Is Road Recycling A Good Community Policy?

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Summary: There is a community expectation that local government needs to be environmentally friendly in all areas. This paper examines the evidence to present a case that road recycling is cost effective, environmentally sound and moves towards meeting ecological sustainable development policies.

1 INTRODUCTION

Road recycling by insitu stabilisation has been practiced by many local government engineers since the 1960s as a cost effective method of reconstructing existing granular or asphalt pavements. The decision in the 1960s and 70s to recycle existing roads by insitu stabilisation was based on prime costs, rather than environmental issues and life-cycle costing.

Today, the decision to recycle roads encompass many environmental issues, such as:

- ❑ communities expectations that government has an obligation to be a leader,
- ❑ conservation of quarry products,
- ❑ speed of construction to reduce traffic delays,
- ❑ reduction in local road construction traffic,
- ❑ less construction tip sites and increasing tip fees, and
- ❑ fuel savings on trucks.

In addition, insitu stabilisation construction reduces local-road construction traffic and traffic noise, and the proliferation of dirt and dust on local roads.

Some skeptics may view that the construction of recycled roads produces low-quality roads, and local government engineers are creating a future liability. This paper will also demonstrate the performance of recycled road pavements in a local government context.

Finally, the paper will suggest future policy directions for road recycling by insitu stabilisation of the local road network.

2 HISTORY

Innovation in the road industry has been steady for the last 100 years in Australia. However, the greatest changes in the last five years has been in the use of recycled products and recycling existing products in the construction and rehabilitation of local government roads. There are basically six types of pavements:

1 Shape correction and compacting the existing material.
2 Importing granular material, compacting and shape, and sealing the surface
3-5 (1) or (2) and lay an asphalt or concrete pavement, or concrete segmental paving.
6 Recycle the exiting materials with the addition of a binder to strengthen the pavement and seal the surface.

Historical evidence shows that concrete pavements have the longest life (i.e. generally 60 years) for local government roads and research is now showing evidence that insitu stabilisation roads are performing for up to 30 years.

Stabilisation commenced as a labour intensive and slow process due to the limitations of mechanical equipment. Recent years have seen the first major change in stabilisation equipment in 30 years with the introduction of the CMI RS500, now followed by a number of machines of a similar style from other manufacturers. Together with the development of accurate binder spreading equipment, it has led to the extension of stabilisation from the Local Government low-traffic roads through to major roads and highway construction with the introduction of deep-lift (i.e.

depths to 400 mm of stabilisation in a single layer Ref.1).

Today, Australia is recognised as a world leader in stabilisation theory and application. Australian technology is being used in Europe and Asia to develop the use of stabilisation in those areas; in particular, our spreaders are the most accurate and advanced in the world. Australian experience has also assisted in the development of new equipment coming out of America.

Many local government engineers have practiced insitu stabilisation and various reports and papers have documented failures and successes. Fairfield City Council in NSW have carried out stabilisation of road pavements since the early 1970s. A great deal of the early work was shoulder stabilisation for wide residential streets with only the main section of the road sealed. This work was carried out in conjunction with curb and gutter construction in order to provide a full-width sealed roadway. This treatment allowed better drainage of the pavement and reduced the deterioration of the edge of the pavement leading to pot holes. In addition, it reduced dust and mud onto residential properties.

Nowadays, most insitu stabilisation is carried out on the full-width of the pavement. For this construction process cross blending areas of good material with the poorer material (i.e. in shoulders) is common. In some cases overlaying the existing pavement with granular material prior to stabilisation assists in improving the pavement strength. The imported material would generally be recycled material from a central recycling depot. In addition, in many cases up to 50 mm of subgrade may be incorporated in the stabilised pavement material.

3 MATERIALS

3.1 General

History will show that recycling was a transition zone from "something that had to be taught" to "part of the everyday living process". This section of the paper identifies the competing nature of raw materials and by-products from various manufacturing processes. It also highlights that building products from demolition sites are being successfully recycled.

3.2 Quarry Material

Typically, pavement engineers of the 1980s would specify a compacted crushed rock subbase for local government streets. The crushed rock would be quarried and delivered to site in a truck. In some instances, the Council would stockpile this material well before its use in the pavement. However, limited funding for road maintenance, limited stockpile space in urban regions, and the rising costs of aggregates is creating a “re-think” on how local government engineers face these limitations along with increasing local traffic, rate payers insisting on value-for-money out of pavements and acknowledging the consequences on the environmental from using natural resources.

At the 20th World Road Congress held in Montreal Canada in August 1995, the increasing use of aggregates in infrastructure was highlighted. For instance, in France from 1950 to 1981 the annual consumption of aggregates was multiplied by 7 with 350 million tonnes in 1985 (Ref.2). The production slowed down during the recession in the late 1980s and production increased to 390 million tonnes in 1991. Whilst France undertakes research to have a method to reduce the environmental affects of quarries, the Netherlands is keen to highlight that insitu stabilisation is a satisfactory solution to environmental responsibility (Ref.3).

3.3 Traditional Binders

Lime and cement have been the fundamental binders for insitu stabilisation in local government road construction for at least 30 years. The use of lime and cement for road stabilisation represents about 5% and 3% of the annual Australian production respectively. These materials have been applied in numerous environmentally sensitive areas and no consequential damage has occurred.

In most road recycling projects about 50% of the cost of the construction is attributed to the cost of the binder material (excluding sealing or wearing course). This led to the gradual lowering of the cost of Type GP and GB cement binders, and the development of product specific binders, such as Stabilment. Therefore, many local government engineers have several binders to choose to meet stiffness and working time requirements, and still maintain relative levels of pavement performance. The cement industry is responsive to the needs of the pavement engineers and continue to carry out research in this area on a regular basis.

3.4 Use of By-Products

For some time people had considered fly ash and slag as waste materials. In the 1960s it would be true to say that these materials were dumped in large landfill sites whereas today the material is known as either manufacturing by-products or supplementary cementitious materials. These materials are generally processed and are classified in Australian Standards AS3582.1 and AS3582.2 (Refs.4 & 5).

Fly ash is the fine ash that is produced when black coal is burnt in a pulverised fuel furnace. Bottom ash is also produced during the burning process but generally represents about 10% of burnt ash. About 9 million tonnes of power station ash is produced annually (Ref.6).

Fly ash from brown coal has yet to be used as a binder for a stabilised pavement.

Slag is a by-product of steel manufacturing and some 2.6 million tonnes per annum of blast-furnace and steel slag is produced (Ref.7). Typically, blast-furnace slag is ground and used with other cementitious binders for road stabilisation.

Crushed concrete from building sites has gain acceptance by many Councils in Australia for road-base material. The difficulty in using recycled concrete is the variability of the product. In 1992 VicRoads developed a standard specification for cement treated crushed concrete and have successfully used the specification on the Western Ring Road Project, Melbourne (Ref.8)

Crushed concrete from demolition sites now finds its way into local and state government roads. Engineers and contractors are now satisfied with the consistency and performance of treated crushed concrete.

4 WASTE DISPOSAL

The practice of reclaiming a swamp or filling in a bushland gully with subbase material is considered as environmentally insensitive by many people in the community. This attitude has forced builders and others to use tip sites to dump waste material. In inner urban areas the long haul distances to these diminishing sites has increased cartage costs. In addition, the cost to tip subgrade material and existing asphalt from roads at these sites as waste is steadily increasing (Table 1). Not all tipping sites cater for recycled material and the costs fluctuate around the country.

Table 1 The average cost of tipping in the Sydney region from 1993 to 1997. The tipping cost is charged according to its classification as a waste material or one that may be reused (Ref.9).

Year	Cost for 5 tonne truck	
	Waste	Recy-cling
June, 1993	$266	$160
June, 1995	$286	$173
June, 1996	$385	$130
Current	$424	$75

Waste Services NSW has been under government pressure to remove the "free" 2 tonne limit and increase fees in order for the construction industry to utilise demolition or excavated material for some other purpose. Also, Waste Services have reduced tipping costs when material received at the tip site is identified as reusable, thus encouraging the construction industry to sort demolition materials prior to tipping.

As long as waste material is neutral to the environment, waste is now becoming a "clever" rather than a "dirty" word. In some instances, treated effluent is being used as a dust suppressant on road projects (Ref.10).

The main principles being identified in the use of waste materials is the ability to categorise the content and produce uniformity of the product by minimise variability. This level of intervention is necessary to ensure that performance of the final product can be predicted with some level of reliability.

5 COST OF RECYCLING

5.1 General

The government is keen to find out the price of looking after our environment. Bedder (Ref.11) notes that economists have started to evaluate or put a price on the environment by asking people what they would be prepared to pay for its preservation.

The progressive shift to long-term management of Local Government infrastructure assets has provided pavement engineers with a better understanding to allocate resources for the construction and maintenance of municipal roads. Most of the asset management is in terms of physical infrastructure costs and this leads to the following short comings when considering recycling.

The cost of recycling can be assessed by the following methods:

- The cost of bringing and removing materials in terms of fuel, equipment and labour charges, disruption costs to the community, and damage to local roads due to heavier axle loads.
- The reduction of tipping space that could be used for other purposes.
- Determining the difference between tipping costs for materials considered as waste or reusable.
- Conservation of quarry supplies.

These charges occur over time and the evaluation of alternatives should be assessed by using a net present worth model to allow future costs to be fairly weighted against low-initial cost solutions.

5.2 Life-cycle costs

Most engineers consider that life-cycle costing of road pavement options has been developed for major road projects in the 1990s. However, an article in Highways in 1928 (Ref.12) demonstrates that the discussion of cost comparisons for municipal roads was well understood. Major R B Hinder carried out a simple life-cycle cost analysis using the following pavement options (a) cement concrete penetration method, (b) cement concrete pre-mixed method, (d) bituminous penetration macadam, (e) premixed bituminous macadam, and (f) bituminous concrete. In 1928 the cement concrete penetration pavement option had the lowest life-cycle cost.

The basic elements in any life-cycle analysis for the pavement are:

- Initial costs
- Pavement life
- Maintenance costs and when
- Salvage value of pavement

Life-cycle analysis can be used at local government level to assess insitu stabilisation versus other pavement types to select a pavement with the lowest net present worth. In appendix A, two pavement options are evaluated using a life-cycle analysis for a project size of 3,000 m^2. The “do nothing” option limits the use of resources to improve the pavement performance, and one could conclude that this has the lowest impact on the environment.

Based on the net present worth analysis the insitu stabilisation alternative is the lowest cost option. The ‘Do Nothing’ option (i.e. essentially patching to ensure road safety) could be more viable over a shorter period, but a worthy consideration is that this option causes more inconvenience (disruption costs) to local residents, as well as having a very poor rideability.

Traditionally the life-cycle analysis has been used on measurable costs applicable to construction activity. Costs, such as fuel usage, less fumes and congestion, disruption to the community and traffic noise, are hard to quantify and are generally ignored due to the lack of reliable data. Research centres in Australia and overseas are now attempting to assess the intangible or environmental costs. In the next decade it is hoped there is sufficient data collected to allow planners and engineers to cost the recycling component in terms of tangible and intangible values.

6 PERFORMANCE OF RECYCLED ROADS

Many research projects have been undertaken over the last ten years at modeling the estimated performance of stabilised pavements using the accelerated loading facility (ALF) from ARRB Transport Research. However, little real work has been done to evaluate the performance of existing roads and where appropriate estimate the remaining life.

Work carried out by Hodgkinson (Ref.13) found that:

"Based on a wide range of experience up to 1975, there is a very high probability of pavements which have been recycled by cement stabilisation surviving for periods well in excess of 15 years without further significant pavement maintenance. This represents a long-term performance better than 75% of typical expectations of new or fully reconstructed flexible pavements."

Visual evidence of the roads carried in Hodgkinson’s research paper appear to be performing satisfactorily five years on.

It is the experience of the authors and other local government engineers, such as Errol Jones (Ref.14), that the insitu stabilisation construction process is meeting the design life of the pavement. Research is currently underway to quantify the performance of some of these pavements to assess ways in identifying the variables that cause poor performance.

7 POLICIES

7.1 Cradle-to-the-Grave

Many European manufacturers have been working for several years at selecting specific components in manufactured goods that meet functional requirements and can be recycled at a later date. Many commentators usually use the expression "cradle-to-the-grave" to compare the process to human life where a product follows a defined path from birth to death. The design process highlights the designers need to bring together a product which can be recycled after it has met its design life.

If one takes this approach to road construction it implies that the selection of materials that compose the final pavement will be used again when the pavement reaches its design life. More importantly, the selection of binder will be one that can be mechanically or chemically altered to allow its residual properties to assist in enhancing the formation of a newer pavement.

For example, many engineers have questioned whether less cement can be used in recycled crushed concrete compared to crushed stone for subbase due to the existing level of cement in the recycled concrete. Research continues on this issue and performance data on existing pavements may identify an answer.

7.2 Balance Approach

The human factor is an important component when developing a road safety policy. Could the analogy be applicable for road recycling?

For instance, the attitudes of drivers, their experience, the state in which they drive and the type of trip are factors which must be taken into account for overall road safety. Policy makers can attempt to modify behaviors of road users by developing regulations and policies or programs aimed at proving safety or preventing road accidents.

In essence, policy makers can approach road safety by "convincing" or "constraining" the road user. Convincing means to increase education and promote road safety by relying on the cooperation and good intentions of road users. Constraining involves compulsion and can be achieved by means of laws, standards and policing (Ref.15).

The NSW Government took on a “constraining” role in 1995 with the introduction of the Waste Minimisation and Management Act 1995. This Act was produced to send a clear message that substantial change in how waste is perceived

Table 2 Waste quantities sent for disposal in NSW for 1990, 1995 and proposed for 2000 (Ref.16).

	1990		1995		2000
	(mt)	(t/person)	(mt)	(t/person)	(mt)
Council/ Community	1.53	0.46	1.38	0.40	1.71
Commercial/ Industrial	1.28	0.38	1.12	0.33	1.43
Building/ Demolition	0.61	0.18	0.46	0.13	0.68
Total	3.42	1.02	2.96	0.86	3.82

and managed. The Act sets out to achieve by the end of 2000 a 60% reduction in waste disposal in NSW with 1990 as the reference year. Table 2 shows the past and future target for waste reduction in NSW.

Road recycling is currently taking on a transition phase from "constraining" to "convincing" as local government engineers become more confident of the outcomes of their research efforts and experiences. Unfortunately, much of this work is not being adequately documented to avoid younger engineers from reinventing the wheel.

Documented solutions must be produced which attempts to demonstrate when an optimal balance can be achieved with due consideration to:

- Economic needs to the regional community
- The personal safety of road users
- Technical requirements
- Environmental demands
- Demands of sustainable development

Creating policies that enforces one to consider using a waste product is also dangerous as one may transfer one waste to another site with no benefit to the community. Roads are essential to the community for communication and movement of goods, and whilst some issues on noise and air pollution are very sensitive, the wider implications for a “do nothing” case is that road congestion and frustration is unhealthy for road users. Policy initiatives should always be a compromise between what the community needs and can afford.

7.3 Closed-Cycle Economy

A closed-cycle economy (Ref.17) is one where virtually all materials are recycled. The use of insitu stabilisation with the addition of a manufactured binder or in combination with a by-product is aimed at closing the cycle. The binder content is generally in the order of 3 to 5% by weight of the soil and this represents a small input to the cycle.

Research in the last 5 years has been based on finding the optimum binder type (i.e. manufactured material) and to reduce the binder input whilst maximising the pavement performance. It may be argued that importing even low-levels of materials is unsatisfactory to meet the closed-cycle, it nevertheless forms a step in the right direction. Alternatively, a Council policy towards closed-cycle solutions, such as to add any binder type from any waste source, may be potentially dangerous and may leave the community with only a cosmetic solution. The binder and process must be verifiable from common engineering research principles.

8 CONCLUSIONS

Road recycling by insitu stabilisation is now a mature industry in Australia. This construction process was initiated at local government level by innovated engineers and contractors with an aim of providing value-for-money solutions to overcome increasing road maintenance expenditures. In the 1960s waste and recycling were not very common local government terms, whereas rates, roads and rubbish collection were frequently used. Yet the beginnings of road recycling were taking shape in terms of reducing the use of quarry materials, utilising the existing material and reducing tipping volume.

Research efforts to tackle both the use of pavement materials and their performance, and the wider implications to the community continue on very limited budgets. A small annual contribution from all local government road maintenance budgets would assist in continued research and usable outcomes to benefit the community.

What are the best policies? This paper has explored the difficulties in introducing and assessing recycling components into road construction. Whilst most governments have introduced legislation to enforce the reduction of waste and recycle materials, the life-cycle cost models are incomplete without data on the environmental costs.

Engineers should give every consideration to the incorporation of reused material for road construction. Preferably by treating in place and where additional material is required, to consider the use of recycled material from another site (i.e. concrete).

As engineers we are too often criticised for damaging the environment and yet engineers have been road recycling by insitu stabilisation for some twenty to thirty years. The process is sound and economical similar to other traditional methods of road reconstruction, and maybe engineers have not sufficiently sold the concept to the wider community.

9 REFEENCES

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Appendix A – Life Cycle Analysis Example

A sealed residential street with an area 3,000 m^2 in an urban environment has a deteriorating pavement which has become quite plastic and so easily develops potholes. Council has developed two options giving the pavement an additional 20 year life:

Option 1 “Do Nothing” but continuously maintain the pavement for 20 years.
Option 2 Insitu stabilise the 200mm of existing pavement material with 2% of cementitious material and reseal.

A life-cycle analysis of these options using the Net Present Worth model with a discount rate of 5% is listed below:

OPTION 1
Construction Cost Major patching to 200mm with granular material and a thin asphalt surface @ $60.00/m 2
Place 3% of the pavement and seal $60 x 0.03 x $2.50 = $4.50/m 2
Maintenance Major patch 3% of the pavement at years 3, 6, 9, 12, 15, 18 (i.e. $60 x 0.03 x (0.864 + 0.746 + 0.645 + 0.557 + 0.481 + 0.416) = $6.68/m 2)

Minor patching to 200mm with granular material and a thin asphalt surface @ \$90.00/m 2
Minor patch 1.25% of the pavement at years 1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19 (i.e. \$90 x 0.0125 x (0.952, 0.907, 0.823, 0.784, 0.711, 0.677, 0.614, 0.585, 0.530, 0.505, 0.458, 0.436, 0.396) = \$9.43/m 2
Resealing @ \$2.50/m 2
Reseal at years 9 and 15 (i.e. \$2.50 x (0.645 + 0.481) = \$2.82/m 2
Residual value Remaining life at end after patching in year 18 (i.e. 33%) \$60 x 0.03 x 0.416 x 0.33 = -\$0.25/m 2
Remaining life at end after resealing in year 15 (i.e. 44%) \$2.50 x 0.481 x 0.44 = -\$0.53/m 2

NPW cost of option 1 \$22.65/m^2 or \$68,000

OPTION 2
Construction Cost Insitu stabilisation to 200mm with seal \$18.00/m 2
Maintenance Patching stabilised pavement to 200mm with asphalt @ \$90.00/m 2
Patch 1.5% of the pavement at year 10 (i.e. \$90 x 0.015 x 0.614 = \$0.83/m 2)
Resealing @ \$2.50/m 2
Reseal at year 15 (i.e. \$2.50 x 0.481 = \$1.20/m 2)
Residual value Remaining life at end after resealing in year 15 (i.e. 50%) (i.e. \$2.50 x 0.481 x 0.5 = -\$0.60/m 2)

NPW cost of option 2 \$19.43/m^2 or \$58,000

The lowest option is 2 at \$19.43/m^2.

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