Recognition of sustainability by using stabilisation in road rehabilitation

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Abstract

Insitu stabilisation techniques have long been used by engineers in Australia and many places throughout the World for pavement (usually roads) construction and rehabilitation. These techniques have historically been chosen by the managers of pavements predominantly because of their significant cost advantages and although the social and environmental benefits have been recognised, they have not been key factors in the pavement managers' evaluation processes.

This paper aims to highlight the cost savings that the social and environmental benefits of using insitu stabilisation can provide to the community by detailing and quantifying in terms of dollars, the previously less tangible advantages of stabilisation techniques.

1 Introduction

Stabilisation is the improvement of a soil or pavement material usually, but not always, through the addition of a binder. The most common methods of stabilisation involve the incorporation of small quantities (1% to 4%) of binders. These binders include cement (Portland, Blended Cements and Cementitious blends with slag[1] and/or fly ash); lime; bitumen and miscellaneous chemicals.

Granular stabilisation involves the mixing of different pavement materials without a binder to improve the material.

Stabilisation is used widely in both the construction of new roads and the rehabilitation or recycling of existing roads (see Figure 1). This paper is to specifically focus on the rehabilitation of existing pavements.

The other alternatives available to managers of pavement networks are –

- Bitumen resealing or asphalt resheeting
- Patching
- Full reconstruction
- Granular overlays
- Deeplift asphalt

[1] Ground granulated blast furnace steel slag is commonly referred as 'slag' for stabilisation binders.

Figure 1 Insitu stabilisation is a simple process of mixing the existing pavement material with a binder (left) and then compacting and resurfacing the road.

2 Advantages of using insitu stabilisation techniques to rehabilitate pavements

2.1 General

The advantages of using insitu stabilisation techniques to upgrade or recycle existing materials in deteriorated pavements, thereby rehabilitating the pavement as a whole, are in the benefits derived from three areas:

- Direct costs benefits
- Social benefits (ie speed of construction and lack of disruption)
- Environmental benefits

2.2 Direct cost benefits

Historically, over the last 50 years since stabilisation has been used in Australia (RTA, 2004), and especially over the last few decades when these techniques have been used more frequently, the decision to choose stabilisation by managers of pavements has been because of the significant cost savings. Where applicable, rehabilitation using stabilisation techniques commonly offer savings of 30% and in some cases even greater than 50% compared to reconstruction alternatives. These cost savings are the direct and most apparent savings (Wilmot 1991).

The direct cost savings from using stabilisation techniques can easily be determined by obtaining the operation or construction costs of the particular stabilisation method to be used. These are then compared with the costs of possible rehabilitation alternatives. These relative, direct costs can be determined by obtaining quotations or from basic, first principal calculations.

While it may be argued that whole-of-life costs should ideally be compared here instead of direct costs, the comparison of such costs on this basis raises a number of issues that are beyond the scope of this paper. Additionally, the complexities of this approach, along with the real political and financial pressures on most road managers, dictate that the direct cost is the value considered in making decisions regarding pavement rehabilitation options.

2.3 Social benefits

Rehabilitation of existing road pavements by insitu stabilisation is usually much quicker than other rehabilitation alternatives since there is effectively no excavation and there are minimal materials both taken away from site and consequently brought onto site. Also, with the materials being recycled in place, there is far less exposure to the risks of poor weather causing extended delays.

The advantages of the speed and lack of disruption of insitu recycling using stabilisation as compared to other pavement rehabilitation alternatives may or may not have been fully recognised in the past in Australia. When they have been recognised, they seem to have been viewed as a bonus to the deciding factor, namely the comparison of direct operational costs. In less relaxed societies, such as in Europe and North America, the time that lanes and whole roads are out of action due to roadworks has been seen as a real cost to the community for some time now. For example in some of our recent dealings in the United Kingdom the relevant agencies valued the lane rental on a moderately trafficked secondary road as £5,000 per day and on a lane on the A21 Highway at £1,000 per hour for daylight hours. Similar principles have been used in some Australian contracts.

The loss of road lanes for periods of time is a definite cost to the community and this cost should be evaluated in dollar terms and taken into account with the direct and other costs in the evaluation of the most appropriate rehabilitation solution.

2.4 Environmental benefits

Since the recycling of existing pavements using insitu stabilisation is quick, involves no excavation and requires either no or minimal removal of materials off site and consequently into the site, the environmental benefits of using these techniques in comparison to using other rehabilitation techniques are quite substantial.

The essence of using stabilisation techniques in the rehabilitation of distressed pavements, is to recycle or rehabilitate the existing road insitu, thereby upgrading the engineering and economic values of existing pavement.

By recycling the existing pavement materials, which still have a useful percentage of their original asset value, insitu stabilisation techniques have advantages (benefits) over other rehabilitation alternatives, saving on:

- excavation of the existing materials
- trucking materials off site
- dumping or disposal of excavated materials which still have a real asset value
- possible landfill usage
- quarrying replacement materials, which are in themselves finite resources
- trucking replacement materials to the site
- energy usage on the abovementioned activities
- gas emissions related to the abovementioned activities

These advantages, added with the previously mentioned advantages of greater speed and less disruption to traffic and the local community, significantly benefit the community as a whole with respect to environmental impact in comparison to other rehabilitation alternatives. Recycling old pavements is a sustainable process in terms of the affects on the overall environment compared with the digging out and disposal of the existing materials that still have some value and replacing them with new quarried and processed materials. When one uses waste products such as fly ash and/or slag in the blended cementitious products to recycle the existing pavements, there is even more benefit in terms of the environment and this is a 'win/win' situation.

Again, as with the comparative speed of using stabilisation to rehabilitate existing pavements, the quite considerable benefits to the environment have not traditionally been fully taken into account when evaluating the most suitable rehabilitation alternative. The evaluations have been essentially done in terms of direct cost analyses and although stabilisation, where practical, offers substantial direct cost savings, the environmental benefits have not been fully assessed. The environmental benefits of recycling pavements have slowly been gaining recognition but have been seen more as a bonus to the direct cost analyses rather than representing considerable commercial benefits in their own right, to the pavement managers and the community as a whole.

With individuals and communities now becoming more aware of the social and environmental factors that affect both their daily existence as well as their futures, they are beginning to ask for more environmentally responsible and sustainable solutions to our everyday needs (EPA, 1997). It is now becoming evident that environmental benefits are not only important because of their intrinsic value in preserving communities, countries and ultimately the World we live in, but these benefits are also of economic significance to the overall community. Hence, these environmental benefits need to be quantified and then should be considered, alongside the similarly quantified speed advantages, with the traditional direct cost comparisons in any truly meaningful evaluation of possible rehabilitation alternatives.

Little (1996) was one of the first people to attempt to quantify the advantages of using stabilisation to recycle roads, namely the speed, reduced traffic impact and environmental benefits. This paper takes his approach further and assigns dollar figures to these quantified savings so they can be better considered in the commercial evaluation of the various alternatives.

3 Case Study

3.1 General

In order to quantify and compare each of the three major identified cost (benefit) factors (or direct cost benefits, social benefits and environmental benefits), possible five rehabilitation options to a given pavement scenario have been compared.

Based on a project carried out by SPA in western Sydney in 2004, the pavement and design criteria as listed in Table 1.

Table 1 Case study details including assumed design values.

Design traffic	**$1x10^6$ ESAs (residential street)**
Existing pavement	250-260mm granular pavement material including surfacing
Subgrade	Silty Clay material with a design CBR 3%
Area of pavement for rehabilitation	2,000m^2

This project was chosen as it represents a fairly typical pavement in western Sydney in that it consisted of a pavement too thin for the traffic that it is required to carry, overlying a low strength subgrade (Refer Table 2).

Table 2 Pavement rehabilitation options providing a similar pavement life based on traffic volume.

Options	Details	Depth (mm)
1. Granular pavement with seal (Reconstruction)	Mill out existing pavement to depth. Replace with DGB/quality granular material Bitumen 2 coat seal wearing surface	520 520
2. Granular pavement with AC surfacing (Reconstruction)	Mill out existing pavement to depth Replace with DGB/quality granular material AC wearing surfacing	520 470 50
3. Stabilised basecourse with AC surfacing	Mill and blend material, remove for given final level Cement stabilise AC wearing surfacing	60 335 50
4. Deep asphalt basecourse	Mill out existing pavement to depth Replace with AC	180 180
5. Stabilised subgrade, stabilised base with AC surfacing	Mill and blend material, remove for given final level Mill and side cast basecourse Subgrade stabilise with lime Reinstate basecourse, cement stabilise AC wearing surfacing	60 250 200 250 50

Each of the options in Table 2 was designed for a similar traffic loading.

Note that in this case, patching options were not considered due to the widespread distress of the pavement, while overlays were not practical due to existing level constraints from kerb and gutter, and drainage structures.

It should be noted that option 3 in Table 2, consisting of conventional basecourse stabilisation, may have been the easiest rehabilitation option, but it was not practical in this case because there was insufficient insitu pavement material in the existing pavement to achieve the required bound layer thickness.

3.2 Direct cost comparisons

The direct costs of each alternative in Table 3 can be calculated using typical Sydney urban construction costs and the costs in Table 3 indicate that Option 3 has the lowest direct costs with Option 2 having the highest construction costs.

Table 3 Direct cost estimates of pavement rehabilitation options.

Option No	Option Description	Direct Cost($/m^2)
1	Granular pavement with thin bituminous seal	$78
2	Granular pavement with 50mm asphalt surfacing	$84
3	Stabilised basecourse with AC surfacing	$29
4	Deep asphalt pavement	$65
5	Stabilised subgrade, stabilised basecourse, 50mm asphalt surfacing	$39

These costs are based on generally accepted construction rates typical for the Sydney area. While it would be expected that the relativity of each value at least would remain comparable in other locations, it must be stressed that they would be affected by regional variation in costs or rates for materials 'ex-bin', transport, labour, establishment, fuel or other cost variations.

Site specific characteristics can also impact upon direct costs.

3.3 Social cost comparisons

It has already been noted that an important consideration when comparing rehabilitation options can be the expected duration of works, particularly at sites with high traffic flow, or areas of special significance. A comparison of construction duration for each rehabilitation option is provided in Table 4.

Table 4 Duration of construction for different rehabilitation options and corresponding road or lane occupancy costs.

Option No.	Option Description	Full Duration (days)	Road/Lane Occupancy Rate ($/day)	Road/Lane Occupancy Cost ($)	Road/Lane Occupancy Cost ($/m²)
1	Granular pavement with thin bituminous seal	12	$1,000.00	$12,000.00	$6.00
2	Granular pavement with 50mm asphalt surfacing	12	$1,000.00	$12,000.00	$6.00
3	Stabilised basecourse with AC surfacing	3	$1,000.00	$3,000.00	$1.50
4	Deep asphalt pavement	5	$1,000.00	$5,000.00	$2.50
5	Stabilised subgrade, stabilised basecourse, 50mm asphalt surfacing	5	$1,000.00	$5,000.00	$2.50

It is the proposal of the authors that the disruption caused by roadworks should be assigned a value (ie Social Cost) in order to properly compare all options to establish the overall best outcome.

Assigning a cost value to works durations (or effectively the ‘lane occupancy’ costs) is difficult to quantify. Whilst a value for ‘renting’ the road from the road authority could be perceived as the value of the road asset divided by the duration of the occupancy (even with an appropriate additional margin to provide a ‘return on investment’), the cost of a (severe) disruption to a designated roadway to the general community is clearly far larger than such a value. Considerations here would include disruption to economic activity/business, personal activity, public services, emergency services etc. as well as costs of a ‘political’ nature, such as the time and expense of the governing authority in dealing with community concerns as a result of the disruption.

One method to scale the cost of road or lane occupancy might be the average (daily) traffic carried by the road (or divided again by the number of lanes for individual lane traffic). This would suitably reflect the significance of the road to the general community, as high traffic freeways would rate as a major concern for traffic disruption, while no through traffic residential streets would rate as a minor concern. It could be debated whether the value of traffic values should be further modified to reflect traffic type and importance, or if locations of special services, such as schools, hospitals or fire stations should be taken into account.

In a current RTA NSW project, lane rentals were estimated to be from $15,000 to $30,000 per lane per hour for major Sydney roads (Transfield, 2004). Looking at these rates for such road or lane occupancy, it would appear that a road like this would attract a charge of somewhere between $500 to $5,000 per day. Taking a value at the lower, or more conservative end, the authors have adopted $1,000 per day for this example site, and this is shown in Table 4.

While disruption costs are low in a residential street, the adverse affects of heavy truck traffic is very detrimental to local residents; in particular, safety of children and also the structural damage to otherwise lightly trafficked pavements in surrounding roads.

3.4 Environmental Cost Comparisons

A number of the previously listed environmental factors can be quantified for each of the possible rehabilitation options for this pavement in terms of *exported and imported materials.*

3.4.1 Exported materials

Excess material from rehabilitation processes needs to be disposed of in some appropriate manner.

In Sydney today, practices have progressed beyond some of the questionable activities of the past to lose material, such as simply tipping over a cliff, dumping in local gullies, filling up mangrove areas or other ways as outlined by Little (1996). Disposal of excess material is a practical issue that needs to be addressed for every project. Tip or landfill space in Sydney is at a premium and there needs to be a corresponding cost allocated to this resource (Wright, 2000).

Road managers may well already be used to considering the cost of disposal of material in the form of a tip fee, either as an internal charge for government authorities or as an external charge for others. This figure may often be incorporated into the direct cost of works by the road manager, but an additional cost should also be considered; the environmental cost of the given option, as material disposal represents a cost ultimately borne by the environment in some sense (transport costs to cart the material to the applicable tip site aside).

The size of the applicable cost could also be debated. As a cost representing the cost or damage to the environment, it clearly should be a figure larger than the administrative and physical cost of maintaining the respective tip site or landfill site, even incorporating a commercial return for the operator (if applicable).

Whilst some materials excavated from some or all of the above possible remediation options may theoretically be able to be reused, either the granular material in a lower order application, or the soil from the subgrade (clay in this case) as clean fill, in reality, this is rarely possible. This is due to a variety of reasons, including that the material excavated usually ends up as a mixture of materials, being neither useable as pavement type material due to the presence of a plastic clay material, nor as clean fill material

In Sydney, disposal fees range from $60 to $100 per tonne for the disposal of inert material. It would therefore appear that at $30 per tonne, a proposed disposal cost or levy may be considered to be far too low, but may well be a suitable starting point. Even at this rate, it can be seen to have a significant impact upon overall project costs as shown in Table 5.

Table 5 Material and transport requirements for rehabilitation options.

Option description	Material IN	Material OUT		Other Quantity Totals			
	Granular (T) 2.1T/m³	Granular (T) 2.1T/m³	Asphalt (T) 2.4T/m³	Total Truck Move[1]	Total Truck Distance[2] (km)	Total Fuel (l)	Total Emiss-ions kgCO²
1. Granular pavement with thin bituminous seal	2184	2184	0	312	3120	1048	2830
2. Granular pavement with 50mm asphalt surfacing	2184	1974	240	315	3150	1058	2857
3. Stabilised basecourse with 50mm asphalt surfacing	252	0	240	36	360	121	327
4. Deep asphalt pavement	756	0	864	117	1160	390	1053
5. Stabilised subgrade stabilised basecourse 50mm asphalt surfacing	252	0	240	36	360	121	327

Notes: 1. Movements of plant items on roads to and from site and does not include those plant movements on site.
2. An estimate of 10km turnaround is assumed in this study.

There is also a cost associated with the loss of an asset in the form of the re-useable material excavated and disposed. In roadmaking materials, the clay material excavated may be of little value. However the granular pavement excavated does have a value. This value may well be significantly less than that of the replacement granular material, the existing material being of lower quality, but a value none the less. In the case given, the unbound reconstruction options involve disposal of all 250 to 260 mm of granular pavement, the deep asphalt option involves the disposal of 180mm of material, while the stabilisation option involves the removal of only 60 mm. The two layer stabilisation option could even allow the removed 60 mm to be comprised of clay only, by excavating directly from the exposed subgrade, following the sidecasting of all the existing granular pavement. Assigning just $2 per tonne to the existing granular materials, the respective costs due to loss of material assets are around $2100 for unbound reconstruction, $1500 for deep asphalt and $500 for stabilisation options as listed in Table 5.

3.4.2 Imported Materials

The supply of new, quality crushed quarry products involves a finite resource. Unnecessary use of such materials means that later, possibly more important, uses for these materials may not be able to be satisfied. The cost of the use of a finite resource should therefore be considered. Additionally, the environmental impacts (costs) of producing this material (excavation, crushing, processing etc) should also be considered. It is therefore believed by the authors that the use of such materials should be considered to incur an environmental cost. Again, this is in addition to the direct cost for the material itself for a number of reasons. Whilst the direct cost represents the cost of production, the environmental effects resulting from the use of this energy is additional and should be considered as such.

In the UK, the future value of this resource has been recognised with the application of a quarry tax (UK, 2005). This tax is currently £1.60/tonne (A$4.00/tonne) with a further increase of £1.95 from April 2008. Some funds from this tax are directed to the research of more sustainable forms of construction. In this paper, A$2.00/tonne has been adopted, which is one half of the tax in the UK.

3.4.3 *Stabilisation binders*

Since the 1990s, the cement suppliers have been working on the development of blended cements consisting of mixtures of GP cement, slag and fly ash. Slag and fly ash are by-products from the steel making industry and black coal burning power stations respectively. The slag is ground to produce a fine powder and is extensively used in road and building construction. The chemical composition of slag and fly ash is listed in Table 6.

The quality of fly ash varies depending upon the type of and power station operation. Cement or lime is used to activate the slag or ash to produce a cementitious product. There are several power stations burning brown coal but the by-products from these power stations are not utilised.

Table 6 Typical chemical characteristics of cement, fly ash and ground granulated blast furnace slag (GGBFS). {Smith, 2003]...

Chemical	**Percentage Composition**		
	Portland Cement	**GGBFS**	**Fly Ash**
CaO	64.0	41.0	4.4
SiO_2	22.0	32.6	55.0
$A1_2O_3$	4.5	12.8	25.0
Fe_2O_3	3.5	1.3	9.0
MgO	1.4	7.2	1.5
Na_2O, K_2O	0.7	2.6	1.8
SO_3	2.4	0.03	0.4

In the late 1990's, various binder suppliers produced proprietary cementitious binders, such as Stabilment and Roadblend, consisting of cement, slag, fly ash and lime in various proportions. These binders suited specific soil types common to urban regions and they became very popular with local government engineers. Due to slag's chemical composition (see Table 6) being similar to that of cement, it is therefore not unusual to find that slag is the most common blend with GP cement for road stabilisation binders,

Today, there appears to be a more consistent approach to the marketing of cementitious blends and a consistent view that the greater use of fly ash and slag is environmentally sound as these waste products are found to compliment the recycling process from the use of road stabilisation (refer to Figure 2).

In the case of the stabilisation option, it is necessary to import cement and lime to site in order to modify the existing materials[2]. Whilst the 'importing' of cement or lime are requirements for this option only, it is not difficult to review the tonnages involved (and corresponding production and transportation requirements etc) are minimal in comparison to other material requirements for the alternate options.

[2] Cement only in the case of the basecourse stabilisation.

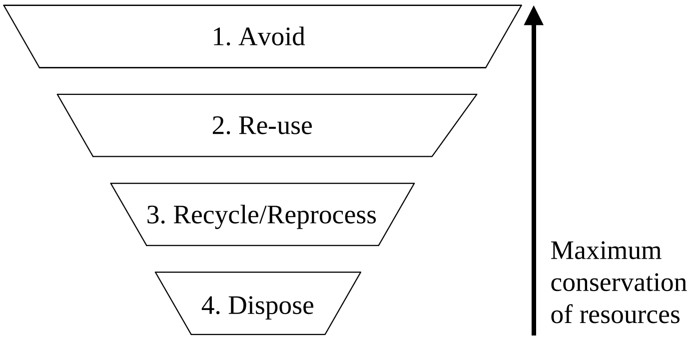

Figure 2 The insitu stabilisation process is regarded as the top level in the waste minimisation hierarchy (Wilmot, 1997).

In the case of cement, the nominated material in Table 2 was a GB (General Blended) Cement, comprising 60% slag and 40% GP cement. The slag component is a waste product of steel production, and hence it is only 40% of the 'cement' that was actually manufactured for this project.

The use of slow setting binders provides benefits in terms of slower setting time (ie longer working time) and reduced susceptibility to reflective cracking, whilst not acting detrimentally to strength generation (Smith, 2003). Whilst these blends were adopted for their improved gravel characteristics, and slight costs benefits, their environmental benefits should be recognised in any cost model.

A similar situation applies to the additional component in asphalt production – bitumen. Whilst it can be argued that bitumen production simply augments the processing of crude oil, or even simply utilises waste materials, it is difficult to envisage a halt to bitumen production if a replacement for conventional oil derived fuels was realised. The production and laying of asphalt is a high energy user, involving temperature rise and emission concerns.

3.5 Truck movements

Truck movements into and out of a work site impact upon the environment in a number of ways. These include noise pollution, air pollution (through emissions), consumption of fuel, additional traffic congestion and causing damage to the existing pavements along the designated haul route. A number of these quantities are tabulated in Table 5 and/or costed in Table 7.

Table 7 Environmental costs for various elements for each of the different options.

Options[1]	Loss of Material Asset Cost	Disposal cost	CO^2 Cost	Noise Cost	Road Injury Cost	Quarried Materials 'Levy'	Use of Energy Levy[2]	Truck Damage Levy[3]	TOTAL	TOTAL ($/m²)
1. Granular	$2,100	$65,520	$343	$119	$134	$4,368	$0	$0	$72,584	36.30
2. Granular	$2,100	$65,520	$346	$120	$135	$4,428	$0	$0	$72,650	36.30
3. Stabilised	$500	$7,560	$39.60	$13.70	$15.50	$480	$0	$0	$8,609	4.30
4. Deep	$1,500	$22,680	$127.60	$44.10	$49.90	$1,728	$0	$0	$26,130	13.10
5. Stabilised	$500	$7,560	$39.60	$13.70	$15.50	$480	$0	$0	$8,609	4.30

Notes: 1. Refer to Table 2 for full description of treatment.
2. Not costed.
3. Site specific.
4. Calculations based on ABS data from Australian Transport and the Environment 1997

Again, there are the political and safety costs arising from annoyed residents faced with increased truck traffic in their own street.

3.6 Emissions and energy use

As already detailed, most processes related to road construction or rehabilitation, including quarrying, transportation, excavation etc are energy consuming processes that consume fossil fuels and contribute emissions to the atmosphere. While the cost of CO^2 emissions is quantified in Table 7, the additional cost of the use of fuel as a finite resource is uncosted, but should also be considered.

3.7 Damage to existing pavements

The damage caused to existing adjoining pavements along the haul route by truck movements can be of particular significance in residential areas. Pavements in these areas are typically designed for lower traffic loadings and are usually constructed in a similar manner, with pavements for entire subdivisions having often been constructed at the same time. This means that in the case of one failed pavement, the entire road network in this area is likely to be at a similar stage in its useful life, and may well be severely damaged simply by the process of rehabilitating one section.

The resulting cost of this is determined by site specific factors (eg the haul route and existing pavement conditions). While the cost may therefore be close to zero in cases where there is little scope for damage to be caused, a worst case scenario could see pavement distress in adjoining streets requiring an otherwise premature rehabilitation of these pavements. While these pavements would likely be upgraded eventually anyway, it is the cost of raising capital that is significant here, given that hundreds of thousands of dollars could be required perhaps 5 years earlier than it would otherwise be needed. Quantifiable environmental costs as described above are tabulated in Table 7.

3.8 Recycling the material again

Many local road authorities in Sydney and Brisbane and have started to recycle again existing cement stabilised pavements that have come to the end of their life with the same treatment due to low costs and rapid construction. Figure 3 shows a typical candidate that had been insitu stabilised with GP cement in the 1970s and was recycled again in 1997 using a triple blend of GP cement, slag and fly ash.

Figure 3 A local road that has been recycled again in the Fairfield City Council (NSW) region showing great performance for the last 10 years.

The salvage cost to this process has not been included in the analysis but it represents an opportunity to main sustainability for the community.

3.9 Total cost comparisons

Summary values for direct, social and environmental costs per square metre are listed in Table 8. These cost components are also displayed in Figure 4. As can be seen, the benefits of the stabilisation based options on a direct cost basis are further emphasised with the additional consideration of social costs and environmental costs.

Of equal importance is that the relative magnitude of the environmental costs for the other options is significant. Whilst the social costs are not so significant in this particular case, as was noted earlier, it could well be of similar significance on a more heavily trafficked project site.

Table 8 Complete costs summaries of all options.

Option No.	Description	Direct Cost ($/m²)	Social Cost ($/m²)	Envir. Cost ($/m²)	Total Cost ($/m²)
1	Granular pavement with thin bituminous seal	$78.00	$6.00	$36.30	$120.30
2	Granular pavement with 50mm asphalt surfacing	$84.00	$6.00	$36.30	$126.30
3	Stabilised basecourse with 50mm asphalt surfacing	$29.00	$1.50	$4.30	$34.80
4	Deep asphalt pavement	$65.00	$2.50	$13.10	$80.60
5	Stabilised subgrade stabilised basecourse 50mm asphalt surfacing	$39.00	$2.50	$4.30	$45.80

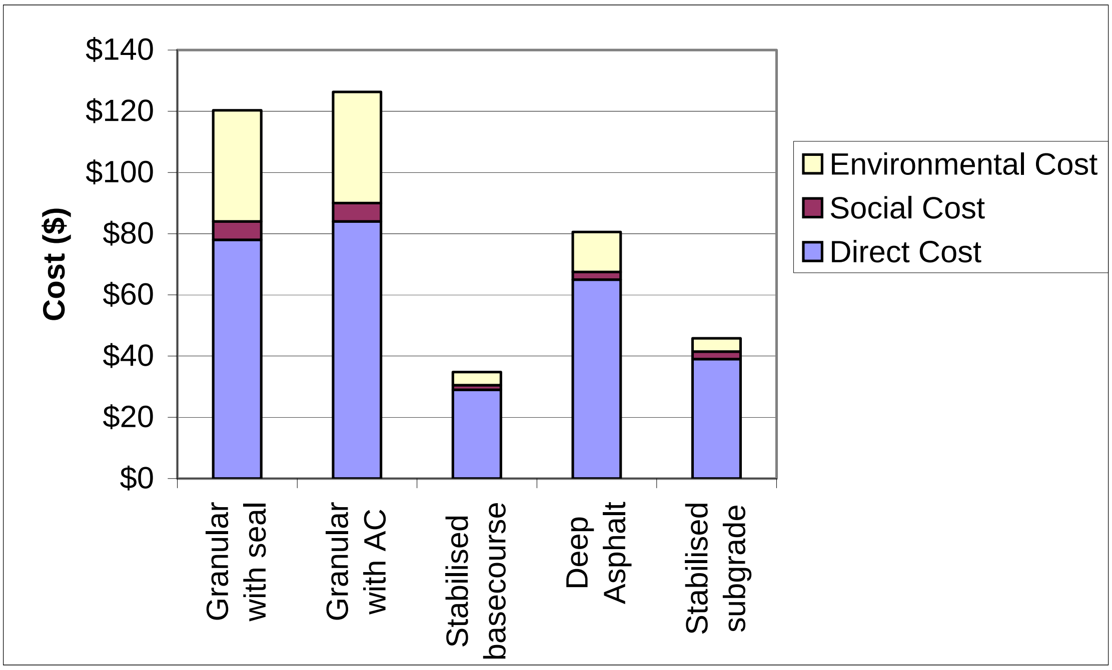

Figure 4 Comparison of direct, social and environmental costs per square metre for example site.

4 Conclusion

Engineers are accustomed to comparing the direct construction costs to determine the optimum solution for pavement rehabilitation works. It is now appropriate that road authorities should be considering and valuing the social and environmental costs of all construction projects. While the quantum and means of evaluating these costs requires further refining, the authors recommend that road authorities and local government should be recognising and assessing the environmental impacts of the projects and future loss of finite resources. Factors such as road safety and truck haul damage can be assessed at a local level, whereas the protection of finite resources, energy usage and emissions would more suitably be addressed at a state or national level. While procedures are in place to recognise the cost of land fill, consideration and action at a State or National level in the form of a quarry tax may be required to ensure preservation of our valuable quarry resources and encourage their use in projects where alternate options are available.

Binders now being used for road stabilisation are blended with industrial by-products, such as slag, resulting in benefits of waste reduction and less reliance on manufactured binders such as lime and cement.

Rehabilitation using insitu stabilisation will normally offer both the lowest direct cost and the greatest benefits, or least cost, when assessed for speed of construction, social and environmental costs. This form of rehabilitation has also the capability for being recycled again leading to longer term benefits to future generations.

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