Technical Guideline

Treatment of overhead structures – objects thrown or dropped

October 2023

Queensland Government

Translating and interpreting assistance

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1 Background

In recent years objects have been deliberately thrown or dropped from overhead road structures (or overpasses) in Queensland onto vehicles passing below. Whilst relatively rare, each incident has the potential to cause serious harm. There are examples where people have died from such incidents in other jurisdictions.

Incidents may occur on exclusive pedestrian overhead structures, combined pedestrian / vehicle overhead structures or on cuttings near roads. Where a vertical retaining structure (e.g. reinforced earth wall) is constructed beside a road, and the distance from the trafficked lane and structure is not great, its risk should be assessed similarly to that of an overhead structure. In this context, the term “overhead structure” contains all of the foregoing roadside features.

New overpasses can have measures included at initial construction to proactively manage the risk, whilst existing sites can be assessed and prioritised for reactive treatment based on the risk assessment methodology described in Section 3. A number of lower-cost infrastructure related measures that can be implemented to reduce the risk, are described in Section 4. These methods include improved maintenance practices, removing or using lightweight options for roadside furniture, improving lighting and surveillance and supporting Queensland Police Service in community-based activities.

The most effective treatment generally is to install screens on the sides of the structure. Technical guidance for the design of protection screens is provided in Section 5.

This technical guideline also supports efforts to manage the risk of self-harm incidents, including risks to other road users, at overpasses.

2 Purpose

This document supports the implementation of Engineering Policy EP177 *Managing the risk of objects thrown from overpass structures onto roads*. It provides technical guidance to assist in the assessment and management of the road infrastructure features that may contribute to the risk.

Implementing EP177 for state-controlled roads in Queensland in accordance with these technical guidelines will supplement actions taken by other agencies (such as law enforcement) to effectively manage this risk and improve safety for road users.

3 Risk assessment

3.1 Pre-amble

This type of incident seems to be extremely rare. A recent review found reports of 14 incidents on state-controlled roads in Queensland over a 10 year period. Empirical evidence suggests that most incidents cause minor injuries or property damage, but all incidents have the potential to result in serious injury or death. The severity of the outcome is probably due to random factors; many incidents are reported as lucky near-misses that could have ended tragically.

Examples of the potential consequences of a crash involving an object being thrown from an overhead structure or self-harm include:

- injuries or possibly death to road users

- social impact on the injured person, the person throwing the object, their families, friends and the community
- financial impact on the health, judicial and corrective services systems, and
- community pressure to fix the problem in the form of public ‘outrage'.

In order to direct limited resources to interventions that deliver the greatest benefit, a mechanism for quantifying the risk is needed. This allows ranking and comparison of sites across the state.

Assessing various infrastructure factors that may contribute to an incident can provide a relative measure of an incident occurring and exposure to this event on a site-by-site basis.

3.2 Existing overpasses

A risk assessment methodology for existing overpasses has been developed and is described in this section. While it is considered a reasonable methodology for the scoring of risk, it is based primarily on the informed opinion of experienced practitioners. In reviewing this methodology in 2021 no published research could be found that establishes a causal link between the risk attributes and injury outcomes. As such, the methodology has not been validated with 'real world' data nor verified for accuracy over a sustained period. Care should be taken in its use, and blind adherence to scoring in the absence of sound engineering judgement is discouraged. It is impossible for any rating system to account for all conditions and appreciation of the road environment and site-specific conditions of an overpass must be considered.

For a particular overhead structure, Tables 3.2.1, 3.2.2 and 3.2.3 list a number of relevant attributes and factors to help quantify the risk through the derivation of a 'risk score.'

3.2.1 Likelihood

Table 3.2.1 provides an overview of point ratings corresponding to a range of infrastructure and social attributes. See Appendix A for detailed information on the definitions and how to interpret site conditions. The particular conditions of the site are identified and the associated points in the table summed to give an aggregate point score, L_1. As the presence of protection screens on the overpass significantly impacts on likelihood, a multiplier (L_M) is applied to L_1 to determine the likelihood component of the risk score, R_L.

Table 3.2.1 – Existing Overpasses, Likelihood risk score - R_L

Attribute	Category / Options	Risk Score	Score
History of incidents in the last 10 years From crash data, police reports or media reports"	1 - No reported incidents	0	
	2 - Each incident within 5 to 10 years	7	
	3 -Each incident within last 1 to 5 years	15	
	4 - Each incident within last 12 months	30	
Function of Structure	1 - Pedestrian/bikeway footbridge only - high usage	9	
	2 - Pedestrian/bikeway footbridge only	7	
	3 - Shared vehicle & pedestrian access with designated pedestrian facilities (i.e. footpath)	3	
	4 - Vehicle access only however informal pedestrian crossing possible (wide shoulders/bike lanes)	1	
	5 - Vehicle access only with very limited or no pedestrian access	0	

Attribute	Category / Options	Risk Score	Score
Loose objects on or near structure - up to 100 metres from structure	1 - Not Present	0	
	2 - Present – only smaller/lighter objects, rocks, rubble and so on	4	
	3 - Present – Large, unsecured objects that could be used as projectiles, such as large rocks or road furniture.	8	
Proximity to children's facilities (schools, playgrounds) where children unaccompanied	1 - None within 2 km	0	
	2 - Present 1 km to 2 km	1	
	3 - Present 500 m to 1 km	3	
	4 - Present within 500 m	6	
Nearby structure with history of prior incidents within 5 years	1 - Not Present	0	
	2 - Present within 3 kms	5	
	3 - Present within 1 km	8	
Public visibility / Lighting	1 - Not Present	8	
	2 - Visible but Unlit	4	
	3 - Visible and Lit	0	
Video Surveillance	1 - Not Present	6	
	2 - Present	0	
Evidence of vandalism	1 - Not Present/Unknown	0	
	2 - Present	4	
"Traffic volume (overpass road)"	1 - Low (up to 5,000)	4	
	2 - Medium (5,000 to 15,000)	2	
	3 - High (15,000 or more)	0	
	4 - Not applicable (no access for motorised vehicles)	4	
Proximity to hotels, clubs, etc,	1 - None within 2 km	0	
	2 - Present 1 km to 2 km	1	
	3 - Present 500 m to 1 km	3	
	4 - Present within 500 m	6	
TOTAL - Sum of the scores above in right hand column, $\mathbf{L_1}$			
Screening of structure, $\mathbf{L_M}$	1 - No screen present	1	
	2 - Screen present - partially effective	0.5	
	3 - Screen present - substantially effective	0.05	

Multiply points score L_1 with the multiplier L_M to obtain the Likelihood Factor, R_1	R_L ➔	

3.2.2 Severity

Table 3.2.2 lists a severity factor, R_S, which relates to the consequences of an object's velocity of impact. For example, a stone of a certain mass may not penetrate the windscreen of a vehicle travelling at 50 km/h but may penetrate the windscreen and cause severe injury to the occupants of a vehicle travelling at 100 km/h. Hence, the risk increases with vehicle speed.

A Safe System approach was taken to determine the relative severity factors for different speeds. Research has shown that survivability for crashes relative to vehicle speeds forms an 'S-curve' <<reference>>. In this case the assumption is that most impacts at 50 km/h and lower are survivable, while most impacts at 80 km/h and above are not survivable.

Table 3.2.2 – Existing Overpasses, Severity Factor – R_S

Posted traffic speed in km/h for underpass	Severity factor R_S
50 and lower	1.0
60	5
70	8
80	9
90 and higher	10

3.2.3 Exposure

Often, exposure to a road safety risk is proportional to the traffic volume. The more road users that drive through a hazardous site, the more road users are exposed to the risk. But in this case the risk also requires an individual to throw an object at the vehicle. There are many factors at play, but exposure is also going to be limited by the number of projectiles present/ available and the rate at which they can be thrown or dropped. So a different approach to subjectively estimating the degree of exposure has been taken.

Table 3.2.3 lists a traffic multiplier factor, R_E, which relates to traffic volumes on the underpass road. The factor considers the potential for a secondary accident resulting from a driver losing control of a vehicle that has been struck by a dropped or thrown object. Another consideration with higher traffic volumes is that a randomly thrown object has an increased probability of hitting a vehicle at some critical point if there are more vehicles on the road. This factor is also moderated after due consideration of increased exposure of the perpetrator when traffic volumes increase.

Table 3.2.3 – Existing Overpasses, Traffic Multiplier – R_E

AADT for underpass road	Traffic multiplier R_E
Up to 5,000	1.00
5,000 to 10,000	1.05
10.000 to 20,000	1.27
20,000 to 30,000	1.33
30,000 to 40,000	1.45
40,000 and above	1.50

To obtain a total risk assessment score, multiply the total points score R_L, from Table 3.2.1 with the speed multiplier R_S from Table 3.2.2 and by the traffic multiplier R_E from Table 3.2.3.

Total risk score = $R_L \times R_S \times R_E$

3.3 New Overpasses

As part of the planning and development of a project that includes the provision of a new overpass, consideration must be given to whether or not protection screens should be in scope. Overpasses of major roads such as motorways in urban areas, generally include protection screens. Traffic volumes are very high and the overpass structure may be accessible to a high volume of foot traffic/ pedestrians. Risk is likely to be much lower for an overpass of a lower order road in a rural/remote location some kilometres away from the nearest residential area.

To assist in deciding on the provision of protection screens for new overpasses, the risk assessment methodology below is suggested. The risk score derived should be one of the factors used by the project customer (Transport and Main Roads Regional or District Director, for example) to determine project scope with respect to protection screens. It is important to note that the input data should be based on the conditions expected 20 years post-construction, not just at day of opening.

If it is decided that protection screens are not required then provision in the design (for example, anchor points for the screens) must still be made for a later retrofit of protection screens. If risk is found to be higher than anticipated during the operational life of the structure, provision of screens will be more affordable if this can be achieved without modifications to the structure itself.

Tables 3.3(a), 3.3(b) and 3.3(c) provide an overview of point ratings corresponding to a range of infrastructure and social attributes. See Appendix A for detailed information on the definitions and how to interpret site conditions. The particular conditions of the site are identified and the associated points allocated as described in the tables. The attribute scores are added and/ or multiplied as described in the formulae to derive the overall risk score.

Table 3.3(a) – New Overpasses, Likelihood risk score – R_L

Attribute	Category / Options	Risk Score	Score
Function of Structure	1 - Pedestrian/bikeway footbridge only - high usage	9	
	2 - Pedestrian/bikeway footbridge only	7	
	3 - Shared vehicle & pedestrian access with designated pedestrian facilities (i.e. footpath)	3	
	4 - Vehicle access only however informal pedestrian crossing possible (wide shoulders/bike lanes)	1	
	5 - Vehicle access only with very limited or no pedestrian access	0	
Proximity to children's facilities (schools, playgrounds) where children unaccompanied	1 - None within 2 km	0	
	2 - Present 1 m to 2 km	1	
	3 - Present 500 m to 1 km	3	
	4 - Present within 500 m	6	
Nearby structure with history of prior incidents within 5 years	1 - Not Present	0	
	2 - Present within 3 kms	5	
	3 - Present within 1 km	8	

Attribute	Category / Options	Risk Score	Score
Public visibility / Lighting	1 - Not Present	8	
	2 - Visible but Unlit	4	
	3 - Visible and Lit	0	
Video Surveillance	1 - Not Present	6	
	2 - Present	0	
Evidence of vandalism	1 - Not Present/Unknown	0	
	2 - Present	4	
Traffic volume (overpass road)	1 - Low (up to 5,000)	4	
	2 - Medium (5,000 to 15,000)	2	
	3 - High (15,000 or more)	0	
	4 - Not applicable (no access for motorised vehicles)	4	
Proximity to hotels, clubs, etc,	1 - None within 2 km	0	
	2 - Present 1 km to 2 km	1	
	3 - Present 500 m to 1 km	3	
	4 - Present within 500 m	6	
TOTAL - Sum of the scores above in right hand column, $\mathbf{L_1}$			
Screening of structure, $\mathbf{L_M}$	1 - No screen present	1	
	2 - Screen present - partially effective	0.5	
	3 - Screen present - substantially effective	0.05	

Likelihood Formula - $\mathbf{R_L = L_1 \times L_M}$

Table 3.3(b) – New Overpasses, Severity Factor – $\mathbf{R_S}$

Posted traffic speed in km/h for underpass	Severity factor $\mathbf{R_S}$
50 and lower	1.0
60	5
70	8
80	9
90 and higher	10

Table 3.3(c) – New Overpasses, Traffic Multiplier – RE

AADT for underpass road	Traffic multiplier RE
Up to 5,000	1.00
5,000 to 10,000	1.05
10.000 to 20,000	1.27
20,000 to 30,000	1.33
30,000 to 40,000	1.45
40,000 and above	1.50

To obtain a total risk assessment score, multiply the total points score R_L, from Table 3.3(a) with the speed multiplier R_S from Table 3.3(b) and by the traffic multiplier R_E from Table 3.3(c).

Total risk score = $R_L \times R_S \times R_E$

4 Reducing risk probability and exposure

Where an overhead structure is being investigated for potential mitigation/ reduction of the risk, road infrastructure based methods may include actions as outlined in the sections below.

4.1 Removal of potential projectiles

Throwing objects from overhead structures may be either ‘opportunistic’ or ‘premeditated’. Removing of convenient loose objects from the immediate vicinity removes a source of potential projectiles for ‘opportunistic’ vandals. It is recommended that enhanced maintenance practices be adopted near structures. Such practices involve removing of loose stones, concrete fragments, litter and sundry objects with potential as missiles.

Figure 4.1 – Potential roadside projectiles – rocks and pit lids

4.2 Replacement of heavy guideposts

Heavy guideposts on the approaches to overhead bridges have been removed and dropped from overhead structures. It is recommended that such guideposts near the grade separated road overpasses be replaced with lightweight alternatives. Some lightweight guidepost designs have a one-way tag, which makes their removal more difficult. These lightweight guideposts do not pose a high risk to motorists if dropped into the path of a vehicle.

Until more detailed information is available on the effectiveness of this replacement strategy, it is recommended that guideposts be replaced for a distance of up to approximately 200 metres on the approaches to the overhead structure.

4.3 Making safe road furniture

There is often other roadside furniture near or attached to overhead structures that could be used as projectiles. Such devices include, but are not limited to, concrete or steel manhole covers, hand railings, advertising devices, road signs, lighting columns, video surveillance mounts, maintenance framework, and luminaires.

It is recommended that roadside furniture be critically assessed and, where necessary, modified or replaced with safer fixing alternatives such as tamper- resistant fastenings, spot welded threads or fitted with steel anchor cables.

4.4 Drainage scuppers

The application of scuppers on bridges and overpasses is an outdated practice. In general, there are two approaches when it comes to bridge / overpass drainage.

- If the bridge / overpass is short enough that flow spread can be kept within the allowable limit. Two conventional pits can be placed on the ground in its immediate upstream and downstream and flows on the deck discharge to these pits.
- If the bridge / overpass is long enough that allowable flow spread is exceeded, a customised approach should be considered. Drainage elements such as proprietary grated trench drains may be utilised instead of scuppers.

Where drainage scuppers are specified for a new overpass, a risk-based decision that considers the potential consequences of 'bombing' for the road users should be made. Some mitigation of the risk could be achieved through use of the remedies described below.

drainage scuppers exist on many overpasses and have been identified as potential sites for “bombing” traffic. Their shape, length and inclination needs to be considered before remedial action is taken. Restricting aperture sizes is unlikely to be a viable solution, as it would be prone to blockage and therefore interfere with drainage. A likely consequence of blocked scuppers is localised ponding of water and possible aquaplaning. Where scuppers on a particular structure have been used as “bombing” sites, a remedy is to either:

- install a shield on the underside of the structure to block the view of oncoming potential targets. Such a shield should not restrict the flow of water from the scupper, or
- connect drainage pipes to the scupper to divert water clear of the trafficked lanes.

4.5 Embankment treatment

Stones and remnant pieces of concrete are often found on road and bridge embankments. Consideration should be given to covering stony embankments (grade permitting) with mulch and possibly including other landscaping such as shrubs. Such treatments may assist in weed control and reduce future maintenance costs. Involvement by community groups may be considered to help foster a joint partnership approach.

Another option is providing a high chain-wire fence or other barrier to prevent access to batters.

Care must be taken not to cause excessive warping of the embankment slope that may affect the stability of an errant vehicle. For example, the undercarriage of some vehicles may snag on low obstacles and roll over.

4.6 Lighting

Road lighting on some overhead structures may be non-existent or inadequate. Installing or upgrading road lighting may be a deterrent to some vandals, as well as providing a general benefit to the areas amenity.

The position of electrical pits, the connection of lighting and the appropriate class of lighting must be considered. Lighting should be designed in accordance with either AS/NZS 1158.1.1 *Lighting for roads and public spaces – part 1.1: Vehicular traffic (Category V) – Performance and design requirements* or AS/NZS 1158.3.1 *Lighting for roads and public spaces – part 3.1: Pedestrian area (Category P) lighting – Performance and design requirements*, depending on whether the structure is for vehicular or pedestrian traffic. Electrical pits should have lids secured so that they do not become potential projectiles.

For grade separated structures involving local roads, discussions should be held with local government on the provision, maintenance and electricity costs and rates of localised lighting.

Lighting of overhead structures is an important consideration in project proposals and an advantage may be gained from its early inclusion in designs.

4.7 Surveillance cameras and signs

The presence of surveillance cameras may deter would-be vandals. Camera installation could be included when upgrading or installing other traffic monitoring systems.

For this strategy to be effective:

- signs should alert pedestrians that activities are being monitored by surveillance cameras
- lighting should be adequate, and
- there is a need for continuous recording with a recommended minimum recording time of the previous 48 hours.

Associated electrical pits should have lids secured so that they do not become potential projectiles.

Information sign TC1880 is an example of the 24 hour behaviour monitoring sign that could accompanied installed surveillance cameras.

4.8 Community education and enforcement activities

The act of throwing or dropping objects from overhead roadside structures onto road users is symptomatic of wider social issues. It can result from deliberate criminal activity or carelessness and a lack of awareness of the risks to others. While the road infrastructure design can be enhanced to limit this risk, it has limited scope for influencing these human behavioural aspects that contribute to the risk.

The Queensland Police Service (QPS) is the lead agency for initiatives that aim to influence and improve behaviour. These initiatives include, amongst other things, education of and engagement with local and school communities and increased surveillance and enforcement activities by local police. Transport and Main Road's Manager's (Road Safety) liaise with and support QPS to deliver these initiatives when requested.

5 Engineering issues relating to the provision of screens on overhead road structures

Where other risk amelioration treatments fail to reduce risk to an acceptable level, adding protection screens to an overhead structure may be the only avenue remaining. Transport and Main Roads' policy and competing priorities need to be considered before screens are installed. It should be noted that protection screens will not ensure complete immunity but will reduce the probability of objects being thrown or dropped from overhead structures.

There are issues to be considered in selecting the type of screens, including the strength of the screen and overhead road structure and overall aesthetics. Factors that need to be considered are covered in the following sections.

5.1 General

It is not intended that there be a generic screen type or configuration. Specific aesthetic and environmental considerations preclude a universal approach. However, standard fixtures should be considered where practicable.

Where protection screens are installed on overhead road structures and dedicated footbridges the following will generally apply:

- When screening an overpass, screens should be placed on both sides of the structure, regardless of variation in features such as the footpath only being on one side, unless there is specific reason not to do so.
- Dedicated pedestrian footbridges should have fully enclosed screens (Refer Figure 5.1).

The design of protection screens should be contextual, responding to the human and natural environment. This issue can be more critical in highly populated and tourist areas. Crime Prevention Through Environmental Design (CPTED) principles should be applied throughout the design process. Protection screens on long structures can create a tunnel effect with limited opportunities for escape where a personal threat is perceived. Choice of screen aperture to improve transparency is one example where design choices can better align with CPTED principles.

It is possible to achieve a more acceptable outcome when protection screens are considered during a structure's design. The screen design should be integrated into the design of the overhead structure giving the designer maximum design freedom.

However, where a protection screen is not initially provided, design should allow possible future fitment by incorporating appropriate anchor points in the structure. The additional cost penalty will be very small in comparison to retrofitting a protection screen onto a standard structure. Consideration of anchor points etc. will require a preliminary screen design.

Figure 5.1 – Example of a fully enclosed protection screen using woven wire mesh

5.2 Design life

As described in AS 5100.1, *Bridge Design, Part 1: Scope and Principles* and the department's *Design Criteria for Bridges and Other Structures*, the life expectancy for a bridge structure is 100 years, while the life expectancy of an ancillary protection screen is nominally 50 years.

5.3 Design standards

Protection screen shall meet the requirements of the following references.

- *Design Criteria for Bridges and Other Structures* (DCBOS), Transport and Main Roads
- AS(/NZS) 5100, *Bridge design* (Protection screens are covered in Clause 16.4), AS 5100.1:2017 *Bridge design, Part 1: Scope and general principle*, and subject to 'Matters for Resolution' 53, 54 and 55, which are dealt with in Appendix B and Section 4.11.10 of DCBOS)
- Transport and Main Roads Technical Specifications, in particular MRTS78 *Fabrication of Structural Steelwork*, MRTS79 *Fabrication of Aluminium Components* and MRTS15 *Noise Fences*.

5.4 Design loads

The protection screen shall be designed in accordance with AS(/NZS) 5100 *Bridge design*, for the most adverse load combination, including the effects of wind and barrier loads.

5.5 Horizontal protection screens

Where a horizontal catch screen is fitted, it shall be designed in accordance with AS 1657 *Fixed Platforms, Walkways, Stairways and Ladders*.

5.6 Material selection and surface finishing

Materials for a protection screen shall be compatible with the environmental conditions to ensure the design life of the structure is met.

The minimum wall thickness of RHS and CHS steel members shall be 4 mm.

A minimum standard of surface treatment for steel products shall be hot dip galvanising. Thin steel sheeting is to be zinc coated.

5.7 Serviceability of posts and panels

Notwithstanding the requirements for transparent panels (refer Section 5.9), the horizontal deflection of posts and panels shall be limited to the requirements of AS(/NZS) 5100 *Bridge design*.

5.8 Sight distances

Adequate sight distances should be maintained for all road users; this includes but is not limited to vehicular traffic, cyclists and pedestrians. Sight distances are of particular issue with screens of solid material or expanded mesh. Where sight distances are less than optimal other measures, such as reducing the speed environment in the area or providing a stop sign, will be necessary to maintain the required safety standard. The use of transparent panels is a good treatment option in this situation.

5.9 Transparent panels

Transparent panels are sometimes preferred for reasons including:

- better forward visibility for pedestrians, cyclists and personal mobility device riders
- increased observation or surveillance, and/or
- maximise visibility of desirable views.

Acrylic panels shall conform to EN ISO 7823-2 - *Plastic, Poly Methyl Methacrylate (PMMA) sheets*.

Toughened safety glass shall conform to AS 2208 *Safety Glazing Materials in Buildings*.

The transparent panels shall be in accordance with the requirements of the Clause 6.14 of the MRTS15 *Noise Fences*.

Coloured transparent panels are available for enhanced urban design outcomes and may be integrated with other panel types for visual interest. Panels can be etched or have patterned adhesive stencils attached to further enhance aesthetic design outcomes and to mitigate graffiti and bird-strike issues.

5.10 Reflectance

For panels with highly finished surfaces such as glass or acrylic, consideration should be given to the orientation of the panels to prevent reflected sunlight and headlights interfering with motorist’s vision. Some products are available with anti-glare surface treatment. Light reflection and transparency shall conform to the requirements of Appendix E and F of I.S. EN 1794–2.

5.11 Capacity of existing structure

The structural capacity of an existing structure is a critical element in the retrofitting of a protection screen. A detailed site inspection should be performed to establish the condition of existing rails, attachment fasteners and concrete. Where future accessibility to these items will be restricted due to the protection screen, consideration should be given to performing any maintenance work prior to the fitting the protection screen. In this regard, fitting a protection screen may have secondary cost implications such as bring forward maintenance costs.

5.12 Impact resistance and strength

The screens shall be able to withstand the impact of a 4 kg ball dropped from a height of 3 metres onto a panel supported horizontally above the ground[1].

For this test, the panel shall be supported at the ends with a similar edge distance to that used in service. The test panel size shall be the worst case of the span and width proposed.

The impact may cause superficial dents. The depth of permanent deformation considered acceptable is 4 mm within a circle of 20 mm diameter, however it shall not cause any structural damage to the protection screen. The impact of the ball shall not cause failures to welds on welded wire fabric or tearing to sheet material.

Where welded wire fabric is used, the shear strength of the resistance welds should be specified and shall be greater than or equal to 0.5 times the tensile strength of the fabric wire.

5.13 Mesh and metal screens

Woven, welded wire, expanded metal mesh and perforated metal sheets may be used in the construction of screening structures. The designer to select the most appropriate product consistent with maximum aperture size, design parameters and aesthetic requirements.

To minimise the louvre effect of expanded metal mesh, the elongated aperture should be parallel to the horizontal. The sheet should also be orientated so that the upward view of motorists and downward view of pedestrians is afforded the least obstruction.

Perforated steel or aluminium panels may also be used. Customized punched and laser cut perforations allow for the integration of aesthetic patterning for enhanced urban design outcomes and integration of unique art themes of local context.

5.14 Screen aperture requirements

In AS(/NZS) 5100 *Bridge design* the nominated maximum clear opening in protection screens or mesh is 50 x 50 mm. It is, however, important to understand the relationship between mesh aperture size, vehicle speeds and the impact resistance of vehicle windscreens. Testing[2] on windscreen samples using concrete and steel balls impacting at a range of speeds has established that the criteria for screen design and for selection of suitable screen material shall be such that the maximum aperture of any part of the screening system will retain a 25 mm diameter sphere. This requirement applies to all joins and openings over or immediately adjacent to traffic movement (Refer Figure 5.14(a)).

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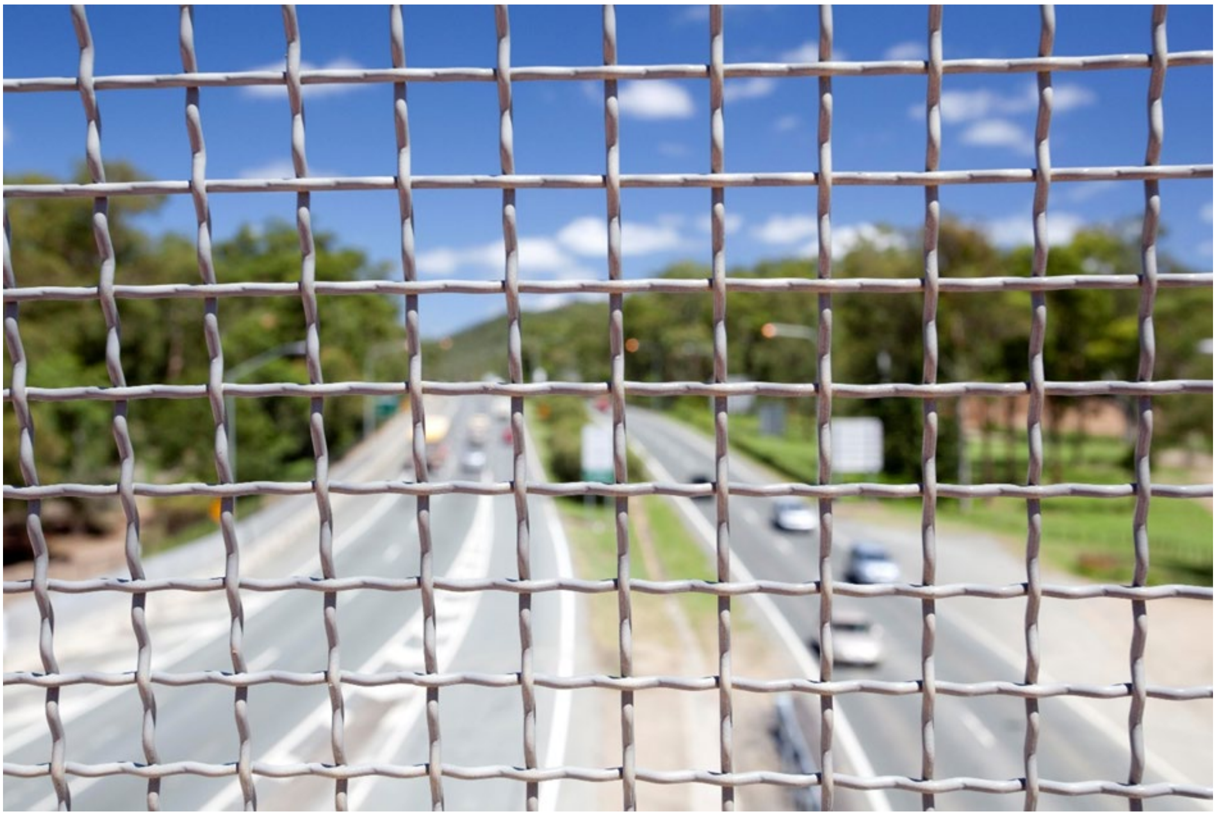
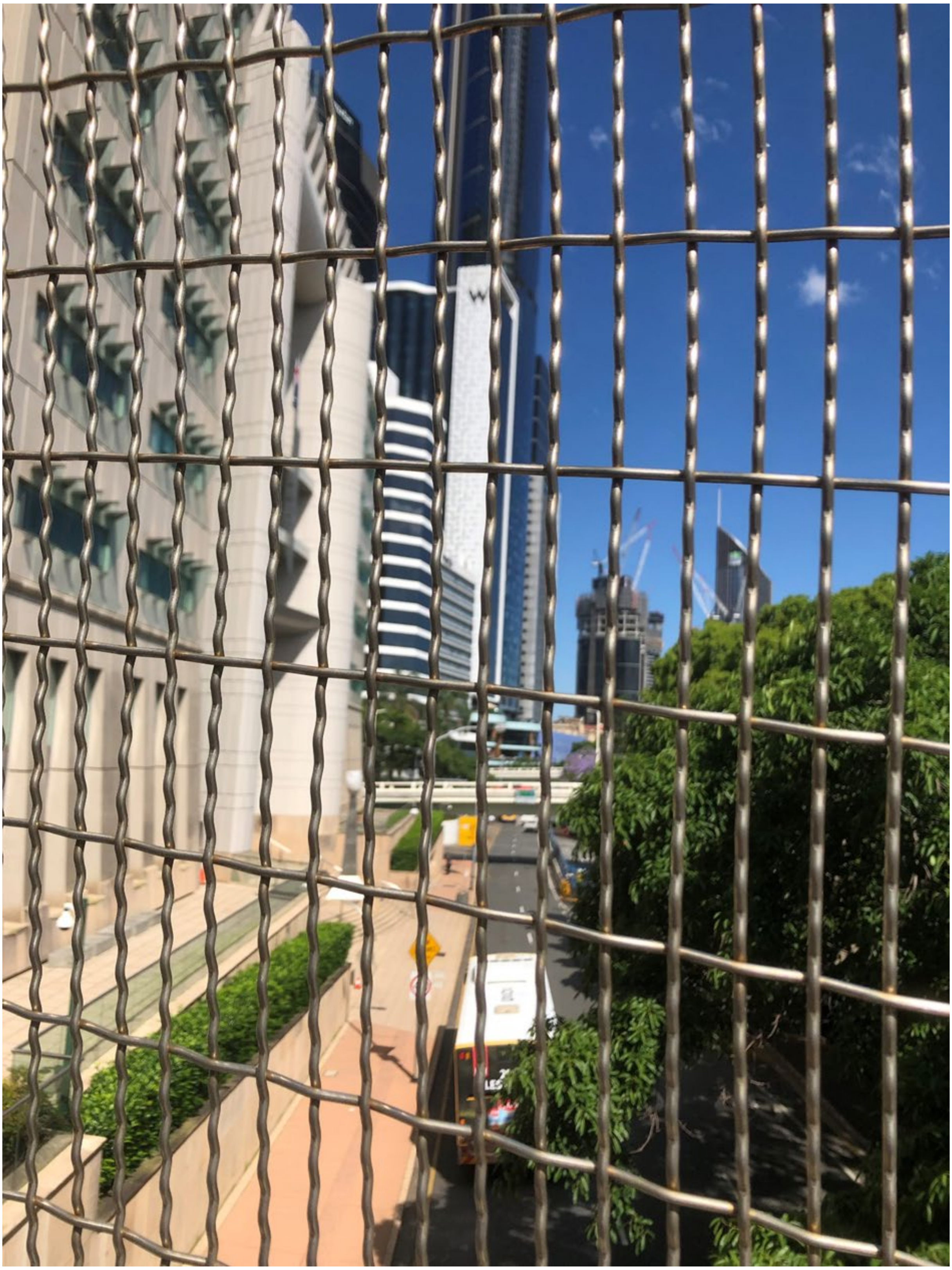
[1] Transport and Main Roads Technical Specification, MRTS15 *Noise Fences*
[2] Transport and Main Roads report – *Testing to determine impact resistance of vehicle windscreens*

Figure 5.14(a) – Woven wire mesh with preferred 25 mm x 25 mm aperture



An opening of 100 mm x 25 mm, with nominal 4 mm wire for mesh screens, is permitted. Additionally, the horizontal wires should be positioned to discourage a potential climber. The 100 mm dimension should preferably be vertical and the 25 mm dimension horizontal (Refer Figure 5.14(b)).

Figure 5.14(b) – Woven wire mesh with vertically orientated aperture



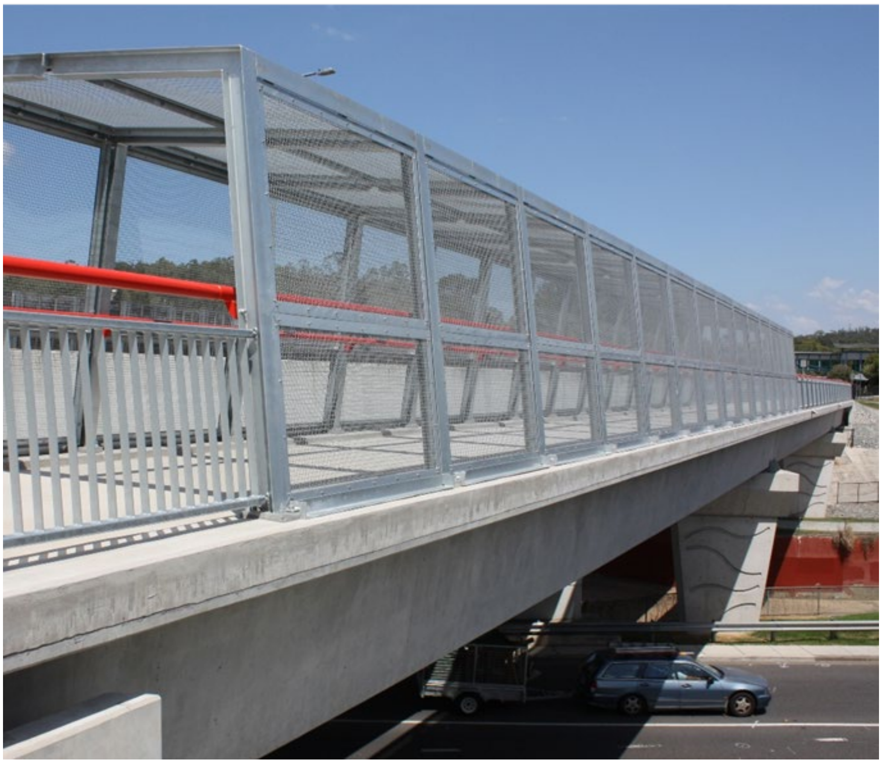
Smaller aperture sizes are permitted.

Slots or gaps in panels, where flat projectiles may pass through (such as road signs, guide posts, manhole covers etc), are not permitted. Such slots and gaps (see Figure 5.14(c)) should be eliminated in the design by using cover-strips (see Figure 5.14(d)) or providing a more torturous path for such objects (see Figure 5.14(e)). Additional detail is required over expansion and hinge joints in bridge decks.

Figure 5.14(c) – Older screen with 50 mm x 50 mm x 4mm welded wire mesh

Note the 50 mm high opening along bottom edge of screen – this should be avoided.

Figure 5.14(d) – Use of cover strips to close slots and gaps



Note the provision of angle cover strip to close gap at base of screens.

Figure 5.14(e) – Example of a panel joint slot effectively covered by a frame member

Note the use of expanded mesh – orientation may cause a louvre effect.

5.15 Noise and vibration

The protection screen should not rattle due to wind or traffic induced vibrations. Where necessary, a durable, corrosion-resistant and acoustic-seal material shall be placed between components so that no audible noise emanates from protection screens.

5.16 Restriction of access

Access to the sides and top of protection screens should be restricted. Where a screen design could permit such a practice, counter measures should be instigated.

To restrict access to an overhead structure, an anti-personnel barrier may be incorporated into the accessible ends of a screen or at other locations where access could occur. This could be in the form of a flange outstand and/or by making it extremely difficult for a normal person to traverse the end roof sections of the screen

5.17 Screening for high-risk situations

In certain situations a higher security protection screen may be required. These screens should usually include solid screen material or additional design features and will be usually higher in price and/or more visually intrusive. There is also the potential to create negative impacts on regular overpass users by reducing the perception of safety and security – CPTED principles should be considered. In addition, the wind loads for solid screens will be considerably higher than open mesh screens. Solid screens are prone to vandalism through surface scratching and painted graffiti.

Screening options for high-risk situations include:

- Mesh with a smaller aperture size.
- Laminated glass or PMMA sheet to full or partial screen height. The reflection of the sun onto road users should be considered. The objective of this type of screen is to stop small objects that may be passed through an open “mesh” type screen.
- solid sheet (non-transparent) screen. The impact on visual amenity is likely to be considerably higher than for other screen types. The objective of this screen type is to stop small objects that may otherwise be passed through an open “mesh” type screen and remove traffic targets from view. However, a solid sheet screen has the disadvantage of shielding offenders, from the view of passing motorists. This issue will require careful consideration, especially where there is no immediate vehicular access to the overhead structure to assist apprehension.
- A secondary catch screen, which is a new concept, needs to be tested to verify its practicality. A secondary catch screen could be mounted almost horizontally on the outside of the overhead structure and angled back toward the structure. To minimise intrusion on visual amenity, the screen should be positioned so that it is not part of the profile of the structure when viewed from a distance. For visual amenity and to reduce wind loading, the screen would be covered with mesh.

  A horizontal catch screen will catch a percentage of smaller objects pushed through the main vertical screen and a percentage of objects thrown over the top of the screen. While this screen may not catch 100 per cent of objects, it will interfere with the accuracy of targeting vehicles.

  A method for safely removing built-up debris should be considered at the design stage. The use of a “bucket truck” operating from the adjacent carriageway or grade-separated road may be considered. Alternatively, the screen may have to be designed for direct access by maintenance personnel. Closing an underpass traffic lane on a busy highway should be avoided where possible. Barring unauthorised access to the catch screen is a necessity and will require careful design consideration.

Transparent panel sheeting to full or partial screen height should be in accordance with the requirements of the Clause 6.14 of the MRTS15 *Noise Fences*. Solid screens may include patterned perforations displaying imagery for enhanced urban design outcomes.

5.18 Signs

Advertising billboards or large traffic signs may be attached to the face of protection screens. Such signage will induce additional wind and dead loads on the protection screen and the overhead structure. The physical parameters and access requirements for such devices should be established at the earliest time. Ideally, this should occur during the structures design. The additional loads will need to be investigated so that the connection and other details become an integral part of the structural design.

Advertising companies require regular access to advertising billboards (may be monthly) to change advertising material. Companies should be asked how they would change the advertising material. Transport and Main Roads districts should not permit unsafe work practices during the changing. It should preferably be performed without closing busy traffic lanes. Consideration should be given to both the personnel who are changing the advertising sign as well as the safety of the traffic underneath (from accidentally dropped tools etc.).

5.19 Screen dimensions

Designs for protection screens will need to establish the limits to which the screen will extend along the overhead structure to ensure risk is adequately reduced. As a guide, the screen should extend approximately 10 metres past the edge of the closest trafficked lane, pedestrian footpath or bikeway notwithstanding the advice in AS(/NZS) 5100 *Bridge design* that this distance can be 6 metres. In certain instances, the protection screen may need to be extended more than 10 metres past the edge of traffic lane to suit specific site conditions, and/or past the end of the overhead structure or wrap across the top of the embankment.

Notwithstanding the above, the protection screen may satisfy this requirement without extending the full length of the overhead structure. In these cases the decision to extend the screen to the full width of the structure will depend on visual amenity issues (symmetry, balance, form etc.), traffic sight distances and whether planned development would alter this requirement at some time in the future. An option may be to postpone protection screen extensions until development occurs (eg. installation of additional traffic lanes.)

Notwithstanding the advice in AS(/NZS) 5100 *Bridge design* that the minimum screen height is 3 metres, it is recommended that – except for fully enclosed screens - the basic screen height should extend 3.5 metres above the area where objects could be launched. This screen height is based on objects thrown or dropped by people. Objects falling from vehicles should be addressed on an individual basis. A protection screen should curve over a pedestrian walkway to increase the difficulty of throwing an object over the top of the screen. Vertical flat protection screen designs are permitted where it is impractical to fit a curved screen.

The minimum height clearance within a fully enclosed protection screen structure shall me 2.7 metres, except where ambulance access is required where 3.0 metres shall be adopted.

The framework, screen material, bracing etc. should be designed in a manner to discourage people climbing the structure. Potential footholds, such as handrails, should be avoided.

A handrail / bike-rail may be provided if it is essential due to:

- high pedestrian traffic flows, or
- need to protect cyclists from projecting parts of the screen structure, or
- the handrail is required to satisfy Design Codes.

Where a pedestrian handrail is provided, it should not facilitate the launching of objects over the top of the screen. Where a handrail is provided and could be used as a foothold, the height of the protection screen shall be extended vertically or an arched or fully enclosed screen considered.

Figure 5.19 – Handrail provides an easy foothold. Open roof design is not recommended

In some instances, a safety railing, concrete barrier or other structure is used as a separator between the traffic lane and pedestrian footway. Where it is possible that a person could stand on such a barrier to launch projectiles from the overhead structure, the height of the protection screen should be extended, or fully enclosed screen considered.

5.20 Overheight / overwidth vehicles

Protection screens should not extend into the airspace of traffic lanes unless suitable vehicle clearances are met. The screening will need to consider vehicle heights and widths and the movement of vehicles under a variety of conditions. For example, high-sided trucks and trailers may lean excessively under the combined actions of road cross-fall, road curvature, wind loads and vehicle dynamics.

The use of the route by over-dimension vehicles should also be considered. Protection screens on both sides of an overhead structure may limit the carriage of over-width loads on that structure. Where this would occur, discussions should be held with Transport and Main Roads and other stakeholders to ensure alternative routes exist.

6 Urban design and aesthetics

Protection screens perform an important aesthetic role. To a large extent they will establish or change the visual character of a bridge. How the appearance of a structure contributes to its wider context is an important consideration. Once established, structures become prominent features than contribute to the character of the surrounding context. Design of structures can maximise the positive contribution to the public realm.

The screen should blend in with the structure's visual design and character. This may be especially important where the overhead structure (bridge) has cultural or historical significance, high community value, or where it experiences high volumes of tourist traffic. Higher costs and more elaborate designs may result.

Some of the factors to consider include colour, form, shape, curvature, texture, and the impact on views. For example, a highly transparent screen could meet all the safety standards, while not impeding views or light.

To achieve a successful design, several considerations should be addressed simultaneously, including social, economic, functional, environmental and aesthetic factors. They should be considered by key stakeholders to achieve common goals and appropriate solutions. For most undeveloped rural areas in the state, stakeholders typically include local government and Queensland Police Service. In urbanised environments and tourism areas, stakeholder groups may be extended to include regional tourism associations, community and environmental groups.

Additionally, public consultation can help to bring issues forward. This will assist in understanding local values, goals and potential impacts on the community. Locals may value a visual setting. Consulting on all aspects at an early design stage may improve appearance, economy, community acceptance and ownership. Consultation will help focus and foster the support of the community to combat the problem of irresponsible individuals throwing objects from overhead structures.

Each proposed screen should be evaluated for aesthetics. Normally, it is not practical to provide premium cost aesthetic treatments without a specific demand. The designer's challenge is to optimise the design through creativity while minimising cost increases.

The designer should consider the predominant viewing directions of the proposed structure. In a rural environment, the predominant views are from the approaching underpass road and from the bridge deck. In an urban environment the bridge may be viewed from a wider variety of directions due to more widespread development.

Generally, the high-speed traveller will not have the time exposure to perceive detail. For high-speed travellers or distant viewers, the main consideration is the fundamental form and colour of the structure. In general, this means that the structure's appearance needs to be simple with clean lines and edges. Small changes in pattern, colour or texture are likely to be lost, so should generally be designed to be clearly appreciable from viewing points in a typically high-speed environment.

Screen posts should be spaced to visually relate to or align with or have a visually symmetrical relationship to other structural elements of the bridge structure, piers, headstocks, light poles and parapet barrier joints for example. Preference should be given to design outcomes that do not disrupt the clean lines and outer face of bridge parapets.

On the other hand, pedestrian and low speed traffic will perceive detail. Detail can contribute to the visual environment and offer visual stimulus. The quality of material, its finish, colour and construction, becomes particularly important in a pedestrian situation and consideration should be given to a higher level of aesthetic treatment to each end of caged structures to create a 'portal' element for enhanced pedestrian experience. End treatments should also seek to achieve a level of visual and structural integration with abutting barriers, railings and other road furniture. Provision of pedestrian shade amenity and weather protection in the form of canopy elements integrated with portal treatments should also be considered.

Consideration should be given to how the screen is attached to the bridging structure to avoid long term aesthetic issues such as staining to the outer parapet.

The following is a list of considerations that may affect aesthetic quality:

- Colour
- Line
- Shape
- Architectural shape and form
- Texture
- Proportion
- Rhythm
- Order
- Harmony
- Balance
- Contrast
- Scale
- Unity
- Impact on views
- Stakeholder consultation
- Impact on pedestrians
- Impact of wind loading on design
- Fitness for purpose
- Ease of maintenance
- Critical access points
- Cleaning and removal of litter
- Materiality, including mixed use of materials
- Site and local context
- Graffiti/vandalism mitigation and management measures.

As considerable literature has been written on the aesthetics of design, it is not the intention of this guideline to replicate that information. The reader is therefore directed to more authoritative references on the subject.

7 References

- Engineering Policy EP177 *Managing the Risk of Objects Thrown From Overpass Structures Onto Roads*, Transport and Main Roads
- *Overpass Safety: Review of Guidelines and Assessment and Prioritisation of Existing Overpasses*, Australian Road Research Board
- AS/NZS 1158.1.1 *Lighting for roads and public spaces – part 1.1: Vehicular traffic (Category V) – Performance and design requirements*, SAI Global
- AS/NZS 1158.3.1 *Lighting for roads and public spaces – part 3.1: Pedestrian area (Category P) lighting – Performance and design requirements*, SAI Global
- AS/NZS 5100 *Australian Bridge Code*, SAI Global
- MRTS78 *Fabrication of Structural Steelwork*, Transport and Main Roads
- MRTS79 *Fabrication of Aluminium Components*, Transport and Main Roads
- AS/NZS 1170 *Structural Design Actions*, SAI Global
- AS 1657 *Fixed Platforms, Walkways, Stairways and Ladders*, SAI Global
- TC1880 – *Information Sign for 24-hour behaviour monitoring*, Transport and Main Roads
- EN ISO 7823-2 - *Plastic, Poly (Methyl Methacrylate) sheets*, International Organization for Standardization
- AS 2208 *Safety Glazing Materials in Buildings*, SAI Global
- MRTS15 *Noise Fences*, Transport and Main Roads
- QDesign: Queensland Urban Design Principles, Queensland Government

Appendix A – Risk assessment methodology for existing overpasses

This appendix provides additional information to support the assessment of risk at individual overpasses using the methodology described in Section 3 of this technical guideline. An example of how the risk assessment methodology is used is provided in Appendix B.

Where multiple assessments are undertaken to develop a ranking list of all overpasses, a desktop exercise should suffice. When the need for an assessment is triggered by an incident (Appendix B example), a site visit is recommended to collect current data for the assessment as well as other information to enable an accurate briefing on the incident.

Table A – Description of attributes

Attribute	Description
History of incidents in the last 10 years. From crash data, police reports or media reports	Include all incidents, such as deliberate and accidental throwing/ dropping of objects and self-harm. Each incident contributes to the score, depending on the timing of the incident. Multiple acts on one day counts as one incident. This attribute is considered a primary indicator of risk, particularly where there have been multiple incidents at one site.
Function of Structure	Risk is considered higher where there is good pedestrian / cyclist access and vehicular access is constrained on the overpass. The presence of passing motorists is seen as a potential deterrent.
Loose objects on or near structure - up to 100 metres from structure	This includes any objects that may be picked up and thrown or dropped onto the road below. This can be loose rubble, pavers, roadside furniture and litter for example. Heavier objects are more likely to do significant damage, although objects that are too heavy to lift may not be practically used as projectiles. As a rule of thumb, assume a large object would need two hands to be lifted by an adult, while a smaller/ lighter object could be thrown in one hand.
Proximity to children's facilities (schools, playgrounds) where children unaccompanied	Older unsupervised children are considered a higher risk group for dropping/throwing incidents. Locations where they may be walking to/from home are potential sites, so these should receive a higher score under this attribute.
Nearby structure with history of prior incidents within 5 years	There is anecdotal evidence that the risk of deliberate acts could migrate to nearby sites, particularly when a site is treated following reports of incidents.
Public visibility / Lighting	The risk of an incident is reduced where the site is well lit and close to centres of activity, such as residential areas and/or recreation amenities where there is night-time activity. Being visible to others is a deterrent due to the risk of being caught. Locations that have no or poor lighting and in more isolated locations are a lower risk of apprehension.

Attribute	Description
Video Surveillance	Video surveillance cameras with signs (see TC1880 – *Information Sign for 24-hour behaviour monitoring*) can act as a deterrent. Installing cameras to treat a site should be done in consultation with Queensland Police Service.
Evidence of vandalism	It is believed that deliberate acts at overpasses are more likely in areas that suffer from other forms of undesirable behaviour, such as graffiti or wilful damage of property. Evidence could be viewed during a site visit and/or received from local police.
Traffic volume (overpass road)	Vehicles passing frequently on the overpass can act as a deterrent, particularly at night when the risk is higher. Choose the relevant category based on annual average daily traffic. These data are available at most sites and gives a sufficient indicator of the relative traffic volumes during the night for all sites. This approach is preferred to specifying night-time traffic flows to minimise the need for new traffic counts.
Proximity to hotels, clubs, etc,	Patrons are considered a higher risk group for dropping / throwing incidents. Locations where they may be walking home are potential sites, so these should receive a higher score under this attribute.
Screening of structure, L_M	A 'substantially effective' protection screen is expected to significantly reduce the risk at a site, so much so that the problem may be all but eliminated. However, in some cases screens could be only partially effective if objects can still be dropped or thrown over them or from the side.
Traffic volume - AADT (underpass road)	See Section 3.1.3. Use the annual average daily traffic (all lanes and both directions).
Posted speed limit	This is an important factor as the velocity of the impacted vehicle (and occupants) is a key determinant of the potential trauma to occupants. The posted speed limit should be sufficient (rather than actual surveyed speeds).

Appendix B – Risk Assessment Methodology for existing overpasses – Worked example

In this example an urban arterial road passes over a major divided highway (90 km/h posted speed limit) on the outskirts of a major conurbation. The arterial carries 8,500 vehicles per day and provides good pedestrian and cyclist access while the highway carries 24,000 vehicles per day.

There have been reports of 'near misses' from objects thrown at two cars last night. A site visit has found that the nearest school is about 1 kilometre away and there are two hotels within 2 kilometres. The overpass is within sight of dwellings in an adjacent sub-division but has poor lighting. There is no video surveillance. Recent wet weather has caused some erosion of the embankment on one approach, exposing aggregate that could be a source of small objects to throw.

A review of information sources finds that there was one incident at the same site 9 years ago.

To assess the risk (relative to other overpasses) a risk score is calculated following the methodology set out in Section 3.1 and Appendix A.

Using same table template of Table 3.2.1, see below a worked example.

Table B – Worked example of Existing Overpasses, Likelihood risk score - R_L.

Attribute	Category / Options	Risk Score	Score
History of incidents in the last 10 years From crash data, police reports or media reports	1 - No reported incidents	0	37
	2 - Each incident within 5 to 10 years	7	
	3 -Each incident within last 1 to 5 years	15	
	4 - Each incident within last 12 months	30	
Function of Structure	1 - Pedestrian/bikeway footbridge only - high usage	9	3
	2 - Pedestrian/bikeway footbridge only	7	
	3 - Shared vehicle & pedestrian access with designated pedestrian facilities (i.e. footpath)	3	
	4 - Vehicle access only however informal pedestrian crossing possible (wide shoulders/bike lanes)	1	
	5 - Vehicle access only with very limited or no pedestrian access	0	
Loose objects on or near structure - up to 100 metres from structure	1 - Not Present	0	4
	2 - Present – only smaller/lighter objects, rocks, rubble and so on	4	
	3 - Present – Large, unsecured objects that could be used as projectiles, such as large rocks or road furniture.	8	
Proximity to children's facilities (schools, playgrounds) where children unaccompanied	1 - None within 2 km	0	1
	2 - Present 1 m to 2 km	1	
	3 - Present 500 m to 1 km	3	
	4 - Present within 500 m	6	
Nearby structure with history of prior incidents within 5 years	1 - Not Present	0	0
	2 - Present within 3 kms	5	
	3 - Present within 1 km	8	

Attribute	Category / Options	Risk Score	Score
Public visibility / Lighting	1 - Not Present	8	4
	2 - Visible but Unlit	4	
	3 - Visible and Lit	0	
Video Surveillance	1 - Not Present	6	6
	2 - Present	0	
Evidence of vandalism	1 - Not Present/Unknown	0	0
	2 - Present	4	
Traffic volume (overpass road)"	1 - Low (up to 5,000)	4	2
	2 - Medium (5,000 to 15,000)	2	
	3 - High (15,000 or more)	0	
	4 - Not applicable (no access for motorised vehicles)	4	
Proximity to hotels, clubs, etc,	1 - None within 2 km	0	1
	2 - Present 1 km to 2 km	1	
	3 - Present 500 m to 1 km	3	
	4 - Present within 500 m	6	
TOTAL - Sum of the scores above in right hand column, $\mathbf{L_1}$			58
Screening of structure, $\mathbf{L_M}$	1 - No screen present	1	1
	2 - Screen present - partially effective	0.5	
	3 - Screen present - substantially effective	0.05	

The Likelihood Formula is - $R_L = L_1 \times L_M$

$R_L = 58$

And from Tables 3.2.2 and 3.2.3, Severity, $R_S = 10$

Exposure, $R_E = 1.33$

Total risk score, $R_L \times R_S \times R_E$

$58 \times 10 \times 1.33$

Total risk score = 770