Technical guidelines for the treatment of overhead structures – objects thrown or dropped
# TABLE OF CONTENTS

1. **BACKGROUND** ................................................................. 3
2. **PURPOSE** ........................................................................... 3
3. **RISK ASSESSMENT** .......................................................... 4
4. **REDUCING RISK PROBABILITY AND EXPOSURE** ................. 7
   4.1 Removal of potential projectiles ........................................... 7
   4.2 Replacement of heavy guideposts ....................................... 8
   4.3 Making safe road furniture .................................................. 8
   4.4 Drainage scuppers ............................................................. 8
   4.5 Embankment treatment ....................................................... 8
   4.6 Lighting .............................................................................. 9
   4.7 Surveillance cameras & signs .............................................. 9
   4.8 Discussion with local government and community groups ....... 9
   4.9 Letterbox drops .................................................................. 10
   4.10 Local newspapers and Neighbourhood Watch newsletters .... 10
   4.11 School education programs .............................................. 10
   4.12 Increased policing ............................................................ 10
5. **ENGINEERING ISSUES RELATING TO THE PROVISION OF SCREENS ON OVERHEAD ROAD STRUCTURES** ................................................. 10
   5.1 General ............................................................................. 11
   5.2 Design life .......................................................................... 12
   5.3 Design standards ............................................................... 12
   5.4 Design loads for a vertical protective screen ......................... 12
   5.5 Design loads for horizontal protective screens .................... 13
   5.6 Material selection and surface finishing ............................... 13
   5.7 Serviceability of posts and panels ....................................... 14
   5.8 Transparent panels ............................................................ 14
   5.9 Reflectance ......................................................................... 14
   5.10 Capacity of existing structure ............................................ 14
   5.11 Impact resistance and strength ........................................... 15
   5.12 Welded wire mesh or expanded mesh? ............................... 15
   5.13 Screen aperture requirements .......................................... 16
   5.14 Noise and vibration ......................................................... 18
   5.15 Restriction of access ........................................................ 18
   5.16 Screening for high risk situations ...................................... 19
   5.17 Signs ................................................................................ 20
   5.18 Sight distances ................................................................. 20
   5.19 Screen dimensions ........................................................... 21
   5.20 Overheight / overwidth vehicles ........................................ 22
6. **AESTHETIC AND OTHER ISSUES** ...................................... 23
1. Background

A dangerous practice has occurred in Queensland, Australia, and other parts of the world where objects have been deliberately thrown or dropped from overhead road structures. These incidents pose a risk to the vehicle occupants and other road users such as pedestrians.

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.

There are other areas and situations within the road network that exhibit a higher than average accident rate. Main Roads funds road safety initiatives on a priority needs basis. When considered under this context, a specific location or intersection on a road with an accident history commonly may have a higher relative priority than retrofitting a protective screen to a bridge. Such active competition for funding ensures the most cost-effective use of the limited funds available.

Main Roads has a policy on Reduction of Risk from Objects Thrown From Overpass Structures onto Roads. This technical guideline should be read in conjunction with the policy.

2. Purpose

The guideline was created for Main Roads for state-controlled roads. It provides risk assessment and technical criteria, which will help identify high-risk areas and provide guidance on treatment to reduce the risk.

The guideline provides guidance for assessing the risk of objects being deliberately thrown from overhead structures by using risk assessment tables to generate a risk score. A numerical risk score will allow prioritisation and comparison of works. The guideline also describes preventative measures and contains detailed technical design criteria to ameliorate risk.

Short of enclosing an entire overpass structure with a high security solid metal barrier, screening of structures will not provide a 100 per cent guarantee of motorist safety. Protective screens will, however, provide the highest available safety given physical, social and economic constraints. However,
other measures and competing priorities need to be considered before overpass structures are screened.

3. Risk assessment

Risk may be defined as the combination of events, the consequences of an event, the probability of the event and the exposure to this event.

Examples of the consequences of an accident involving an object being thrown from an overhead structure 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;
- community pressure to fix the problem in the form of public ‘outrage’\(^1\).

Assessing various factors that may contribute to an incident can approximate the probability of an incident occurring and exposure to this event.

A risk assessment may become necessary as a result of a history of incidents at a particular overhead structure. Alternatively, it may form a means to assess a number of structures and rank them for ameliorative treatment or to identify likely future trouble spots so that remedial action may be taken in advance.

For a particular overhead structure, Tables 1, 2 & 3 list a number of relevant conditions and factors.

Table 1 lists point ratings corresponding to a range of conditions. If particular conditions are identified as applicable, then the associated points may be summed to give an aggregate point score, \(R_1\). However, if this summation results in a negative answer, the aggregate point score is taken to be equal to one.

\(^1\) AS 4360-1999 Risk Management.
<table>
<thead>
<tr>
<th>Area</th>
<th>Item</th>
<th>Specific Conditions</th>
<th>Possible Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>Sites where objects could be launched are visible to surrounding residents.</td>
<td>- 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>There is video surveillance of the structure with video signage.</td>
<td>- 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Police have a high visual presence in the area.</td>
<td>- 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>The structure is lit but to a low standard</td>
<td>- 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>It is difficult for a pedestrian to gain access to an overpass structure in the case of vehicular traffic only overpass. This may be due to lack of connectivity to areas outside the road reserve, high fences or barriers blocking access, access is via long approach ramps.</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>The structure is lit to a high standard</td>
<td>- 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Police advise there are active youth gangs in the area.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Evidence of vandalism is present on or near the structure.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>The structure is part of a commuter route between urban suburbs or a high usage route to nearby public transport facilities such as bus or rail.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Overhead structure is within 1 km of a screened structure.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Overhead structure is within 1 km of a structure (screened or unscreened) and that structure has had reports of objects being thrown within the last two years.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Overhead structure is in the vicinity of a club, adult sporting facility, hotel or other adult facility that is likely to generate pedestrian traffic from patrons of these facilities.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Overhead structure is in the vicinity of a school, playground, park, juvenile sporting facility or other facility which is likely to generate pedestrian traffic and whose nature would indicate that children unaccompanied by an adult would use the overhead roadside structure.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Overhead structure has had prior reports of objects being thrown within the last two years.</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Loose objects such as rocks, solid delineator posts etc, are located close to and readily accessible from the structure’s surrounding environment.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Overhead structure has pedestrian footway(s) incorporated into its design.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Overhead structure is exclusively a pedestrian/bikeway footbridge with no vehicular traffic. If 17 is selected do not select 19 to 24.</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>It is difficult for the occupants of a targeted vehicle or other nearby vehicles to apprehend the offender who threw an object. This situation occurs where there are no access ramps (only steep abutments), as would be the case for a grade separated local road or pedestrian footbridge, or if driving in a loop to the overpass road is time consuming.</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>AADT for overhead road up to 5,000</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>AADT for overhead road 5,000 to 15,000</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>AADT for overhead road 15,000 to 25,000</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>AADT for overhead road 25,000 to 35,000</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>AADT for overhead road 35,000 to 45,000</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>AADT for overhead road 45,000 and above</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** If 19 to 24 is selected do not select 17

**Table 1 Site Conditions risk score - R1**

2 AADT means the annual average daily traffic count for a particular section of road
3 If R1 is a negative number, +1 should be substituted.
Table 2 lists a speed multiplier factor, $R_2$, which relates to the consequences of an object's velocity of impact, combined with the likelihood of an offender accurately targeting a specific vehicle. For example, a stone of a certain mass may not penetrate the windscreen of a vehicle travelling at 50km/h but may penetrate the windscreen and cause severe injury to the occupants of a vehicle travelling at 100km/h. Hence, the risk increases with vehicle speed. Although the energy of impact varies with speed squared, a linear approach has been adopted because at higher speeds, vehicles are more difficult to accurately target.

<table>
<thead>
<tr>
<th>Posted traffic speed in km/h for underpass</th>
<th>Speed factor multiplier $R_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 and less</td>
<td>1.0</td>
</tr>
<tr>
<td>60</td>
<td>1.2</td>
</tr>
<tr>
<td>70</td>
<td>1.4</td>
</tr>
<tr>
<td>80</td>
<td>1.6</td>
</tr>
<tr>
<td>90</td>
<td>1.8</td>
</tr>
<tr>
<td>$\geq$ 100</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 2. Speed Multiplier - $R_2$

Table 3 lists a traffic multiplier factor, $R_3$, 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. This factor is also moderated after due consideration of increased exposure of the perpetrator when traffic volumes increase.

<table>
<thead>
<tr>
<th>AADT for underpass road</th>
<th>Traffic multiplier $R_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 5,000</td>
<td>1.00</td>
</tr>
<tr>
<td>5,000 to 10,000</td>
<td>1.05</td>
</tr>
<tr>
<td>10,000 to 20,000</td>
<td>1.27</td>
</tr>
<tr>
<td>20,000 to 30,000</td>
<td>1.33</td>
</tr>
<tr>
<td>30,000 to 40,000</td>
<td>1.45</td>
</tr>
<tr>
<td>40,000 and above</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Table 3. Traffic Multiplier - $R_3$

To obtain a total risk assessment score, multiplied the total points score $R_1$, from Table 1 with the speed multiplier $R_2$ from Table 2 and by the traffic multiplier $R_3$ from Table 3.

Total risk assessment score = $R_1 \times R_2 \times R_3$
This risk assessment methodology is based on empirical evidence and, as there is little statistical data available, it has not been verified for accuracy over a sustained period. It is proposed as a reasonable methodology for assessing risk. In the absence of more substantial data, the risk assessment scores may be interpreted as:

Low risk  0 – 30  
Medium risk  30 – 60  
High risk  60 and above

These categories should be reviewed after assessments are conducted and experience gained. In addition to Table 1, practitioners should also consider other local issues and modify the assessment accordingly.

The table is a guide and should be used in conjunction with sound engineering judgement, local knowledge and common sense. As the information listed in Tables 1, 2 and 3 is empirical, local factors must be addressed by thorough field assessment to ensure results are free from anomalies or perverse outcomes.

4. Reducing risk probability and exposure

Where an overhead structure is identified as being of medium to high-risk, action should be taken to reduce the risk. Risk reduction methods may include:

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 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
Drainage scuppers above traffic lanes have been identified as potential sites for “bombing” traffic. This shape, length and inclination needs to be considered before remedial action. 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.

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 junction boxes, the connection of lighting and the appropriate class of lighting must be considered. A recognised standard for overhead structures and immediate vicinities is Category B1 in AS1158.0 – 1997.

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 it’s early inclusion in designs.

4.7 Surveillance cameras & 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;
- there is a need for continuous recording with a recommended minimum recording time of the previous 48 hours.

4.8 Discussion with local government and community groups
The act of throwing objects from overhead roadside structures onto road users is symptomatic of wider social problems. Dealing with this matter will be more effective if local governments and community groups jointly share its management. Each group may wish to contribute in a different way. It is important that local governments and various community groups are made aware of the issues and discussions should be held at a local level. Consideration should be given to talking to youth workers at youth drop-in centres about types of offenders, safety issues and likely successful strategies.

Consultation will help educate the community and ensure better alignment between the perceived risk and the actual risk reducing “public outrage” from accidents involving objects thrown from overhead structures.
4.9 Letterbox drops
Letterbox-drops may be used to advise local residents of recent events and safety issues. Another objective is to raise parental awareness and contribute to a limited form of “self policing”.

In addition local residents who live near and overlook overhead structures could assist in policing them if they are aware of the issues and what action they should take if they observe inappropriate or suspicious behaviour.

4.10 Local newspapers and Neighbourhood Watch newsletters
Apart from letterbox-drops, consideration may be given to providing press releases in local newspapers and Neighbourhood Watch newsletters. Articles should be carefully worded to avoid copycat incidents.

4.11 School education programs
Queensland Transport’s Regional Safety Managers should be consulted with the objective of providing school education programs. An education program should highlight the fact that throwing objects from overpasses is a criminal offence. It has been identified that youths often do not understand the full consequences of their actions and this program may help to remedy this. They should be made aware of the possible injury or death to road users, possible jailing of offenders, criminal records associated with such offences and the impact on the lives of all concerned.

4.12 Increased policing
For trouble-spot areas in urban areas, immediate action may be taken by providing increased surveillance of the particular overhead structure. Queensland Police Service may assist by routing routine patrols through the trouble-spot area. Where this is not possible, consideration should be given to using security patrols that already call in the particular area.

Before any major action, discussions should be held with local governments to keep them informed of the action and to seek their active involvement.

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 protective screens to an overhead structure may be the only avenue remaining. Main Road’s policy and competing priorities need to be considered before protective screens are installed. It should be noted
protective 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, standardisation of fixing should be considered where practicable.

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

- Protective screens should preferably be fitted to both sides of an overhead road structures regardless of the number and location of pedestrian footways on the structure.
- Dedicated pedestrian footbridges should have fully enclosed screens.

Where the risk assessment indicates a protective screen, the screens should be designed to harmonise with the human and natural environment as far as practicable. This issue can be more critical in highly populated and tourist areas.

It is possible to achieve a more acceptable outcome when protective 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 risk analysis indicates that a protective screen is not initially required, 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 protective screen onto a standard structure. Consideration of anchor points etc. will require a preliminary screen design.
5.2 Design life
The serviceability and life expectancy for a bridge structure is typically 120 years. The life expectancy of a protective screen is considerably less, typically 50 years. Life expectancy may be varied to suit conditions at each site. For example, a screen in a marine environment may have a lower life expectancy (30 years) while a screen within a busy city precinct may be designed to a much higher standard.

In marine applications, more expensive corrosion resistant materials and treatments such as aluminium, stainless steel, plastics and epoxy coatings are required.

5.3 Design standards
Where a protective screen serves the purpose of primary structural railings for pedestrian or vehicular traffic, its design shall be in accordance with the Australian Bridge Design Code.

Specifications and standards for steelwork, aluminium, fasteners, hot dip galvanising, paint film thickness, material grades etc. shall comply with the Australian Bridge Design Code, Main Roads standard specifications and Australian Standards. In particular, MRS 11.78 - Fabrication of Structural Steelwork is applicable.

5.4 Design loads for a vertical protective screen
Unless higher loads are applied by the Australian Bridge Design Code, the
following minimum design loads shall apply:

Wind loads
The protective screen shall be designed in accordance with the SAA Loading Code Part 2: Wind Loads AS 1170.2. The importance factor to be used in the design calculations shall be \( M_i = 1.0 \)

Live loads
Where a protective screen serves as the primary pedestrian safety railing, the applied design loads shall conform to the requirements of the Australian Bridge Design Code.

The screen shall also be designed to cater for horizontal loads applied at pedestrian shoulder height as well as a top edge load to cater for a person hanging or climbing on the screen.

Horizontal loads shall be applied 1.5 metres from the ground or at any other point where a horizontal load can be conveniently and forcibly applied. The screen shall be designed for a 0.75kN/m line load applied horizontally and vertically at this height. The loads may be applied separately. The load factor for serviceability design shall be 1.0 and for ultimate design shall be 2.0.

A point load of 1.5kN shall be applied in any direction and at any location, along the top edge of the screen. The edge shall not suffer permanent distortion.

Additionally, where products (eg. primary products such as coal, timber) are transported via an overhead structure and have a high probability of falling from transport vehicles, the screen shall be specifically designed to cater for such occurrences. This may entail increases in screen height and strength and changes to screen aperture size.

5.5 Design loads for horizontal protective screens
Where a horizontal catch screen is fitted, it shall be designed in accordance with Australian Standard – Fixed platforms, walkways, stairs and ladders – Design, construction and installation – AS 1657.

5.6 Material selection and surface finishing
Materials for a protective 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 4mm.

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

In marine environments, or as an alternative to steel, aluminium may be used
to extend the service life of a protective screen.

Prior to applying powder coating or epoxy coating to galvanised components, galvanised surfaces shall be lightly abrasively blasted or chemically etched to promote bonding and to remove surface chemicals. Surface coating materials, application methods and film thicknesses shall comply with Main Roads specifications.

5.7 Serviceability of posts and panels
The horizontal deflection of posts and panels shall be limited to the height or span/150 under the action of wind or live loads. These loads should be applied separately. Where the protective screen provides structural support for the handrail system and is required to resist live loads, the deflection at handrail level shall be limited to the height or span/250

This specification is not applicable to transparent panels.

5.8 Transparent panels
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 maximum deflection of transparent panels shall conform to the requirements set out in MRS 11.15 supplement “Transparent Noise Barriers”.

5.9 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.

5.10 Capacity of existing structure
The structural capacity of an existing structure is a critical element in the retrofitting of a protective 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 protective screen, consideration should be given to performing any maintenance work prior to the fitting the protective screen. In this regard, fitting a protective screen may have secondary cost implications such as bring forward maintenance costs.
5.11 Impact resistance and strength
The following test shall apply to all screen materials. The screens shall be able to withstand the impact of a 4kg ball dropped from a height of 3 metres onto a panel supported horizontally above the ground\textsuperscript{4}.

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 dents and superficial damage, however it shall not cause any structural damage to the protective 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.

5.12 Welded wire mesh or expanded mesh?
Both welded wire mesh and expanded mesh may be used in the construction of screening structures. As may be seen from the table below, both products have relative strengths and weaknesses and it is left up to the designer to select the most appropriate product consistent with maximum aperture size, design parameters and aesthetic requirements.

Manufacturers of welded wire mesh and expanded mesh have advised that various size sheets can be made to order. This includes the particular orientation of the apertures. Also with welded wire mesh, additional wires can be installed at strategic locations (such as along edges).

To minimise the louvre effect of expanded 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.

\textsuperscript{4} Main Roads Standard Specification – MRS11.15 Noise Barriers
Advantages and disadvantages between welded mesh (fabric)and expanded mesh

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>light weight</td>
<td>may need additional strength if used as railing system</td>
<td>high strength therefore may in certain cases dispense with other railing systems</td>
<td>panels are heavy</td>
</tr>
<tr>
<td>very flexible</td>
<td>flexible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>low cost</td>
<td></td>
<td>higher cost than welded mesh</td>
<td></td>
</tr>
<tr>
<td>large sheet sizes</td>
<td>sheets sizes can be made to order</td>
<td>sheets sizes can be made to order</td>
<td></td>
</tr>
<tr>
<td>sheets sizes can be made to order</td>
<td>may be cut with simple handtools</td>
<td>harder to cut with simple handtools tools</td>
<td></td>
</tr>
<tr>
<td>low solidity %</td>
<td></td>
<td>higher solidity % than welded mesh</td>
<td></td>
</tr>
<tr>
<td>no louvre effect</td>
<td></td>
<td>can have louvre effect dependent on viewing angle</td>
<td></td>
</tr>
</tbody>
</table>

5.13 Screen aperture requirements
In the past, the generally accepted nominal mesh size used in protective screens has been 50 x 50mm. In establishing this guide, it was important to understand the relationship between mesh aperture size, vehicle speeds and the impact resistance of vehicle windscreens. Testing\(^5\) was performed on windscreen samples using concrete and steel balls impacting at a range of speeds. This testing was used as the primary reference in determining the most appropriate mesh aperture for different speed environments.

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 25mm diameter sphere. This requirement applies to all joins and openings over or immediately adjacent to traffic movement. Where conventional welded wire fabric is used, the recommended mesh to use is 100mm x 25mm with 4mm wire. Additionally, the horizontal wires should be positioned to discourage a potential climber. The 100mm dimension should preferably be vertical and the 25mm dimension horizontal. Aperture sizes smaller that that specified are permitted.

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

\(^5\) Main Roads report --'Testing to determine impact resistance of vehicle windscreens'
Figure 3. Footbridge with 50 x 50 x 4mm welded wire mesh. Note the 50mm high opening along bottom edge of screen – this should be avoided.

Figure 4. Example of a panel joint effectively covered by a frame member. Note the use of expanded mesh – orientation may cause a louvre effect.
5.14 Noise and vibration
The protective screen should not rattle due to wind or traffic induced vibrations. Where necessary, a durable, corrosion resistant material shall be placed between components so that no audible noise emanates from protective screens.

5.15 Restriction of access
In the past, adventurous youths have fallen and died while walking along the top of protective screens. Where a screen design could permit such a practice, counter measures should be instigated. This is particularly pertinent to fully enclosed pedestrian footbridges.

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 were 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. One method of restricting movement along the roof is to use tensioned stainless steel cables at approximately 150mm centres in the end panels of a screen.

The placement of the horizontal wires in welded mesh needs consideration. A potential climber will find it more difficult to climb a screen if presented with smooth vertical wires with no cross wires therefore:

- For a fully enclosed screen the climbing deterrent should be on the outside of the screen. The horizontal wires should therefore be located on the inside.
- For a vertical screen the climbing deterrent should be on the inside of the screen. The horizontal wires should therefore be located on the outside.
5.16 Screening for high risk situations
In certain situations a higher security protective 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. 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.

5.17 Signs
Advertising billboards or large traffic signs may be attached to the face of protective screens. Such signage will induce additional wind and dead loads on the protective 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. 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.).

5.18 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.
5.19 Screen dimensions
Designs for protective 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 meters past the edge of the closest trafficked lane, pedestrian footpath or bikeway. In certain instances the protective screen may need to be extended past the end of the overhead structure or wrap across the top of the embankment.

Notwithstanding the above, the protective 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 protective screen extensions until development actually occurs (eg. installation of additional traffic lanes.)

It is recommended that 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 protective screen should curve over a pedestrian walkway to increase the difficulty of throwing an object over the top of the screen. Vertical flat protective screen designs are permitted where it is impractical to fit a curved screen.

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 eliminated.

A waist height handrail may be provided if it is considered to be 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 be able to be used to launch objects over the top of the screen. Where a handrail is provided and could be used as a foothold, the height of the protective screen shall be extended vertically or it shall form an arch over the footway. This arch should project back over the footway as far as practicable. However, the outer edge of this arch should be no closer than 0.3 metres to the face of a barrier kerb or 0.5 metres to the face of a mountable or semi mountable kerb that forms the edge of the carriageway or any surface used by vehicles.
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 protective screen should be extended.

5.20 Overheight / overwidth vehicles
Protective 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. Protective screens on both sides of an overhead structure may limit the carriage of overwidth loads on that structure. Where this would occur, discussions should be held with Queensland Transport and other stakeholders to ensure alternative routes exist.
6. Aesthetic and other issues

Protective screens perform an important aesthetic role. To a large extent they will establish or change the visual character of a bridge. The blending of a structure into the wider visual setting is an important aesthetic consideration. Once a structure is established it will become a prominent landscape feature, immediately changing the character of the surrounding visual environment.

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.

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.

The issue of aesthetics will require more attention in highly populated areas, areas with a high proportion of local and overseas visitors, areas with cultural and historical values and social interaction. Higher costs and more elaborate designs may result.

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, Queensland Transport 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.

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

- Colour
- Line
- Shape
- 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

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 subject⁶.

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⁶ Queensland Department of Main Roads, Corporate Communication Unit (1996), Draft Public Consultation Policy and Guidelines.

Queensland Department of Main Roads, Technology and Environment Division, (1997), Road Landscape Manual.


Minnesota Department of Transport, Aesthetic Guidelines for Bridge Design.