A REVIEW OF PATCHING AS A PAVEMENT MAINTENANCE TOOL

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ABSTRACT

The aim of this paper is to try to analyse the effectiveness of patching in comparison to other common pavement maintenance tools. This analysis of the comparative effectiveness is done within the criteria of design, construction, environment and cost, including both initial and whole of life costs. Since this analysis could be complicated and confused by many different variables a number of assumptions are made to clarify and identify general trends.

Following on from the results of this comparative investigation, recommendations are made to produce the most efficient and effective pavement maintenance regime, and enunciate what significance patching should have in that regime.

INTRODUCTION

Patching of flexible pavements is a commonly used tool for the maintenance of pavements in Australia and throughout the world. Ironically, as the unfortunate trend of decreasing funds for pavement maintenance continues to prevail, there has been an increasing expectation from road users for better maintained roads. The resulting political pressure on road network managers to retain acceptable standards throughout their entire networks, under adverse conditions, has led many to increase their use of patching relative to other pavement maintenance tools.

The maintenance problem

Throughout Australia, and indeed the world, the problems for pavement network managers are the same. Pavements are ageing. A significant amount of pavements are either approaching or have exceeded their effective design lives and are now composed of materials that have deteriorated and lost their original properties. These pavements are also usually too thin for their present required loadings. Also the maintenance of these pavements is becoming more difficult since all related costs such as labour, stone, materials, bitumen, fuel, trucking etc. are increasing rapidly.

The maintenance problem is being exacerbated by the fact that, throughout the world, there has actually been a reduction in money being allocated to pavement maintenance in real terms. The irony is that road loadings are generally increasing as the money invested into existing pavements is decreasing. Apart from the significant increase in vehicles, the number of heavy vehicles has been increasing, as well as allowable axle loads, number of axles and tyre pressures. All these factors are impacting negatively on the situation.

Maintenance options

Although there are numerous minor postulated and relatively unproven pavement maintenance treatments, due to economic and technical considerations, there are realistically only a limited number of maintenance options available to the network managers. These include:

a) Bitumen Resealing or Asphalt Resheeting

These are only wearing surface solutions and will not overcome pavement problems.

b) Patching

This option will be analysed in more detail throughout this paper.

c) Pavement Overlays

Overlays are relatively expensive, time consuming and disruptive to traffic. They are also limited in their use by level restrictions. For example, they are seldom able to be used in urban situations, because of the requirement to retain existing pavement levels which match into existing kerb and gutter, and other level dependent features. They are also restricted in some rural situations where flood drainage requirements do not allow for increasing pavement heights.

d) Excavate and Replace Old Pavement with New

This option involves the replacement of the old pavement with a new granular full depth pavement or with a deep lift asphalt pavement.

- Either alternative is hugely expensive, very time consuming and disruptive to traffic, underground services and the local social and business community. It is also a very unsound method of asset management in terms of its environmental impact.
- Due to the high costs of this option it drains the pavement maintenance budget and hence is limited in its widespread use. Similarly, the significant environmental disadvantages of this option with respect to high usage of finite resources of stone and/or bitumen, high energy usage and high levels of emissions, make the future of this option even more in doubt in responsible asset management.

e) Recycling Pavements using Stabilisation Techniques

This rehabilitation option usually involves the upgrading of existing pavement materials, with the insitu option having cost and environmental advantages over the offsite pugmill option. This option has many variations, depending on the existing pavement conditions and the final pavement requirements. These variations include lime stabilisation of the subgrade, or improvement of the basecourse using cementitious or bitumen stabilisation.

Although this option has had overall success in Australia and around the world, it has suffered, in limited quarters, through a lack of understanding of how to use its techniques properly.

However, due to the cost, speed and lack of disruption, and the environmental advantages of this recycling option relative to the other maintenance options, there has been a steady, but slow, leaning toward this option when all considerations have been evaluated.

Present trends

Over the last decade or more, the costs of the more traditional pavement maintenance options, ie overlays and full depth replacement, have increased so much, with a corresponding slowing of maintenance funds in real terms, that to keep up with maintenance requirements these options are no longer feasible over an entire network.

Although rehabilitating pavements using stabilisation techniques has been embraced by many as a viable alternative, this option has yet to recognise its full potential. Hence we have many managers of pavement networks caught in this transition position, where they are under political pressure to maintain their pavements to acceptable levels for the owners, users and/or public, but they have static or decreasing funds, and their traditional maintenance methods are no longer financially feasible. This has resulted in recent times in an increase in the use of patching of pavements by many network managers in an attempt to overcome their dilemma in the short term.

Types of patches and construction methods

The majority of patches fall into three main categories – granular patches, stabilised patches or asphalt patches.

i.) Granular Patches

Granular patches usually range in size from as little as 10m² up to 500m². An area over 500m² is usually not regarded as a patch but as a section of reconstruction.

The construction method for these granular patches varies slightly with location and the number undertaken, but usually follows the following process: setting up of traffic control; excavation of existing pavement material with a small skidsteer loader, backhoe or possibly a small profiler; loading onto trucks and carting away for disposal; trucking in of new granular material; placement with a bobcat, backhoe or grader; compaction with a water cart and small mobile roller (four to eight tonnes) and trimming to a level slightly higher than the surrounding road. After a few days when the granular patch dries back and settles down, the patch is trimmed again to the required level and the wearing course is applied. This is usually in the form of a sprayed bitumen seal, but in urban or higher traffic situations may also involve the later application of a thin asphalt layer.

Due to practicality and the fact that light mobile rollers are usually used, the depths of granular patches are usually in the range of 150mm to 200mm. (See Figure 1)

ii.) Stabilised Patches

Patches that are stabilised are usually stabilised with cement and infrequently lime or a chemical may be used. Cement or lime “stabilisation” is usually in the modification or lightly bound stabilisation range, i.e. with additive percentages of 1% to 2% or 2% to 4% by weight respectively. Similar to granular patches, stabilised patches usually range in size from as little as 10m² up to 500m², with greater areas usually considered as reconstruction rather than pavement maintenance patching.

The construction methods for these types of patches can vary significantly after the setting up of the common traffic control phase. For smaller size patching the cement or other binder additive is usually spread by bags and by hand and the mixing is undertaken using a mixing head fixed to a skidsteer machine. (See Figures 2 & 3) For larger patches a proper, purpose-built cement or binder spreader and stabilising mixer may be used. After the “stabilisation” is performed the stabilised patch is compacted with a small mobile roller (four to eight tonnes) and with a water cart. The patch is again trimmed slightly high with a small skidsteer loader or grader depending on the size of the patch and the equipment utilised. The little excess is loaded onto a truck and carted away for disposal. Prior to the application of the wearing course the patches are trimmed down to the correct level.

Again, due to practicality and the fact that light mobile rollers are usually used, the depths of stabilised patches usually range from 150mm to 200mm. Where skidsteers or other light machines are used for the stabilising mixing, because of their lightness, their cutting configuration and lack of power compared to purpose-built stabilising mixers, the actual resultant depth of the patches may be restricted to 150mm.

iii.) Asphalt Patches

Asphalt patches usually range in size from as little as 2-3m² to 300m². Asphalt patches much greater than 300m² are relatively uncommon due to high costs.

The construction method for these type of patches usually involves: the setting up of traffic control; excavation using a small road profiler (for very small patches hand tools or a small skidsteer loader with cutting head may be used); loading and carting away by truck the excavated material for disposal; importation of hot asphalt from an asphalt plant up to 100km distant; placement with a skidsteer or asphalt paver and compaction with a small mobile roller (four to eight tonnes).

Due to practicality and asphalt stability problems at greater depths, asphalt patches are usually in the order of 100mm deep, with 150mm deep patches used on heavier trafficked roads (See Figure 4).

Issues associated with patch design

Unfortunately, due to factors such as the availability and required mobility of plant, practical restrictions such as compaction and the overriding desire for a low cost, short term solution, historically there has not been a great deal of engineering input into the design of patches. Despite the vast amounts of money spent on patches annually over a broad area, within individual organisations there does not seem to be the required technical input with regard to design, construction practices and monitoring of performance. Most of the activities associated with patching are a repeat of what has been done in the past and there has been little technical review or improvements.

Due to the many variables that affect patches, it is difficult to look at the design aspects of patching. These variables include: particular site conditions, existing pavement and subgrade, traffic loadings, types and nature of patches etc. To try to clarify the significance of design to the effectiveness of patching, a "general" situation was selected, for which design aspects of patching could be investigated.

To be relevant to the maximum number of people in the industry, this general situation was chosen as a moderately trafficked State Road Authority highway or a relatively heavily trafficked Local Government road. Hence, to fit into these criteria and also represent the most prevalent and realistic situation the details of the example pavement are:

Required pavement life, ESA's = 2x106

Subgrade CBR = 3%

Existing granular pavement depth = 350mm

Existing wearing course: Sprayed Bitumen Seal

It should be noted here that doing a simplistic design for the required traffic life, using Fig. 8.4 of the Austroads Pavement Design Guide, the required granular pavement depth would be 560mm. However, the example situation with only 350mm of granular material accurately represents the maintenance problem, in that existing pavements are generally far less in thickness than what is actually required for their traffic loadings.

i.) Granular Patch Design

As already indicated, for a granular patch to provide a long term solution for rehabilitating the road in the example scenario, the patch should be to a depth of 560mm. However, due to restrictions in the plant used in this type of work, problems with gaining adequate compaction, even to 200mm depth, and cost considerations, granular patches are invariably constructed to 150mm or 200mm maximum depth (See Figure 5).

ii.) Stabilised Patches

Similarly, using Austroads design methodology, a cementitious stabilised patch, with an elastic modulus of 2,000MPa, for this scenario should have a pavement thickness in the order of 400mm. Again, in practice due to plant restrictions especially when using skidsteers or small rotomills (instead of purpose-built stabilising mixers), compaction restrictions and cost considerations, these stabilised patches are usually constructed to 150mm to 200mm maximum depth (See Figure 6).

iii.) Asphalt Patches

Using Austroads design methodology, an asphalt pavement with an elastic modulus of 2,800MPa should have a thickness of 200mm for the required life. However, in practice asphalt patches are invariably constructed to 100mm depth with two 50mm layers of asphalt. This is

due again to plant restrictions, stability problems over 100/150mm depths and cost considerations.

Performance of patches

As with many aspects of patching, there is very little documentation on the performance of patches. This is despite the cumulative, very significant amount of money being spent continuously on many small patching sites over nearly all pavement networks. The author has accumulated his information on the performance of patching from a number of different sources, including his nearly 40 years of experience directly involved in construction of patches for Local Government and State Road Authorities throughout Australia, South East Asia, the Pacific Rim and the United Kingdom. This experience has also included the observation of the performance of patches under varying circumstances throughout the world. For the formulation of this paper, the author has also interviewed and discussed with many representatives from site to management levels, those who control and manage different pavement networks, as well as many patching practitioners throughout Australia and overseas.

In terms of actual structural performance of all types of patches, it is clear from information and observations across different situations and different variables, that the lives of patches are limited. The majority of patches retain their integrity for only short periods of time relative to the expected lives of the entire road pavements. The majority of patches display significant distress within two to four years of construction. A minority of patches have effective lives over five years, however, conversely a proportion of patches fail within months of construction.

The failure modes of patching consist of pavement failure of the actual patched area, failure of the existing pavement immediately surrounding the patched area and/or failure of the existing pavement between patches.

Logically, the life of patches is to be expected to be limited to a relatively short period. The previous simple analysis of their designs indicates that they are not only under designed, but significantly under designed for the expectations of the lives of the road pavements in which they are constructed.

Since, by their intrinsic nature, patches are relatively small in area, during their construction there is a high level of activity of the construction plant on the existing pavement adjacent to the patches. Although these areas may originally show less signs of distress than the particular area actually being patched, these adjacent areas are usually themselves in a precarious position coping with existing traffic loadings. The extra construction traffic stress around new patches invariably causes failures in the existing pavement adjacent to newly constructed patches. This is a common feature of patching and can begin to appear within months of the patch construction.

Also since patches only address localised areas in the particular road pavement length, it is a continuing process rehabilitating the sections between patches with further patches, as new areas of distress occur in the overall pavement.

Apart from the overriding design deficiencies of patches and the fact that they only deal with localised areas, the performance of patches is also limited by their construction quality. Due to the intrinsic size of patches the plant usually used in their construction is small in size as compared to conventional sized pavement works. This smaller, mobile plant invariably leads to lower standards of construction as compared to larger works. For example the rollers used in patching are much smaller than standard rollers and lead to significant deficiencies in compaction quality as compared to standard pavement specifications. Similarly for stabilised patches, the binder spreading and the quality of mixing is usually significantly compromised when using smaller patching equipment such as skidsteers with “mixing” heads.

The fact that there is little or no compliance testing conducted with patching work, reinforces and propagates the continuation of a quality of construction in patching, which is generally sub standard in comparison to pavement works on a larger, conventional scale.

Cost comparisons

When reviewing the costs of patching relative to other rehabilitation options, it is important that, as well as initial direct costs of construction, the whole of life costs for the entire section of the particular pavement are determined and evaluated.

To analyse the costs of patches, there was again a need to overcome the many variables that complicate review of patches. To this affect, the general situation which was used in the investigation of design aspects of patching was again used. Also some common assumptions were used with regard to factors including distance from sources of materials, size and number of patches and production rates. To get a better understanding of the relative costs of patching, two example scenarios were investigated, one being a high traffic local government road approximately 10km from quarry and asphalt products and the other a light to moderately trafficked rural highway approximately 60km from quarry to asphalt products.

A number of situations with varying total patching areas and a number of patches per day, which are typical of what is actually being achieved in the field, were also used to help investigate costs. For the granular and stabilised patch examples, these patches were looked at in groups of one each of 20m², 50m² and 100m² patches.

The respective costs for different types of patches under these typical scenarios situations are tabulated in Table 1.

Although the tabulated initial construction costs of patches may vary due to specific site conditions, these typical general examples do give good insights into the actual relativity of the costs of patches. The overriding feature of the cost of patching is the high cost of initial construction per square metre of actual pavement repaired. This is regardless of what type of patching is used.

The second part of the analysis of the cost effectiveness of patching required the investigation of the costs over a period of time or a whole of life analysis. As an example, a 5,000m² section of road pavement with the same parameters as for the design investigation and which was at or near the end of its useable life, was used to investigate costs over a period of time. Table 2 compares the initial costs in the first year for different types of patches over typical achievable production rates for a day's work. The costs of these patching regimes over the section of pavement over a 10 year period are also presented using annual inflation rates of 3% and 4% respectively.

One feature of these figures is relative similarity of costs between types of patching over a period of time, when considering typical attainable productions. However, the main feature of these figures is the high costs that a typical section of road pavement absorbs through constant patching. When one takes these relatively high costs into perspective with the performance of patching and the fact that they have very limited design lives, the effectiveness of patching has to be seriously questioned.

To exemplify the cost and technical ineffectiveness of using patching as a pavement maintenance alternative, a simple comparison to just one other alternative was made. For example, using the required pavement life of ESA's = 2x106 with a subgrade CBR=3% would require a rehabilitation of this pavement with 225mm depth of Foamed Bitumen stabilisation. The cost of this alternative with a production of 2,500m² per day would be $31.28/m² including a two coat bitumen seal wearing course. Table 3 lists the costs of this maintenance/rehabilitation alternative using stabilisation, again using 3% and 4% inflation figures.

By using patching over this 5,000m² section of road, the costs over a 10 year period are in the order of $320,000. Significantly, at the end of the 10 year period, there is no real added value in the pavement as the majority of the pavement will be still under extreme distress as it will have no effective increase in design life.

Alternatively, by using a form of stabilisation to rehabilitate the whole pavement area entirely in the first year, or half in the first year and the second half in a subsequent year, would involve a total cost of approximately $160,000. Apart from this cost being half that of patching, it would result in a pavement with its whole area having an extended design life of 2x106ESA's, in

comparison with the patching alternative with effectively no future design life, and the road section requiring even more ongoing maintenance.

Environment

Some types of patches may have some environmental benefits with respect to others. For example, stabilised patches affect the environment less than replacement type patches such as granular or asphalt. This is because they “recycle” existing material and do not rely on removal and disposal of materials and the replacement with new, finite resource, materials. However, all patches use valuable resources of materials and energy with no real net gain in the asset value of the road pavement over a period of time. Also patching requires continuous commitment of these resources to try to maintain the status quo without adding any value.

Hence, patching is an unsustainable activity in terms of environmental factors. Apart from its own poor position with regard to sustainability, it compares even more unfavourably to sustainable alternatives available to pavement managers, such as recycling pavement sections using stabilisation techniques.

Summary

Worldwide there is a problem maintaining road pavement networks with increasing vehicles, loads, tyre pressures etc., while all cost elements are increasing in an environment of decreasing availability of maintenance and rehabilitation funds. Due to increasing political pressure on road managers to maintain present road standards in the short term, many managers have relied heavily on patching under these adverse conditions.

However, the general performance of all types of patches, over many varying situations, is quite poor when reviewed objectively. The lives of the actual patches are generally low with most patches failing within two to four years. Similarly, the areas immediately adjoining patches usually fail within a relatively short period after construction of the patches. Added to this, patches are only a short term solution for localised areas, and provide little or no value to the structural integrity of the entire section of the pavement in question.

Although across Australia and throughout the world there are vast amounts of funds being spent on patching, these operations are usually small individual job sites disseminated over broad areas. This seems to have led to little up-to-date technical input with regard to design, construction practices, compliance testing and reporting with respect to patching.

As a result, after reviewing different types of patches in terms of actual design characteristics and actual design requirements, it is not surprising that the performance of patches, other than in the short term, is poor. Patches are actually designed to fail early. Similarly, a clinical look at construction plant and practices used, and the lack of compliance testing, also assists in explaining the poor performance of patching in reality.

However, it is when the costs of patches, in both the short term and over a period of time, are evaluated, in comparison to other maintenance/rehabilitation options which have long term benefit, that it can be seen that patching does not provide a value for money solution.

Recommendations

After analysing the comparative effectiveness of patching with respect to performance, design, construction, environment and cost, it is clear that patching does not represent an effective or sustainable method of maintaining pavement networks. It is far more economical and sustainably effective to rehabilitate sections of pavement using, say, stabilisation techniques rather than use patching.

All decisions on maintenance of pavements should be taken using whole of life costing and taken with consideration of the whole of the pavement network. This clearly indicates that in any pavement network patching should be kept to a minimum, while sections of road should be

rehabilitated for the appropriate traffic loadings, thus improving the design life and asset value of the network.

Where a minimal amount of patching is required for short term necessity, more attention should be put into design, construction practices and testing compliance to obtain better performance.

Since patching has proven to be technically unsound, significantly cost disadvantageous and environmentally unsustainable, while not adding long term value to the pavement asset, caution should be taken when considering maintenance contracts. A lot of maintenance contracts tend to evolve into patching contracts, which disadvantage the client by locking them into wasteful systems that are expensive with regard to whole of life. These patching contracts do not have long term benefit to the pavement network, but perpetuate high income practices for the patching contractors into the future at the expense of the pavement network client.

REFERENCES

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Austroads Report Review of Foamed Bitumen Stabilisation Mix Design Methods June 2010

AustStab (2006) AustStab Construction Tip, No.2B, Skidsteer Stabilisers

AustStab Construction Tip, Stabilisation Patch Width

Figure 1: Small Mobile Roller

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Figure 2: Bag Spreading for Stabilised Patches

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Figure 3: Skidsteer with "Stabilising" Head

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Figure 4: Asphalt Patches

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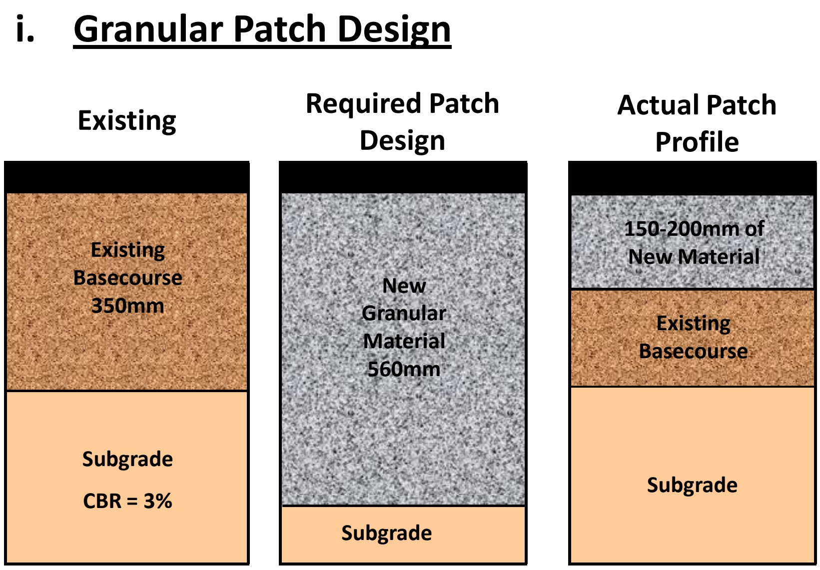

Figure 5: Granular Patch Design

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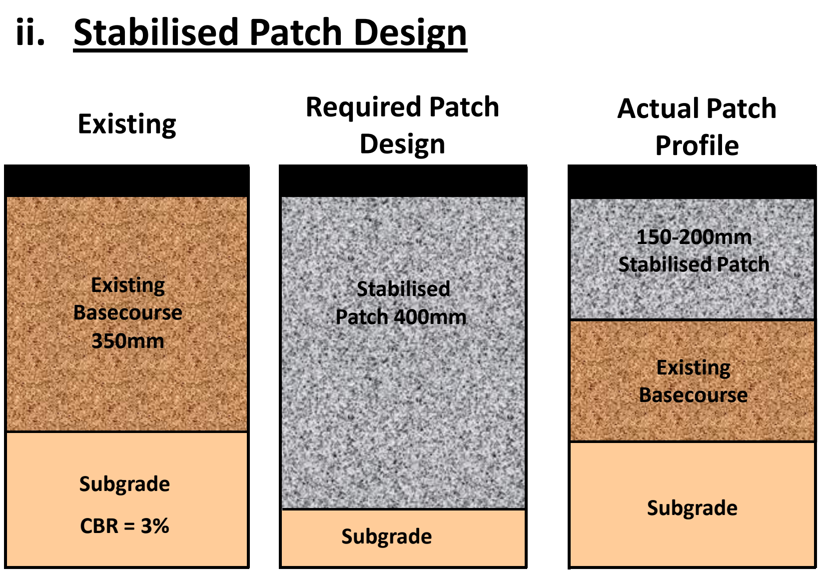

Figure 6: Stabilised Patch Design

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Appendix A

Table 1: Initial Cost Comparisons for Types of Patches

	Type of Patch					
	Granular		**Stabilised**		**Asphalt**	
Situation & Production	150mm Depth per m²	200mm Depth per m²	h150mm Depth per m²	200mm Depth per m²	100mm Depth per m²	150mm Depth per m²
A) Local Govt Road (highly trafficked, approx. 10km from quarry and asphalt products)						
170m²/day	$118.50	$125.97	-	-	-	-
250m²/day	-	-	-	-	$123.32	$153.21
300m²/day	-	-	-	-	$112.73	$142.62
340m²/day	$79.11	$84.55	$73.34	$76.20	-	-
350m²/day	-	-	-	-	$105.16	$135.82
510m²/day	-	-	$59.43	$61.59	-	-
B) Rural Hwy (moderate traffic, approx. 60km from quarry and asphalt products)						
170m²/day	$131.73	$139.96	-	-	-	-
250m²/day	-	-	-	-	$126.68	$157.83
300m²/day	-	-	-	-	$115.95	$147.10
340m²/day	$87.90	$93.94	$81.49	$84.67	-	-
350m²/day	-	-	-	-	$108.29	$139.44
510m²/day	-	-	$66.03	$68.43	-	-

A) Local Government road, highly trafficked, approximately 10km from quarry and asphalt products

B) State Road Authority rural highway, moderate traffic, approximately 60km from quarry and asphalt products

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Table 2: Typical Cost of Patching over a Period

Type of Patch	Typical Cost m²	Daily Prod'n m²/day	Daily Cost 1st Year	10 year Cost @3% inflation	10 year Cost @4% inflation
Stabilised (150MM)	$83.00	300	$24,900	$285,450	$298,952
Granular (150MM)	$90.00	300	$27,000	$309,525	$324,165
Asphalt (100mm)	$115.00	300	$34,500	$395,504	$414,211

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Table 3: Example of Costing using Foamed Bitumen Stabilisation to Rehabilitate Sections of Pavement (including 2 Coat Seal)

1st Year Costs for 2,500m²	2nd Year Costs for 2,500m²	2nd Year Costs for 2,500m²	Total Costs	
			1st & 2nd Year	1st & 3rd Year
$78,200				
3% Inflation	$80,546.00	$82,962.38	$158,746.00	$160,892.38
4% Inflation	$81,328.00	$84,581.12	$159,528.00	$162,781.12

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Warren is a Director of the Stabilised Pavements Group of Companies working throughout Australia, SE Asia and the UK. For over 30 years he has worked specifically in the stabilisation and rehabilitation industry and 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 both in Australia and overseas. He has had significant input into the ongoing introduction of new technologies in stabilisation equipment, practices and different additives. Warren is a member of the Executive Council of the Pavement Recycling and Stabilisation Association (AustStab) and served as President of the Association for 5 years.

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