ROAD CRASHES AT BRIDGES AND CULVERTS: A PRO-ACTIVE TRAFFIC SAFETY STUDY

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1. PRO-ACTIVE TRAFFIC ENGINEERING SAFETY

Traffic engineering approaches to road safety typically rely on treatment of individual sites, identified through their recorded crash history. A pro-active approach to traffic engineering safety involves identifying sites which have the potential to develop a poor safety record and treating them before this happens.

This paper reports research on the development of a pro-active traffic engineering safety study of crashes at bridge sites in the State of Victoria, Australia. Victoria is located in the south-eastern part of Australia. It has an area of 227,000 sq km, and a population of 4.2 million people. Of these, 3.0 million live in the state capital, Melbourne. There are 2.5 million registered motor vehicles in Victoria.

The primary purpose of the study was to develop guidelines to help traffic engineers identify bridge and culvert sites which are likely to become abnormally hazardous to road users, especially sites which are not yet experiencing exceptional reported crash frequencies or rates. The aim of such early identification is to enable preventative measures to be implemented to reduce longer term hazards at the sites.

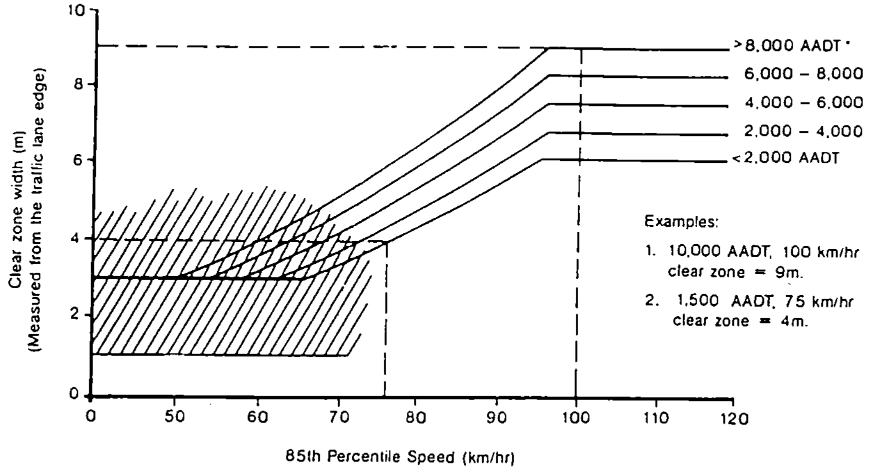
The bridge study is part of a larger study of pro-active traffic engineering road safety being undertaken by the Monash University Accident Research Centre, an independent research centre established at Monash University by the Victorian State Government.

2. CRASHES AT BRIDGES AND CULVERTS

Crashes at bridges and culverts include those involving vehicles (or pedestrians, cyclists, etc) travelling over the bridge, under the bridge, or on the approaches to the bridge.

Bridges are inherently hazardous because their abutments, railings or piers intrude into at least the roadside, and often into the shoulder of the road; in some cases they also intrude into the normal lane width. Culverts may be hazardous for the same reasons, or because of the culvert end wall or the drainage embankment is located adjacent to the roadway. This inherent hazard of bridges and culverts is emphasised by Figure 1, which indicates a desirable "clear zone" beside a road; any fixed object within that clear zone would be designated as a hazard (1). It is clear that the great majority of bridges would have their end posts and railings within the desirable clear zone, and that the bridge piers of many overbridges and many culvert end walls would also be within that zone.

Crashes at bridges have been found in various studies to be a significant proportion of total road accidents, especially in rural areas (2, 3, 4, 5).



Examples:

1. 10,000 AADT, 100 km/hr clear zone = 9m.
2. 1,500 AADT, 75 km/hr clear zone = 4m.

▨ In low speed environments of urban areas, a clear zone of not less than 1m wide may be accepted to achieve an appropriate balance between traffic safety and other aesthetic considerations.

* AADT – Average annual daily traffic. (Two Way)

Source: Reference (1)

FIGURE 1. DESIRABLE CLEAR ZONE WIDTHS

In general, crashes at bridges may be divided into three categories, as follows (3, 6):

- vehicles colliding with the bridge or culvert (e.g. end posts, railings, piers) or its approaches,

- collisions between vehicles, due to the presence of the bridge (e.g. lateral position of the vehicles, visibility restrictions due to road or bridge geometry), and

- collisions near bridges, where the presence of the bridge is not a contributing factor.

There have been a number of studies of crash patterns at bridges and culverts (2, 3, 7, 8, 9, 10). These studies have shown that several factors are significant in such crashes. These include:

- bridge width
- bridge relative width (i.e. ratio of bridge width to roadway width)
- traffic volume (for which road classification may be a surrogate)
- bridge length

- geometric factors, of which the most important are:
    - : curvature on approach to bridge
    - : curvature on bridge itself
    - : grade on approach to bridge
- perhaps a greater incidence of night-time crashes
- these last two perhaps also imply a visibility factor as well
- weather.

3. DRIVER BEHAVIOUR AT BRIDGES

Research on driver behaviour at bridges has focused on two main factors - lateral placement and speed. Reviewing this work, one study (6) concluded that "vehicle speed is not significantly affected on narrow pavements even when in the presence of opposing traffic. However, lateral placement is affected, both by pavement width and by the width and type of shoulder." Another (11) noted that "in experimental test situations, it has been found that drivers displace their vehicles laterally away from fixed roadside hazards ... even when the object is somewhat removed from the path of the vehicle."

These general conclusions have been quantified in a US study (2). Field observations were undertaken at 25 two-lane, two-way bridge sites in the US. The main observations were:

- drivers slow down approx 3.2 km/h (2 mph) when approaching a bridge,

- even if drivers recognise the bridge as a potential hazard, this does not result in significant speed reductions,

- driver reaction to the presence of a bridge is indicated primarily by the lateral movement of the vehicle towards the centre-line,

- the extent of the movement towards the centre line depends on both the absolute width of the bridge, and the relative width of the bridge with respect to the approach roadway width,

- although there is considerable scatter in the observed results, lateral repositioning varies from around 0.3 m (1') on bridges more than 8.2 m (27') wide to more than 0.6 m (2') on bridges 4.5 m (15') wide,

- little lateral adjustment takes place if the relative width (bridge:pavement) is less than 1.25,

- for a relative width of 1.0 (i.e. bridge and roadway width equal), the lateral repositioning averages about 0.25 m.

In the above results, "width" generally refers to pavement width, except in the case of roads or bridges with paved shoulders, in which case the shoulder width is also included.

4. CRASHES AT BRIDGES AND CULVERTS IN VICTORIA

A comprehensive analysis was undertaken of all reported crashes occurring at bridges and culverts in Victoria in the 5-year period 1982-86. The data base was the Victoria State Accident Record, and included all casualty crashes (i.e. those involving a fatality, a hospital admission, or medical treatment) which included a bridge or culvert as a road characteristic associated with the crash, or which recorded a bridge or culvert as one of the objects hit.

In this way, a total of 867 casualty crashes were identified. This represents only 1.07% of the total of 80,724 casualty crashes which occurred in Victoria in the 5 year period under study. However, bridge and culvert crashes were more severe than crashes as a whole; 120 out of 3442 persons killed in the period (3.48%) were involved in bridge and culvert crashes. About 44% of these crashes were in the Melbourne metropolitan area.

4.1 Road User Movements

Bridge and culvert crashes were concentrated into a small number of road user movement categories, namely:

- left or right off carriageway into a fixed object,
- off left or right bend into a fixed object,
- striking a permanent obstruction, or
- rear end collision between vehicles.

In the Melbourne metropolitan area, these categories accounted for just over half of all bridge and culvert crashes. In many of these crashes, it would seem that the bridge was incidental to the crash; the crash merely occurred in the vicinity of the bridge. The "permanent obstruction" coding apparently refers mainly to bridge piers (rather than to the bridge or its approaches, which would presumably be coded as a fixed object), or to high vehicles striking a bridge with low overhead clearance.

In rural areas, the pattern is clearer; 60% of bridge and culvert crashes involved vehicles striking the bridge or another fixed object.

Road curvature appears to be associated with bridge and culvert crashes, especially the more severe ones. About 15% of rural bridge and culvert crashes occurred on left hand bends, and 10% on right hand bends. Overall, crashes at bridges and culverts on bends accounted for 33.4% of bridge fatalities from 18.9% of crashes.

4.2 Locations

Bridge and culvert crashes are very widespread, with little concentration into "black-spots". This is an important observation, since it points to the need for a mass-application, pro-active approach, rather than a reactive approach based on crash history.

The most crashes at any one site over the five-year period was 7, and that occurred at only 3 sites. Only 22 sites had more 3 or more crashes.

The high frequency sites were almost all in the metropolitan area (all sites with 7 crashes, and 19 of the 22 with three or more crashes were in the metropolitan area). However, in many of these cases it is likely that the presence of the bridge itself was coincidental. Railway bridges featured significantly, especially in the metropolitan area.

4.3 Vehicle Type

Most vehicles involved in bridge crashes were small vehicles (i.e. mostly passenger cars), as would be expected. Large vehicles appear to be over-represented in on-path crashes, especially in the metropolitan area (possibly as a result of colliding with over-bridges), and in crashes on bends in rural areas.

4.4 Road Features

In the majority of bridge crashes, the bridge and its approach safety rail were not struck; these features were struck in only about 27% of metropolitan and 39% of rural bridge crashes. This means that countermeasures must be directed not only at preventing collisions (or alleviating the consequences of collisions) between vehicles and the bridge or its approach, but also at vehicle/vehicle and vehicle/other fixed object collisions.

Single vehicle crashes at bridges mostly involved a collision between a vehicle and the bridge or its safety rail (although even here, a significant proportion of crashes involved a collision with another fixed object). Road geometry (horizontal curvature) appears to be a factor here, especially in rural areas, as noted above.

Multi-vehicle crashes rarely involved the bridge or its approach safety rail being hit, and indeed it is likely that in many of these crashes, the presence of the bridge was coincidental.

Once again, these observations point to the need for a mass application approach to bridge and culvert safety. Since there is no predominant type of crash, countermeasures cannot be directed at reducing specific crashes, but rather need to be general in their application.

4.5 Environmental Conditions

Light condition and road condition do not appear to be related in a significant way to crashes at bridges and culverts.

4.6 Summary

Since there is only a small probability of any given bridge being associated with a crash, and since the crash patterns are quite widespread, the best approach to the development of countermeasures is likely to involve a mass application of low cost treatments, applied to a very large number of bridges. Those few bridges which are revealed through crash data records as being worthy of treatment as a "black spot" should of course be treated as such, but for all but a handful of bridges, the black spot approach is inapplicable.

5. TREATMENT OF BRIDGE HAZARDS

5.1 Roadside Hazard Treatment

A number of bridge and culvert safety treatments are potentially available. These generally fall into five categories, as follows:

- warning and delineation,
- safety barriers (especially the provision of guard fences),
- alignment, especially of the bridge approaches, but in some cases the bridge itself,
- environment, relating for example to street lighting, skid resistance, batter slopes, overhead protection, etc, and
- bridge design and construction.

These approaches are briefly reviewed below.

5.2 Warning and Delineation

Delineation is important because most of the information which the driver uses to control a vehicle is visual. Delineation is vital in enabling the driver to locate the vehicle on the roadway and to make navigation and control decisions. Adequate delineation enables the driver (12) to:

- keep the vehicle within the traffic lane (short range delineation), and
- plan the immediate forward route driving task (long range delineation).

A number of delineation devices are available for use at bridge and culvert sites, as follows:

5.2.1 Guide Posts and Post Mounted Delineators. The combination of centrelines and guideposts with reflectors enhances static direction judgements at night (13). Increasing the number of posts on the outside of a bend improves these judgements. Post mounted delineators (PMDs) have been found to be the best form of long range delineation, and a combination of PMDs and wide (150 mm) edgelines cater best for drivers' needs for both long and short range delineation (12).

Long range delineation enables the driver to plan the forward route, and thus it needs to be consistent and continuous; it is not restricted to locations where forward visibility is particularly confusing or critical (e.g horizontal curves over a crest vertical curve), but has application to a road as a whole. Even if it is not provided throughout the length of a road, its use on an approach to a bridge can be beneficial since it will assist the driver to locate the vehicle satisfactorily; this is especially the case if the bridge is on a curve.

5.2.2 Bridge Width Markers. A delineation device which is particularly relevant to this discussion is the bridge width marker - a rectangular signboard with alternate black and white diagonal stripes to indicate the presence of the bridge end post or pier.

These markers are typically used in situations where the bridge is narrower than the normal approach formation width. Where the bridge is wider than this, normal delineation (especially PMDs) is carried across the bridge; i.e. the route and not the hazard is delineated.

5.2.3 Edge Lines and Centre Lines. Centre lines have long been considered a standard form of road delineation and are virtually standard on all multi-lane roads; they assist the driver to locate the vehicle laterally on the roadway, and thus assist in avoiding collisions with both roadside objects and opposing vehicles.

Edgelines have been found to give marginal advantages in driving performance (14). Their main advantage is in short-term lane positioning (15); this is particularly relevant to bridges, since safe negotiation of the bridge involves successfully locating the vehicle with respect to the bridge rails or piers, which in general are much closer to the vehicle than other roadside objects. Edgelines are as effective, if not more so, on straight alignments as on curves (16).

5.2.4 Raised Reflective Pavement Markers. RRPMs provide better night time delineation than painted centre lines and edgelines, especially under adverse weather conditions. Crash reductions of 15% - 18% have been reported (17). RRPMs are considered to be most effective when used in combination with edgelining on curves.

A review of crashes at narrow bridges in the US where RRPMs were installed reported that RRPMs were effective in reducing encroachment across the centre line, and appeared to have a beneficial effect on safety (18).

5.2.5 Chevrons. Delineation is critical on horizontal curves, especially isolated curves with a radius less than 600 m. A major study of safety and driver behaviour at horizontal curves determined that the most effective form of delineation was a combination of wide (150 mm) edgelines and post-mounted chevron signs (13, 19). The combination was especially effective for alcohol-affected drivers; chevron signs alone were almost as effective as the combination for sober drivers.

This has relevance to bridges because of the fact that a high proportion of crashes at bridges occur where the bridge is on a horizontal curve (see above); to the extent that improved delineation assists the driver to negotiate the curve, it will also assist in ensuring that the driver safely crosses the bridge.

5.2.6 Delineation and Bridge Safety. In summary, effective delineation is a vital component of bridge safety, and appropriate delineation devices should be provided at every bridge. Delineation assists the driver to plan the forward driving task (long range delineation) and maintain lane control (short range delineation). Both are relevant to bridges; the driver needs to be able to align the vehicle and adopt an appropriate speed on approach to the bridge, and ensure that the vehicle stays within its lane so that it does not collide with the bridge rails or piers or another vehicle while negotiating the bridge.

While delineation is important to all components of the road system, it is particularly important in the case of bridges because most bridges have piers and/or rails closer to the travelled way than most other roadside objects. The clear zone width described above is rarely provided for bridges (except in the case of some freeway structures where the piers are kept well away from the through lanes).

Delineation is also critical on horizontal curves, especially those with a radius of less than 600 m (19). Since many bridges are on curves, and curves have been shown to a factor in a high proportion of bridge crashes, particular attention should be paid to delineation on bridges on curves, especially where the curve radius is less than 600 m.

5.3 Guard Fencing

Guard fencing has three basic purposes:

- it can reduce crash severity by redirecting errant vehicles,
- it can minimise the effect of vehicle collision with vulnerable roadside objects, and
- it assists in delineation of the roadway.

However, collisions with guard fences almost always result in property damage, and sometimes injury or death, so the use of guard fencing must be carefully assessed to ensure that there is likely to be a net benefit from its use. It is not a panacea, but in certain applications its installation (when performed properly) can be beneficial.

Guard fencing acts by resolving the kinetic energy possessed by an impacting vehicle into components in three dimensions (vertical, parallel to the rail and perpendicular to the rail). If the vehicle is to be redirected effectively, the perpendicular and vertical components must be reduced or dissipated. This energy dissipation is accomplished through bending and crushing of various parts of the vehicle and barrier, including the soil.

To be effective, guard fencing must be installed in such a way that this energy dissipation can occur. This requires attention to detail in the assembly and installation of all of the components of the barrier, including rail, posts, blocks, rubbing rail and anchorages.

Existing barriers need to be assessed to ensure that they conform to current practice. The factors to be considered include (20):

- potential hazard of the barrier compared with that of the feature being shielded or with that of a modern barrier,

- suitability of the barrier, its post spacing, terminals, transitions, etc,

- barrier length, alignment, clearances, and location relative to the adjacent lanes,

- barrier height,
- condition of the roadside between the traffic lane and the barrier, and

- alignment of the adjacent traffic lane.

These considerations are especially cogent in the case of bridges. Because bridges are readily recognised as hazardous roadside locations, they have long been prime targets for treatment, and one of the obvious treatments is the installation of guard fences. As a result, many bridges have guard fences on their approach, but in many cases its installation goes back many years, or the installation was not carried out in a proper engineering fashion. Even a cursory inspection of sample of bridge guard fencing in Victoria would find many examples of deficiencies of the sort listed above. Perhaps the most common (or most serious) deficiencies are poor or non-existent transitions between guard fence and bridge end post; excessive post spacing; inadequate or non-existent anchorages; unflared ends, and exposed ends.

5.4 Alignment

As noted above, horizontal curves of less than 600 m radius are associated with a high accident rate (19). In new works therefore, this should be regarded as a minimum desirable curve radius.

A gradient of 3% or less on rural roads may be regarded as "good", between 3% and 5% is "medium", and greater than 5% is "poor" from a safety viewpoint (21). Steep grades above about 6% are also associated with a higher accident rate (22).

The coincidence of horizontal and vertical alignment should be noted here. A driver's desired speed is determined by the perception of the overall standard of the road section, particularly horizontal alignment. Vertical alignment is less significant, so a long or steep grade will not discourage the driver from adopting a high speed if the horizontal alignment encourages it. It is important therefore that horizontal curves at the foot of long or steep grades are designed with a high design speed (23).

Sealing or partial sealing of road shoulders has been found to reduce crashes by between 20% and 50% (24). There is no direct evidence that sealing shoulders in the vicinity of bridges is especially effective in reducing crashes at the bridge. However, if research (24, 25) can be interpreted, it seems that sealed shoulders reduce crashes by giving a driver a little extra width within which to regain control of a vehicle which has strayed from the traffic lane. Further, since such straying from the road is more or less a random occurrence (26), it follows that sealing shoulders in the vicinity of bridges should be of assistance, as a driver whose vehicle strayed near the approach to a bridge would have a better chance or regaining control with a sealed shoulder.

5.5 Road Environment

Included under this strategy is a range of fairly ad hoc treatments, which would in practice need to be considered in specific circumstances where each may be useful. These include the use of crash cushions, skid resistant treatments, overhead clearance, street lighting, access control, etc.

5.6 Bridge Design and Construction

In general, new bridges which are designed and constructed to contemporary standards are considered to be safe. This extends to such considerations as width between kerbs, design of end posts and rails, crossfall, etc. Also, application of current practice in respect of delineation and guard fencing is considered adequate to produce a safe bridge.

However, it must also be said that a comprehensive safety audit of current standards and practices has not been undertaken. While there are no obvious areas of concern, it would nevertheless be a useful exercise to conduct such an audit to attempt to ascertain any features of the design and installation which are particularly safe, or where cost-effective improvements could be introduced. A research program to investigate this aspect is suggested.

In some cases of narrow bridges, it may be appropriate to widen the bridge itself. Depending upon the current bridge width, a satisfactory solution can sometimes be obtained by modifying the existing cross-section and bridge rail arrangement to increase the between-kerb width. Typically this might involve removing the bridge posts, rails and kerbs from the top of the bridge, and bolting new posts on the outside edge of the bridge to give an increased width of up to perhaps 1 metre.

6. PRIORITIES FOR BRIDGE TREATMENTS

As noted above, this research has shown that there is only a small probability of any given bridge in the State being associated with a crash, and that bridge crash patterns are quite widespread. Hence, it follows that the only valid approach to bridge safety is to develop and apply countermeasures which involve a mass application of low cost treatments, applied to a large number of bridges.

However, it must also be recognised that there may be a few bridge sites which have a sufficiently high crash experience to justify treatment as part of a "black spot" program. Where crash data records reveal that this is the case, those sites should be treated as black spots. However, this will be rare.

Recommendations concerning mass application approaches to the treatment of bridge hazards need to be placed in priority order for two reasons:

- resources are limited and thus the actions which are outlined below will need to be introduced over an extended time frame; however, the highest priority sites should be treated first, and

- it is important that there be a degree of consistency in the road system so that drivers do not unwittingly fall into traps and make mistakes of judgement; this principle would decree, for example, that narrow bridges would be treated before wide bridges, and heavily trafficked roads before lightly trafficked roads, etc. Further, the treatment would be similar (but not necessarily identical) at similar sites.

To be useful in identifying sites for treatment as part of a pro-active traffic safety program, predictive guidelines need to be based on physical and operational characteristics. These need to be characteristics that are relatively easy to observe and measure, preferably characteristics that are easily recognisable by traffic engineering practitioners.

Taking note of these factors, the basis of the priority ranking developed in this study is the bridge assessment tabulation developed during the 1985 Roads Study conducted by the National Association of Australian State Road Authorities (27). This is presented as Table 1. This is a useful and necessary starting point, for two reasons:

- it is based on an overall assessment of the Australian road system, and its use should thus ensure consistency across road segments, and between bridge treatments and other road improvements, and

- the actual bridge width and traffic volume (AADT) values used in the table reflect the experience and judgement of road engineers in the Australian context.

However, this table can only be a starting point for the development of priorities, as the entries in the table are very broad (e.g. there is likely to be several years work in even treating all sites with a "poor" assessment). In other words, a way must be found to rank specific sites according to explicit and easily applied criteria.

This implies the use of a bridge safety model of some sort. However, there are no comprehensive bridge crash prediction models developed for Australian conditions. Data deficiencies preclude the development of such a model in the context of the present study; crash data are not comprehensive and uniform, and site and traffic data for bridges which have a crash history cannot be related to the crash data.

Thus, there is no alternative but to use a bridge safety model developed elsewhere. This is not necessarily a major disadvantage, as the factors which contribute to the safety or otherwise of a bridge are unlikely to vary significantly from place to place, and if advantage can be taken of research conducted elsewhere, based upon more explicit and more comprehensive data, then there is every reason to do so.

Several bridge safety models were examined, especially a Texas model (7). It was not considered necessary or appropriate to use this model in developing a ranking of priority for bridge treatments in Victoria, because to operationalise it requires the collection of much data, and the use of complex relationships to express the variables in terms of indices or factors. Rather, the model was used to make three powerful, and relevant, observations:

Bridge Width (m) (between kerbs)	Quality of Service for traffic flow (veh/d) Poor	Fair	Good
under 4.9	>100	61-100	<60
5.0 - 5.9	>300	151-300	<150
6.0 - 6.9	>4000	1001-4000	<1000
7.0 - 7.9	>6000	4001-6000	<4000
>7.9	-	-	all

Source: Reference (27)

TABLE 1.TRAFFIC VOLUME CRITERIA FOR BRIDGE WIDTHS

- bridge width is more important than traffic flow in assessing bridge safety,
- bridge width is the most important factor, and
- bridge length is the next most important factor.

These conclusions lead readily to a suggested priority ranking for the treatment of bridges. Bearing in mind the above requirements concerning simplicity and measurability, the recommended priority ranking for the treatment of bridges is as follows:

(i) all bridge sites which are identified as "black spots" be treated as such,

(ii) all remaining bridges be considered for treatment in a priority determined by:

(a) the NAASRA bridge assessment table (Table 1 above),

(b) within each NAASRA category of "poor", "fair", and "good", the narrowest bridges be treated first, and

(c) for bridges in equivalent width categories, treatment be in order of bridge length.

These recommendations are summarised in Table 2. It should be noted that this table implicitly concerns bridges with one or two running lanes only; this will be the vast majority of bridges in the State, and those with three or more lanes will be confined to major roads or freeways. As such, each would be likely to have high-standard delineation devices and safety barriers fitted. The above recommendations would therefore need to be interpreted on a case by case basis for such bridges.

7. RECOMMENDATIONS

Recommendations for the safety treatment of bridges comprise three program elements:

(a) Delineation
(b) Safety Barriers
(c) Other

Programs (a) and (b) are on-going programs, while program (c) includes mainly once-off elements (e.g. training, research), or relates to current practice (e.g. standards).

7.1 Delineation

The following delineation devices should be introduced in priority order at all sites in Victoria which meet the respective warrants of the state road authority (Road Construction Authority, RCA (28)) at:

- bridges, in both rural and urban areas, where the bridge end post, rail, or (in the case of underpasses) pier or abutment is within the clear zone width described above (Figure 1).

- culverts with a drop greater than 1 m, or where the culvert end wall encroaches on the normal formation width (i.e. within the shoulder). Where a guardfence is provided adjacent to a culvert end wall, the guard fence should be regarded as equivalent to a bridge rail, as above.

Priority	Bridge width (m)	AADT (veh/d)
1	< 4.9	> 100
2	5.0 - 5.9	> 300
3	6.0 - 6.9	> 4,000
4	7.0 - 7.9	> 6,000
5	< 4.9	61 - 100
6	5.0 - 5.9	151 - 300
7	6.0 - 6.9	1,001 - 4,000
8	7.0 - 7.9	4,001 - 6,000
9	< 4.9	< 60
10	5.0 - 5.9	< 150
11	6.0 - 6.9	< 1,000
12	7.0 - 7.9	< 4,000
13	> 7.9	all

Notes:

(a) within each of the above priority rankings, bridges are to be ranked in order of bridge length (with the longest bridges having the higher priority)

(b) bridges which are identified as "black spots" through data records as to be treated as such.

TABLE 2. RECOMMENDED PRIORITIES FOR THE TREATMENT OF BRIDGES

(i) Unless street lighting is present, install guideposts with corner cube reflective delineators, or similar. (Where guard fencing is used, the RRPMs would normally be mounted on the guard fencing.) This will provide effective long range delineation and thus assist the driver to plan the immediate driving task, in terms of navigation and speed,

(ii) Where warranted, install bridge width markers on or adjacent to the bridge end posts, piers, or abutments on both the left and right side of the carriageway. This will provide visual warning about the presence of the hazard.

(iii) Where bridge width markers are installed, provide edge lining, together with raised reflective pavement markers. This should commence a standard distance in advance of the bridge and continue across the full length of the bridge. The edge line should be 100 mm wide unless the bridge is on a curve with radius less than 600 m, in which case the edgeline should be 150 mm wide. This will provide short range delineation and thus facilitate good lane control.

(iv) Except for road sections with an overall low geometric standard, where the bridge is on or adjacent to a curve with a radius of 600 m or less, install chevron signs on the outside of the curve. This will assist the driver to negotiate both curve and bridge.

7.2 Guard Fencing

The following program should be carried out, in priority order (see above) at all existing bridges and underpasses in the State:

(i) Where the bridge does not have guard fencing installed, ascertain whether guard fencing is warranted, and if so, install in accord with the current standards.

(ii) Where the bridge has guard fencing already in place, determine whether the fencing conforms with the requirements of current design and installation practice. Where it does not, upgrade the installation to conform with the current standards.

7.3 Other Programs

Apart from the above program, recommendations in relation to guard fencing are that:

(i) For new bridges, install guard fencing according to standards.

(ii) Develop a range of effective transition arrangements between guard fencing and various bridge end posts; these arrangements should then be applied to existing bridges, as part of the program of upgrading.

(iii) Guard fencing, once installed, must be repaired when and if it is hit, and must also be routinely maintained to ensure that it can continue to perform as intended.

(iv) Develop an educational program, aimed at field personnel and design staff in local government; this would have the objective of improving practice by disseminating information about the importance of correct design, installation and maintenance of guard fencing.

In relation to road alignment in the vicinity of bridges, it is recommended that:

(i) Current design standards be adopted in any realignment. This would include curve radius (with a minimum of 600 m being recommended), gradient, crossfall and superelevation. Particular attention should be given to isolated horizontal curves, or those located at the end of a section with a higher design standard, or at the foot of a long grade.

(ii) Research be undertaken to determine the safety benefits, if any, of sealed shoulders in the vicinity of bridges.

In relation to bridge design and construction, it is recommended that:

(i) A safety audit be performed to appraise currently used bridge design standards and practices. This might include such aspects as bridge width (including the provision of full-width shoulders); end post and bridge rail design; transition between guard fence and end post; pier and abutment design and location on underpasses; delineation on the bridge and its approach; etc.

(ii) An investigation be conducted into the potential value of instituting a program of bridge widening in Victoria, through the re-construction of the kerb, end posts and bridge railing on selected existing bridges.

Finally, in relation to data collection and analysis, it is recommended that particular attention be paid in any re-design of the Victorian accident report form to ensuring that crashes at bridges and culverts clearly distinguish between crashes involving the bridge or culvert and those which do not, and that the data generally be defined coded and analysed in such a way that maximum usefulness from the viewpoint of accident analysis is possible.

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