Sustainability Principles as the Backbone for Road Design, Construction and Maintenance and the Advantages of Concrete Pavements

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1 ABSTRACT

This paper evaluates the intended meanings of sustainability and the requirements from the point of a view of pavement construction and of a Civil Engineer. It gives a brief overview of the quite ambiguous topic of "sustainability" and then suggests a common sense approach for the achievement of sustainability as it would apply to roadworks.

It is demonstrated that to achieve sustainability in road construction, it has to be a joint effort between the clients, consultants and contractors, ie industry. Such joint effort will be required to satisfy the common sense principles that need to be applied.

As an adjunct, the paper also illustrates that many of the sustainability outcomes are already built into the rigid pavement characteristics and lists some of the exciting options for conservation of resources that are already or will be available in the near future.

2 BACKGROUND

There are over 10 widely varying definitions for sustainability. This immediately creates problems with the interpretation, goals and ways to achieve them.

For these reasons sustainability is perceived at one extreme as nothing more than a feel good buzzword with ambiguous meaning or substance, but on the other as an important, but an unfocused concept like "liberty" or "justice". It has also been described as a **dialogue of values that defy consensual definition**.

The Brundtland Commission (1987) defined sustainable development as : "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs". This can be interpreted to mean to live off the interest and leave the capital untouched. Such a simplistic approach would not provide a practical outcome in the real World.

The question remains – what is to be sustained? Sustainability is a shifting concept that is frequently used in an arbitrary manner. Often it is also used as a synonym for "lasting". This fits well in the expression that beauty is not in the eyes of the beholder, it is in the eyes of the senior beholder.

There has been an extraordinary growth of sustainability literature in the past decade or so, which in itself may be creating an unsustainable process. Much of the discussion of the topic remains mired in terminological and conceptual ambiguities as well as in disagreements about facts and practical implications. Practitioners in different fields see different parts of the picture and use also different timescales.

Sustainability has become a catchword starting with environmentalists and activists. As there is no consensus for its definition, it has created a myriad of peripheral consultancies providing advice from global warming to risk management of the so called non-sustainable activities. One cannot help but think of the expert advices that predicted catastrophes with the arrival of Y2K.

May be we should just talk about the "carrying capacity (ie sustainability) of the planet earth, ie the destruction of biophysical resources like energy, water, food and materials? How to minimise or replace them?

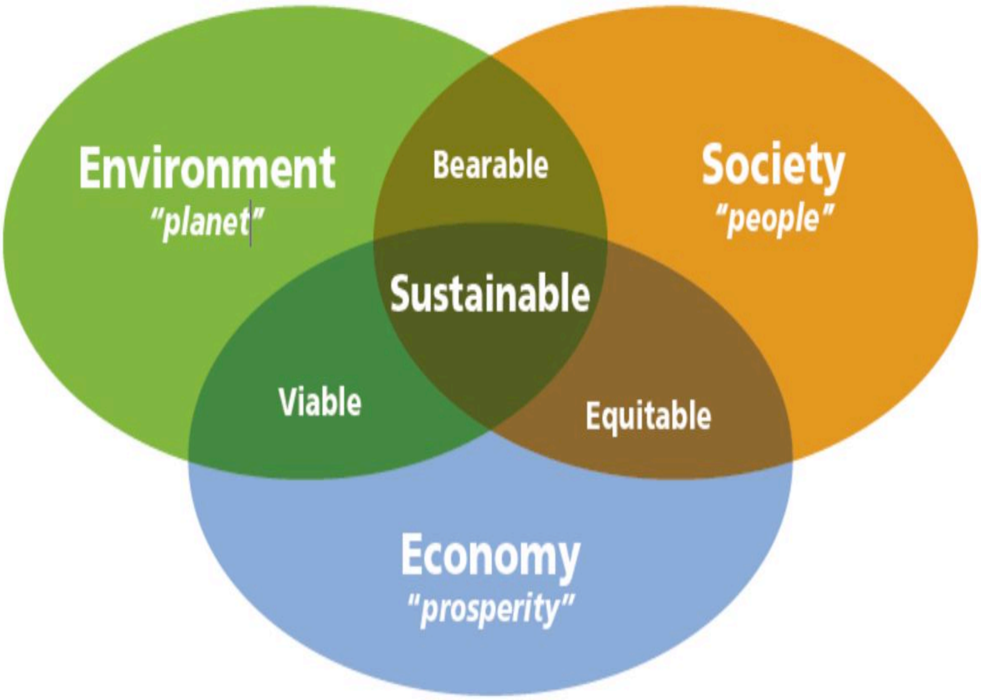
In human context, sustainability is the potential for long term maintenance of well being which (we say) has environmental, social and economic dimensions. Our problem is that we have no means of objectively quantifying these nor would there ever be a consensus on weightings. Some argue that reduction in the negative human input to sustainability can be achieved through environmental management and management of human consumption of resources. These are, of course, realistic conclusions, but we still need the quantification as to what is the accepted level of "reduction".

There are a number of theories how to represent sustainability collectively and graphically. **One of the accepted theories is that there are three pillars upholding sustainability. The three pillar theory is made up by environmental, social and economic considerations and represented by three overlapping circles, resulting in what is called the Venn Diagram.** Where the three overlap, it creates the classic sustainability condition which theoretically balances the conflicting requirements as illustrated below:

There are, however, a number of flaws in this:

- It assumes that the weighting of the three pillars is always equal, regardless where or by whom the assessment is made. This instantly allows various groups to emphasise the importance of their “pillar” and automatically constrain the others;
- It can also be argued that it is possible to have a society without economy, but economies cannot exist without societies and
- Similarly, it is possible to have a built environment without a society, but societies do not exist without built or natural environments.
-

A better presentation could be:



3 SUSTAINABILITY IN ROAD CONSTRUCTION

If one accepts that every economic activity produces material that may be classified as waste, then the following hierarchy can be developed to reduce waste:

- **Prevention**
- **Minimisation**
- **Re-use**
- **Recycling**
- **Energy recovery, and**
- **Disposal as the last resort**

For roadwork situations, it now becomes reasonably straightforward to apply these principles.

The following commentary relates to road construction and also to the inbuilt advantages of concrete pavements. It draws attention to the need for dedication and co-operation by the industry and the road authorities (as the clients) for both to champion sustainability principles and be prepared to accept innovation and change. It is not an one way street.

Significant changes to the better and opportunities can occur through innovations, use of new technologies and clever use of materials. For this to happen, there has to be a mutual desire by the industry and the authorities. Unfortunately the current modus operandi does not provide for this and actually inhibits innovation. This is because of the extraordinarily detailed and strict Specifications which have grown to some 90% method specifications and at best 10% end product.

Sustainable design, construction, rehabilitation, preservation and repair is simply good engineering utilising limited resources to achieve design objectives. It is not necessarily about perfection, but about balancing competing and often contradictory interests. It must consider life-cycle, economic, environmental and social factors. For best results there must be flexibility without the regimentation to the nth degree.

4 COMMON SENSE PRINCIPLES OF SUSTAINABILITY

- Be smart and awake
- Design to serve the community
- Choose what you use
- Less is more
- Minimise impact
- Take care of what you have
- Innovate

4.1 Be Smart and Awake

- Design for what you need
    - ➢ No more and no less
    - ➢ Don't sacrifice engineering quality
    - ➢ Look for alternatives
    - ➢ Compare Life Cycle Costs
    - ➢ Look for possible innovations, eg diamond grinding vs OGA
    - ➢ Give the client costed options
- Ensure that relevant design criteria are met
    - ➢ Use a holistic approach to design
    - ➢ Remove unwarranted frills
    - ➢ Think of innovations
    - ➢ Use Value Analysis where applicable

4.2 Design to Serve the Community

- Create and manage Focus Groups;
- Listen to the communities being affected;
- Design to address the specific needs of the community
    - ➢ Ride quality
    - ➢ Noise

- Delays
- Access
- Explain reasons and costs

4.3 Choose What You Use

- Recycle – zero waste (concrete is 100% recyclable, steel, etc.)
- On-site recycling reduces time, energy, pollution, and makes money
- Cement and concrete industries consume the majority of coal combustion bi-products. Evaluate new alternative cements, eg HVFA
- Local first – minimize transportation
- Select the materials to use – don't let the materials select themselves
  - Understand what is available
  - Import only what you need
  - Be adaptable

4.4 Less is More

- All things equal, less material means less impact;
- Using less Portland cement can improve sustainability
  - Blended and performance specified cements
  - Supplementary cementitious materials (fly ash, slag, etc.)
  - Aggregate grading
  - Optimized mix design

4.5 Minimise Impact

- Noise – Construction and traffic
- Safety
  - Splash and spray
  - Lighting
  - Maintenance episodes
- Delays – During construction and rehabilitation
- Emissions
  - Green house gases
  - Pollution
  - Particulates
- Energy efficiency
  - Construction
  - Operation
- Urban heat island effect;
- Portland cement is responsible for approximately 90% of the CO_2 and 85% of the embodied energy in concrete.

Phases of a Pavement's Life

- Design (cut & fill, design life, drainage, construction method, thickness, LCC, material selection, capacity);
- Construction (Virgin materials, dust, noise pollution, energy, CO_2, delay time, LCC);
- Operation (Maintenance, longevity, capacity, noise pollution, water runoff, heat island, safety, skid resistance, ride quality);

- Rehabilitation, Recycling & Removal (Removal = waste disposal); Repair / Rebuild = similar issues to construction; Recycling materials into other construction material);
- Remove only as the last resort.

4.6 Take Care of What you Have

- Use the equity already in the existing subgrades & pavement;
- Well timed maintenance and rehabilitation is essential;
- Design to maintain (e.g. additional thickness to accommodate future diamond grinding).

4.7 Innovate

- Identify problems/opportunities, generate solutions, implement, and reiterate;
- Learn from mistakes;
- Good specifications;
- Question old standards;
- Evaluate emerging technologies and adopt those with demonstrated promise;
- Educate and challenge yourself and your workforce;
- Conduct research to fill the gaps in knowledge.

5 BUILT-IN ADVANTAGES OF CONCRETE PAVEMENTS

It can be argued that the provision of concrete pavements in itself already adds to the sustainability of resources. For example:

Longevity may be regarded as a crucial element of sustainability:

- It results in lower consumption of raw materials, cement, aggregate, steel etc;It results in lower energy consumption for raw material processing resulting from the infrequent rehabilitation and reconstruction requirements, which in turn;
- Results in reduction of pollutants from manufacturing, construction, maintenance and also the frequency of delays or congestion.

Safety and saving of lives:

- Rigid structure, profile durability, infrequent construction zones and infrequent maintenance requirements.

Built in sustainability:

- All the above translate to real economic, social and environmental benefits.

Fuel economy over flexible pavements:

- An in-depth study by NRC Canada demonstrated that there can be fuel savings of 0.8 to 6.9%;
- Over 100,000 km this equates to 5.1 t/truck. If there are 3000 truck movements/day over the design life of 40 years, this amounts to 223,000,000 tons of CO_2 over that time;
- In June 2008 a study by the Swedish VTI demonstrated that a concrete surface had 1.1% lower fuel consumption than an asphalt one. Assuming that there are 10,000,000 vehicles in Australia, averaging 15,000 km/annum, using 10 l/100

km @ \$1.29/l and all travelled on concrete roads, then the saving amounts to \$200,000,000 pa;
- Construction of a Deep Strength Asphalt pavement uses 5.5 times more diesel than the equivalent concrete pavement (FHWA TA T 5080.3);
- OGA overlays have to be replaced every 10 years at ~\$20/m^2 compared to diamond grinding of the concrete at \$12/m^2 every 17 years.

The light colour of concrete:
- mitigates the heat island effect by ~5º-8°C resulting in less energy use; for cooling and consequent pollution;
- lowers city temperatures;
- reduces smog formation;
- provides enhanced night visibility;
- reduces street lighting requirements (up to ⅓ energy savings).

Use of waste products:
- Concrete provides for maximum use of industrial waste products.

The attached schedule lists nearly 60 economic, environmental and social benefits from the use of concrete pavements

6 CURRENT INNOVATIONS

The following are some of the significant innovations being considered:
- **Energetically Modified Cements** (EMC) – mechanical processing of pozzolans using a special milling system. It results in only small volumes of Portland cement being used in concrete, eg 10%;
- **Self Healing Concrete** – use of embedded microencapsulated sodium silicate as healing agent in the concrete mix;
- Use of **Stone Mastic Asphalt** instead of Open Graded Asphalt;
- Non-destructive **Maturity Testing** of strength of concrete;
- **New Generation Concrete Surfacing** (NGCS) – longitudinally double diamond ground surface for low noise emission;
- **Internal Curing** of Concrete pavements by incorporating saturated light weight concrete particles;
- **High Volume Fly Ash** cements (HVFA), eg a 50/50 mix.

SUSTAINABILITY ASPECTS OF CONCRETE PAVEMENTS

Ser	Attribute	Eco-nomic Aspect	Enviro-mental Aspect	Social Aspect
1	**Longevity:**	x	x	x
2	Results in lower consumption of raw materials, cement, aggregate,			
	steel etc	x	x	
3	Results in lower energy consumption for raw material processing from			
	the infrequent rehabilitation and reconstruction, requirements,			
	which in turn:	x	x	
4	Results in reduction of pollutants from manufacturing, construction,			
	maintenance and also the frequency of delays or congestion		x	x
5	**Life Cycle Costs**			
6	Low Life cycle Costs	x	x	
7	Concrete pavements have the lowest ownership costs over 40 years	x		
8	Traffic energy cost savings	x	x	
9	A 2002 RTA NSW study of costs of maintenance over a 20 year period			
	found that flexible pavements had cost \$55-\$75/m2, compared with the			
	quality concrete pavements at \$3/m2 and the worst quality at \$30/m2	x	x	
10	Maintenance costs of concrete pavements have a better price stability			
	because mostly local materials are used.	x		
11	**Reduction of traffic delays:**			x
12	Result in long term savings in raw materials, transport costs and energy			
	use	x	x	
13	Reduction pf delays due to maintenance works cuts fuel consumption			
	and hence exhaust gas emissions		x	x
14	Concrete will stand up to the worst seasonal conditions, including the			
	freeze/thaw cycles in cold climates	x	x	
15	Concrete does not contain any hazardous leaching products		x	
16	Concrete does not emit any noxious gases under heat		x	
	The light colour of concrete			
17	Has superior reflectivity		x	
18	Light reflection (ie energy) is measured by the "albedo" ratio or			
	percentage from given surfaces. The higher the percentage, the more			
	energy is reflected, eg fresh snow - 85%, exposed earth - 35%,			
	concrete 15-25%, asphalt 5-10%.The higher the reflection, the lower			
	"global warming"		x	
19	Mitigates the "heat island" effect in cities by at least 5ºC, resulting in			
	less energy use for cooling and consequent pollution		x	x
20	Lowers city temperatures			x
21	Reduces smog formation		x	x
22	Provides enhanced night visibility			x
23	Reduces street lighting requirements with up to about ⅓ energy savings.	x	x	

24	A Canadian study demonstrated that if 14 light standards are required on			
	1 km of concrete road, then for equivalent lighting , 20 are required for			
	an asphalt road	x	x	
25	Concrete provides for maximum use of industrial waste products, eg			
	flyash, slag etc		x	
	Safety and saving of lives:			
26	Rigid structure profile, durability, infrequent construction zones and			
	infrequent maintenance requirements			x
27	Fewer roadwork - less disruption. Reduction in fuel consumption and			
	emission gases.		x	x
28	Long term superior ride comfort			x
29	Immune to rut formation - no trapped water	x		x
30	Fire safety in tunnels (noxious gases)		x	x
31	Excellent surface drainage - no ponding of water			x
	Fuel economy:			
32	An in-depth study by NRC Canada demonstrated that there can be fuel			
	savings of 0.8-6.9% on concrete roads over flexible pavements	x		x
33	As an example, if there are 3000 trucks travelling 100,000 km over the			
	40 years, this saving amounts to 223,000,000 of CO_2 over that time		x	
34	In June 2008 a study by the Swedish VTI demonstrated that concrete			
	surface had 1.1% lower fuel consumption than an asphalt one.		x	x
35	Assuming that there are 10M vehicles in Australia, averaging 15,000 km			
	per annum, using 10 l/100 km at $1.29/l and travelled on concrete			
	roads, then the saving amounts to $200,000,000 pa.	x	x	
36	Construction of Deep Strength Asphalt pavement uses 5.5 times more			
	diesel than the equivalent concrete pavement (FHWA TA T5080.3)	x	x	
37	A study by TRL in Great Britain showed that the reduced deflection of			
	concrete pavements resulted in a reduction of 5.7% in rolling resistance			
	Which corresponds to 1.14% saving in fuel	x	x	
38	OGA Overlays have to be replaced every 8-10 years at ~$25/m2,			
	compared to achieving the same result with diamond grinding at			
	$12/m2 every 20 years	x	x	
39	Concrete pavements are 100% recyclable		x	
40	**All the above translate to real economic, social and environmental benefits which:**			
	equate to built-in superior sustainability in concrete pavements			