SUSTAINABILITY IN HIGHWAY ENGINEERING – AN AUSTRALIAN PERSPECTIVE

Phil Hawley, Director, PEECE Pty Ltd

Abstract

Sustainability is a key issue for all of the earth's inhabitants and one that is rapidly gaining prominence as climate change is accepted as an established fact and resources are rapidly becoming scarcer.

Road agencies can play a major role in the journey toward sustainability through the design of the road network and in construction and maintenance techniques. This paper provides a snapshot of the sustainability practices in use in highway engineering in Australia. Many of the practises discussed in the paper are considered to be every-day or even "old hat". It is only when they are considered in a holistic context that their sustainability impact becomes evident. For comparison purposes, the paper also draws some parallels with practices in North-Eastern China.

Key Words: Sustainability, Highway Engineering, Environment, Pavements

Introduction

The sustainability of our environment is paramount to the survival of mankind on our planet. This is now demonstrated through rapidly accelerating climate change, ongoing environmental degradation and the ever increasing difficulty in obtaining the resources needed to drive economic development and satisfy an insatiable desire to improve our standards of living.

Greenhouse gas emissions (GHG) are considered to be a major contributor toward climate change and the environmental degradation that accompanies it. Further, transport is responsible for around 15% of all greenhouse gas emissions and this percentage is forecast to increase by around two-thirds over the next thirty years.

The International Road Federation has recognised this and has recently released a policy position on sustainability. It also recognises that economic development and road transport are inextricably linked.

Hence, there is a need to do what we can to ensure that the road transportation task has as small an environmental footprint as possible. The design and construction of the road network is a major element in this drive toward sustainability.

The balance of this paper examines the practices that are in general use in Australia to minimise the environmental impact of the road network. Some are generic to most if not all of Australia; others may be of particular relevance to a particular region or state.

Much of the information in this paper was originally presented to engineers of the Jilin Provincial Communications Department (JPCD) - which is the regional expressway authority in NE China, in September 2010. Since then the author has had the opportunity to view first hand the practices currently used in NE China and is able to draw some parallels between Chinese and Australian practice.

Environmental Assessment and Approval

As the geologically oldest continent on the planet and being relatively isolated, Australia has many unique and also fragile environmental features that require careful management and protection. These can be flora, fauna, geological formations or items of cultural significance to the aboriginal population. Protection of waterways is also a critical issue in Australia where there is generally low rainfall (Australia is the second driest continent) and disturbance of catchments leads to problems with salinity or in many areas exposure of acid sulphate soils. There are also heritage listed items relating to early European settlement that are considered worthy of preservation.

Australian legislation requires that an environmental assessment be undertaken and an approval granted before any road construction can take place. The actual assessment requirements vary from state to state (the assessments are controlled by state and federal legislation) and the extent of the assessment will vary depending on the scale of the development as well as what any initial investigations may uncover.

In broad terms, the assessment is required to take into consideration:

- Need for the project;
- Impact on the built environment;
- Impact on the natural environment i.e. habitats, flora, fauna, geology, water;
- Heritage i.e. either Aboriginal or European;
- Impact on threatened species; and
- Impact on users and also on those living near the development e.g. noise, air quality etc.

At the very least, the project will be subjected to a review of environmental factors and for major or sensitive projects a number of detailed studies resulting in an environmental impact statement will be required.

Chinese environmental assessments aren't as detailed, with the primary emphasis appearing to be ensuring efficiency in the road transport task. The rapid construction of many thousands of kilometres of freeways throughout China means that many communities are being disturbed, although the government provides at least some compensation to those displaced or losing their traditional livelihoods due to freeway alignments.

Road Geometry

Although advances in the design of vehicle systems have done much to reduce the environmental impact of vehicles i.e. through building them from recycled materials, designing them to be deconstructed for recycling at end-of life and reducing energy consumption and emissions, road geometry also plays a major part in determining fuel consumption and hence GHG emissions.

a. Toll roads

One way of minimising the impact of the road design on creation of GHG emissions is to design the road in such a way as to minimise unnecessary braking and acceleration. This is a generally a difficult task with respect to minimising congestion on the network as the funding isn't available to construct additional lanes and grade separated intersections.

However, one area that is relatively easily controlled is on toll roads. To this end Australia's toll roads are gradually being converted to a cashless system. All new toll roads are now cashless and utilise a "free flow" tolling system where tolling takes place at normal travel speed. An electronic tag containing an RFID chip (E-Tag) is attached to the inside of the windscreen of the vehicle and the tag is interrogated by a transponder mounted on a gantry over the roadway. The linked computer system deducts the toll from the user's account with the tollway authority. Australian E-Tags are acceptable on all cashless tollways throughout Australia.

For casual users without an E-Tag the vehicle is photographed and the driver has (usually) up to 48 hours to pay the toll either by contacting the toll operator or in some cases by purchasing a temporary voucher that is available from a number of retail outlets. Currently cashless tollways are in use in New South Wales and Victoria and are now being introduced into Queensland.

The benefits of this form of cashless tolls are that vehicles don't have to stop or even slow to pay the toll, tolls can be easily calculated based on the entry and exit points of the toll road, there is a reduction in congestion and also labour (no toll collectors and the attendant occupational health and safety issues) as well as a substantial saving in fuel costs and vehicle emissions. The system can also be adapted to monitor vehicle travel times and hence enable speeding motorists to be identified. In Australia this is a particular issue with heavy vehicles although this method of enforcement is not yet used.

In some cases where manual toll booths have been replaced with cashless tolls e.g. Sydney Harbour Bridge, vehicles still have to slow through the tolling point.

All Chinese expressways inspected are toll roads, as are many 1st and 2nd class regional roads. Most tolling is manual with a boom gate controlled by the operator. Cashless tolls are now starting to be introduced but it is still necessary for a vehicle to slow to around 20km/hr when passing through the toll plaza. The electronic tolling lane (termed “ETC”) still has a boom gate but it is automatically raised once the vehicle transponder is recognised.

b. Gradeability / Climbing Lanes

There is a trade-off between construction costs in hilly terrain and fuel consumption. Many of the roads along the east coast of Australia traverse hilly or even mountainous terrain and where possible grades are eased to reduce fuel consumption and travel times, particularly for heavy vehicles. Where this isn’t possible “climbing” lanes are often installed (generally on uphill grades but also on some steep downhill sections) to allow light vehicles or empty heavy vehicles to safely pass slower vehicles and hence maintain their momentum, thereby minimising fuel consumption and GHG emissions. This is a cost-effective solution where funding limitations won’t allow construction of continuous multi-lane carriageways. In fact climbing lanes were first introduced as a means of assisting traffic flow. Sustainability wasn’t a major consideration at that time but is one of the outcomes of this practice.

Climbing lanes are almost unknown in China. However, rural freeways are all built to a common 4-lane dual-carriageway standard.

Pavement Construction

The key to sustainable pavement construction is in using recovered or recycled materials wherever possible. This applies equally to both rigid and flexible pavements. In many parts of Australia where very long haul distances can be involved, some adaptation is required to use local materials and many innovative solutions have been developed. The most common is to stabilise the in-situ material with hydrated lime.

Recycled materials generally used in pavements include:

- Truck tyres
- Reuse of pavement material by stabilising with cement, lime or bitumen
- Recycled asphalt pavement (RAP)
- Crumbed recycled rubber and rubber aggregates used in bitumen binders
- Steel making (blast furnace) slag
- Crushed glass
- Concrete aggregate (crushed and re-used either as concrete aggregate or as a bedding or drainage layer)

The use of some of these products such as stabilised pavement, crumbed rubber, RAP and recycled concrete aggregate is well known and not described further in this paper.

The balance of this paper focuses on some of the more innovative practises used in Australia.

a. Slag Road Base

Slag road base is extensively utilised as road base, sub-base or select fill in areas in reasonable proximity to Australia’s steel making plants, which are mainly on the east coast. It is also used as aggregate in both asphalt and Portland cement concrete (PCC).

There is a range of specifications that have been developed for these products.

The main advantages in road construction are:

- Utilises a waste material
- Lighter weight than dense rock with a maximum dry density typically in the range 1.8 – 2.1 tonnes/m^3 (hence lower transport costs as lower tonnage required per cubic metre)
- It has inherent cementitious properties
- Interlocking particle shape

- Ease of compaction
- Long term strength gain

No evidence of this material use was seen in China, although the areas investigated were remote from steel making plants. Discussion with Chinese engineers did not indicate that the practice is used elsewhere.

b. Glass

Use of recycled crushed glass (RCG) in pavements is in its infancy in Australia and is currently the subject of much research. Although glass cullet is easily recycled, glass fines have typically been a difficult material to re-use and there are large stockpiles of this material in Australia. Much of it is landfilled.

Specifications for state road authorities are being developed and trial pavements are now being laid. To date these have been mostly in car parks and urban streets where crushed and graded glass fines (>5mm particle size) have been used as a replacement material for fine aggregate in the asphalt.

To ensure all engineering requirements are met it is recommended that the content of RCG in fine aggregates not exceed 20%. In addition, an adverse result of using glass cullet in PCC is the alkali-silica reaction. In addition, when mixed in PCC, sugar contamination in the glass cullet can cause an unpredictable increase in setting time and a decrease in the ultimate strength. This implies that RCG should only be used in PCC in applications where unpredictable final strength will not endanger the public i.e. it is unsuitable for structures but quite acceptable for road paving material.

RCG is also quite acceptable as bedding material for pavers and drainage.

No evidence of this material use was seen in China.

c. Tyre Reinforced Pavement

An innovative but relatively unknown pavement design known as E-Pave has been developed and patented in Australia that utilises used truck tyres and crushed rock. This system was originally designed for heavy-haul mine roads but is now used in road construction in areas where there are sub-grades with low bearing capacity or very high water tables. This system would also be suitable for pavements subjected to freeze thaw action and heaving. It is also used for hard stand areas and foundations under raft slabs. An adaptation of the system is used to construct retaining walls, either as mass gravity or reinforced walls.

The system can be licensed for use by construction contractors.

E-Pave projects are constructed using a unique adaptable container – The Ecoflex Unit. Derived from quality controlled recycled tyres, the Ecoflex Unit utilises the pre-existing high tensile strength of steel wire in the tyre to form an incredibly strong containment unit. Once filled with appropriate material, this container becomes a round porous unit capable of supporting heavy wheel surcharge loads. The containers are then laid in a bee-hive like matrix to form a very strong pavement. Creation of these “containers” requires that one of the tyre side walls is removed.

When combined in various cellular arrangements the Ecoflex units perform as a durable, flexible road. For heavy loads two or more layers of the units will be used. In smaller applications or for retaining walls car tyres can be used in lieu of truck tyres.

A particularly useful application of this technology is as a bridging layer across very poor CBR or water charged ground. The design allows water to pass through the pavement without any loss of strength or structural integrity. A layer of geotechnical fabric below the units ensures that fines aren’t transmitted from one zone to the other.

The system has the following advantages:

- Speed and ease of construction;
- Excellent load distribution and high tensile strength;
- Excellent drainage characteristics for better performance in saturated conditions;
- Durability and longevity well in excess of the most stringent design requirements; and

- Easy to deconstruct, remove & reuse for temporary access roads and construction pads.

The system is readily capable of withstanding axle loads in excess of 40 tonnes.

A recent use of this system in Australia has been for the construction of pile driver and crane pads for the construction of 4 bridges over a flood plain in northern Queensland. The crane pads were subjected to seasonal flooding and the design allowed them to be unaffected by the flooding and quickly returned to service once the floodwaters had receded.

In this case the Eco-flex units were purchased from another job and so the recycled material was again recycled.

The system was chosen because of its speed of construction, lower initial cost, minimal disturbance of the site environment and its ability to be reused. In this case the design also allowed for construction in a saline environment.

This combination of recycled tyres and granular material has proven to be a versatile and cost effective means of construction, particularly for foundations. It is also versatile in retaining walls where it lends itself to varied finishes ranging from the exposed tyres to bolt-on facings, sprayed concrete or masonry.

Although a relatively new development that was initially developed for the mining industry, this construction technique is readily gaining acceptance, particularly where poor sub-grade conditions provide a challenging construction environment that requires a detailed engineered solution.

The system (E-Wall) was also used for the construction of a retaining wall for the Lane Cove Tunnel project in Sydney.

There is no evidence of this application in China and in fact Chinese engineers expressed great interest in this approach. Seasonally frozen soils are a particular problem in the north of China and the use of E-Pave is seen as a potential solution to this problem, particularly over permeable soils of low bearing capacity.

Conclusion

There are many initiatives being pursued in Australia with respect to sustainability in highway design and construction. Some of these have been in use for many years and are taken for granted as part of everyday engineering. Others, such as the use of RGC as a fine aggregate substitute and Eco-flex are relatively new to Australian practice and are still undergoing development.

Each of these initiatives goes some way to reducing the environmental impact of the Australian road network and preserving our planet for future generations.

It has been interesting to learn that some of these initiatives are also not in widespread use internationally and so Australia potentially has much that it can pass on to developing nations.

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References

"IRF Policy Statement – Environment"
International Road Federation – 2010

Author Biography

As well as managing his own consultancy, Phil Hawley is a director of PEECE Consulting, a company providing specialist consulting services mostly to local government in the fields of transportation planning, transport economics and asset management.

Phil's consulting experience includes project management, management consulting and he specialises in the management of solid waste.

Phil has graduate qualifications in Civil Engineering and post graduate qualifications in Local Government Engineering and in Business Administration. He is a Fellow of both Engineers Australian and the IPWEA.

PO Box 3009 Nowra North NSW 2541

Email: phawley@peece.com.au

Web: www.peece.com.au

Phone 02 4446 0310 or Mobile 04 1946 0310

Fax 02 4446 0511