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Considerations for installing Public safety Barriers on Long Span Bridges.

Considerations for Installing Public Safety Barriers on Long Span Bridges

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Abstract

Long span bridges by virtue of their iconic status and typically high elevation have historically presented a public safety concern for their owners from acts and attempted acts of suicide. These cause a variety of problems including operational disruption and cost, negative publicity and psychological impact on workers and others involved.

Increasingly many bridge owners are considering the installation of Public Safety Barriers (or anti-suicide fences) to address this issue. However, retro fitting of such barriers to an existing bridge is complex and requires consideration of many factors. Many of which would also be applicable to new build bridges.

This paper explores these factors to demonstrate how these challenges can successfully be met whilst preserving or even enhancing the bridge's visual appeal.

Keywords
Suicide, Barriers, Bridge, Cable Stayed, Suspension, Public, Safety, Fence

1. Introduction

Many long span bridges due to their height, location or prominent status provide a draw for those seeking to intentionally kill themselves. This presents a multitude of problems for bridge owners including the disruption and trauma caused to the public, emergency crews and bridge staff by the incident itself, potential loss of revenue due to temporary closure, negative publicity, and the generation of copycat incidents. There are several ways to reduce the incidence of suicide at a particular site; the installation of a physical barrier being the most effective, but even this should be considered as part of a wider strategy.

This paper describes the factors that need to be considered when contemplating the installation of a barrier on either a new or existing crossing. It considers functional objectives for the barrier, provides design guidance, recommends tests and trials for verifying performance, and covers the assessment of the impact of the barrier on the bridge itself. Reference is made to previous examples, in particular the recent successful installation of a barrier on West Gate Bridge in Melbourne Australia.

2. The Case for Public Safety Barriers and the Wider Strategy

Knowledge of background research on suicides at bridge sites and the role of barriers is very useful in providing both a sound business case for their installation, and motivation and inspiration for doing so. In this respect there are several key research findings[1] which are relevant:

- Most incidents happen at bridges which are readily accessible and close to urban areas;
- Notoriety for incidents increases the draw;
- A romanticized location increases the draw;
- There is little evidence that putting up the barriers transfers the problem to another site (unless there is a nearby bridge or building that also satisfies the above);
- Around a quarter to half of incidents are impulsive;
- The majority of those who make a suicide attempt at a bridge site would not defer to another method;
- Those who fail are unlikely to repeat the attempt;
- Witnessing a suicide increases the risk of that person committing suicide in later life.

The above provides a compelling argument to consider barriers. Barriers although very effective are best supported by a wider strategy which includes: restricting or controlling access; emergency help phones; minimising publicity; trained bridge staff to monitor bridge users with rapid response professional services to intervene; and surveillance cameras. (In the absence of barriers fast emergency response times and water rescue capability for bridges over water can help to increase survival rates.)

3. Functionality Requirements for Public Safety Barriers

Careful consideration of the barrier's functionally requirements provides the platform for developing the design of the barrier. Common factors to consider include the following:

- Providing a strong visual presence and deterrent to those considering scaling the barrier. I.e. if the barrier looks imposing enough many attempts will be discouraged before they start.
- Is climb resistant, noting that the effectiveness of the barrier can be set at different levels and no barrier can completely resist a tool-assisted attempt or the use of climbing aids.
- Is low maintenance;
- Provides space for any existing vehicular parapet to deform upon impact and for maintenance and rescue personnel to work at the foot of the barrier;
- Maintains views from the bridge and does not detract from the experience of driving across the bridge or the visual appearance of the bridge itself;
- Permits access to underdeck maintenance gantries;
- Fits in with existing street furniture and barriers. It is likely that along the edge of the bridge there will be directional signs, emergency phones, variable speed signs, navigation warning signs etc, all of which could act as aids to a person attempting to scale the barrier.
- The barrier caters for imposed and environmental loads;
- The barrier does not cause aerodynamic instability of the bridge deck.

4. Performance Level

In general, the aim of a barrier is to prevent all future suicides, however the higher and more sophisticated the barrier the higher the cost. A lower less secure barrier will greatly reduce the risks, and the presence of any barrier will deter some, but it should be noted that the people who jump from bridges tend to be significantly younger than those committing suicide by other methods and more often male[3]. For example, at Bosphorous Bridge the male/female ratio for attempts was 15:1 in contrast to the male/female ratio of 1.6:1 for all suicidal cases. The average age of subjects was 29.2 and most came from the 15-24 age group[4]. Hence, a highly effective barrier needs to be targeted to be secure against young potentially athletic males. However, in trading off the cost, practicalities and impact of the barrier on the bridge, some reduction in protection from 100% is usually necessary and accepted, and this will vary according to site.

5. Key features of Public Safety Barriers

From research undertaken to examine the forms of barrier installed and considered for a number of bridges world-wide the following common features in deterring those seeking to climb over became evident:

- Height
- Predominantly smooth vertical members or fine mesh
- Gaps between members of less than 100mm
- No foot or hand holds which might assist in climbing
- A return at the top of the barrier back towards the pedestrian side
- Provide the impression of a daunting visible deterrent
- Separation from potential climbing aids

Examples of existing and proposed barriers are given in Table 1 below to illustrate approaches:

Table 1: Examples of Public Safety Barriers

	West Gate Bridge, Melbourne Australia - Security mesh infill panels incorporating a top rail are slotted in between T-section posts. The top rail has a return towards the pedestrian side, with a large radius curved edge profile to prevent hand grip. Around 4.2km of barrier was installed including two large expansion joint sections. The dark colour of the security mesh maintains the apparent transparency of the mesh which has 9mm x 71mm gaps between the 4mm wire. The barrier is placed behind a vehicular barrier and is just over 4m in height from deck level. It was completed in 2011 as part or a wider upgrade
	Clifton Suspension Bridge, Bristol, UK – A curved addition was added to the top of an existing latticed barrier. Rows of wire are strung along the top of barrier. The wires sag when load is applied, making the barrier difficult to climb. The arrangement was selected from a number of trialled options, and was considered the most effective form. Heritage was also important at this historic site and was a major consideration in the lightness of the form selected. The barriers are 1.25m tall with a 5 wire extension taking the total height to 2.0m. Total length installed was 193m each side of the main span only and they were installed in 1998.
	Prince Edward (Bloor Street) Viaduct, Toronto, Canada – The Infill is provided through vertical post-tensioned stainless steel rods (8mm diameter, 120mm spacing) which provide a very transparent barrier. Just over 1km of barrier is provided which is 5m in height. Installation was in 2003.

	Erskine Bridge, Glasgow, UK – New public safety barrier incorporates large top rail to prevent handhold and smooth vertical members. The inwards inclination also helps to increase the difficulty of scaling. The overall length of barrier fitted was 2.6km, and the height was 2.4m. The barrier was completed in 2012. Further details of the barrier installation may be found in the paper "Erskine Bridge Parapet Replacement"[5] also presented at this conference.
	Sydney Harbour Bridge, Sydney, Australia – View down walkways showing two different types of mesh used with curved top returns in towards pedestrian path from the outside of the bridge. Installed 1983
	Humber Bridge Study, Hull, UK - a similar design to that used at Erskine Bridge. Height was 2.3m and a trial section of 100m length was installed in 2009.
 	Golden Gate Bridge Studies, San Francisco, USA - Many options have been considered over the years. Again predominately vertical bars are considered and/or top returns. A net system was also under consideration.

Additional examples are the George Washington Memorial (Aurora) Bridge in Seattle, and the Nusle Bridge in Prague, not to mention others which show similar features.

6. Structural Requirements for Public Safety Barriers

There are no codified requirements for public safety barriers, so the approach has be one from first principles to establish their function and what loads they could be subjected to. In this regard their location on the bridge cross section is critical and whether the barriers are supplementing or replacing other types of barrier. Considerations are whether they will be subject to traffic impact loads, either directly, or due to the deformation of road barriers placed in front of them; if they will be subject to pedestrian crowd loading, or whether an existing parapet or barrier is in place which prevents this.

This has a direct effect on the height required (due to existing barriers potentially providing assistance in scaling the barrier), and the strength of the barrier. At a minimum if a barrier is protected by existing traffic and pedestrian barriers it only has to cater for human loads on the barrier of the person trying to scale it and rescue personnel, at a maximum the barrier may be required to act as a full traffic barrier. The form and robustness of the resulting barrier will clearly be markedly different. At the lower end it is suggested that robustness criteria are also specified. At the higher end, different criteria can be applied to the lower and higher sections of the barrier to reflect the fact that the higher levels of the barrier will not see the same load effects from traffic or crowd loading.

Windloads are likely to be significant on barriers and consequently the underlying bridge structure, and for certain locations loads due to icing up of the barrier must also be considered, particularly for mesh barriers.

Temperature effects must be catered for, so that thermal movement of the barrier and differential movements between the barrier and bridge deck is accommodated.

Crossing bridge movement joints with the barrier is usually challenging for long span bridges where movements can be well over a metre. It is desirable to carry the same barrier form through the joint for aesthetic reasons, but additional effort is required to eliminate foot and hand holds from a complex overlapping or sliding barrier joint. The concept for the barrier movement joint is therefore equally as important to establish as the normal barrier form. Figure 1 shows the West Gate Bridge movement joint barrier section.

Figure 1: West Gate Bridge Barrier movement joint being installed. View from top of sliding top rail joint and overlapping mesh panels

7. Effects of Public Safety Barriers on the bridge

Long span bridges are aerodynamically sensitive, particularly to details at their edges. It is therefore necessary to reconfirm that the bridge will still be aerodynamically stable with the barrier in place. Due to the sensitivity it is wise to keep a number of options available and for comparison, should performance prove negative. Computational fluid dynamics (CFD) may be useful for initial studies and option comparison prior to confirmatory wind tunnel tests. Sectional model testing in wind tunnels is an effective way of demonstrating stability with barrier options able to be produced relatively quickly with 3-D printers (Figure 2). It is recommended to conduct aerodynamic stability, and vortex shedding tests for different angles of wind incidence, as well as obtaining static wind load coefficients for both the original bridge layout and the one with the barriers added.

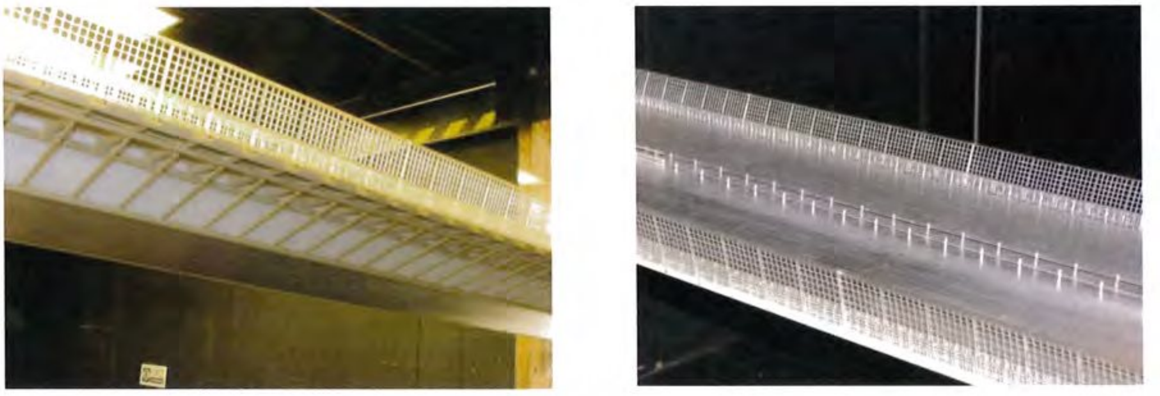

Figure 2: Sectional Model Wind Tunnel Testing of West Gate Public Safety Barriers

8. Trials and Testing

During development of public safety barrier design it is advisable to conduct a series of trials and tests to prove the concept. This is particularly important to ensure function and economy given most barriers will need to be of considerable length. During the development of the West Gate Bridge Public Safety Barrier[2] the trials described below were undertaken to verify that the key requirements of deterrence, aesthetic appeal and climbing resistance were met. The functionality tests were undertaken with a full scale mock up of the upper part of a panel and are typical of the type of tests required. The climbing test in particular is regarded as essential.

For a tensioned bar panel system option spread tests were undertaken (Figure 3). The test involved pulling the bars apart manually to determine if a sufficient gap could be made for the person to pass through. A scaling test was also undertaken (Figure 4). Attempts were made to scale the barrier, by manual climbing, by young, tall, athletic males.

For the security mesh fill panel option, point load tests were undertaken on a mesh panel option to verify the design criteria loading (Figure 5). In this case a ULS point load of 1.8kN was specified, though the mesh panel was able to sustain a load far in excess of this of 10kN with 80mm deformation.

Figure 3: Bar spread test

Figure 4: Scaling Trial

Figure 5: Mesh Panel Testing

Following the initial tests, and the results of wind tunnel testing a prototype barrier section was constructed to the early detailed design drawings (Figure 6). This was to promote internal discussion, confirm costs, verify the fit up of connections, and details for mesh fixing, test lifting arrangements, and the like. The test section was also painted to review colour schemes and for use in gaining acceptance from external stakeholders.

Figure 6: First Prototype Barrier

Finally, a third trial panel was constructed by the fabrication company who won the tender to provide the barriers for the bridge. This represented an opportunity to test the individual company's construction procedures, the fit up of the mesh within the final panel geometry (based on survey information), and also the structural performance of the mesh proposed by the fabricator.

9. Installation

Efficient installation is a key consideration given the lengths of barriers most long span bridges will require. Safety is also paramount given the usual barrier location at the edge of the structure. For West Gate Bridge these items were given high priority during the design development resulting in a design that could be installed with a highly mechanised system using specially adapted vehicles. The T-shaped posts are placed first and incorporate a splice low down in the post to adjust both height and angular alignment (Figure 7). Afterwards the panels are lifted in and clipped over the top of the posts (Figure 8). At this stage they are already stable as they lie back on the flanges of the T-posts. Each panel requires a single bolt at the bottom which serves as a pin for the next panel.

Figure 7: Placing of Posts

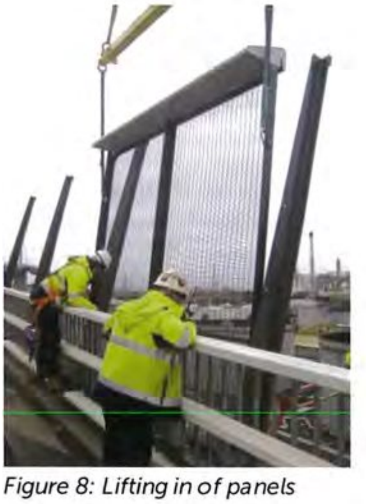

Figure 8: Lifting in of panels

10. Costs

Construction costs will depend greatly on country, form of the barrier or extension to existing barriers, whether it is new build or retrofit, and the difficulty of attaching the barrier to the existing structure. A typical range would be £500 to £3,000 per metre run of barrier depending upon the sophistication.

11. Conclusion

Public pressure has increasingly demanded that more is done to prevent suicides from bridges, and justifiably so, since evidence suggests that a suicide prevented at a bridge site may well be a life saved. Whilst other measures can assist in saving lives, a physical barrier remains the most effective solution. Long span bridges are often a draw for suicide attempts whilst at the same time being costly and technically difficult to retrofit with a public safety barrier. Nevertheless providing the key early steps of investing in the development of the barrier in terms of effectiveness of form, and structural efficiency in response to appropriate loads are taken, an effective and attractive solution can be successfully implemented. A programme of tests, trials and prototypes is considered essential in achieving this.

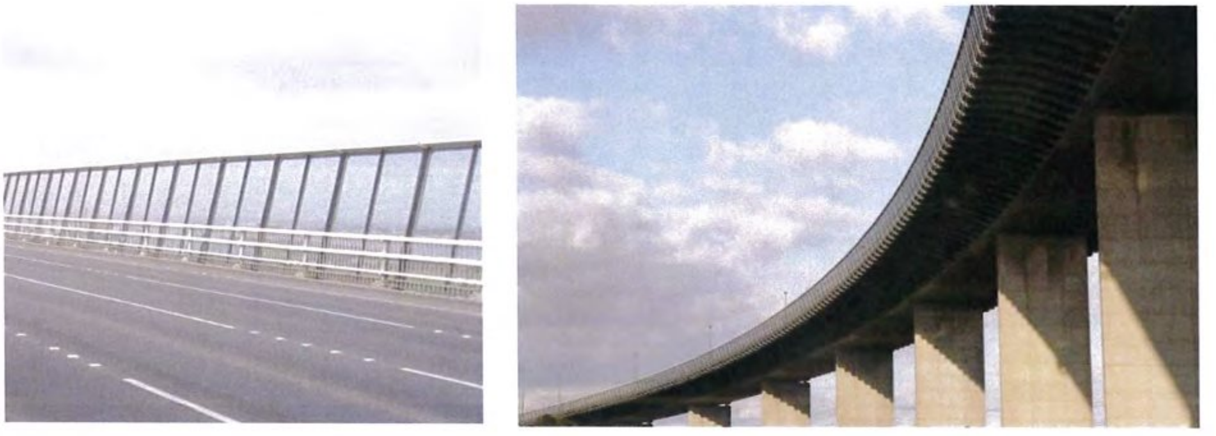

Figure 9: Views of Completed West Gate Bridge Public Safety Barrier

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