A basic definition of sustainability is the capacity to maintain a process or state of being into perpetuity. Sustainability is further described as activity or development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

**SUSTAINABILITY AS A BALANCED CONSIDERATION**

The sustainability of a road is a consideration, over the road’s entire life, of the benefits and costs with respect to the balanced aspects of economic, environmental and social performance.

True sustainability is the equilibrium of these considerations as illustrated in Figure 1.

**Figure 1** Sustainabilty graphically depicted by the overlapping area between economic, environmental and social performance.
The balanced evaluation of the sustainability of a concrete road requires consideration of the following aspects:

- **Economic** Over their lifetime, concrete roads provide an extremely attractive economic performance due to:
  - Low life-cycle cost
  - Lower night lighting costs
  - Traffic energy cost savings
  - Recycling at end of life.

- **Environmental** Over a concrete road's life its environmental performance is attractive due to:
  - Life-cycle assessment of environmental impact
  - Climate change proofing
  - Preserving earth's scarce resources
  - Energy savings for traffic
  - Better reflection of light.

- **Social** A concrete road provides a durable, safe pavement surface which facilitates travel for business and leisure. Considerations include:
  - Safety
    - Skid resistance
    - Improved night visibility
  - Driving comfort: Resistance to rutting and surface deformation
  - Fewer delays as a result of lesser maintenance needs.

**ECONOMIC CONSIDERATIONS**

Concrete roads are an attractive economic proposition with their cost of construction, operation and maintenance distributed over their long service life, combined with the additional economic bonus of attractive energy cost savings for the traffic using them and for lighting.

**Life-cycle cost**

Concrete pavements are very durable and typically have service lives of over 40 years. They also require very little maintenance in comparison to other types of pavement. Consequently, with their initial construction cost amortised over a longer period combined with a lower annual maintenance requirement their whole-of-life cost produces the most economical form of pavement on a life-cycle cost basis.

An example demonstrating concrete's economy is in the study conducted by the Highway Administration of Belgium in 2001. This study is a life-cycle cost analysis over a period of fifty years based on six operational pavements. The pavements were observed for construction and maintenance over a period of thirty years using actual cost and performance data.

In comparing continuously reinforced concrete pavements with alternative types, the study found that the concrete pavements became economically advantageous after the seventh year of a fifty-year operational period, and continued to increase their commercial advantage each year thereafter.

Concrete's long service life and low annual maintenance cost make it the most economically favoured pavement on a life-cycle basis.

**Traffic energy cost**

The type of pavement surface and its resistance to a rolling wheel influences the energy efficiency of a travelling vehicle's performance. Concrete is a material that does not elastically deform to the dynamic application of a rolling wheel on its surface, does not rut, shove or plastically deform and consequently has a higher energy efficiency and results in lower fuel consumption for heavy vehicles.

This has been demonstrated in research conducted in Canada by the National Research Council which revealed an average fuel saving of 2.35% on concrete roads by freight trucks. This represents a considerable saving in the operational costs of the heavy vehicles using concrete pavements and a significant saving in life-cycle operational cost of the road transport system.

Figure 2 A recently slip formed concrete subbase to form the foundation for a sustainable concrete pavement

Figure 3 Concrete roads for major infrastructure projects are often chosen on the basis of low life-cycle cost, low environmental impact and high societal benefit.
Night lighting costs
The lighter colour and superior reflectivity of concrete make it possible to achieve savings in the cost of the night lighting of streets and motorways. Savings can be achieved by installing fewer lighting columns or lamps of lower power and energy consumption. A Canadian study\(^3\) showed that a concrete carriageway, being light coloured, required only 14 lighting columns per kilometre as compared to 20 per kilometre for an equivalent darker surfaced roadway, representing a night time lighting energy saving of 30%.

Recycling
Concrete is one hundred per cent recyclable and at the end of the pavement’s service life can be crushed and recycled into road bases and sub-bases for use as a bound or unbound aggregate. It can also be crushed into recycled aggregate and combined with new cement to make recycled concrete. Economically this means that the material value of a concrete pavement is recovered at the end of its service life, contributing further to its lower life-cycle cost.

ENVIRONMENTAL CONSIDERATIONS
Concrete roads are a responsible environmental choice when their environmental impacts are considered over their lifetime.

Life-cycle assessment of environmental impact
In assessing the environmental impact of any development it is important to assess its impact over its whole life, taking into consideration its construction, operation, maintenance over this entire period, and disposal at the end of its life.

Concrete roads with their long service life, normally at least 40 years, have the advantage of amortisation of their initial construction environmental impacts over this long period.

The initial environmental impacts of embodied energy and greenhouse gas production are amortised over a lengthy period so that their annual amortised rates are very low.

In a forty-year period they are built only once (rather than being built twice as for less durable pavement types) which produces a two-fold saving to the depletion of the natural earth resources used to build the road.

Concrete roads have a low maintenance requirement over their lifetime, so that their annual maintenance environmental impact is the lowest of any form of road construction.

At the end of its service life concrete is one hundred percent recyclable so that a concrete road’s disposal represents a partial recovery of its environmental resource value.

During its life, concrete offers a unique benefit of carbon capture in the form of carbonation by the concrete material during its lifetime. Concrete actually removes carbon dioxide from the air by the process of carbonation whereby the carbon atom is fixated into calcium carbonate and locked into the concrete. Concrete actually becomes a carbon sink over its lifetime by absorbing carbon from the atmosphere.

Research\(^3\) showed that carbon uptake by a concrete road over its service life of forty years is 10 kg/m\(^3\), a significant offset of its initial impact.

A further reduction of environmental impact is possible by the co-incineration of industrial wastes in the cement kiln during the manufacture of cement. Industrial wastes such as rubber tyres, solvents, waste oil, waste water-treatment sludge and paint residues are used as alternative fuels to fire the cement kiln. When these waste materials are not incinerated during cement production they have to be eliminated by means of traditional incineration; utilising co-incineration in cement kilns thus reduces concrete’s overall environmental impact.

The environmental impact of concrete is further reduced when portland cement is partially replaced by the recycled by-products of coal power station fly ash and steel works slag. These materials are supplementary to the portland cement and, as a recycled industrial waste, have a lower level of embodied energy, thus further reducing concrete’s environmental impact.

Figure 4 [above] Laying the steel for a continuously reinforced concrete pavement

Figure 5 [left] A modern slip formed concrete pavement under construction
Additionally, the environmental impact of cement can be further reduced by the mineral additions of limestone and cement kiln dust (a recycled product from cement works).

**Concrete reflects light and energy**

Concrete reflects 15–25% of light and energy compared to a dark road surface which reflects only 5–10%. Greater reflection of solar energy is an aspect of contribution to the control of global warming; concrete’s greater reflectivity assists in this regard.

**Climate change proof pavements**

The consequences of climate change for Australia are likely to include a change in our patterns of temperature and rainfall. Concrete pavements are the most robust and resistant to changes in temperature and rainfall, their performance is only marginally affected by shifts in these conditions. The performance of other pavement materials, however, can be adversely affected by increased ambient temperatures which cause them to become more fluid and prone to rutting and shoving failures. Alternative pavement materials are also less tolerant of wetter subgrades which cause their premature structural failure. Both of these aspects make concrete a far more durable and robust pavement material and more resistant to the possible consequences of climate change.
Traffic emissions
As mentioned previously, concrete is a material that does not elastically deform as a result of the dynamic application of a rolling wheel on its surface, and consequently has a higher energy efficiency and a lower fuel consumption of 2.35% for heavy vehicles.

This saving in fuel consumption for heavy vehicles also represents a corresponding saving in pollutant emissions from the operating traffic, which constitutes a bonus saving for the environment.

Recycling
As explained earlier, concrete is one hundred per cent recyclable. Environmentally this means that the resources used to manufacture concrete are preserved and re-used over and again.

Preserving earth’s scarce resources
Crude oil and its derivatives are valuable earth resources which are in limited supply and will one day be exhausted. These hydrocarbons are not only used for the road-building industry but find application in many other diverse areas including plastics, building materials and synthetics manufacture. In contrast, concrete is made from the abundant earth supplies of limestone, clay, sand and stone. Constructing more roads from concrete instead of crude oil derivatives will conserve the earth’s scarce materials for future generations.

Driving comfort
Technology has continually improved the construction of concrete pavements. New generations of slipform pavers with sophisticated level control guidance systems are capable of constructing even and smooth pavements with a comfortable ride.

Concrete roads are robust and resistant to surface deformation over time, which means that their smoothness and ride comfort is preserved. A concrete road that initially gives a smooth ride will maintain its quality of ride throughout its service life and not be subject to rutting and surface deterioration.

Additionally, continuously reinforced concrete pavements eliminate the need for transverse joints, creating an even higher quality pavement with superior ride and comfort characteristics.

Fewer delays from maintenance works
The naturally low maintenance requirement of concrete pavements means that fewer repairs are required during the lifetime of the pavement. This translates into fewer disruptions to traffic and a higher degree of unencumbered use and enjoyment by the travelling public.

Figure 8 Sydney’s M7 Motorway pavement during construction

Figure 9 The slip former preparing to pave a continuously reinforced concrete pavement

SOCIAL CONSIDERATIONS
Concrete roads provide a durable, safe pavement surface which facilitates travel for business and leisure.

Safety
Concrete roads provide a robust, tough, smooth surface which is resistant to rutting and pot holes. Providing a surface resistant to deformation and deterioration produces an enduring safe pavement profile for the user.

Concrete also provides a surface of naturally high skid resistance which is an important factor in safety. The skid resistance results from both surface texturing and a variety of aspects of the concrete mix.

Surface texture options for concrete pavements include hessian drag, transverse and longitudinal tyning, porous concrete, exposed aggregate and diamond grinding.

With better light reflection from a concrete surface, night visibility is far greater on a concrete pavement, making concrete roads inherently safer in poor lighting conditions.

Concrete provides a durable traffic surface with high skid resistance and good visibility.
SUMMARY

Roads are an important element of our society’s infrastructure, helping to develop, maintain and sustain civilisation. Concrete roads present excellent value in the aspects of economic, environmental and social parameters of sustainability.

Concrete roads have good economic value because of their naturally inherent long life, giving a low life-cycle cost. Operational savings are made from lower energy costs for night lighting due to their greater reflectivity and traffic energy savings from reduced rolling resistance. At the end of their service life their costs are partially recouped from salvage and recycling.

Concrete roads have a diminished impact on the environment when considered with respect to their long service life. Their light coloured surface better reflects solar energy from the surface of the earth, they make a contribution to the climate proofing of roads, they help to reduce pollutant emission from vehicles and they contribute to preserving earth’s scarce resources.

For our society they provide a durable, safe driving surface providing access for the movement of goods and travel for leisure.

Concrete is a sustainable construction material. Concrete is a responsible choice for roads based on a balanced consideration of the principles of sustainability.

REFERENCES


2 Concrete – the responsible choice, Cement Concrete & Aggregates Australia, 2010.

3 Concrete Roads: A Smart and Sustainable Choice, European Concrete Paving Association, L. Rens, Brussels, 2009.

OTHER BRIEFINGS available online from www.ccaa.com.au are:

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