THE APPLICATION OF ASYMMETRICAL DESIGN PRINCIPLES TO RURAL ROADS

A Road Safety Study by Stephen Levett

ABSTRACT

The aim of this paper is to introduce alternative and pragmatic “brownfield” design principles that when retrofitted to existing high speed, undivided rural roads are expected to have a significant effect on reducing the road toll, yet also provide considerable savings in ongoing road maintenance costs.

Although the percentage of run off road crashes varies according to individual routes, they usually form the major component of total road crashes on the rural road network. Run off the road crashes on high speed, undivided rural roads cost the NSW community about $360 million per year and result in approximately 80 deaths per year. The only way to reduce the high number of these type of crashes is to take a more pragmatic view of what is practical and achievable in reconstructing and maintaining the existing rural two lane road network in a safe but affordable way.

Previously, Road Design Guides concentrated on “best practice” principles for designing “greenfield” type road projects and rarely addressed what was practical and achievable for existing road alignments and formations. The implementation of asymmetrical design principles is aimed at addressing this lack of design direction when confronted with what is regarded as acceptable practice on ”brownfield” projects. It concentrates on reducing crashes as the major concern and achieves maximum impact by focusing scarce road safety and road maintenance funding resources towards those sections of rural road that have the most off road crashes and that will return the most safety benefits. It also has the extra benefit of curbing the over-design of “brownfield” maintenance and reconstruction projects by restricting the design parameters to a practical level of maximum benefit return for a minimum construction cost.

Most of the effective behavioural and driver-focused crash reduction programs have been in place for a number of years and have had their maximum impact. The continuation of these programs will only have a holding effect on reducing the NSW road toll and it is now expected that most road toll reduction will have to be achieved by safety engineering works that make the existing road network safer.

The application of Asymmetrical design principles is seen as a more practical and economical alternative in applying safety engineering on two lane rural roads and could be expected to have a major long-term impact on reducing casualty crashes in NSW.

AN ASSESSMENT OF THE RURAL ROAD SAFETY PROBLEM

Crashes on country roads in NSW have not decreased as much as metropolitan crashes in recent years. People living in rural areas are approximately three times more likely to be killed when involved in a road crash than people living in metropolitan areas.

The existing country road network in NSW is administered either by the State Government or by Local Councils. Many country roads were built many years ago to lower design standards that may have been appropriate for the time but are now inadequate to cope with the high-speed vehicles of today.

The NSW Roads & Traffic Authority (RTA) manages 17,624 km of State Roads, including 3,105 km of National Highways. This includes facilities such as traffic lights, roundabouts, signs and line marking. It also manages nearly 3,000 km of Regional Roads and Local Roads in the unincorporated area of NSW where there are no local councils.

The ongoing upgrading of rural roads has lead to high-speed sections of new road alignment abutting older sections with a lower standard of alignment and narrow formation. This type of network can result in inappropriate speeding though the lower standard sections.

Country crashes often result in greater numbers of fatalities and injuries because;

* vehicles are usually travelling at higher speeds.
* long distance travel is more susceptible to fatigue.
* the roadside environment of trees and other objects is less forgiving at these high speeds.
* crashes are more likely to occur in remote locations where it is difficult to contact emergency services.
* emergency service response times are longer.

The road environment is a partial contributing causal factor in 28% of all crashes, however it often has a much higher impact on the outcome of crashes.

CURRENT ROAD DESIGN PRACTICES

The current practice in rural road design is to use “Greenfield” design standards for parallel lanes, medians and shoulders, except for some minor widening of the lanes in curves to allow for vehicle tracking. This is considered to be acceptable on high speed dual carriageway freeway type roads but on two lane undivided rural roads it has lead to limited resources being spent on trying to achieve cross section standards that in many cases are economically unjustifiable or physically unattainable.

CURRENT ROAD MAINTENANCE PRACTICES

Historically, road maintenance practices have continued to perpetuate these design requirements by persisting to maintain the existing road formation and pavement.

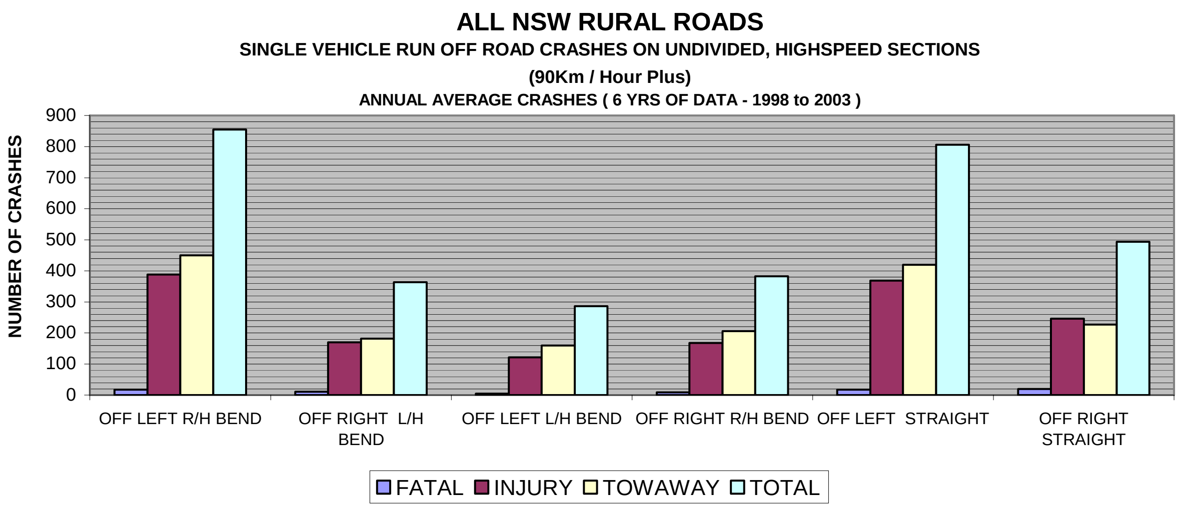
A recent study of single vehicle crash types on undivided rural roads, as well as an interrogation of Road Safety Strategy's stereotypical rural road crash database has prompted a re-visiting of how existing rural roads should be best maintained and/or upgraded to minimise expenditure yet maximise road safety outcomes on the rural road network.

This study has lead to the development of alternative design principles whose pragmatic application could lead to savings in road maintenance costs but still have a significant effect in reducing the rural road toll.

JUSTIFICATION FOR APPLYING ASYMMETRICAL DESIGN PRINCIPLES

A study of current crash data shows a consistently high level of run off the road crashes on high speed (90km/hr plus), undivided roads in New South Wales. There has been an annual average of 3,187 run off the road crashes on this road type over the six years between 1998 and 2003. These have resulted in high numbers of fatal crashes (Ave. 79 per year) and injury crashes (Ave. 1,464 per year) and have a total annual average community cost of $361.7 million (2003 crash costs).

A recent investigation of run off road crashes by crash type shows that 27% of those occurring on high speed, undivided roads are run off the road to the left on a right hand curve (OL/RHC) crashes. It also shows that off the road to the right on a left hand curve (OR/LHC) crashes comprise 11% of all run off road crashes. This difference of 16% can be explained by assuming that many vehicles that lose control on a left hand curve regain control in the pavement area made up of the opposing lane and shoulder, if they are not involved in a head-on crash first. The obvious conclusion from the difference in these two types of crashes indicates that widening the outside of curves (the left hand side of right hand curves in both directions) will have a similar effect in reducing OL/RHC crashes, the major type of run of road crashes on high speed rural roads.



A study of fatal crash reports for the three years from 2002 to 2004 showed that a conservative figure of 38% of off road to the right on a right hand curve (OR/RHC) crashes *(12% of total off road crashes)* were initially a loss of control on the left hand side of the curve with over-correction. This figure is regarded as very conservative as another 40% of the police fatality reports hinted at a loss of control on the left hand side of the road but did not categorically state it. This indicates that well over

50% of OR/RHC crashes could be reduced by appropriate safety remedial works undertaken on the left hand side of right hand curves.

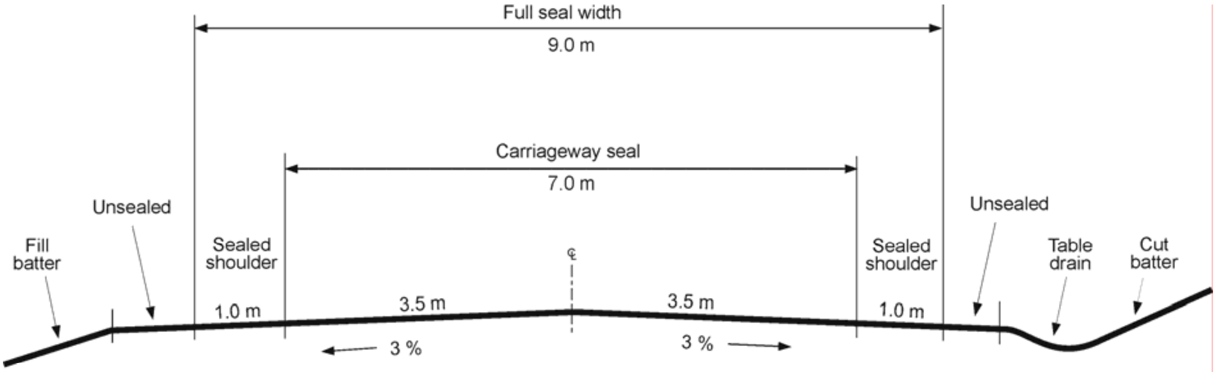
As the percentage of curved road alignment is small in relation to the total length of any road, the actual occurrence for these types of crashes is proportionally much larger than for straight road alignment type crashes. These figures also indicate that concentrating remedial works on high speed rural roads to the left hand side of right hand curves in both directions could reduce up to 45% of run off road crashes by varying percentage rates according to the treatments being implemented.

STRAIGHT ROAD SECTIONS

On straight sections of high speed rural roads, off road to the left crashes contribute to 25% of the total off road crashes, with off road to the right crashes contributing only 15% of the total off road crashes. This is despite the fact that straight sections of alignment form the major proportion of most rural roads.

An analysis of the RTA's stereotypical rural road crash database indicates that where a straight section of road has no sealed shoulders then the crash rate averages 42.5 crashes per 100 million vehicle kilometres (100MVK). If the shoulders are sealed to a width of 0.5 metres then the crash rate falls to 31.8 crashes per 100MVK, a reduction in crash rate of 25%. Extending this sealed shoulder width to 1.0 metre, further reduces the crash rate to 26.4 crashes per 100MVK, a reduction of 38% in crash rate. The crash rate for 1.5 metre sealed shoulders is 24.5 crashes per 100MVK (42% reduction) so there is only a 4% improvement in crash rate reduction in sealing shoulders on straight sections of rural road to greater than 1.0 metre. This does not include standard requirements for standing areas off the carriageway, which do not have to be paved to be functional.

The outcome from this analysis indicates that if the shoulders on straight sections of rural roads are sealed to between 0.5 metres to 1.0 metre in width then there is a 25% to 38% reduction in crash rates. Sealing any wider than this along straight sections has only a very small incremental benefit in further reducing run off road crashes.



STRAIGHT ALIGNMENT

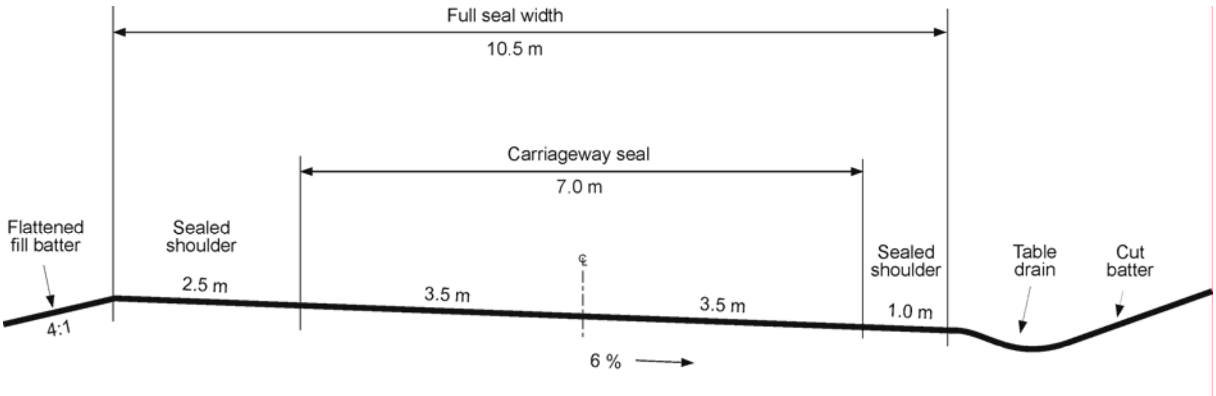
(ANY EXTRA EXISTING PAVEMENT WIDTH SHOULD BE USED TO SEPARATE OPPOSING TRAFFIC BY INSTALLING A PAINTED MEDIAN)

It is considered more important that adequate traversable clear zones are available along straight sections of road, as more fatal crashes occur off to the right on straights than off to the left. This is probably an indication that off to the left on a straight crashes are often a result of inattentive driving where some braking is applied before impact. The converse is that off to the right on a straight are more likely to be fatigue related and are at a higher speed due to the lack of braking at impact.

An investigation into off road crashes on rural roads into trees shows an average of 44 fatal crashes per annum along with 505 injury crashes per annum. These, along with 621 towaway crashes, give an annual average community cost of $156 million (6 years data from 1997 to 2002 at 2003 crash costs) in NSW. This shows that crashes into trees contribute to 43% of the total off road crash costs each year and it also indicates that there would be good value in ensuring that appropriate clearzones on rural roads are well maintained.

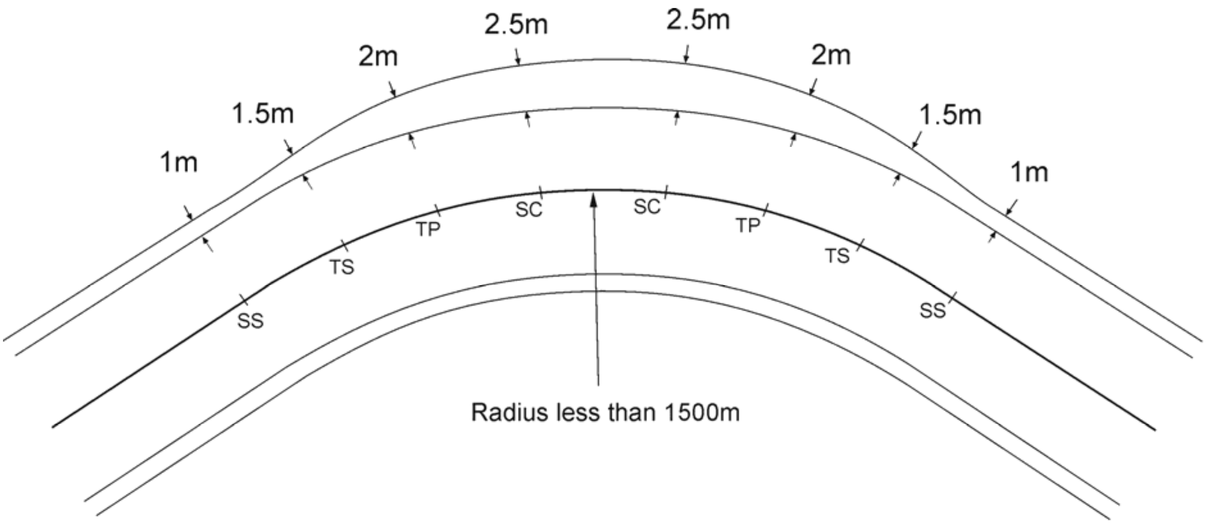
CURVED ROAD SECTIONS

The above crash data indicate that to maximise the reduction in run off road crashes and their severity on high speed rural roads then remedial works should be concentrated on the curved sections of alignment. They should then be further concentrated to the left hand side of right hand curves. This is because it is considered that safety remedial treatments on these curves would greatly reduce OL/RHC crashes, OR/LHC crashes as well as many OR/RHC crashes.



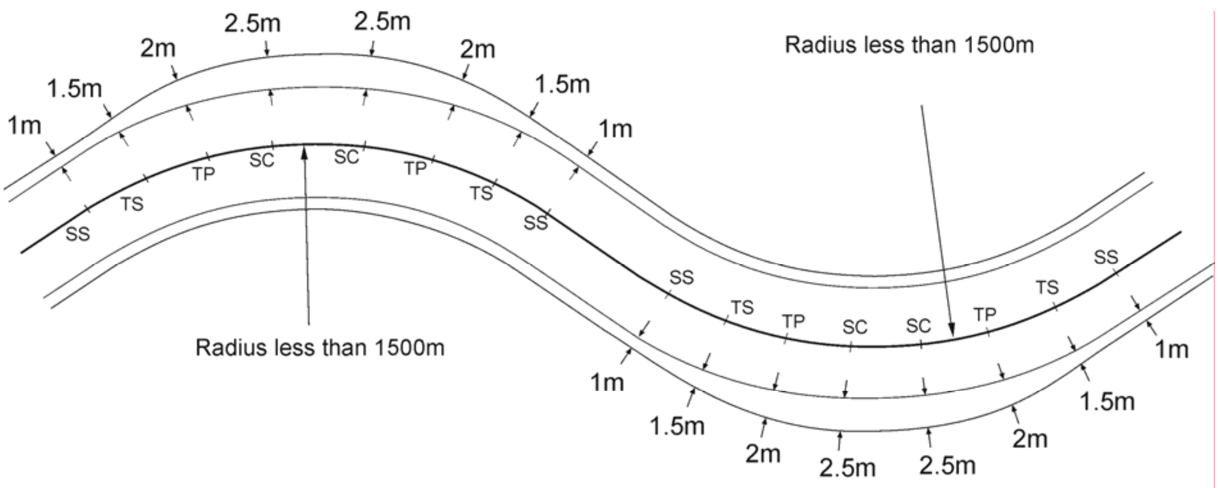
RIGHT HAND CURVE ALIGNMENT
(RADIUS 400 METRES)

Where the alignment is made up of long straights and isolated curves then the outside of all curves less than 1500m in radius should be treated.



GENERALLY STRAIGHT HORIZONTAL ALIGNMENT WITH SINGLE ISOLATED CURVES

Where the alignment is comprised of long straights and reverse curves with radii of less than 1500 metres then the outside of each curve should be treated.



GENERALLY STRAIGHT HORIZONTAL ALIGNMENT WITH REVERSE CURVES

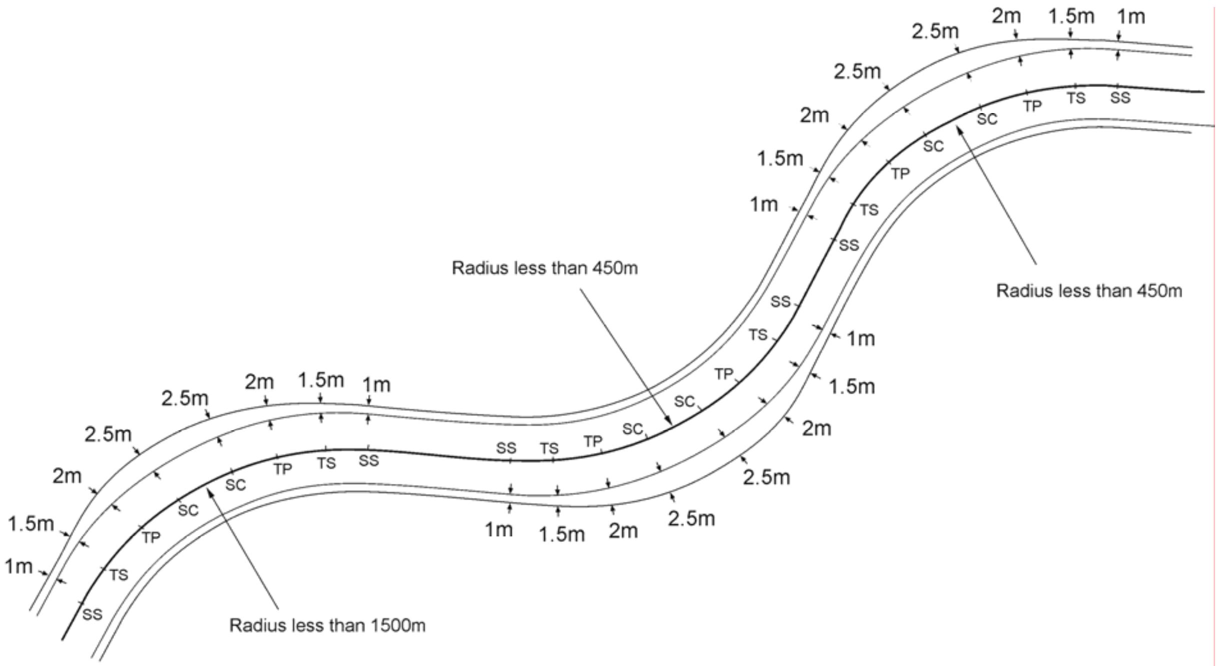
The remedial treatments available are:

- widen and seal shoulders from 1.0m wide at the start of the superelevation transition through to 1.5 metres wide at the Tangent/Spiral point then to 2.5 metres wide at the Spiral/Circular Curve point and carry this 2.5m width through the curve and then transition back to 1.0m wide at the finish of the superelevation transition. NB: Where these shoulder widths are unattainable due to terrain constraints then they should be the best that can be achieved under the circumstances and other complementary treatments such as safety barrier added.

- install advisory curve speed warning signs where appropriate
- install profile edge-line marking and/or raised retro-reflective pavement markers from the start of the superelevation transition to the finish of the superelevation transition
- increase super-elevation on sealed shoulders through the curve from approach Spiral/Circular Curve point to the departing Spiral/Circular Curve point where possible
- install Curve Alignment Markers (CAMS)
- remove roadside hazards at the back of the curve and level out batter slopes to at least 4:1 to create a safe run-off area **OR** install an appropriate safety barrier where a run-off area is not available or achievable.

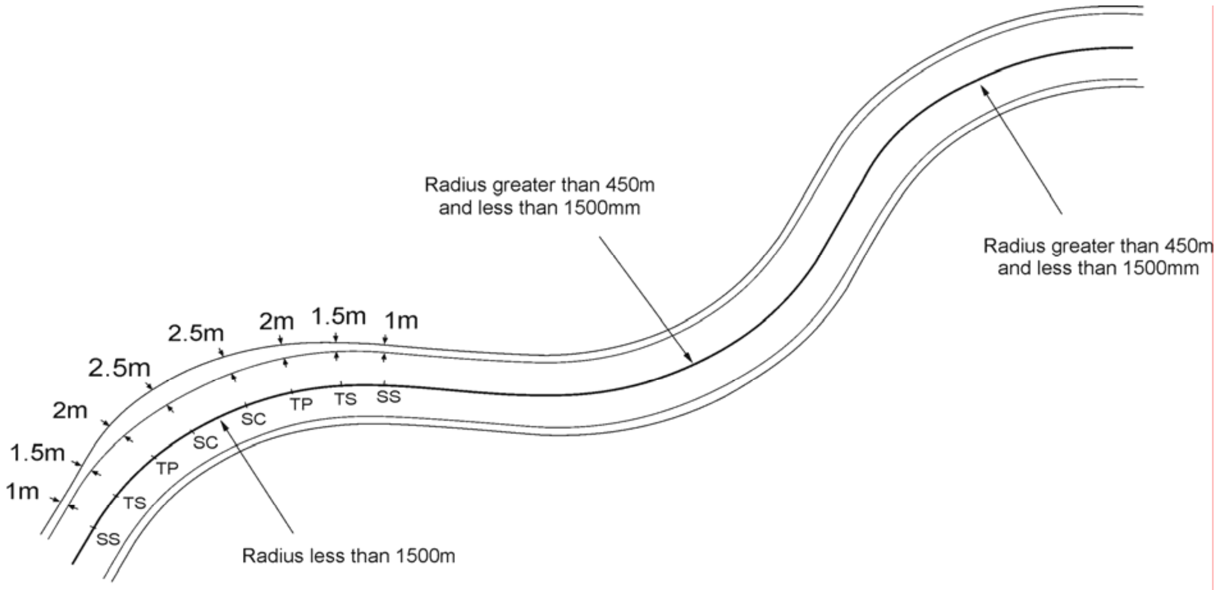
Where the horizontal alignment is mainly curvilinear and the road is made up of combinations of curves of similar radii then remedial treatments should be targeted at the left hand side of:

- the first curve after a straight within a series of curves if it is right handed and less than 1500m in radius
- right hand curves that have advisory speed signs more than 20% below the sign-posted legal speed
- all curves of less than 450 metre radius.



GENERALLY WINDING HORIZONTAL ALIGNMENT WITH MULTIPLE CURVES

However, where the first curve is less than 1500 metres in radius but the following curves are greater than 450 metres in radius then the widening is only required on the first curve.



GENERALLY WINDING HORIZONTAL ALIGNMENT WITH MULTIPLE CURVES

Available treatments include:

- widen and seal shoulders from 1.0m wide at the start of the superelevation transition through to 1.5 metres wide at the Tangent/Spiral point then to 2.5 metres wide at the Spiral/Circular Curve point and carry this 2.5m width through the curve and then transition back to 1.0m wide at the finish of the superelevation transition. NB: Where these shoulder widths are unattainable due to terrain constraints then they should be the best that can be achieved under the circumstances and other treatments such as safety barrier added

- install advisory curve speed warning signs where appropriate

- install profile edge-line marking from the start of the superelevation transition to the finish of the superelevation transition.

- increase superelevation on sealed shoulders through the curve from approach Spiral/Circular Curve point to the departing Spiral/Circular Curve point where possible

- install Curve Alignment Markers (CAMS)

- remove roadside hazards where a run-off area is available at the back of the curve and level out batter slopes to at least 4:1 **OR** install an appropriate safety barrier

- install appropriate rumble strips within the shoulder between the Tangent/Spiral point to the Tangent point . NB: It should be noted that when installing rumble strips in the shoulder, consideration must be given to the needs of pedal and motor cyclists. (refer to FHWA “ Technical Advisory Roadway Shoulder Rumble Strips”)

7 ROAD SAFETY UPDATE NO.16

A methodology for calculating a Curve Alignment Exposure (CAE) ratio as well as a Relative Crash Index (RCI) along selected road sections is outlined in *Road Safety Update No.16 - “Procedure to Target Run Off the Road to the Left on a Right Hand Curve Crashes”.* This methodology can be used to prioritise those sections of road that require early intervention. A simple single page spreadsheet has been compiled to quickly calculate the CAE and RCI and to identify those road sections with the worst run off road crash problem.

8 CONCLUSIONS

Although the percentage of run off road on curve crashes varies according to individual routes, they often form the major component of total run off road crashes on the rural road network. They cost the NSW community approximately $360 million per year and result in approximately 80 deaths per year. The only way to reduce the high number of these types of crashes is to take a more pragmatic view of what is practical and achievable in reconstructing and maintaining the existing two lane rural road network in a safe but affordable way.

In the past, Road Design Guides only concentrated on “best practice” principles for designing “greenfield” type road projects and did not address what was practical and achievable for existing road alignments and formations. The implementation of asymmetrical design principles is aimed at addressing this lack of design direction when confronted with what is regarded as acceptable practice on ”brownfield” projects. It concentrates on reducing crashes as the major concern and achieves maximum impact by focusing scarce road safety and road maintenance funding resources to those sections of rural road that will return the most safety benefits and that have the most off road crashes. It also has the extra benefit of curbing the over-design of “brownfield” maintenance and reconstruction projects by restricting the design parameters to a practical level of maximum benefit return for a minimum construction cost.

The application of Asymmetrical design principles is seen as a practical and economical alternative in applying safety engineering on two lane rural roads and is expected to have a major long-term impact on reducing casualty crashes in NSW.

9 REFERENCES

“*Country Road Safety Summit - Road Environment Safety Issues Paper”* – Authors: Levett S and others (2004)

Road Environment Safety - Safety Update No.16 – *“Procedure to Target Run Off Road to the Left on a Right Hand Curve Crashes on Undivided High Speed Rural Roads”* Author: Levett S (2002)