives in practically all instances of infrastructure design and construction. The objective in building sustainable infrastructure becomes one of providing the necessary facilities, while minimising any adverse environmental impacts. One important step in this process is to use building materials that deliver strongly in respect of environmental sustainability, while providing long-lasting and fit-for-purpose infrastructure facilities.

Socially sustainable infrastructure allows societies to develop both socially and economically. For example, the reduction in quality of life and health in society resulting from not having sewerage treatment, clean water, efficient transportation, safe and efficient medical and hospital systems would be unthinkable.

Environmental sustainability must be analysed over the entire life of the project. The only true method of assessing a project's environmental impact is via an environmental life-cycle assessment.

The methodology is an established and rigorous scientific platform that is covered by an international standard³ which sets out the process and the environmental indicators. In the case of a building, a life-cycle includes extraction of raw materials, manufacture, construction, operation (commonly 50 to 100 years) and re-use or recycle phases. Life-cycle assessments of a range of concrete buildings, commissioned by CCAA, can be found on its website⁴. These case studies show that concrete buildings perform well across all environmental indicators, including energy use and greenhouse gas emissions.

Economic sustainability must also be analysed over the entire life of the project. An economic life-cycle analysis needs to include its purchase and acquisition cost, maintenance cost and disposal cost or salvage value at the end of the building's economic life. All of these costs need to be based on the same point in time, normally taken as the project's starting date. The whole-of-life cost can be expressed as a net present value (NPV).

BUILDING SUSTAINABLE INFRASTRUCTURE

Utility and aesthetics

While the utilitarian aspects of sustainability are critical to our modern lifestyle, we must not lose sight of the importance of aesthetics. Tumbarumba Bridge in NSW extends the normal utilitarian objectives of infrastructure projects by the thoughtful integration of graceful architecture, injecting a graceful addition seamlessly into the environment **Figure 1**.

Fit-for-purpose concrete materials for infrastructure

The unique performance requirements of infrastructure projects present considerable challenges for building materials. They must be durable over long periods of time (100 years +), resistant to corrosion, insect attack, abrasion, collision, impact, explosion, vandalism, flooding, drought, low temperatures, high temperatures, wind, fire, earthquake and salt, acid and chemical attack.

In addition they need to be in an abundant supply, readily available, and affordable. Concrete, with its strength, durability and resistance to aggressive exterior environments, is a unique building material which satisfies all of these requirements.

Concrete has natural resistance to the effects of disaster. Designed properly, concrete is used to create infrastructure that is resistant to fire, impact, wind, flood, storm, explosion and earthquake. The ability of concrete structures to survive major disasters, in working order, is essential to the disaster recovery process.

Concrete is clearly the most fit-for-purpose building material for infrastructure.

Sustainable concrete building materials

To be sustainable, building materials must be derived from sources that are inexhaustible in the foreseeable future (unlike oil and petrol reserves). The main ingredients of concrete are rock, sand, clay and limestone, all of which are in abundant supply.

It is preferable that building materials be sourced close to building sites, to avoid expensive and wasteful importation and transportation. The constituent materials in concrete occur naturally in all parts of the developed world. In Australia concrete is manufactured totally from local raw materials, using local skills and expertise. In fact Australian concrete technology has developed to a point where it leads the world in many areas⁵.

Table 1 summarises concrete's strong sustainability, using the 'three-pillar framework'.

Sustainable road infrastructure

Concrete roads provide particular benefits for sustainable infrastructure, due to their long life (typically 40 years +), low maintenance and strong economic performance. A good example is Sydney's Westlink M7, **Figure 3**.

A practical and commonsense approach to sustainable concrete road infrastructure is outlined by a major road contractor⁷.



Figure 1 Tumbarumba Bridge, Wagga Wagga NSW (winner of the bridges category, 2009 Public Domain Awards)

Judges comments: Artwork is integrated to strong and memorable effect and concrete employed in many ways to achieve the deceptive simplicity of the overall composition



Figure 2 Gateway Bridge duplication under construction, Brisbane 2009



Figure 3 Sydney's Westlink M7 motorway, a continuously reinforced concrete road pavement⁸

TABLE 1

Social

- The construction industry is a vital part of our economy, representing approximately 10% of GDP, and concrete is an essential part of the construction industry.
- Construction provides a secure livelihood for hundreds of thousands of Australians, and concrete is an integral part of that security.
- Concrete can be formed in an endless array of shapes to create structures, which are aesthetically and socially pleasing in architecture, civil engineering and landscape architecture.
- Concrete is used to create buildings that provide safe shelter for human habitation.
- Without concrete there is no built environment.

Environmental

- Concrete is a key enabler of renewable energy technology being a vital building material for these projects.
- Concrete projects have superior environmental performance when analysed on a whole-of-life basis because:
 - concrete's thermal mass reduces heating and cooling energy usage in buildings;
 - concrete structures are durable (100 years+ is achievable) and have very low maintenance requirements;
 - concrete has relatively low embodied energy;
 - carefully designed concrete structures can be adapted and reused many times over;
 - at the end of a structure's life, concrete can be recycled into other useful applications.
- Concrete construction technology is continually advancing and improving structural efficiency:
 - Prefabrication (precast concrete) can improve construction efficiency and structural performance. For example, 'Super T beams', noise walls, box culverts, prefabricated wharves in tidal zones and railway sleepers;
 - The use of post-tensioning in long-span bridge girders minimises beam sizes, reducing overall material usage. The recently completed Gateway Bridge in Brisbane, a 260-m-span post-tensioned precast concrete box girder construction provides an excellent example **Figure 2**. This bridge is the first infrastructure project in Australia to have a design life of 300 years.

Economic

- Concrete has a relatively low cost of manufacture, and has a low purchase price compared to other building materials.
- Concrete's unique properties ensure it has the lowest whole-of-life cost (NPV), including initial cost and maintenance cost, for practically all forms of infrastructure – buildings, bridges, dams, wharves and water facilities. For example, a recent study has confirmed that concrete framed buildings are the lowest cost alternative for building in Australia⁶.
- Concrete is ubiquitous and abundantly available in all developed regions, thus minimising transportation costs.
- Concrete's inherent durability minimises maintenance costs.

Seven 'commonsense principles of sustainability' are proposed:

1 Get smart

- Design for what you need: no more no less.

2 Design to serve the community

- Listen to the communities being affected
- Design to address the specific needs of the community
 - ride quality
 - delays.

3 Choose what you use

- Local first, minimise transportation
- Recycle – zero waste (concrete is 100% recyclable).

4 Less is more

- Less material means less impact
- Minimising portland cement, and making use of the following materials and techniques, can reduce environmental impact:
 - blended cements
 - supplementary cementitious materials (fly ash, slag, etc)
 - aggregate grading
 - optimised mix design.

5 Minimise impact

- Noise – construction and traffic
- Safety
 - splash and spray
 - lighting
- Delays – during construction and rehabilitation
- Emissions
 - greenhouse gases
 - pollution
 - particulates
- Energy efficiency
 - construction
 - operation
- Urban heat island effect.

6 Take care of what you have

- Use the equity already in the existing subgrades and pavement
- Well-timed maintenance and rehabilitation
- Design to maintain (eg additional thickness to accommodate future diamond grinding).

7 Innovate

- Learn from mistakes
- Evaluate emerging technologies
- Educate and challenge yourself.

This concise seven-step framework can also be applied more broadly to other infrastructure applications.

Concrete – the responsible choice

Infrastructure is a vital component in the provision of food and shelter. It provides a safe, clean and healthy lifestyle, housing, medical centres and hospitals, provides safe and efficient transportation, and underpins the essential services of education and law-and-order. Infrastructure is essential for the survival, growth and prosperity of human societies.

Concrete is the essential foundation and building block for strong, reliable and durable infrastructure. Importantly, concrete as an infrastructure building material has a very strong performance across all aspects of sustainability – economic, social and environmental outcomes. Studies from whole-of-life economic and whole-of-life environmental analyses of a range of building applications show concrete to have an impressive performance in these key measures of sustainability⁴.

Without concrete, economical, efficient, long-lasting and low maintenance infrastructure to service large cities would be difficult to provide. Concrete is abundantly available, affordable, robust and durable. Concrete can be formed to an infinite array of shapes to create pleasing, artistic and creative structures. It is uniquely fit-for-purpose for infrastructure design and construction.

Infrastructure is necessary to develop and maintain modern society; concrete is the essential building material from which sustainable infrastructure is constructed. For sustainable infrastructure, for sustainable societies, for sustainable cities, concrete is the responsible choice.

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