The Effectiveness of the Application of High Friction Surfacing on Crash Reduction

ABSTRACT

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Transit New Zealand initiated an annual monitoring process of crashes on Auckland motorways in 1992. From the outset, Beca has been involved, continuously providing the consultant and road safety expert inputs into the Team comprising Transit, the LTSA (now Land Transport New Zealand (LTNZ)), the NZ Police and various network management personnel.

Beca' continuous involvement has led to an in depth understanding of issues peculiar to Auckland's Motorway network. While the range of the crash types and issues on motorways are generally limited, every now and then a site presents itself whereby the extent of the problem, the causes or even the solutions are not straight forward.

The Great North Road (Waterview) city bound on ramp on to Auckland's Northwestern Motorway (SH16) is just one such example.

Initially the extent of the crash problem was disguised due to how the Police Traffic Crash Reports (TCR's) are coded. However, when identified it was thought that the loss of control crashes at this site were a simple speed related issue. However closer exanimation showed that speed along with the ramp geometry, seal choice, paint markings, runoff, the shade and the seal types and limits all had a part to play.

A traditional approach may have seen this site simply classified as a 'slippery seal' site resulting in a more frequent reseal programme. However, new treatment solutions are always presenting themselves, and the use of high friction surfacing is one of the more recent engineering solutions to be used in New Zealand.

Hence, the final choice of treatment was high friction surfacing using Calcined Bauxite aggregate, safe hit posts and changes to the sealing programme.

Will the Calcined Bauxite treatment work here? Calcined Bauxite has a very high skid resistance and is generally very effective at reducing rear end and loss of control type crashes and the stone can last for 20 years without polishing. However, we are still learning the limitations of this treatment and its successful application. Wiri Station Road, an urban state highway with a very high percentage of HCV's in south Auckland has shown that such material does not always adhere well when exposed to high braking forces of the heavy vehicles if the road surface is not prepared appropriately. The Greenlane roundabout also initially had issues with premature delamination of the calcined bauxite, yet other sites such as Queen Street in Auckland City centre are a great success with no apparent adhesion issues at present.

1.0 INTRODUCTION

As our knowledge of calcined bauxite treatments increase so to has its use as a means to improve safety on New Zealand roads. However, this product / treatment is still a relatively new tool in New Zealand for the traffic safety engineer, hence the roading industry is still learning about its limitations, correct application proceedures and also just how good it can be.

K. C. Hudson of Duffill Watts & Tse Ltd, presented a paper at the 2003 Traffic Management Workshop in Christchurch that outlined the trails and ultimate success of applying a calcined bauxite treatment to the Wainuiomata Hill Road in Hutt City. This site was a four laned rural strategic road with steep gradients with tight continuous curves. It proved to be a very successful use of calcined bauxite and has dramatically improved safety over the Wainuiomata Hill.

In contrast, this paper reports on the use of calcined bauxite on Auckland's high volume and heavily congested motorway network. The sites under consideration are all Crash Reduction Study Sites that have typically had a number of alternative treatment options trialled prior to the application of calcined bauxite.

All the sites reported in this paper are motorway interchange and ramp sites. No consideration has been given to using calcined bauxite on the motorway itself at present.

- SH16 – Northwestern Motorway: Great North Road On Ramp (eastbound)
- SH16 / 18 Intersection: Motorway On Ramp (eastbound)
- SH1 – Southern Motorway: Greenlane Off Ramp (southbound)
- SH1 – Southern Motorway: Greenlane Off Ramp (northbound)
- SH1 – Southern Motorway: Ellerslie Penrose Interchange

This paper is structured as outlined below:

- Abstract
- Introduction
- Summary of Results
- What are Crash Reduction Studies?
- Surfacing Types & Performance
- Calcined Bauxite – what is it?
- Case Studies

2.0 SUMMARY OF RESULTS

The purpose of this paper is to provide an overview of the calcined bauxite treated sites on the Auckland Motorway network. As the after monitoring period is too short to undertake a detailed analysis at this time, the general trends have been looked at to assist with the selection of other sites that may be considered for treatment.

Both of the on ramp sites (Great North Road & SH16/18) investigated had a loss of control while cornering crash problem. These crashes appear to have been eliminated with the application of the calcined bauxite.

The off ramp sites (Greenlane and Ellerslie-Penrose) in direct contrast have shown little improvement in reducing the crash problems. These sites predominately have a rear end and cross traffic type crash problem. However both sites are heavily trafficked throughout the day and highly congested in the commuter peak periods resulting in aggressive and impatient driver behaviour.

It is therefore our cautious conclusion at this point in time, that while calcined bauxite has proven to be a very successful tool for reducing or even eliminating loss of control and rear end crashes at most sites that it has been used at around the country, its usefulness in addressing these types of crashes in heavily congested areas where aggressive driver behaviour is prevalent is limited (or certainly with respect to Auckland's Motorway network).

3.0 WHAT ARE CRASH REDUCTION STUDIES?

The definition provided in the Land Transport New Zealand 'A New Zealand Guide to the treatment of crash locations' as to what a Crash Reduction Study is, as follows:

> 'CRSs are the process of identifying treatable crash problems by the analysis of historical crash data, inspection of the site and the selection, implementation and monitoring of appropriate countermeasures to relieve those identified problems'

Typically in New Zealand these studies focus on low cost, quick fix solutions. While many larger scale projects may be able to achieve significant crash savings, they are often driven by other factors such as travel time savings and/or for strategic reasons.

3.1 CRASH REDUCTION STUDIES AND AUCKLAND MOTORWAYS

Transit New Zealand initiated an annual monitoring of crashes on Auckland's motorways in 1992. From the outset, Beca has been continuously involved, providing the consultant and road safety expert inputs and advice to a Team comprising Transit, the LTSA (as it was) the NZ Police and various network management personnel.

Beca's continuous involvement in the Auckland motorway CRSs has lead to an in depth understanding of issues peculiar to motorways and Auckland's motorways and interchanges.

Typically, with motorways being multi-laned, median divided roads without intersections, the crash patterns tend to be somewhat limited. Generally speaking, there are three main categories of crashes reported:

- Loss of Control
- Rear End; and
- Lane Changing.

The highest concentrations of crashes on the motorways tend to be near the interchanges or where lane changing occurs associated with the interchanges.

However, the motorway interchange ramp intersections with local roads tend to have a broader range of crash types, typically including a variety of turning type and rear end type crashes. The on ramps themselves are often dominated by loss of control type crashes.

The sites reported on in this paper are a variety of off ramp / arterial road intersections and mid section on ramps with varying degrees of congestion.

3.1.1 Note on Crash Rates

Care needs to be taken when comparing crash statistics associated with Auckland motorways with typical averages for the country. While it can be assumed that the reporting rate for fatal and serious crashes are consistent throughout the country, the same cannot be said for the minor and non-injury type crashes on Auckland motorways. Based on experience using data from the LTNZ AIS & CAS databases, it has been calculated that the reporting rate on Auckland's motorways can be as much as 3 times higher than the rate for all other 100kph roads in New Zealand. This is largely due to the heavily congested nature of the Auckland Motorways, meaning that even a very minor (non-injury) crash can cause major disruption to the traffic and hence requires police intervention and consequently reporting. A second factor is that over the past few years there has been a significant increase in the policing of the motorways, again resulting in higher reporting, and therefore skewing the reporting rates on the motorways themselves over the last ten years.

For the five year period 1993-1997, the motorway injury crash rate was 13.4 crashes per 100 million vehicle kilometres (100MVK). By the conclusion of the 2004 monitoring round (the five year period 1999-2003) this had fallen to 11.6 per 100MVK.

Adjusting these rates to take account of the higher reporting rate on the motorways has these figures drop to 6.1 and 3.2 per 100MVK respectively for each of the above periods.

It should also be noted that due to the high level of congestion, and hence lower vehicle speeds a large proportion of the reported crashes on the motorway are either non-injury or minor crashes.

4.0 SURFACING TYPES & PERFORMANCE

The current pavement of choice on Auckland's motorway network is OGPA for its water shedding ability, i.e. resulting in a reduction in aquaplaning and water spray). However, some international practice seems to indicate a tendency to be leaning towards the use of SMA surfacing as they have better friction and durability / longevity characteristics. Auckland does experience high rainfall in comparison to other cities around the world and hence the use of SMA may not be as appropriate, however some sites are currently being trialled.

Both OGPA and SMA have there own characteristics, benefits and drawbacks. These are briefly described below:

SMA: A GAP graded asphalt mix, with or without fibres containing a large proportion of course aggregate, which interlocks to form a skeletal structure to resist permanent deformation. It has relatively high binder content; approximately 7% to provide mix cohesion. SMA has good short-term skid resistance characteristics; say around two years (as the stone polishes over time). SMA has an excellent texture of which meets Transit requirements.

OGPA: OGPA is a bituminous mix using predominately coarse aggregate and containing only a small amount of fie material, and provide a high percentage of air voids, approximately 25%. It has a porous surfacing and is used to reduce water spray, mainly on high-speed routes, say >80kph environment. OGPA polishes quickly with time resulting in a poor skid resistant surface.

5.0 CALCINED BAUXITE – WHAT IS IT

All calcined bauxite chip is currently imported into New Zealand, a key source of the chip is from mainland China. It is manufactured by roasting bauxite ore in a kiln at high tempretures. It typically has a Polished Stone Value (PSV) greater than 70 and a chip diameter of 1 – 3mm. The chip is very hard, and due to its small size it is very resistant to polishing.

Calcined bauxite is used as a surface treatment only as it has no structural properties. It relies on the integrity of the pavement below and appropriate surface preparation to ensure proper adhesion. The binder used is a thermosetting modified epoxy compound. It cannot be applied directly onto OGPA surfaces, rather it is applied to a dense graded asphalt mixes.

The advantages of a calcined bauxite surfacing are:

- Reduced braking distances;
- High skid resistance in wet and dry weather;
- Proven crash reduction record;
- It is a long-term treatment;
- Excellent colour delineation; and
- It is oil resistant.

5.1 PSV SELECTION REQUIREMENTS

Selection of PSV requirements in NZ is driven by the formula defined in the TNZ T/10 specification. The formula requires a higher PSV as the percentage of HCV (heavy commercial vehicles) increases. The formula is:

PSV = 100 x SR + 0.00663 x CVD + 2.5

Where SR is the investigatory level (currently 0.55 for approaches to roundabouts, traffic lights, stop and Give Way Controlled intersections). CVD is the number of commercial vehicles per lane per day at the end of the surfacing life.

6.0 CASE STUDIES

6.1 OVERVIEW

The following sites discussed in this paper:

- SH16 – Northwestern Motorway: Great North Road On Ramp (eastbound)
- SH16 / 18 Intersection: Motorway On Ramp (eastbound)
- SH1 – Southern Motorway: Greenlane Off Ramp (southbound)
- SH1 – Southern Motorway: Greenlane Off Ramp (northbound)
- SH1 – Southern Motorway: Ellerslie-Penrose Interchange

6.1.1 Notes

The reader should note that at many CRS sites under investigation throughout the country deal with between 6-12 crashes of commonality over a typical 5 year evaluation period. For motorways sites, it is quite common to get 6 – 12 crashes reported per year due to the shear volume of traffic and high level of police monitoring and hence reporting. This aspect needs to be kept in consideration when reviewing the number of crashes on the motorways.

All reported crash history comes from the land Transport New Zealand (LTNZ) Crash Analysis System (CAS) database. The period extracted is from 1994 – 2004. Due to the timing of this paper it is likely that not 2004 data is currently entered into the database and this needs to be kept in mind when reviewing the crash record.

It is also difficult at this point in time to state the overall benefits of the various calcined bauxite treated sites due to the limited time since some of the applications. However general trends are evident.

Experience has shown that reseals on the Motorways generally result in no, or very few crashes being reported for up to 12 months following the reseal date. This can be used a guide as to the overall effectiveness of the calcined bauxite treatments in the motorway environment due to the limited ‘after’ evaluation period.

6.2 SH16, NORTHWESTERN MOTORWAY, HOBSONVILLE ROAD (SH18) ON RAMP, EASTBOUND

6.2.1 Site Description and Issues

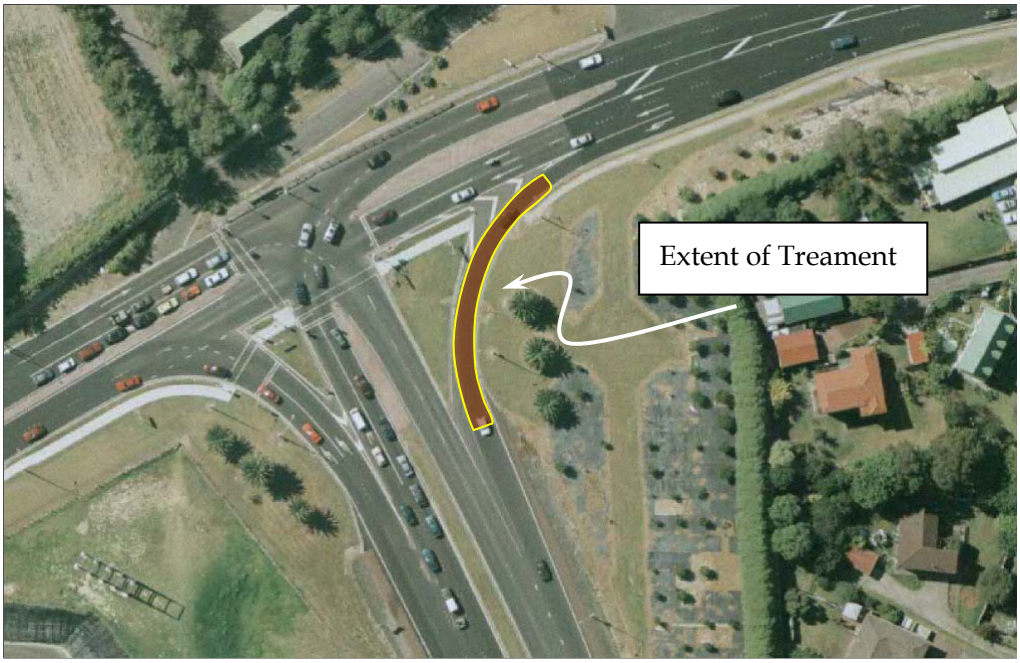
This was the first of the Auckland motorway sites to be treated with calcined bauxite. This site had proved problematic for some time prior to this treatment with respect to 'DB' loss of control type crashes while cornering. The key issue with the site is the relatively tight on ramp radius combined with the drivers expectation of being able to accelerate up to motorway speeds.

Consideration was given to altering the super elevation of the curve but this was not practical based on the funding criteria at the time. Consideration was also given to repositioning the speed advisory sign and adding a 'Turn left with care' sign, however it was not felt that they would have any more than a minor impact. The final recommendation was to trial a calcined bauxite treatment at this site.

The aerial photo below shows the horizontal geometry and the extent of the calcined bauxite treatment at this site.

Figure 1

Northwestern Motorway, SH16 / 18 Intersection, Eastbound



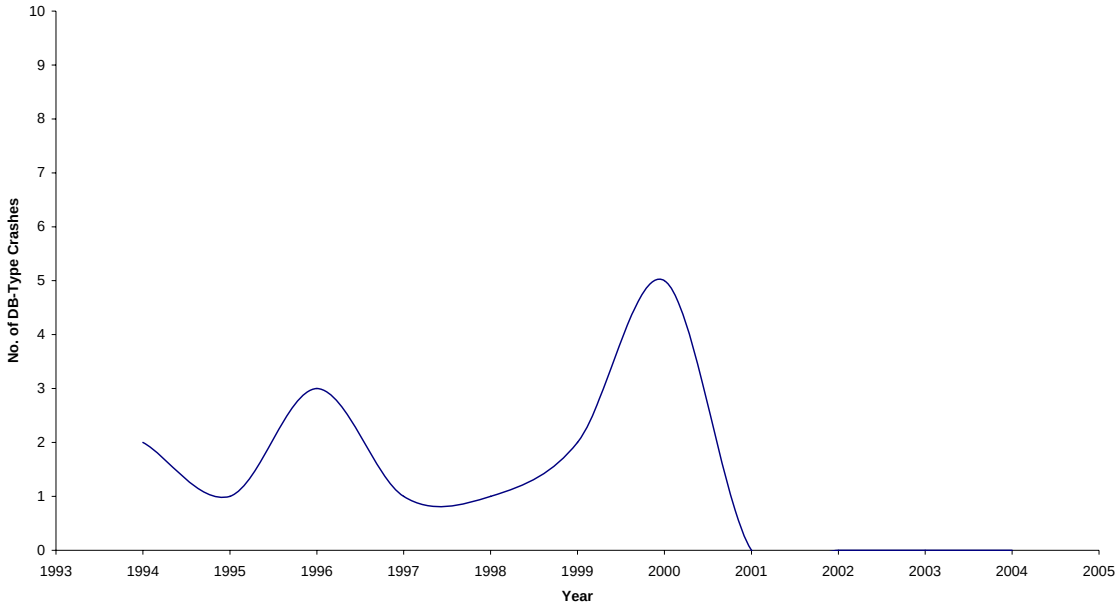
6.2.2 Crash History

The reported crash history for this site was extracted from the LTSA CAS database and is summarised below:

Table 1
Reported Crash History, 1994 - 2004

Year	Loss of Control (DB Crashes)	Comments
1994	2	
1995	1	
1996	3	
1997	1	
1998	1	
1999	2	
2000	5	
2001	-	Calcined bauxite treatment applied April 2001
2002	-	
2003	-	
2004	-	

Figure 2
Reported Crash History, 1994 - 2004



6.2.3 Discussion

It is evident from the reported crash history that the use of calcined bauxite at this site has been a great success. This site was treated in April 2001 and no loss of control type crashes have been reported since the calcined bauxite was put in place and no other crash types are being reported on the treated section of this on ramp.

6.3 SH16, NORTHWESTERN MOTORWAY, GREAT NORTH ROAD ON RAMP, EASTBOUND

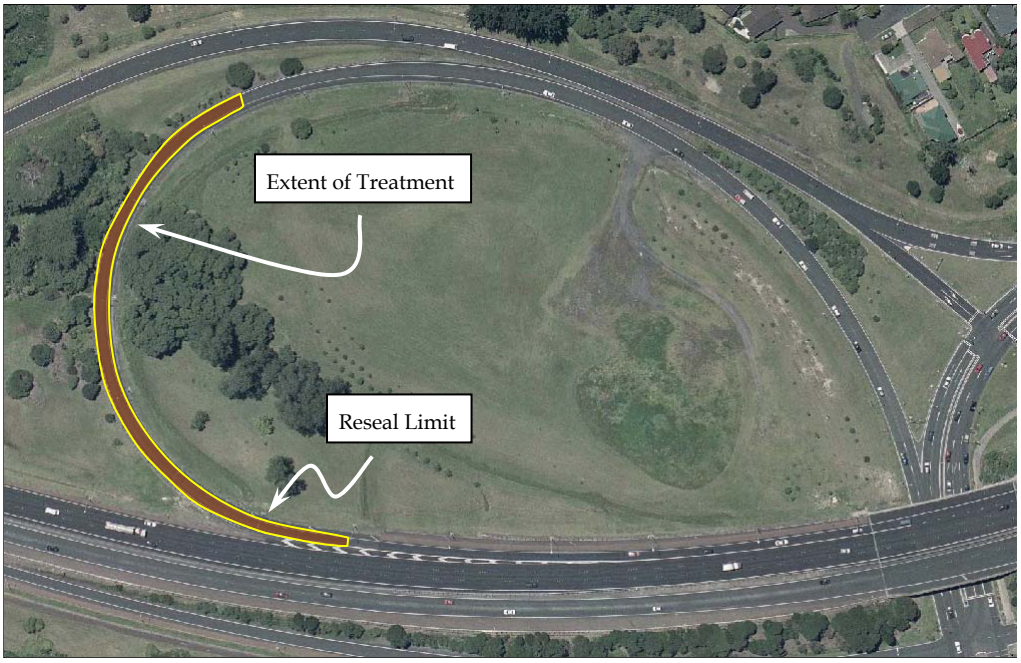
6.3.1 Site Description and Issues

This was the second Auckland motorway site to be treated with calcinded bauxite. This site had proved problematic for some time prior to treatment and had a poor crash history. The key issue with the site is that the ramp radius tightens on the approach to the motorway merge. Being a motorway on ramp, motorists are inclined to try to accelerate up to motorway speed despite the decreasing radius and the 55kph speed advisory sign. The consequence is the concentration of reported loss of control crashes at this site.

Other issues and features of this site include a pavement surface that is kept in the shade and is damp due to adjacent trees and watercourse; a seal joint near the end of the on ramp, that is part way through a horizontal curve; and traffic merging across the painted gore area.

The aerial photo of the site shows the horizontal geometry, the extent of the calcinded bauxite treatment, the vegetated area and the location of the two adjacent seal areas.

Figure 3
Great North Road On Ramp
Aerial Photo



6.3.2 Crash History

The reported crash history for this site was extracted from the LTNZ CAS database and is summarised below:

Table 2

Northwestern Motorway, Great North Road On Ramp, Eastbound

Reported Crash History, 1994 - 2004

Year	AADT	Total Reported Crashes	Loss of Control Crashes	Lane Changing Crashes	Rear End	Comments
1994	13,593	2	2			
1995	14,595	4	4			
1996	14,896	10	9	1		
1997	12,784	6	5	1		
1998	13,243	6	6			
1999	13,438	-	-			Resealed in March 1999
2000	13,272	7	7			
2001	14,420	7	6		1	
2002	16,040	8	6	1	1	
2003	16,190	3*	3*			Calcined bauxite treatment applied April 2003
2004		-	-			

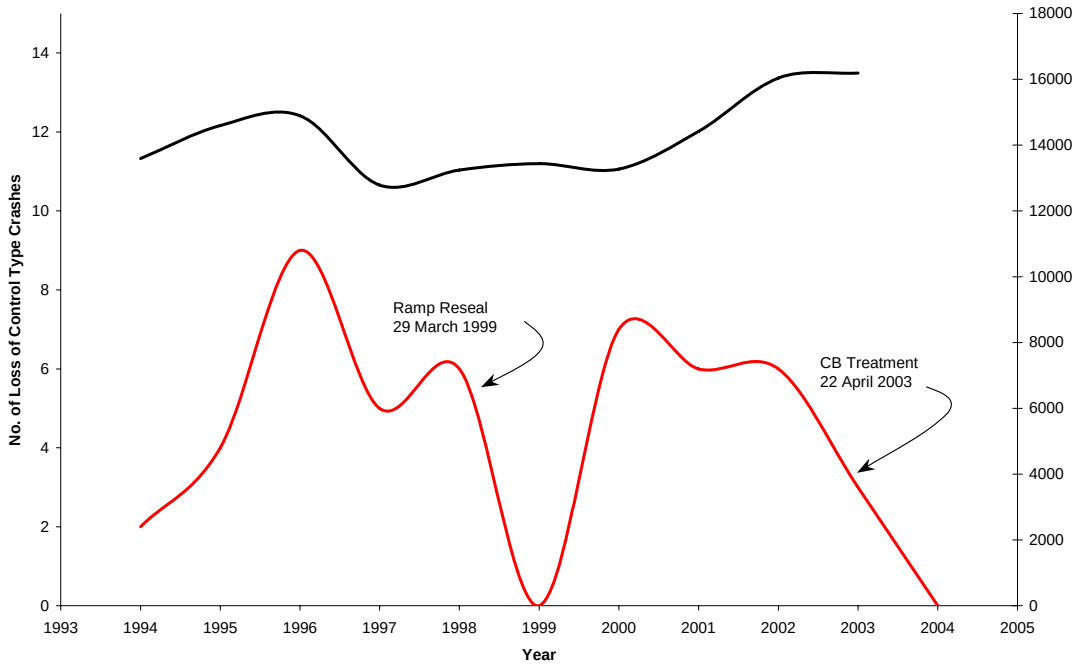
* These three crashes were reported as occurring prior to the 2003 calcined bauxite treatment.

Note: There are a number of crashes that are reported in the merge area that are not included in the table above as they do not directly relate to the CB treatment. They predominately relate to loss of control crashes associated with the seal joint prior to the merge, loss of control from vehicles accelerating across the painted merge area, and merging type crashes. These crash types have also been eliminated by these works.

Figure 4

Northwestern Motorway, Great North Road On Ramp, Eastbound

Loss of Control Type Crashes & AADT



Key: AADT No. of Crashes

6.3.3 Discussion

To fully understand the issues at this site, the following paragraph briefly describes two other issues and measures that were implemented around the time of the calcined bauxite treatment.

The extent of the crash problem at this site was partially disguised due to the manner in which the crashes are recorded in the Police Traffic Crash Reports (TCR's) and coded into the LTNZ CAS database. There were many loss of control type crashes reported as occurring at the merge area that involved vehicles that had lost control on the on ramp or when crossing the painted gore area but were recorded as being on the motorway itself as that is where the vehicle came to rest and hence were not initially associated with the on ramp geometrics.

The bulk of these crashes were addressed by two additional remedial works. The first measure was to redefine the seal programme extents to move the current seal limit on the on ramp further east to a point where it was no longer on the horizontal curve. The problem was that the two adjacent seals were being done at different dates and wearing differently meaning a change in surface friction from one seal to the next, hence resulting in loss of control type crashes. The second measure was to install safe hit posts to stop motorists from crossing the painted gore area, as it appeared that motorists were losing control on paint markings themselves.

Both of these measures were implemented prior to the calcined bauxite surfacing and would have been considered necessary as part of the calcined bauxite treatment to ensure that

motorists stayed on the treated area and also had seal with the same properties throughout the horizontal curve.

The crashes contained in Table 2 and Figure 4 relate solely to the crashes considered to be a consequence of the horizontal geometry of the on ramp and do not include any merging type crashes.

This on ramp was resealed in its entirety in March 1999 with OGPA. As could be expected this resulted in an immediate reduction in the number of crashes being reported. In fact there were no crashes for a nine month period, but after this time as the surface polished the crash problem returned. As of February 2005, it is 22 months since the calcined bauxite treatment was implemented and only one loss of control type crash has been reported. This solitary crash involved a truck; and the TCR indicates that the driver was charged with careless driving. Hence it was unlikely that any engineering solution would have prevented that crash. While it is still early in the monitoring period, it is expected that this site will continue with its impressive start to eliminating the loss of control problem at this site.

6.4 SH1, SOUTHERN MOTORWAY, GREENLANE OFF RAMPS

6.4.1 Site Description and Issues

Both the Greenlane and the Ellerslie-Penrose (see next section) Interchanges have been monitored continuously from the onset of the Motorway CRS Studies in 1992. Both interchanges have an overhead roundabout connecting the on and off ramps and feed key urban arterial roads. Both sites are very heavily trafficked and have had a poor crash record. Both have had different calcined bauxite treatments applied.

The aerial photo below shows the Greenlane Interchange and the extent of the calcined bauxite treatment at this site.

Figure 5
Greenlane Interchange

6.4.2 Crash History

The reported crash history for this site was extracted from the LTNZ CAS database and is summarised below:

Table 3
Greenlane Off Ramp, Southbound
Reported Crash History, 1994 - 2004

Year	AADT	Total Crashes	Rear End	Cross Traffic	Other	Comments
1994	15,254	5	3	2		
1995	15,238	9	7	2		
1996	15,720	9	9			
1997	15,273	7	7			
1998	13,890	4	4			
1999	13,799	8	8			
2000	13,928	5	4		1	
2001	14,165	6	6			
2002	13,132	7	7			Calcined Bauxite Treatment in January 2002
2003	14,267	5	5			
2004		4	4			

Table 4
Greenlane Off Ramp, Northbound
Reported Crash History, 1994 - 2004

Year	AADT	Total Crashes	Rear End	Merging	Other	Comments
1994	8419	5	5	1		
1995	8349	3	2	1	1	
1996	8740	5	3			
1997	9179	2	2	1		
1998	9168	5	4		1	
1999	8678	3	2			
2000	8728	5	5	1	1	
2001	8651	11	9		1	
2002	8233	8	7	2	1	Calcined Bauxite Treatment in January 2002
2003	9638	9	6			
2004		5	5			

Figure 6
Greenlane Off Ramp, Southbound
Reported Crash History, 1994 - 2004

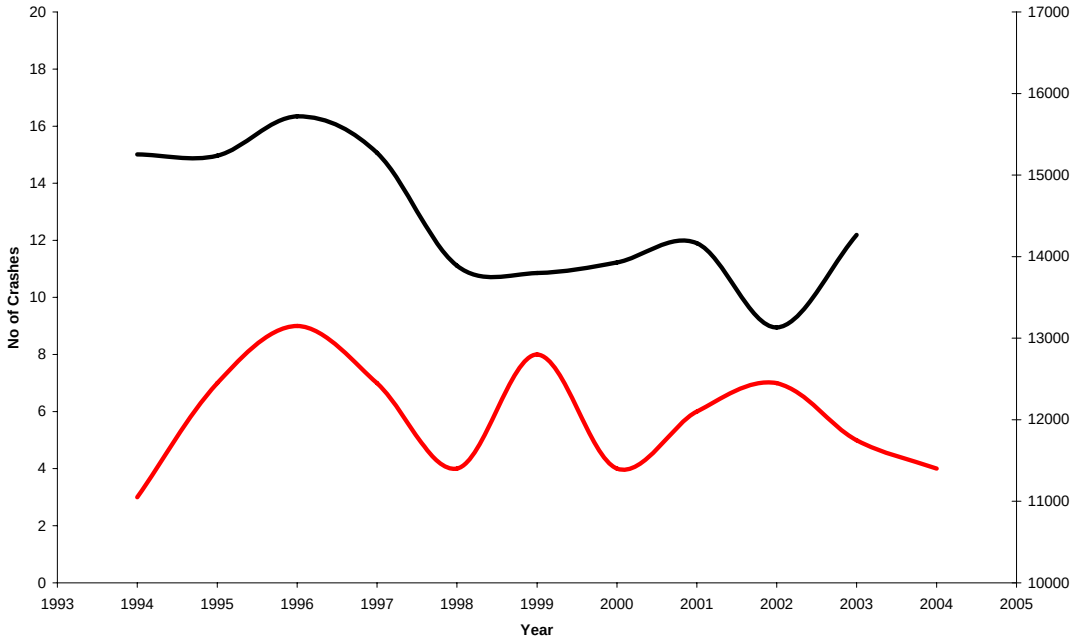
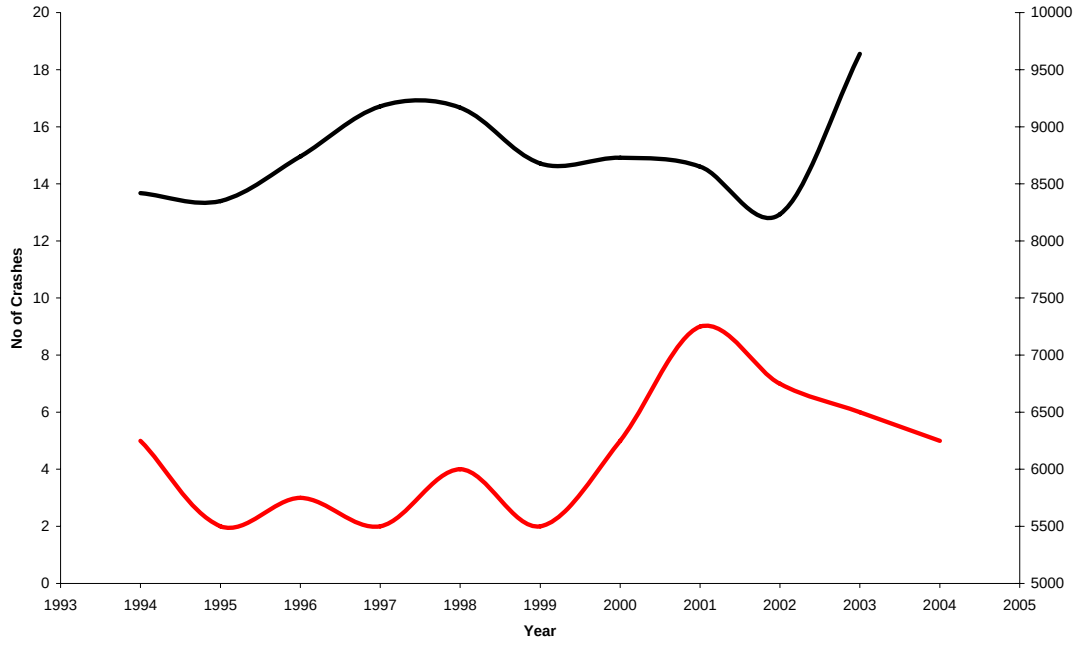


Figure 7
Greenlane Off Ramp, Northbound
Reported Crash History, 1994 - 2004



Key: AADT No. of Crashes

6.4.3 Discussion

Both the Greenlane on and off ramps were treated with a calcined bauxite surfacing in January 2002. The ensuing three years has indicated little change in the number of crashes or any change in crash severity. It is known that this site initially had some problems with delamination of the calcined bauxite, a problem that has been evident at several sites throughout Auckland. However the delamination, which has since been rectified is not considered to have impacted on the lack of reduction in the number of crashes being reported.

With calcined bauxite being a contrasting colour to the typical SMA and OGPA, or any asphaltic surfacing, it is highly visible when any delamination occurs, even when it is only very small areas (say the size of a fifty cent coin) that is effected. Hence we believe that it is often results in an aesthetic issue rather than any real reduction in the over effectiveness of the treated site.

It is our opinion that the key issue with this site is the high level of congestion that is present in terms of the lack of noticeable improvement in the crash trends. This interchange serves a key urban arterial road (Greenlane East and West) and hence is heavily trafficked throughout the day and highly congested during the morning and evening commuter peak periods. It is therefore now appears that the provision of a high friction surfacing will have little impact on the crash record. This is primarily due to driver impatience and aggressiveness resulting in following distances between vehicles that are generally too small and the hence the reaction time is insufficient to prevent the crashes from occurring, regardless of the surfacing. Hence the choice of this type of surfacing treatment should be used with caution at sites such as this. While very early in the monitoring period, it is anticipated that the Ellerslie-Penrose site will display similar results.

6.5 SH1, SOUTHERN MOTORWAY, ELLERSLIE-PENROSE INTERCHANGE

6.5.1 Site Description and Issues

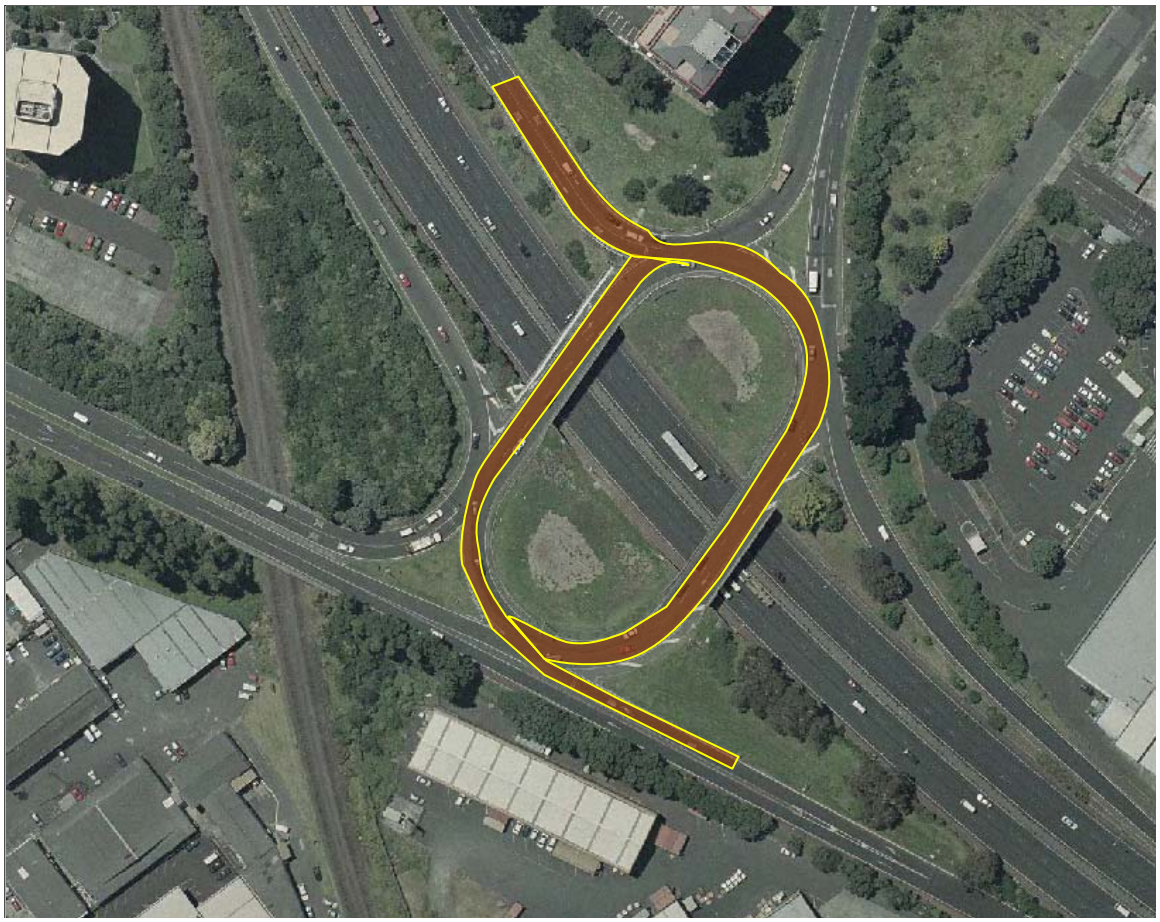
Both the Ellerslie-Penrose and GreenLane Interchanges have been monitored continuously from the onset of the Motorway CRS Studies in 1992. Both interchanges have an overhead roundabout connecting the on and off ramps and feed key urban arterial roads. Both sites are very heavily trafficked and have had a poor crash record. Both have had different calcined bauxite treatments applied.

The aerial photo following shows the Ellerslie-Penrose Interchange and the extent of the calcined bauxite treatment at this site.

Figure 8

Ellerslie-Penrose Interchange

Extent of Calcined Bauxite Treatment



6.5.2 Crash History

The reported crash history for this site was extracted from the LTSA CAS database and is summarised in the following Table:

Table 5

Reported Crash History, 1994 - 2004

Year	Total Crashes	Comments
1994	24	
1995	21	
1996	31	
1997	23	
1998	13	
1999	14	
2000	23	
2001	23	
2002	16	
2003	34	
2004	11	Calcined Bauxite Treatment in June 2004

6.5.3 Discussion

Like the Greenlane interchange, this site is heavily trafficked throughout the day and highly congested during the commuter peak periods.

This site has had both of the off ramps as well as the circulating lanes of the roundabout sealed with calcined bauxite. This was undertaken in June 2004, meaning that the monitoring period is too short to start to draw any conclusions from, especially as the CAS database is unlikely to be up to date with the last six months data from 2004. Taking this into account, it would appear that like the Greenlane site, the calcined bauxite is going to have little effect on reducing the number of crashes at this site. This again is due to the high level of congestion present and reaction times being insufficient for the following distances and aggressiveness displayed by drivers at this location.