RECOGNITION OF ENVIRONMENTAL AND SOCIAL ADVANTAGES OF USING STABILISATION IN ROAD REHABILITATION

Warren Smith warsm@ozemail.com.au
General Manager, Stabilised Pavements of Australia Pty. Limited www.stabilisedpavements.com
NSW Australia

Paper Summary

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.

Introduction

Stabilisation is the improvement of a soil or pavement material usually, but not always, through the addition of a binder or additive.

Granular stabilisation involves the mixing of different pavement materials to improve the material.

The most common methods of stabilisation involve the incorporation of small quantities (1% to 4%) of binders. These binders include: Cements (Portland, Blended Cements and Cementitious blends); Lime; Bitumen and miscellaneous Chemicals.

Stabilisation is used widely in both the construction of new roads and the rehabilitation or recycling of existing roads. 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

The Advantages of Using Insitu Stabilisation Techniques to Rehabilitate Pavements

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 (speed and lack of disruption)
- Environmental Benefits

Direct Cost Benefits

Historically, over the last 50 years since stabilisation has been used in Australia, 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 figure considered in making decisions regarding pavement rehabilitation options.

Social Benefits (Speed and Lack of Disruption)

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 in. 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.

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 flyash and/or slag in the blended cementitious products to recycle the existing pavements, there is even more benefit in terms of the environment and 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 this approach further and assigns dollar figures to these quantified savings so that they can be better considered in the commercial evaluation of the various alternatives.

Case Study

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 rehabilitation options to a given pavement scenario have been compared.

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

Table 1 Pavement configuration details.

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

This project was chosen as it represents a fairly typical pavement in western Sydney (and many parts of Australia for that matter) 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 1).

Importantly, each of the above options was designed for a similar traffic loading, or "design life". They are therefore all equal in terms of expected life or performance.

Note that in this case, patching options were not considered due to the widespread failure of the pavement, while overlays were not practical due to existing levels.

It should be noted that option 3 in Table 1, consisting of "conventional" basecourse stabilisation, may have been the easiest rehabilitation option, but it was not practical in this case because there was insufficient pavement material in the existing pavement to achieve the required bound layer thickness.

Direct Cost Comparisons

The direct costs of each alternative can be calculated and compared as below.

They are based on generally accepted construction rates typical for the Sydney area, and while it would be expected that the relativity of each figure 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.

Table 2 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

As can be seen from Table 2 above, the direct costs of the stabilisation based options compare favourably with those of the alternatives. This is indeed a common occurrence where stabilisation options are technically appropriate. If a conventional basecourse stabilisation option were technically feasible here, it would significantly reduce costs even further.

Social Cost Comparisons

It has already been noted that an important consideration when comparing rehabilitation options can be the expected duration of works, particularly in high traffic flow areas, or areas of special significance. A comparison of expected duration for each rehabilitation option is presented (Refer Table 3).

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

Assigning a cost value to works durations (or effectively to "lane occupancy") is difficult to quantify. Whilst a value for "renting" the road from the respective authority might be able to 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 figure. 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 of that road pavement in dealing with the results 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 a terminating residential street 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 are 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 figure at the lower, or more conservative end, we have adopted $1,000 per day for this example site.

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

Environmental Cost Comparisons

A number of the previously listed environmental factors can be quantified for each of the possible rehabilitation options for this pavement (Refer Table 4).

Exported and Imported materials

Exported materials

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

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 attributed 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; an 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 & 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 re-used, 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 up to $100 per tonne to public or commercial customers for disposal of inert material. It would therefore appear that at $30 per tonne, a proposed disposal cost or levy might be considered still 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 (Refer Table 5).

There is also a cost associated with the loss of an asset in the form of the re-useable material excavated and disposed. In a roadmaking sense, 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 250-260mm of granular pavement, the deep asphalt option involves the disposal of 180mm of material, while the stabilisation option involves the removal of only 60mm. The 2 layer stabilisation option could even allow the removed 60mm 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. These figures are included in Table 5.

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 author 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. This tax is currently £1.60/tonne (A$4.00/tonne) with a further increase proposed for the near future. Some funds from this tax are directed to the research of more sustainable forms of construction. In the workings for this paper, A$2.00/tonne has been adopted, which is one half of the tax in the UK.

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.

In the case of the stabilisation option, it is required to import cement and lime to site in order to modify the existing materials. (Cement only in the case of the basecourse stabilisation only option). Whilst these are requirements for this option only, it is not difficult to see that the tonnages involved (and corresponding production and transportation requirements etc) are minimal in comparison to other material requirements for the alternate options.

In the case of the cement, the nominated material was a GB (General Blended) Cement, comprising 60% Slag (Ground Granulated Blast Furnace Slag) and 40% GP (General Purpose, or Portland) 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.

This is a specific blend in the family of GB Cements, which are blends of GP Cement with slag and or flyash, another waste product. In the cement blend for this project, the slag component provided 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 & Hansen, 2003). Whilst these blends were adopted for their improved technical characteristics, and slight costs benefits, their co-incidental environmental benefits should be recognised.

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 4 and/or costed in Table 5.

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

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 5, the additional cost of the use of fuel as a finite resource is uncosted, but should also be considered.

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, likely to be at a similar stage in its useful life, may well be severely damaged simply by the process of rehabilitating one section.

The resulting cost of this is obviously entirely 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 failures 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 5.

Total Cost Comparisons

Summary values for direct, social and environmental costs are listed and totalled below (Refer Table 6). These cost components are also displayed graphically as shown in Figure 1.

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 particularly with the addition of environmental costs.

Of equal importance is that the relative magnitude of the environmental costs for the other options are 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.

Conclusion

Engineers are accustomed to comparing the direct construction costs to determine the optimum solution for pavement rehabilitation works. It is now time that we 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 author recommends 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 trucking 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.

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.

References

ABS Data from *Australian Transport and the Environment* (1979)

Australian Government *Australian Greenhouse Office Website*

Environmental Protection Authority (NSW) (EPA) *State of the Environment 1997*

Little C. (1996) *Practice and Future of Recycled Roads,* Joint AustStab and C&CAA Seminar

Smith W. & Hansen B (2003) *Detailed Investigation of the Performance of GB Cements in Pavement Stabilisation Works,* 21st ARRB Conference, Cairns, May 2003

Transfield Private Communication with Contract Engineers (2004)

Wilmot T.D. (1991) *Recycling Opportunities in the Effective Management of Road Pavements,* Local Government Engineering Conference, Hobart

Wilmot T.D. & Wilmot S. (2003) *Strategies for Sustainable Roads,* 21st ARRB Conference, Cairns, May 2003

Wright A.J. *Independent Public Assessment Landfill Capacity and Demand*

Table 1 Pavement rehabilitation options providing a similar pavement life**.**

Options	Details	Depth (mm)
1. Granular pavement with seal (Reconstruction)	Mill out existing pavement to depth Replace with DGB/quality granular material Apply bitumen seal (2 coats)	520 520
2. Granular pavement with AC surfacing (Reconstruction)	Mill out existing pavement to depth Replace with DGB/quality granular material Apply AC surfacing	520 470 50
3. Stabilised basecourse with AC surfacing	Mill and blend material, remove for given final level CementStabilise Apply AC surfacing	60 335 50
4. Deep Asphalt Pavement	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 sidecast basecourse Subgrade stabilise with lime Reinstate basecourse, cement stabilise Apply AC surfacing	60 250 200 250 50

Table 3 Durations 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

Table 4 Material and transport requirements for rehabilitation options.

		Material IN	Material OUT		Other Quantity Totals			
	Option Description	Granular (T) 2.1T/m³	Granular (T) 2.1T/m³	Asphalt (T) 2.4T/m³	Total Truck Move	Total Truck Distance 10km turnaround km	Total Fuel litres	Total Emiss 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	Stabilisedbasecoursewith 50mmasphaltsurfacing	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

Note: Movements of plant items on site not included above

Table 5 Environmental costs for various elements for each of the different options.

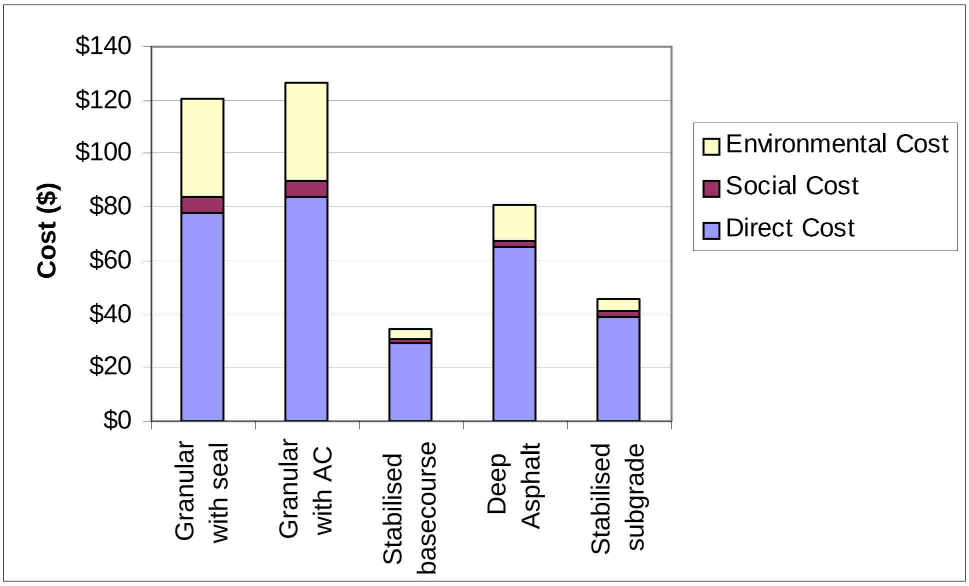
Option Description	Loss of Material Asset Cost ($)	Disposal cost ($)	CO2 cost ($)	Noise cost ($)	Road Injury Cost ($)	Quarried Materials "Levy" ($)	Use of Energy "Levy" ($)	Truck Damage "Levy" ($)	TOTAL ($)	TOTAL ($/m²)
1. Granular pavement with thin bituminous seal	2,100.00	65,520	343.20	118.56	134.16	4,368.00	Uncosted	Site Specific	72,583.92	36.29
2. Granular pavement with 50mm asphalt surfacing	2,100.00	65,520	346.50	119.70	135.45	4,428.00	Uncosted	Site Specific	72,649.65	36.32
3. Stabilised basecourse with 50mm asphalt surfacing	500.00	7,560	39.60	13.68	15.48	480.00	Uncosted	Site Specific	8,608.76	4.30
4. Deep asphalt pavement	1,500.00	22,680	127.60	44.08	49.88	1,728.00	Uncosted	Site Specific	26,129.56	13.06
5. Stabilised subgrade stabilised basecourse 50mm asphalt surfacing	500.00	7,560	39.60	13.68	15.48	480.00	Uncosted	Site Specific	8,608.76	4.30

NOTE: Calculations based on ABS data from Australian Transport and the Environment 1997.

Table 6 Complete costs summaries of all options.

Option No.	Option Description	Direct Cost ($/m²)	Social Cost ($/m²)	Envi Cost ($/m²)	Total Cost ($/m²)
1	Granular pavement with thin bituminous seal	$78.00	$6.00	$36.29	$120.29
2	Granular pavement with 50mm asphalt surfacing	$84.00	$6.00	$36.32	$126.32
3	Stabilised basecourse with 50mm asphalt surfacing	$29.00	$1.50	$4.30	$34.80
4	Deep asphalt pavement	$65.00	$2.50	$13.06	$80.56
5	Stabilised subgrade stabilised basecourse 50mm asphalt surfacing	$39.00	$2.50	$4.30	$45.80

Figure 1 Graphical comparison of direct, social and environmental costs for example site.



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

Author Biography

Warren Smith is the General Manager of Stabilised Pavements of Australia Pty. Limited and has more than 25 years experience in pavement design and construction. For over 20 years Warren has worked specifically in the stabilisation and rehabilitation industry. As such he has been involved in the development of the different methods and procedures of stabilised pavement design and construction in many varied situations throughout Australia. He has had significant input into the ongoing introduction of new technologies in both stabilisation equipment and additive fields.

Warren is now one of Australia's most experienced and well versed Engineers in the fields of stabilisation and road rehabilitation, and as such is frequently involved in seminars and workshops with State and Local Government Authorities, Consultants and other interested groups throughout Australia and other parts of the World including Europe and Asia. Warren has also been directly involved in stabilisation and recycling operations in the Pacific Rim, throughout Asia and in the UK.

Postal Address: Warren Smith, Stabilised Pavements of Australia Pty. Limited, P.O. Box 240, Gymea, NSW, 2227

Tel: 61 2 9526 1066

Fax: 61 2 9525 7380

E-mail: warsm@ozemail.com.au

Website: www.stabilisedpavements.com