Bridge Aesthetics: Design guidelines to improve the appearance of bridges in New South Wales

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Abstract  In 2004 the Roads and Traffic Authority of New South Wales published Bridge Aesthetics. It was prepared by the RTA’s bridge designers, urban designers and the NSW Government Architect. Seven years on the RTA has built over 500 new bridges of different types, at different scales, in different urban and rural contexts and under different contractual types – all in accordance with the guideline. Many lessons, both good and bad, have been learnt and new issues have arisen. In the light of this, the RTA has reviewed and updated its guideline. This paper in summarising the guideline, argues for a commitment to aesthetics, puts forward key design values including sustainability and outlines the principles of design that need to be considered at the level of the ‘Whole’, the ‘Parts’ and the ‘Details’. The importance of design methodology, of collaboration in the design team and of capturing aesthetic requirements in the tender and delivery phases is also stressed. Backed by examples it shows how aesthetics can be successfully integrated with the science and practice of engineering to create an enduring and context sensitive result for the community.

Introduction

This paper addresses the subject of bridge aesthetics. It highlights the key principles in the RTA’s recently updated and revised document Bridge Aesthetics: Design guidelines to improve the appearance of bridges in NSW, 2011. This update reflects seven years of experience and lessons learnt in systematically applying aesthetic principles on the building of over 500 new bridges designed and built over this period. Also, it continues the collaborative effort between the RTA’s bridge designers, the RTA’s urban designers and the NSW Government Architect in formulating aesthetic guidelines and monitoring and recording the aesthetic quality of bridge design.
Importantly, the underlying philosophy of the 2004 guideline has remained unchanged, and the fundamental procedural and substantive principles relating to the making of bridges are found to still apply. The procedural principles hinge around design collaboration from the inception of a project while the substantive principles relate to how we design at the level of the whole, the parts and the details.

What has changed is the range of examples to illustrate and reinforce the philosophy and to demonstrate both good and bad design practice. In response to emerging issues there are new sections on pedestrian bridges, heritage bridges and rail bridges. As well, there is additional supporting material on the theory and practice of bridge aesthetics; bridge aesthetics is not something new but an ongoing concern and pursuit of engineers and designers internationally.

A particularly useful aspect of the document, in the original version and update, has been the definition and illustration of a consistent bridge technical terminology that can be clearly understood by all involved in bridge design.

![Bridge terminology illustration from Bridge Aesthetics](image)

**Fig. 1.** Bridge terminology illustration from Bridge Aesthetics

The 2011 version of *Bridge Aesthetics* sits as a compendium document under the RTA’s urban design policy (no. PN204) *Beyond the Pavement: RTA urban design policy, procedures and design principles*. First published in 1999, *Beyond the Pavement* was substantially revised and re-published as a policy document in 2009. It is applicable to all infrastructure that the RTA builds, including bridges, and so requires them to be sensitive to the natural and built environments in which they sit, to provide good connections for communities and consider all transport
modes including walking and cycling, and to contribute to the quality of the public
domain in terms of their architecture and the way in which a bridge is
experienced. Also, under the RTA’s Beyond the Pavement policy, bridges must
be safe for users and the community, cost effective, and sustainable.

It is therefore interesting that Beyond the Pavement, coming as it does out of an
engineering organisation, won five prestigious awards, including the 2010
Australia Award for Urban Design and the Australian Institute of Landscape
Architects 2010 National Award for Excellence; such awards give credence to the
fact that good aesthetics and good engineering are synonymous and that bridges
make a contribution to the built environment.

**The nature of bridge aesthetics and its importance**

Aesthetics is defined as: “Relating to the sense of the beautiful or the science of
aesthetics, that is, deduction from nature and taste of rules and principles of
beauty” (The Macquarie Concise Dictionary). It is not a cosmetic treatment or
‘add on’ to bridges but an integral part of their function, practicality, economy and
technology. Not only is it unnecessary to decorate or ornament a bridge to make it
beautiful, but this adds cost and in some cases clutter. The aesthetic quality of a
bridge involves our sensory perception of it – how it appears to us visually. This
results, at least, from the fundamentals of: its form, proportions and scale;
expression of forces and technology; its strength and durability; its relationship to
the surrounding natural and built landscape; the relationship of bridge elements to
one another; and factors such as the use of texture, colour and lighting. Bridges,
however large or small, need to be attractive and durable as they serve many
generations, are part of our landscape, are seen from many angles and provide
views. They should never look cheap or blight the environment.
Fig. 2. The twin bridges over the Mooney Mooney Creek demonstrate how good engineering and good aesthetics are synonymous. This bridge has graceful curved haunches reflecting the forces within, a symmetrical form balancing the cantilevered girders, and a deep shadow line from the deck over the girder demonstrating refinement of materials. The bridge has both beauty and honesty of form and function.

Design values

Good bridges come from principled, informed and supportive clients working with excellent creative and practical designers. Both clients and designers must understand and strive for the following six key design values if high quality aesthetic outcomes are to be achieved.

Commitment to aesthetics

It seems obvious, but the point must be made that if clients are not committed to good aesthetics then beautiful bridges will not occur, or at least are more unlikely to occur. The RTA’s urban design policy and its formulation and adoption of design guidelines to improve the appearance of the bridges, places the organisation in the position of enlightened client. It sets expectations and encourages desired aesthetic outcomes from designers and associated industry.
**Addressing context sensitivity**

Historically, context sensitivity used to be a natural unavoidable outcome. Local materials, local building styles and a minimal effect on the topography were logical, sensible approaches leading to unique, context-sensitive bridges. Today technology, machinery and a centralised building and design approach make context sensitivity harder to achieve, yet the best bridges have a relevance to place and time and this aspect must be carefully and tastefully considered.

**Recognising sustainability**

Bridges offer an unparalleled opportunity for sustainability. As well as creating connections that can stimulate decades of development and commercial activity, they can be built to last many years with no planned obsolescence common to many products today. Through their appearance and function they can contribute to the identity and liveability of areas creating iconic and much valued places in the community.

![Fig. 3. The Sea Cliff Bridge near Wollongong has proved to be an icon and major tourist attraction for the area, a vital connection in the future sustainability of the Illawarra coastal villages and an ecologically and culturally sensitive solution to the site.](image)

**Cost effectiveness and aesthetics can be complementary**

Good aesthetics need not be costly but can be compromised by cost cutting, as can the very durability of a bridge. Integrated engineering and aesthetic solutions are
generally good investment and the fact that everything can be achieved a little cheaper is no reason to ignore aesthetics. Design quality in the aesthetic sense needs to be weighed up in relation to cost and not devalued because of cost alone.

**Adopting a comprehensive approach to design**

Good aesthetics is not something that can be thought about and added on at the tail end of a project. It needs to be considered in the very scoping and shaping of the concept. If it is not considered at the start (and also pursued throughout the design and construction phases) the opportunity to shape the design is lost. The only solution to ameliorating a poor aesthetic outcome is to then cover it up or decorate the bridge. Bridge aesthetic outcomes are difficult to achieve without a comprehensive design process.

**Design collaboration is essential**

Today’s infrastructure projects need to reconcile many issues - environmental, community, sustainability, asset and safety as well as the in-depth technical engineering. Consequently bridge project development, detailed design and building have become exceedingly complex. Bridge designers are rarely tasked with addressing all requirements and design teams are generally multidisciplinary made up of specialised interests. This means that collaboration and communication within design teams, under guiding project management direction, is more important than ever.

While there are some civil engineers who excel in both the visual arts and engineering, for example Santiago Calatrava and Michel Virlogeux in Europe, design collaboration between architectural and engineering professionals is generally the best approach and can lead to outstanding outcomes (for example Virlogeux worked with the architect Norman Foster on the Millau Viaduct). This is provided that both professional viewpoints are respected and both professions work together in practice to produce creative and structurally refined solutions.
**Process**

There are two, parallel, processes required to ensure that aesthetics is considered, and the best outcomes are produced. One relates to project management and the other to design.

The RTA’s project management process, termed *ProjectPack* or *MinorProject* (depending on the size of project), now explicitly incorporates bridge aesthetics. There are four phases of project management: the initiation phase of a project in which strategies are developed and objectives set; the development phase in which options are examined; the concept design phase in which concepts are developed and an environmental assessment produced; and the implementation phase in which design is developed in detail, contracts let and the project built. There is a further finalisation phase in which the project is reviewed and monitored so that its operation is successful and management achievable.

In each of these phases there are key bridge design actions required to address and incorporate aesthetics. For example in the initiation stage, requirements regarding the approach to bridge design are set in corridor plans such as the Pacific Highway Urban Design Framework. These design objectives are then translated into design principles and design solutions in the development phase. At this point project managers are required to involve urban designers to work with bridge engineers and help produce an outcome in accordance with *Bridge Aesthetics* and *Beyond the Pavement*. The implementation phase likewise requires urban design involvement to ensure the details are commensurate with the concept design and
that the design is implemented in accordance with the concept. This, effectively, mainstreams aesthetics in the project management process.

The design process on the other hand sets out what needs to be done in actual design from an aesthetic point of view and can apply at all project phases. It involves firstly an understanding of context; then the setting of design objectives and principles to guide the project; and finally the exploration and development of the design itself at the level of the whole, the parts and the elements.

**The components of design in the whole, the parts the details and the finishes**

A bridge needs to form an aesthetic whole, greater than the sum of its parts. The quality of the whole depends primarily on how the following aspects are dealt with and the interrelationship between these:

- The context of the bridge setting and its purpose.
- The choice of bridge type in relation to span.
- The form of the bridge.
- The parts of a bridge.
- The details.
- The finishes, in terms of colour, texture, concrete quality and lighting.

Some principles explaining these are summarised below.

**Context**

All design requires an understanding of context. With bridges, the immediate setting offers both constraints and opportunities that must be considered in the design process such as landform, landscape and near and distant views. The technological advances in bridge engineering together with new technical standards and requirements (such as those governing span, cambers, super-elevation, lane width and sight lines) encourage a centralised design approach rather than a site specific one. While this in itself can result in designs that are as visually interesting and innovative, design that is sensitive to context, either by fitting in well (disappearing in the landscape) or complementing the setting (making the bridge distinctive and adding a new quality to a place), is valued by communities. In the latter case such designs are good for community pride and local identity and often result in bridges that are more sustainable and self-reliant and that are seen to serve more than just the present generation.
Bridges that are not place related can too often appear as jarring and inappropriate pieces of engineering, serving mainly a utilitarian purpose. This is nonetheless a complex matter as a bridge that appears good in one setting may have the opposite effect somewhere else.

Designing a new bridge next to an existing one can itself be a significant contextual challenge. Competition between structural forms can create clutter and neither bridge can be presented well. Alternatively, where structural forms are complementary a memorable landmark can be created where the two bridges have an harmonious interplay and the experience of crossing the bridge is enhanced by the view of the existing bridge.

![Iron Cove bridge duplication](image)

Fig. 5. Iron Cove bridge duplication: the new bridge is separated from the old, which provides respectful setback. Rather than duplicating the old design and creating pastiche, an entirely different bridge type - equally confident aesthetically - has been produced. It complements the old bridge by using simple curved and tapered forms which frame, not compete with, the more complex truss.

The guidelines set out some key principles of design that should be considered to achieve a sensitive relationship between a bridge and the landscape. Keeping the profile of a bridge to a minimum allows the landscape to dominate the view and be appreciated from all viewpoints. Allowing good views of the landscape from the bridge creates a natural landmark for the user, reducing the need for a ‘created’ gateway. Avoiding complexity of detail design and keeping simple shapes helps to keep the bridge elegant and avoids it competing visually with the landscape. In general, bridges with a horizontal form are preferable to bridges on a grade over flat, simple landscapes and significant expanses of water; water always forms a horizontal plane, and a structure which is skewed to the plane appears discordant. Justification of design in contextual terms needs to be supported by a character analysis of the setting and systematic assessment of visual impacts of a proposed
location and design in relation to the landscape and any existing bridge within that landscape.

**Bridge type**

Perhaps the most fundamental response to context is the choice of bridge structure related to its function, whether vehicular bridge, pedestrian bridge or rail bridge. Any of these function types may be bridges of historical or cultural significance.

The choice of bridge structure (either from a range of known structural types or consideration of a new structural type) is affected by many contextual factors. These include: the distance the bridge needs to span; the topography either side of the span; local geology; the nature of the load to be carried; and the visibility or visual presence of the structure. However in most instances it is the span length that is the initial factor in dictating bridge type. Thus, a short span bridge (up to approximately 18m) may only require a pre-stressed concrete plank; a medium span (approximately 40-80m) may suggest steel or post-tensioned box girders or incrementally launched girders; while long and very long spans (up to approximately 800m and longer than this) may suggest the use of a cable stay or a suspension type, in the very longest bridges, as the case may be.

![Fig. 6. the Anzac Bridge in Sydney, is a cable stay bridge with a main span of 345m. Only suspension bridges offer an option to span further than this.](image)

There are a number of important differences between pedestrian and vehicular bridges that influence design. Pedestrian bridges carry lighter loads than vehicular bridges. This allows the designer to exploit greater flexibility in the shape and proportion of the bridge. Depending on context, the rules normally applicable to
road bridges may be stretched when using cable stay, truss, arch and suspension which are suitable for light loads. Since pedestrians and cyclists spend more time on a pedestrian and shared path bridge than a traffic bridge so that there is greater potential to maximise views from the bridge and also pay more attention to design detail. Pedestrian bridges are also characterized by ramps, safety screens, lifts and stairs each of which have special design requirements from an aesthetic point of view.

![Image](image-url)

**Fig. 7.** The lighter loads on pedestrian and cyclist bridges afford flexibility in design. In this example, of the Beatrice Bush Bridge at the end of the Anzac Bridge, an arcing steel box girder slenderly spans the full width of the Western Distributor.

In terms of rail bridges, there are a number of aesthetic issues to consider that are not general to all bridges. A railway bridge should be true to its purpose and easily recognized as such. The bridge needs to cater for infrequent, high mass vehicles with different shock absorbing capabilities to road vehicles. Decks are relatively narrow and the vertical alignments and gradients, are more constrained than roads. The design of rail bridges should therefore address these qualities in an aesthetically pleasing manner. Proportions of girders and spans should differ from road and pedestrian bridges. Deep girders are often necessary and the appearance of these girders where they are publicly visible, needs to be considered. Alternatives to deep girders, such as arches should be considered.
Fig. 8. The use of colour and lighting are important aspects of bridge design and can be used to emphasize aesthetic qualities such as on this rail bridge over the Pacific Highway at Coffs Harbour. Its arched form is both visually expressive and reflects the rail purpose of the bridge.

**Form**

The form of a bridge – its overall shape and composition - results mainly from its proportions, symmetry, order and rhythm and unity of design. Proportion involves the relationship between different elements of a bridge. As there are no hard and fast rules, given the nature of design, guidelines can help eliminate what can be considered to be the worst ratios between bridge elements and assist in achieving ‘proper’ proportion.

Care should be taken to avoid using excessively imbalanced proportions between significant elements. Repeating similar proportions or ratios throughout a structure can lead to a harmonious composition. The proportion between depth of superstructure and bridge spans is a particularly important ratio; this is referred to as the slenderness of the bridge and is defined as the span divided by the beam depth. Also important is the ratio between bridge height and span, and while it is generally not practical to vary span to bridge depth, a wider span is more suited to a higher bridge. A ratio of 5 can result in a bridge of strong appearance but very chunky, while 30 can lead to a bridge that is very slender in appearance. Also the ratio of pier dimension to superstructure depth should be considered, for example, bridges with thin piers relative to superstructure depth can sometimes appear odd. Finally, the ratio of deck overhang relative to parapet depth also affects proportion and therefore the aesthetic appearance of a bridge.
Another important aspect of form to be considered in design is symmetry. Symmetrical bridges in general are often more aesthetically pleasing than non-symmetrical bridges since they appear balanced and refined. Symmetry need not necessarily be the rule however, for example, asymmetry can be perfectly justifiable due to such factors as the function of the bridge, site constraints, technological innovation and symbolic imperatives that make new forms possible.

Designing a rational order and rhythm to a bridge, its parts and individual bridge elements can improve appearance. For example, spans should match each other where possible or at least demonstrate a consistent order. Not only should there be such an order and rhythm on an individual bridge, but consistency of form is an important aesthetic consideration along an entire corridor.

**The parts**

The essential parts of bridge design affecting aesthetic quality are the superstructure and the substructure.

The main visual elements of the bridge superstructure are the parapet, the deck and the girder. The outer face of the parapet can be one of the most important aesthetic elements of a beam bridge. It is the highest piece of the bridge and often the most dominant in long distance views. Also, it can be the longest piece of the bridge and therefore an opportunity to express the span and horizontal nature of the structure. Parapets should appear as continuous, uninterrupted lines extending the full length of the bridge, with a generous overlap of the abutments. The proportions between their depth, the deck overhang and the girder depth should be carefully considered and the shadow cast on the superstructure should be maximized. Also, the outer face should be a smooth, single plane surface, slanted slightly outwards towards the bottom, to better catch the sunlight.

![Fig 9. The parapet on the outer bridge of triple bridges over the Brunswick River accentuate the horizontal nature of the structure, are angled to catch the light and with the deck provide a strong shadow on the girder.](image)

The critical design elements of a bridge substructure are the headstocks, piers, pile caps and abutments. Headstocks are a potentially large design problem and should be integral to the pier rather than an additional, protruding element across the outer face of the girder; if avoided, they better allow the superstructure to dominate the bridge view.

Pier choice and spacing themselves have a major affect on the appearance of a bridge. Too many piers can appear cluttered, while too few can create the need for an overly dominating deep girder. A slender appearance depends on the context and the ratio of span to superstructure depth. Pier shape and taper are equally important issues. Pile caps should mimic the shape of the pier as far as possible and imbalanced proportions of pier size top pile cap should be avoided.

![Diagram of bridge proportions](image)

**Fig. 10.** The proportions of deck overhang to parapet depth to girder depth need to be considered. A ratio diagram, developed by the Cardiff University School of Engineering, (see above) illustrates these and has been applied on the Windsor flood evacuation bridge (Jim Anderson bridge).

**The details**

Good detailing is essential to good bridge design and lack of attention to detail can spoil an otherwise beautiful bridge. There are four important aesthetic
considerations in the detailing of a bridge: the aesthetics of the bridge details must be considered as part of the whole bridge design; the design of the details should minimize the potential for unsightly staining; the bridge detail should not impair the view from the bridge; and access for maintenance should be considered early in the design process. The following figures demonstrate some of these issues.

**Fig. 11.** Pedestrian bridge over Parramatta Road at Auburn. The configuration of the long ramps, piers and lighting and unrefined connection of the ramp to the girder create a poor, cluttered visual outcome, which obscures a fine building.

**Fig. 12.** The expressed joints on the piers of the Sheehan Bridge at Gundegai are an opportunity to enhance a bridge design by breaking down the massing of large piers and providing another level of detailed interest.
When all the details are considered well, including such things as barrier transitions, parapet depths and angles, abutments sizes and shapes, pier composition and cutting gradients, even the normal run of the mill bridges all highways can be neat, elegant and cost effective (bridge over the Pacific Highway at Bonville).

If noise walls are necessary they should also be an integral part of the whole bridge design. They should be transparent so they do not affect slenderness or block views out from the bridge. (M7)

The finishes

The last bridge aesthetic aspect is the finish or presentation of a bridge. The key areas are concrete quality, texture (eg of abutment walls), paint colours (only required on steel elements) and importantly, as a bridge can be in darkness for half its life, how it is lit as distinct from road lighting which is a detail issue.
Fig. 15. Lighting of the M4 M7 interchange presents the bridge at night and highlights key forms and architectural finishes to best effect.

**Conclusion**

Bridge aesthetics is not achieved by chance and should not be left to chance. This is especially important in a big engineering organisation that either designs and builds bridges directly or facilitates and manages such design and building under different forms of contract. This requires policy, technical and procedural commitment to aesthetic outcomes and reinforcement and championing at the executive level of the organisation. This paper, using the guidelines and work of the RTA, shows how bridge aesthetics can be achieved. What is presented here captures the state of play at this point in time in integrating engineering and aesthetics, and will be subject to more testing and scrutiny in the coming years. Hopefully, it can be of benefit to broader fraternity that might be interested in achieving bridges of aesthetic quality.